Master of Science Thesis

PROJECT MANAGEMENT AND LEADERSHIP SKILLS IN POWER ELECTRONICS RESEARCH ENGINEERING

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CONTENTS:

Introduction

Each two years 4 basic *IEEE* [1]sections in the field of Power Engineering make an open call for Competition for all of the Universities throughout the world expecting the students to develop new energy solutions through their work and innovation, but to be aware of manufacturability and practical use of what they bring as a final prototype. Students World Contest: **Future Energy Challenge** (http://www.energychallenge.org) is organized in order to bring innovations in the field of Energy Science and to attract more and more students to think on the way of saving the energy.

Energy saving is a modern trend in electrical engineering, experiencing a great boom in last decades. Reasons are constant rise of energy prices and awareness of limited energy resources on Earth. Saving electrical energy is of outmost importance since it is the purest form of energy that can be easily converted to any other form. According to some data, electrical drives in the developed world consume between 60% and 70% of all the electric energy produced in these countries.

Electric motors impact almost every aspect of modern living. Refrigerators, vacuum cleaners, air conditioners, fans, computer hard drives, automatic car windows, and multitudes of other appliances and devices all use electric motors to convert electrical energy into useful mechanical energy. In addition to running the common place appliances that we use every day, electric motors are also responsible for a very large portion of industrial processes. Electric motors are used at some point in the manufacturing process of nearly every conceivable product that is produced in modern factories. Because of the unlimited number of applications for electric motors, it is not hard to imagine that there are over 700 million motors of various sizes in operation across the world. This enormous number of motors and motor drives has a significant impact on the world because of the amount of power they consume.

[1] Institute of Electrical and Electronics Engineers (IEEE) Power Electronics Society, Industry Applications Society, Power Engineering Society, Industrial Electronics Society, European Power Electronics Association & National Renewable Energy Laboratory

Electric motor drive technology is constantly evolving and expanding to new applications. More advanced electric motor drives are now replacing older motor drives to gain better performance, efficiency, and precision. Advanced electric motor drives are capable of better precision because they use more sophisticated microprocessor or DSP controllers to monitor and regulate motor output. They also offer better efficiency by using more efficient converter topologies and more efficient electric motors. The more advanced drives of today also offer a performance boost, by utilizing superior switching schemes to provide more output power while using lighter motors and more compact electronics.

Under the conditions of the challenge, our team has taken on the task of creating innovations in motor that would provide the user with large cuts on operating cost through improved efficiency. The purpose is to document future design innovations and their effect on overall efficiency. This is where the 2005 International Future Energy Challenge comes into play.

A few years ago, project management in engineering was often an afterthought in assembling a project team, and organizations turned to project managers only when their projects turned sour—as they usually did. Today, project managers in Electrical engineering are in demand, and few organizations would initiate projects without ensuring that they are managed.

Here, in my work, I will try to explain how important is the use of Project Management in Electrical Engineering and I will show it on a practical example. I will try to demonstrate the way we were running and managing one Project in power Electronics, showing step-by-step the progress of the project, technical documentation and reports, gaining the final result – prototype.

Thesis is organized by following Chapters:

Chapter 1 – This Chapter explains the **Fundamentals of Electrical Drives**, speaking about energy efficiency and electrical energy generation in coming years, as well as electric motors consummation. Current motor technologies are presented here, with examples of control drives topologies, especially the Digital Controlled AC Electrical Drive topology, which is the topic of the Power Electronics Project. The technical goal of the Project was to construct adjustable speed motor system costing less than US $40 (scaled on 1 million units production) for a 500 W unit, achieving maximum efficiency and operating requirements while maintaining acceptable levels of performance, reliability and safety. The purpose of using Digital Controlled AC Drives together with trends and control techniques of AC Drives will show how great research in this field of Power Electronics can make results in global energy savings. But, such great objectives need a serious Project planning. These Electrical Engineering project are very complex because of necessity of Engineers from different field of research: Electronics, Powers, Automation, Software, Communication etc. Because of the complexity it is very important to manage and lead the project properly, carrying about project structure, time consummation, team members, tasks progress, technical documentation, in order to produce desired result.

Chapter 2 – Typical Phases of the Project in Power Electronics are shown in the 2nd chapter, that presents the logical steps need to be done in one project. Everything starts with an idea, vision and mission. Choosing the right team members, the core of the project, members that will understand and be obsessed with a project idea. Every project need to be carefully planed so, the purpose of planning is to realize how much time, money, human recourses and finance are needed, so the requirements, scope, and plan are important element of the Power Electronics project. If the project is defined appropriately, the steps of Planning Phase will help make sure as well as schedule and costs will. When the planning phase is over (and agreed), the "doing" phase begins, where establishing control is main process. In Power Electronics projects, very important are testing and quality, this means that no activity is completed until it has passed the (objectively) defined criteria which establish its quality, and these are best defined (objectively) at the beginning as part of the planning.

Chapter 3 – This chapter presents **The Project Managers' and Team Leaders' role in a Power Electronics Projects**. The manger of a small team has three major roles to play: to be a planner, provider and a protector, but also to take a long-term view. He/she has access to information and materials which the team needs; but also an experience in managing the project in power Electronics, which means the optimum number of steps in simulations, testing, program coding etc…

Manager is a person who will define a problem and offer several solutions by his/her practical experience. It is about motivation, setting the targets - and in selecting these targets, making a dramatic effect upon team's sense of achievement. On the other hand, leadership is a way of focusing and motivating group of engineers to achieve their aims – to do the project right. The chapter explains leaders' necessity to have a wide range of skills, techniques and strategies which include: Planning, Communication skills, Organization and Awareness of the wider environment in which the team operates, as well as project progress and technical documentation, which are most important. The leader is a multicultural person, that develops own cultural sensitivity by observing and understanding cultural differences.

Time Management is about controlling the use of most valuable (and undervalued) resource. The managers' role is to care about the deadlines and time consummation on the project, knowing the complexity of the tasks and processes on the electrical engineering projects. It's up to them to estimate the time for different procedures like simulations, implementations, testing…

On the other hand, it is about leaders to define the team, but teams are like relationships – so, managers and leaders have to work at them. Team Leader's role is implementing the Team Quality, but also building Quality into the project.

Chapter 4 – The 4th Chapter is about purpose of **Project Methodologies**, where methodology is a set of guidelines or principles hat can be tailored and applied to a specific situation. In a project environment, these guidelines might be a list of things to do, especially in Electrical Engineering.

Strategy always comes before any tactics. It's similar to thinking before doing. The strategy must be correct before we select a project or development methodology. By simply assessing those project methodologies that exist today, it is obvious that a universal project approach simply won't work. A project life cycle is, therefore, a collection of project phases, explained here.

It is essential that the management of any organization identify and articulate its critical success factors (CSFs). These are the ground rules that determine the appropriateness of the environment in which the organization operates. When trying to place any project life cycle or methodology into perspective, it is always going back to the Client, Input, Process, Output, Clients (**CIPOC**) approach.

The project manager's first task is to become familiar with the feasibility of the project. The focus is how project methodologies can be developed to support projects in a team. Developing a project methodology and adapting it to the situation often deal with changes on many levels—changes in procedures, processes, and information systems. The one effective way to lay out the envisaged framework of a project methodology is to illustrate or mind map it on paper first, thereby addressing all areas of the organization.

Chapter 5 – This chapter explains the process of **Managing Power Electronics Project for IEEE Contest**. It illustrates entire Power Electronics project with all project phases, done by MiniDrive team consisted of 19 students from Laboratory of Digital Control of Electrical Drives, University of Belgrade. The chapter explains in detail objective and vision, break-down structure, task description, team organization of concrete Power Electronics project.

Special interest was given to technical documentation and progress reports because that help leaders to control and monitor the whole project. Weekly reports examples are given, case studies, as an instrument for choosing the right option in timeless situation, presentations of current results and progress as well as way of combining the different results of one group to final project goal.

Because Students' Contest organizers set up the milestones, which required three progress reports for duration of the project, step-by-step activities are given, presenting easily how final Digital Drive prototype is generated for 15 months of working.

Activities like simulating, testing, code generating, components assembling, cost estimating, analyzing, regulating the safety, are main for one Power Electronics project, and are separately showed in this chapter, as well as results of these activities.

Chapter 6 – The final chapter called **Conclusions and Suggestions** presents the final comments that can help in upgrading existing project and final prototype, but also it is need to know that Project overruns are the norm. It is hard enough to keep a project on track in those disciplines where the road has been traveled before, the activities are familiar, and the pitfalls are clearly marked.

Similarly, the project manager has to be all eyes and ears; he or she has to get the project back on track when the project's integrity is threatened by the dysfunctions of the team, the institution, or the technologies. A significant challenge to the project manager is to know when and how to intervene but, for the most part, as they say, just "let them play."

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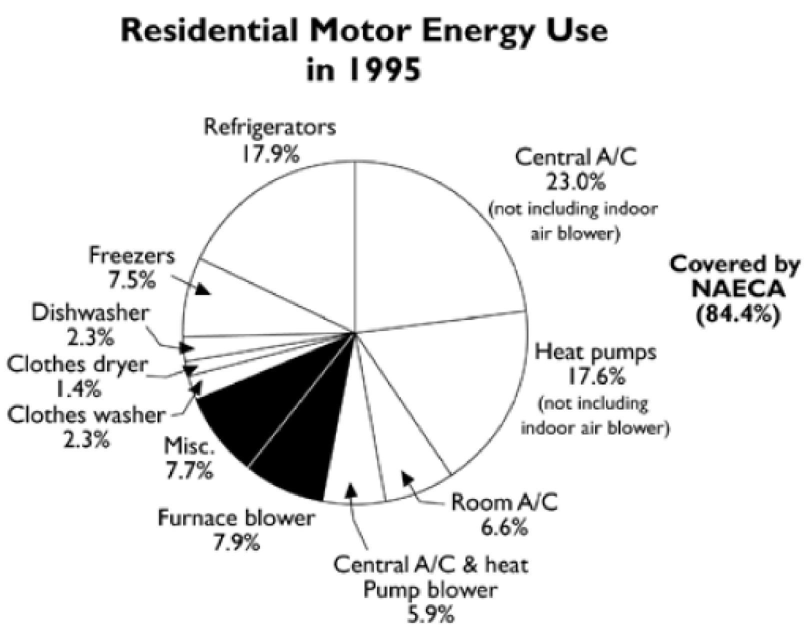
1. Electrical Drives Fundamentals

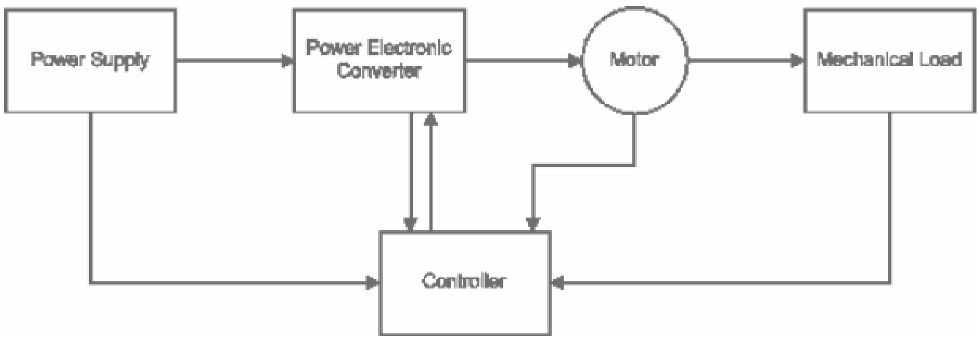
More than half of total electrical energy produced in developed countries is converted into mechanical energy in electric motors. Among many types of the motors, three-phase induction machines still enjoy the same unparalleled popularity as they did centuries ago. At least 90% of industrial drive systems employ induction motors.

As environmental and other concerns slow the growth of electrical energy generation in coming years, it becomes essential that we conserve and use this limited and precious resource more efficiently. Conserving electricity and making it a better fuel relies on the widespread adoption of the power conversion process, which takes electricity from a source and converts it to a form exactly suited to the electrical load.
Electric motors consume more than 75% of all electrical power in the US. Adjustable-speed motors can improve the efficiency of these motors by about 50% in many applications. They can also reduce costs considerably. Power electronics allows us to develop efficient speed and torque control of electric motors at low costs. This, in turn, calls for development of optimized electromechanical power conversion units.



Picture 1.1: *Residential motor energy use in 1995 (courtesy of NAECA).*

The systems that controlled electric motors in the past suffered from very poor performance and were very inefficient and expensive. In recent decades, the demand for greater performance and precision in electric motors, combined with the development of better solid state electronics and cheap microprocessors has led to the creation of modern adjustable-speed drives. An adjustable speed drive is a system that includes an electric motor as well as the system that drives and controls it. Any adjustable-speed drive can be viewed as five separate parts: the power supply, the power electronic converter, the electric motor, the controller, and the mechanical load, presented on a Picture 1.2 below.

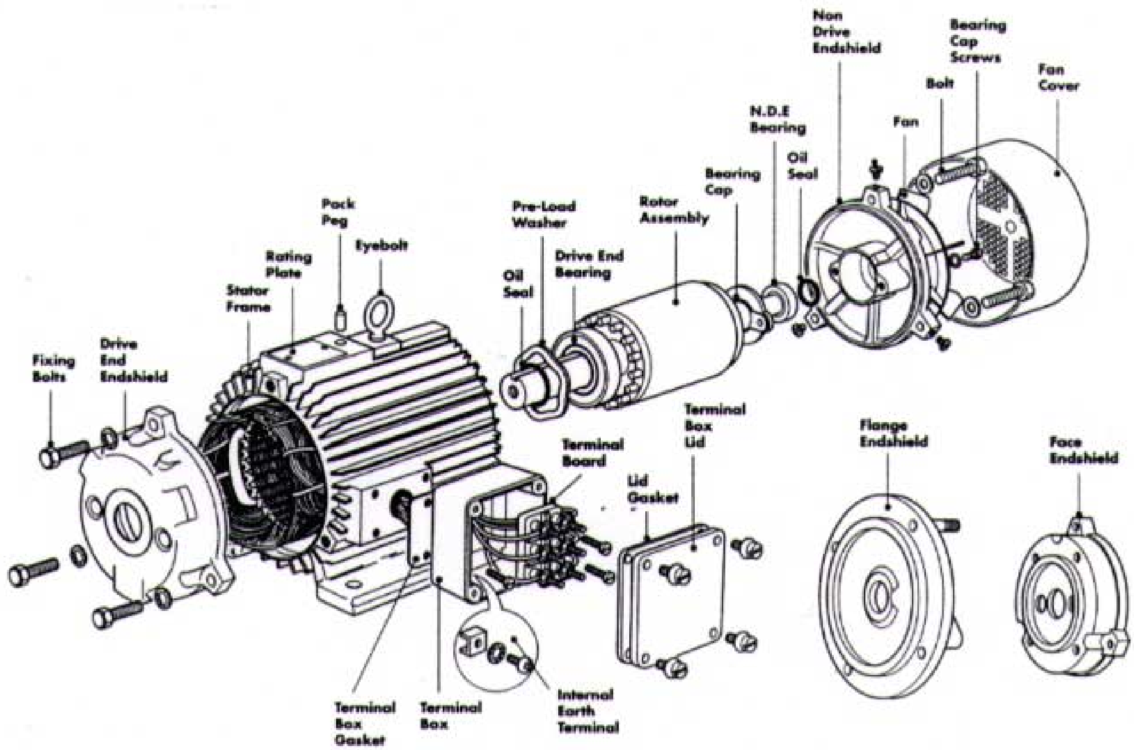


Picture 1.2: *A typical adjustable-speed drive system.*

The **power supply** is the source of electric energy for the system. The power supply can provide electric energy in the form of AC or DC at any voltage level. The **power electronic converter** provides the interface between the power supply and the motor. Because of this interface, nearly any type of power supply can be used with nearly any type of electric motor. The **controller** is the circuit responsible for controlling the motor output. This is accomplished by manipulating the operation of the power electronic converter to adjust the frequency, voltage, or current sent to the motor. The controller can be relatively simple, or as complex as a microprocessor. The **electric motor** is usually, but not necessarily, a DC motor or an AC induction motor. The **mechanical load** is the mechanical system that requires the energy from the motor drive. The mechanical load can be the blades of a fan, the compressor of an air conditioner, the rollers in a conveyor belt, or nearly anything that can be driven by the cyclical motion of a rotating shaft.

1.1. Current Motor Technology

In today's modern world, electronics are everywhere from handheld computers to air conditioners to projection TVs. However, even in this world, over half of all power consumption in the World can be accounted for by motors. These motors can vary from a simple blender and fan motor to an industrial motor used for assembly lines in automobile factories. When considering the mass power that the whole World consumes in a year, it becomes apparent that if one can make these motors run even a couple tenths of a percent more efficient, it can make a huge difference in power savings.



Picture 1.3: *All parts of a typical electrical induction motor*

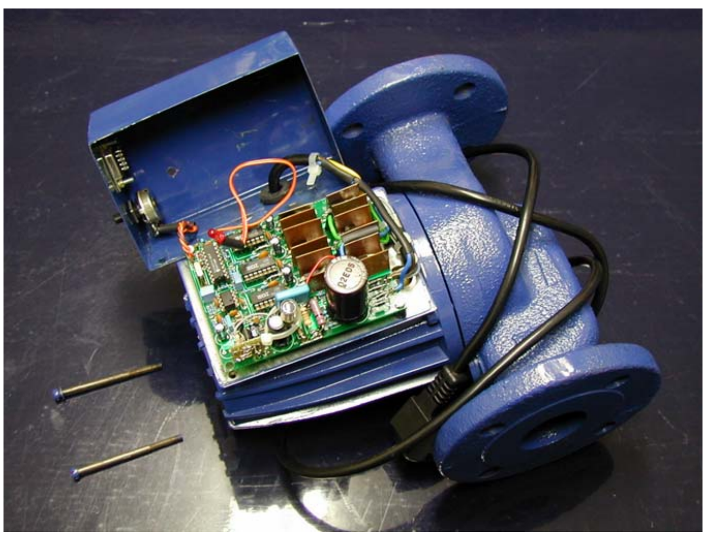
Electric motors convert electrical energy into useful mechanical energy. This energy can then be used to drive man household appliance, i.e., fans, compressors, etc.; but, even in home applications not all motors are alike. Different types have varying characteristics (and thus different efficiencies) making them suitable for certain situations and not for others. Single speed induction motors are presently being used for most residential applications ranging from portable fans to compressors commonly found in refrigerators. These include both your single and three phase squirrel cage induction motors. There is a noteworthy dissimilarity and a rather wide range of efficiency between these single-speed induction motors. It is also worth mentioning that in general motor efficiency comes at the price of horsepower and for this reason motor smaller motors are generally less efficient. Universal AC/DC motors are commonly used for sporadic applications where high speed is needed. Examples of this would be drills, food processors, and vacuums. These are the “brush motors” (given its name for the set of brushes that constantly change volt thus keeping the motor spinning in an attempt to align polarity). The main problem with these types is significant losses associated with the windings wear and tear on the brushes (most small motors fail due to worn brushes).

Induction motors include refrigerators and air conditioners but in many cases also include washing machines. It is in this area that a greater efficiency would yield huge return in he long run.

1.2. Digital Controlled AC Electrical Drives

Most of the motors are uncontrolled, but the share of adjustable speed induction motor drives fed from power electronic converters is steadily increasing. It is estimated that more than 50 billion dollars could be saved annually by replacing all “dumb” motors with controlled ones. Three-phase induction motors are so common in industry that in many plants no other type of electric machine can be found.

Asynchronous (AC) motors employ a simple but clever scheme of electromechanical energy conversion. In the squirrel-cage motors, which constitute a vast majority of induction machines, the rotor is inaccessible. No moving contacts are needed, which arrangement greatly increases reliability of AC motors, permitting squirrel-cage machines to be safely used in harsh environments, even in an explosive atmosphere. Also these motors can run at high speeds and withstand heavy mechanical and electrical overloads. In ***adjustable-speed drives (ACD)***, the low electric time constant speeds up the dynamic response to control commands.



Picture 1.4: *Digital Controlled Electric Drive System used as a water pump*

Although operating principles of induction motors have remained unchanged, significant technological progress has been made over the years, particularly in the last few decades, bringing smaller, lighter, more reliable and more efficient motors to the global market. Conservatively, the average life span of an induction motor can be assumed to be about 12 years (although properly maintained standard motors can work for decades).

An electric motor driving a mechanical load, directly or through a gearbox and the associated control equipment such as power converters, switches, relays, sensors and microprocessors, constitute an ***Digital Controlled Electric Drive System.*** It should be stressed that, as of today, most induction motors drives are still basically uncontrolled, the control functions limited to switching the motor on and off. In applications where the speed, position or torque must be controlled, ASDs with a dc motors are still common.

However, ASDs with induction motors have increasing popularity in industrial practice. The progress in control means and methods for these motors, particularly spectacular in the last decades, has resulted in development of several classes of ac ACDs having a clear competitive edge over the dc drives.

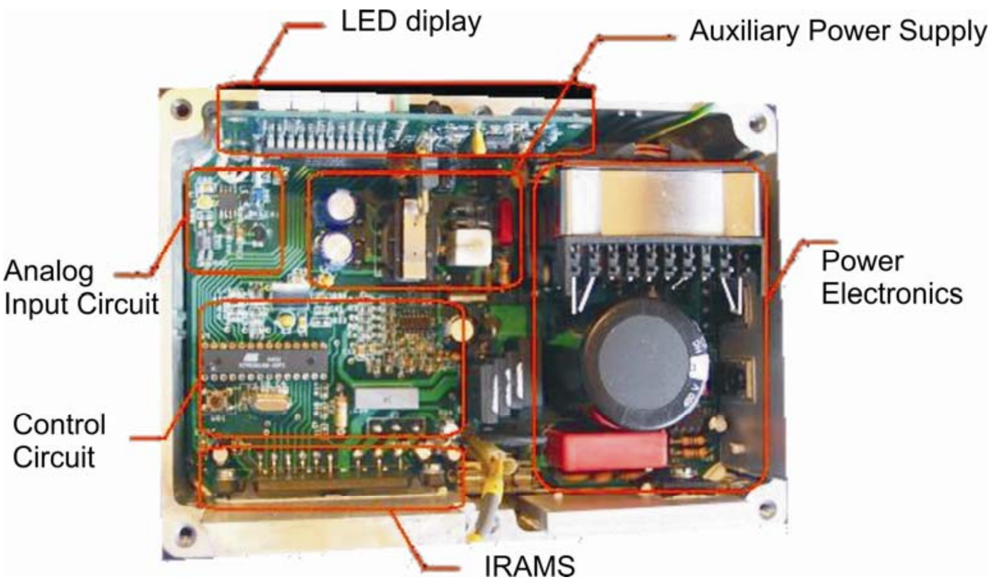
1.3. A Purpose and use of Digital Controlled AC Electrical Drive

Most of the energy consumed in industry by induction motors can be traced to high-powered but relatively unsophisticated machinery such as pumps, fans, blowers, grinders or compressors. Clearly, there is no need for high dynamic performance of these drives, but speed control can bring significant energy savings in most cases. For example, a constant-speed blower, whose output is regulated by choking the air flow in a valve, so the same valve could be kept fully open at all times if the blower were part of an adjustable-speed drive system. At a low air output, the motor would consume less power than that in the uncontrolled case, thanks to the reduced speed and torque.

High-performance induction motor drives, such as those for machine tools or elevators, in which the precise torque and position control is a must, are still relatively rare, although many sophisticated control techniques have already reached the stage particularly. For better drive ability, high-performance adjustable-speed drives are also increasingly used in electrical traction and other electrical vehicles.

Except for simple two-, three- or four-speed schemes based on pole changing, an induction motor ASD must include a variable-frequency source, the so-called ***inverter***.

Inverters are dc to ac converters, for which the dc power must be supplied by a ***rectifier*** fed from the ac power line. The so-called ***dc link***, in the form of capacitor or reactor placed between the rectifier and inverter, gives the rectifier properties of a voltage source or a current source (presented in Picture 1.5).



Picture 1.5: *Electrical circuit for 500W AC induction motor drive*

Because rectifiers draw distorted, no sinusoidal currents from the power system, passive or active filters are required at their input to reduce the low-frequency harmonic content in the supply currents. Inverters, in the other hand, generate high-frequency current noise, which must not be allowed to reach the system. Otherwise, operation of sensitive communication and control equipment could be disturbed by the resultant ***electromagnetic interference*** (EMI). Thus, effective EMI filters are needed too.

For control of ACDs, microcomputers, microcontrollers and digital signal processors (DSPs) are widely used. When sensors of voltage, current, speed or position are added, an ASD represents a much more complex and expensive proposition that does an uncontrolled motor. This is one reason why plant managers are so often wary of installing ASDs. On the other hand, the motion-control industry has been developing increasingly efficient, reliable an user-friendly systems, and in the time to come ASDs with induction motors will certainly gain a substantial share of industrial applications.

1.4. Trends in AC Electrical Drives

Physical size and weight provide the most visible evidence of the remarkable evolution of ac ***variable-frequency drives*** (VFDs) in the past 50 years. However, what's under the skin is even more dramatic for the performance, efficiency, and reliability now delivered by these motor controls. Making it all happen were advances in power-switching transistors, microprocessors, other hardware, plus software functions that ease users' concerns for drive application and maintenance.

Picture 1.6: *Industrial Variable-frequency converter*

Practical industrial variable-frequency drives (VFDs) emerged in the late 1950s, with automation of synthetic-fiber processes being one early application. But, ac drive developments started in 1965. Its first high-speed, rack-style industrial VFD was in production in 1968. It allowed induction grinder motors to operate up to 180,000 rpm. Adoption by heavier industry followed considerably later in the 1970s. Early ac drives operated in open loop and had limited performance. Developments in VFD controls in the next decade or so, coming from hardware and software, these ac drives to challenge the supremacy of dc adjustable-speed drives.

1.4.1. Control Techniques.

Following earlier R&D, first industrial installations of ***Pulse Width Modulation*** PWM drives took place in the '70s. Paper mills and subways set the basis for significant product advancement and robustness. After technology had proved its reliability and competitiveness on these demanding applications, ac drives were accepted as leading control technology, starting to replace dc drives.

The high accuracy and fast dynamic control in today's ac drives was enabled by the "advent of small, relatively inexpensive microprocessors and other high-density digital circuitry." The importance of power transistors to advancing ac drives is because IGBTs allow fairly low loss switching at rates as high as 16 kHz, permitting pulse-width modulated (PWM) drive output that results in a near-sinusoidal current in an ac motor. Besides delivering dynamic motor torque control, PWM technology allows use of higher carrier frequencies for power switching to reduce audible noise in applications requiring a low noise environment. Another significant feature of today's drives is ability to be configured to act as a bidirectional ac-to-dc power converter, which allows the flow of low-harmonic-content power either into or, by regeneration, away from a drive system.

Early ac drives operated in ***open loop control*** but had limited performance. A major step forward was development of ***field-oriented*** (flux vector) control for induction motors by Siemens in 1971—followed by others—which eventually pushed VFDs to meet or exceed dc drive performance in many applications. Sensorless-vector control (eliminating a shaft encoder) and other drive algorithm advances followed. And the evolution is accelerating.

Early ac drives (1980s) employed multiple transistors per phase due to their limited voltage and current ratings. This has changed to all-in-one packages, so that a 10kW drive today has a structure smaller than one transistor pack of the vintage drive. New generations of transistors continue to be improved as manufacturers develop smaller and more efficient power devices, ***insulated-gate bipolar transistors*** (IGBTs) remain present-day workhorse power devices.

Picture 1.7: *IRAMS – IGBTs module*

Flux-vector (field-oriented) control, ***sensorless-vector control***, and newer designs like three-level topology, matrix converter (see main article), and other approaches yet to come should continue to propel the evolution of VFDs. (By the way, “sensorless-vector control” is one of our industry’s misnomers. ***Encoderless-vector control*** is a more exact naming, as the term refers to motor control without using a shaft-mounted encoder or feedback device. However, motor parameters, such as voltage, current, and others are measured or “sensed,” as input to the drive’s dynamic controls.)

1.4.2. Use of Microprocessor.

On the control side, analog was firstly used, giving way to digital control, though initially based on integrated circuits. ***Microprocessor*** (MPU)-based digital drives came somewhat later, and at first offered only ***open-loop*** (V/Hz) control. Continuing advances in MPUs allowed adding multiple control types in the same drive, with only software parameter changes needed to switch control mode.

Picture 1.8: *ATMEL microprocessor used for digital control of Electrical Drive Systems*

Flexibility, intelligence, and user friendliness are state-of the art VFD features. Flexibility means satisfying numerous applications with one drive type that offers simple open-loop, closed-loop, flux vector, and even near-servo control. This capability lowers the drive's cost of ownership by reducing on-site inventory, operator training, and replacement part costs. MPUs and advanced diagnostic capabilities allow users to access intelligence built into a drive, thus lowering commissioning cost and downtime. Soft functions, like Automatic Motor Adaptation and software wizards, remove uncertainty in setting-up a drive/motor combination. 'User-friendly evolution' of the operator interface into software functions also shortens set-up to reduce potential operator error and simplify interaction with the drive.

Multiple control modes mean state-of-the-art in VFDs. Low-end drives typically offer V/Hz and sensorless-vector control, while higher-end drives originally with flux-vector control later added other control modes. V/Hz operation enables control of multiple motors from one drive. One drive type for different applications also helps reduce spare parts inventory. Connectivity is another core VFD feature today, so networked applications now amount to about 50% of all drives—and increases with higher-end units.

In mid 90’ DTC as an advanced technology, able to control motor torque and speed directly without need for separate control of voltage and frequency. Extremely fast torque-response time and accuracy are claimed, 'typically 10 times faster than with PWM.' DTC also is said to optimize motor flux, which improves combined energy efficiency of motor and drive. DTC does not use a modulator and works without motor shaft position or speed feedback. With DTC, 100% torque is available at zero speed and small torque increments can be controlled at low frequencies in less than 1 millisecond

1.4.3. Integrate external functions.

Future VFDs will accelerate integration of various external functions into the drive package. PLC and motion control functionality can now be implemented in a drive at a much lower total system cost. For the most-sophisticated systems application, much of logic and motion control still must be handled by peripheral electronics, but it’s expected to change rapidly. Future drive systems will be composed entirely of enclosures filled with drive units, power wiring and limiting devices, serial communications wiring, and human-machine display and interface devices.

ABB mentions rising environmental concerns and higher energy costs affecting future ac drives. They're destined for wider usage in all industries and developing markets, raising the number of motors under variable-speed control from as low as 5% worldwide, according to ABB. Also noted is continuing shrinkage of drive size, even as more miniature features are added. Future VFDs will see new, non-traditional applications—replacing other types of control (or adding first-time automation).

Future VFDs will participate more in 'green technology' developments, especially with higher energy costs and regional electricity shortages possible. Efficiency and conservation are obvious desired benefits, but lower operating costs, higher reliability, and still more compact drive designs are other promises. Research on new control topologies continues in industry and academia, while newer, existing controls—such as three-level topology and matrix converter—will find expanded application ahead.

Benefits of ***three-level topology*** include lower surge voltage at the motor, lower leakage current, and improved thermal management at low speeds. Even newer ***matrix converter*** looms especially attractive, as it offers enhanced regeneration capabilities for

VFDs and eliminates capacitors in the dc bus. Commercial release of matrix converter is on plan for 2005 for regenerative applications.

1.4.4. Yet to come

Looking a decade ahead, ABB sees VFDs getting still smarter. An extension of assisted startup will allow set-up of smart drives with minimal intervention from the user. Also, a chip embedded in the motor could automate motor identification upon drive startup.Tighter integration with control systems also lies in the future of VFDs. ABB differentiates between numerous existing 'connections' for drives and real integration that is just starting. Such real integration fully involves the drive in the programming and configuration environment of the control system. This capability will work into lower-priced products, coming down from the high-end as a natural migration of drive features.

Danfoss sees growing adoption of distributed drive systems in industry. Fueling the trend are lower-cost, higher-reliability drives that can be located next to [or on] the motor—decreasing installation costs without long motor/drive cable sets and associated conduit trays. In addition, distributed drives have the advantage of minimizing EMC problems arising from long motor cables, reducing the need for costly filters. Distributed systems also will grow from more integration of motion control and PLC functionality into VFDs.

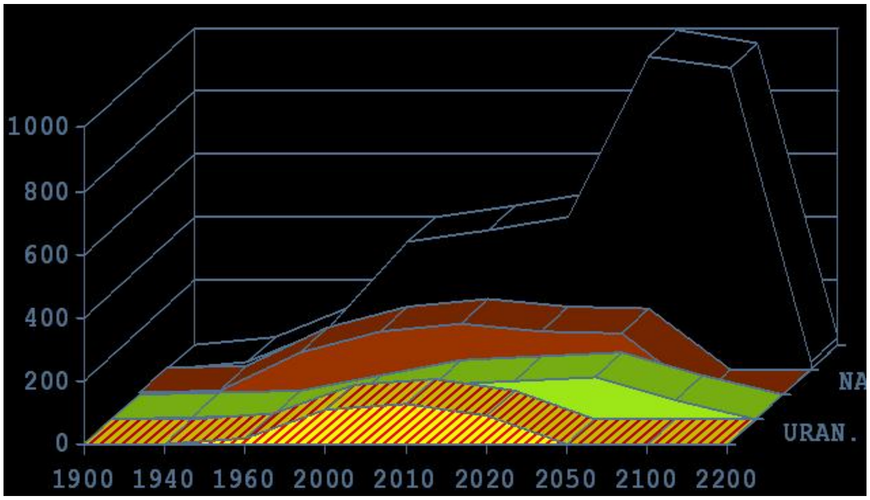
Other developments include greater use of ***Ethernet-compatible*** communication to link application information of drives into plant wide networks and wireless access to drives, especially ones in difficult locations, because ethernet represents the best opportunity for achieving an industry-standard communication system.

Meanwhile, engineers from Bosch think that today's optional drive features will become future necessities. They cite high starting torque, closed-loop speed and torque control, preventive maintenance, and direct data link to manufacturing control systems as prime examples. Other upcoming advances mentioned are:

- Active drive front-end (including harmonic limitation) slowly gaining acceptance as energy costs and grid standards increase; and
- Simple speed actuators evolving to a scalable, distributed, field-level machine/process control unit with PLC or process capability.

1.5. Developing New Technology - IEEE Future Energy Challenge

Energy saving is a modern trend in electrical engineering, experiencing a great boom in the last decades. Reasons are constant rise of energy prices and awareness of limited energy resources on Earth. The picture 1.6. presents the prediction of energy resources up to year 2200.



Picture 1.9: *Energy resources, coal, oil, gas, uranium respectively*

Saving electrical energy is of outmost importance since it is the purest form of energy that can be easily converted to any other form. According to some data, electrical drives in the developed world consume between 60% and 70% of all the electric energy produced in these countries. Some of these motors are in houses of each one of us, in our blenders, vacuum cleaners, washing machines, air-conditioners and usually we pass by them without even noticing them. Everyone household has at least one these appliances, so just imagine what amount of energy they consume and what amount of money as well.

Frost&Sullivan Market Intelligence report that motors with power under 7,5 kW present 40% of USA market, those of powers of 7.5kW to 75kW represent 31% and those over 75kW are 29% of the market. The next well-known fact is that over 90% of all the motors produced in the USA have less than one horse power and overall value of this market share is more than 7 billion US dollars annually.

Due to these facts several IEEE Societies decided to organize a biannual Students Contest in order to encourage development of new technologies and to bring dramatic improvements to low-cost single-phase motor systems for home use. Young engineers need to realize the motor system drive, to incorporate practicality, manufacturability, and affordability into competition process. But also the aim of the contest was to improve education through development of innovative team-based solutions to complex problems.

Following the market trends in Electrical Engineering the objective of this contest was to construct adjustable speed motor drive system that costing less than US $40, scaled in 1 million pieces production, for a 500 W unit. The desired motor drive system have to achieve maximum efficiency and operating requirements, but to maintain acceptable levels of performance, reliability, and safety.

1.6. Complexity of Projects in Power Electronics

The requirements of the Power Electronics Projects are always the same: more efficiency, less expanses and consumption, higher level of communication with other electrical devices, bigger working autonomy of devices etc. Running the project of generating one Power Electronics device, from the beginning to the functional prototype, is not easy at all. It is a process that can take several months long, sometimes years, and it takes lots of practical research approaches with the same objective.

Projects in Power Electronics need several different types of engineers to work on in order to generate digital drive system with certain requirements. Due to the fact, projects dealing with Power Electronics are very complex, where a variety of engineers from department of Electronics, Powers, Automation, Communication, Software design are required. It is necessary to involve all of them because of ideas needed for innovative work, sometimes because of specific point of view in breaking situations, but mostly because the final drive system is consists of plenty small electrical details, so all engineering disciplines are more than necessary.

So, because of plenty of different engineers, it is important to have one (or two) project leaders who will be responsible for people, equipment, support services, deadlines, budget etc. Their responsibility is very big because they need to make the Project structure, delegate work and responsibility to the team members, build a functional communication among team members together with working atmosphere.

Communication skills and team coordination of the manager/leader in Power Electronics Project are highly required. If gaining the same idea, project members will do same efforts on different activities. All members of the project in Electrical Engineering have to answer clearly on questions presented in Picture 1.7, showing that they understand the project objectives and aims. When find a proper answers, there are no doubts the members will bring the success as it is expected from them in each of aspects of the project.

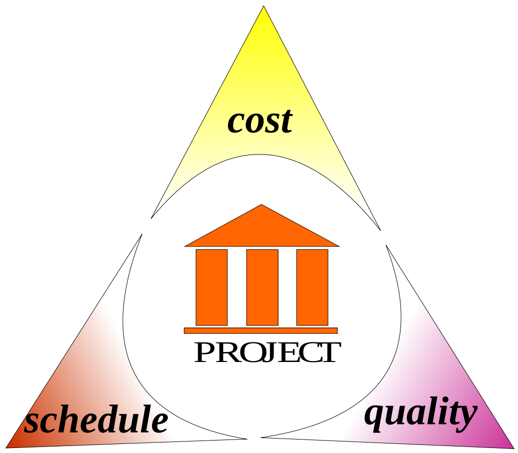
Picture 1.10: *Some questions that are asking to all project members at the beginning*

1.7. The need for a Project Management in Electrical Engineering

Projects in electrical engineering are always complex with a multitude of variables. Most application implementations cut across multiple business units, each with their unique business requirements. A new or altered application must often interface with many other applications, thereby creating an integration challenge that is difficult to estimate in both time and resources. Worse yet, the downstream impact to these other systems may cause adverse consequences that may not be felt until long after "go live" day. Further, assigning and managing scarce resources often cause a project manager to rethink his or her chosen profession.

Who among us has never been associated with a failed project? Some very extensive and well-documented surveys indicate that 84% of projects either fail outright or are delivered late. The project is like the "Bermuda Triangle": ***cost, schedule, quality***.

Effective project management begins with executive commitment and sponsorship. Without the "chief" declaring a sense of urgency and importance to the project, it is doomed to dismal results right from the start. What will be described in this master thesis is a systemic, methodical approach to making project management a part of everyday culture. When ***all*** projects in Electrical engineering field follow a standardized template, then and only then will project management evolve gradually into an everyday way of life. When an organization's maturity reaches a repeatable model, management of projects becomes an institutionalized process. Hence, results become predictable. Therefore, all three corners of the Bermuda Triangle can be achieved on ***every*** project.



Picture 1.11: *Project Management's "Bermuda Triangle"*

Here in my master thesis I will try to present how one International project was led using Project Management. That is the project which took part on Students' World Contest: "Future Energy Challenge 2005" - www.energychallenge.org , organized by four IEEE Societies. Laboratory of Digital Control of Electrical drives with its 20 students made a prototype motor system for wide range of applications (residential and industrial). This work presents the team organization, schedules, schemes, time, financial structure, in order to show what principles were used to make a final product – digital motor prototype.

Using this work, anyone from field of Electrical Engineering will be able to lead project and will spend much less energy and efforts, guided by our experience and results. Thesis is covered by theory of Project Management, and also examples are given from the IEEE project.

2. Typical Phases of Power Electronics Projects

Miyamoto Musashi,
a seventeenth-century samurai:

One can win with the long sword, and one can win with the short sword as well. For this reason, the precise size of the sword is not fixed. The way of my school is the spirit of gaining victory by any means.

2.1. Projects in Electrical Engineering

A Project is a *temporary* endeavor undertaken to create a *unique* product or service.

- ***Temporary***: every project has a definite start and end that finishes with a final product
- ***Unique***: every project is different in some distinguishing way, unique final product

Project is a temporary effort of work, a one-time event that meets the following criteria:

- Has a start and an end date.
- Has schedule, cost, and quality constraints.
- Is a unique endeavor and contains risk.
- Has a certain scope that needs to occur.

Almost any human activity that involves carrying out a non-repetitive task can be a project. But there is a big difference between carrying out a very simple project involving one or two people and one involving a complex mix of people, organizations and tasks. This has been true for millennia, but large-scale projects like the Pyramids often used rather simple control and resource techniques including brute force to 'motivate' the workforce!

In essence a project in electrical engineering can be captured on paper with a few simple elements: a start date, an end date, the tasks that have to be carried out and when they should be finished, dependencies among the activities and some idea of the resources (engineers, computer tools, technical ewuipement, etc) that will be needed during the course of the project. When the plan starts to involve different things happening at different times, some of which are dependent on each other, plus resources required at different times and in different quantities and perhaps working at different rates, the paper plan could start to cover a vast area and be unreadable.

2.2. Project Idea, Vision and Mission

When people speak of projects, they normally mean the large, expensive, visible, cast-of-dozens projects that characterize systems development. Few will argue that these do not require some level of management.

For example, the hardware is being upgraded with additional memory, additional disk capacity, and, coincidentally, a new version of the operating system. Is this a project, or can it be left to the systems people to simply do the work without imposing a project structure on them? There is a gray area between activities that are part of someone's daily responsibilities and activities that constitute a project. As a consequence, many organizations have wrestled with the question "How do we know when we have a project?" Table 2.1. provides a set of criteria and a checklist that should help provide an answer.

Table 2.1: *Project Definition Criteria*

The activities will involve more than two people.
The activities will require more than two weeks of effort.
The activities will require more than one month elapsed time.
The activities involve substantial risk.
If the activities fail, there will be a significant impact.
The activities will require coordination of two or more departments.
The activities will involve outside partners.
The activities will involve new technology.
The activities fall outside the scope of normal operations.

Each project in electrical engineering starts with an idea, mission and vision. It is mostly a final product, a service, an outcome, something which will be the result of the project. So, when one gets an idea what to develop during a project (what is a purpose of the project), it is helpful to make a steps which guide one to the final product. That is ***planning phase***. The idea should be tied to some real-time objective – something which is possible to make and place on the market.

Firstly it is needed to make a ***concept*** of final product, it is necessary to know how it will look like at the end. That is a ***vision*** of the project and the Project Leader is a person that is obsessed with the project vision. He/she cares about the project direction, always knowing the right direction. But the whole process of making the final product starting from the first idea is a project ***mission***, so the team members care that the idea should convert into the prototype – final product.

2.3. Forming the right team of engineers

Before much progress can be made, a core team needs to be formed. The team will investigate the idea further, determine the requirements, decide how to approach the implementation, and set the detailed costs and schedule. Identifying core team members is very tough job. They have to be persons that will be directly responsible for the project progress. They must be aware of the responsibility they have, as a core of the whole organization. Each of them have to be responsible for each section in one project, they will be head of departments that will together bring the technical innovations to the product.

Projects can be divided into teams or sub-teams (groups) that are small enough to foster effective communication. Cross-functional communication between engineering, testing, manufacturing, assembling, servicing, etc. is very important. Power Electronics projects are pretty complex because of lots of different engineers working together on the same mission. They are divided into groups with strict goals, objectives and results.

To accomplish the project goals, it is necessary to assemble the right Team and Leader. To select one empowered “mad person-on-a-mission” who will be the leader of the project. The leader has to believe in the project and be ready to drive it forward! It is technically experienced person, have done on several similar projects before and can recognize the right way to find solution when needed.

We use the term “***project leader***” to emphasize how important it is to exert leadership, not just managing a set of tasks. The Project Leader ensures that the Concept/Planning phase results in a project supported by a sound business case for the company. He leads the team in developing the project definition; getting the right team members involved, etc.

It’s important to realize that leadership is called for in many different situations. One may not be the overall project leader, but might be the leader of a technical sub-team. In that case one’s main objective is to lead own sub team to a sound design that meets the already streaked defined requirements.

The job of the leader has three key components:

- ***Leading the overall effort*** (“Obsessed” Leader)
- ***Dealing with individuals*** - working with team members, understanding styles, communication and listening, motivating and rewarding, managing and resolving conflicts etc.
- ***Managing the work* -** planning, delegating, tracking…

And there are people outside your company who should be considered part of the team! Vendors, customers, contractors are all influencing the outcome of the project, contributing to the work. They need to be included in the project team communication, requirements efforts, and planning. Every team should strive to involve outside experts as well. They might be outside the company; they may be just outside the project team.

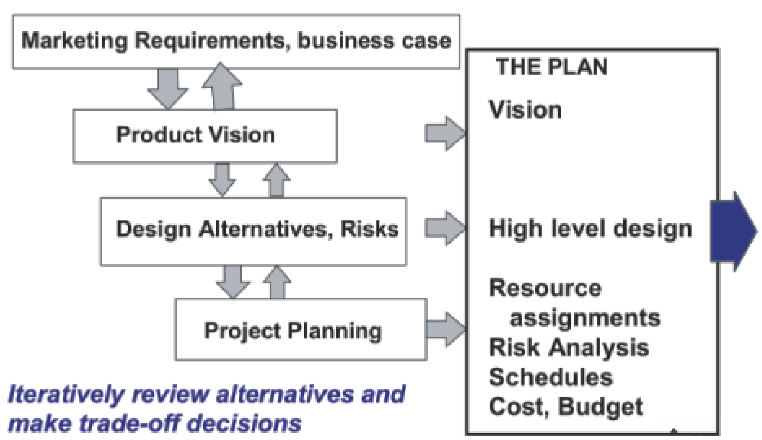
All these outside members should also be considered as potential team members.

2.4. The requirements, scope, and plan of projects in engineering

After the idea come the more specific requirements, assessing risk, and determining the scope of the project we'll commit to. Every project need to be carefully planed so, the purpose of planning is to realize how much time, technical equipment, human recourses and finance are needed. But also very important is that planning the production starts with understanding customer needs, which helps to create a project vision. It is also needed to investigate design alternatives, evaluate cost, make a work-breakdowns, schedules, risks for each alternative. Also, making tradeoff decisions and agree upon requirements are activities that must not be forgotten. In general, plan is done by experience, or estimating process due to the previous similar projects with similar elements, processes, results…

For example, if started with a project where the result will be generating some power electronics components it is necessary to involve engineers that already worked on the projects in field of Power engineering, experience enough to estimate the costs, time, human resources, risk, feasibility… The scope and plan require lots of experience, because of that most of projects have outside experts from different fields that give feasibility studies to estimate requirements.

We need data in each of these areas to make decisions about what we'll do on this project.



Picture 2.1. ***Goals balanced in the planning phase***

2.5. The schedules and costs

When all requirements are took into consideration, next step is to make a detailed work-breakdowns, to finished a schedules, budgets for each activity and a total budget, so that management upon the project can be performed easily. It is needed to execute the Concept/Planning phase of the project in such a way that the original idea is developed into a product or service concept as a technical innovation with a certain value on the market.

The steps of Planning Phase will help make sure the project is defined appropriately. It is important not to forget any step of the project, because later-one the costs can only increase, but the time will be only shorter. The final schedule will give a number of activities, so they need to be divided onto small details in order to be properly estimated. Each activity need to be defined by: time needed, costs and number of engineers working on, like presented in the Table 2.2.

Table 2.2: *Example of activity Definition*

	Activity	Time required	Costs	Human resources
1.	Assembling the circuit board	15 days	120 €	2 electronic engineers
2.	Choose the components for circuit board	20 days	250 €	4 electronic engineers

2.6. Questions to Ask at the Start of a Power Electronics Project

So how do we ensure that we define a project that will benefit the requirements and expectations, and how do project members go about answering these questions about the "project idea"?

After making the outlines of the project, creating the schedules and costs, it is expected to start with asking questions which will help to remove the doubts should or should not start with the project. If one can give direct answers to all asked questions, he/she is committed to start with project. So, what kind of questions should be asked:

What does the customer need, market orientation?
What problem are customers trying to solve?
What features are most important?
When do customers need it?

2.7. Starting with specification

A specification is the definition of the project: a statement of the problem, not the solution. Normally, the specification contains errors, ambiguities, misunderstandings. The work on the specification can seen as the first stage of Quality Assurance since you are looking for and countering problems in the very foundation of the project - from this perspective the creation of the specification clearly merits a large investment of time.

The agreement upon a written specification has several benefits:

- ***the clarity*** will reveal misunderstandings
- ***the completeness*** will remove contradictory assumptions
- ***the rigour*** of the analysis will expose technical and practical details which numbties normally gloss over through ignorance or fear
- ***the agreement*** forces all concerned to actually read and think about the details

From a purely defensive point of view, the agreed specification also affords protection against the one who have second thoughts, or new ideas, half way through the project. Once the project is underway, changes cost time (and money). The existence of a demonstrably-agreed specification enables to resist or to charge for (possibly in terms of extra time) such changes. Further, people tend to forget what they originally thought; you may need proof that you have been working as instructed.

In power electronics projects most specifications show the desired direction of the final product, so specification is making kind of a shape for final product, as presented in Table 2.3.

Table 2.2: *Example of Design specification for one Power Electronics Project*

1	Single-phase source
2	Motor mount compatibility – NEMA #48 Frame Size
3	Coupling dimensions – see specifications
4	Maximum input current 150% of full load current
5	Efficiency > 70% @ 1500 rpm (150-5000 rpm, 50W – 500W)
6	PF > 80% @ 1500 rpm, 500 W
7	IEC 320 input connection
8	Electrical noise – FCC Class A
9	Acoustic noise – Less than 50 dBA sound level measured 0.5 m from the unit
10	Self-protect against continuous stall, over temperature, or loss of input source
11	Environment – Ambient -20C to +40C; suitable for indoor or outdoor domestic applications.
12	10 years maintenance free
13	< 8 kg for complete system
14	Metal casing must be connected to safety ground

2. 8. Providing structure

If decided what the specification intends, next problem is to decide what the team actually need to do, and how to do it. Providing some form of framework, both to plan and to communicate what needs doing. Without a structure, the work is a series of unrelated tasks which provides little sense of achievement and no feeling of advancement. If the team has no grasp of how individual tasks fit together towards an understood goal, then the work will seem pointless and they will feel only frustration.

To take the planning forward, therefore, turning the specification into a complete set of tasks with a linking structure is needed. Fortunately, these two requirements are met at the same time since the derivation of such a structure is the simplest method of arriving at a list of tasks.

2.8.1. Work Breakdown Structure - WBS

Once you have a clear understanding of the project, and have eliminated the vagaries of the numbties, you then describe it as a set of simpler separate *activities*. If any of these are still too complex to easily organize, it is necessary to break them down also into another level of simpler descriptions, and so on until can manage everything. Thus one complex project is organized as a set of simple tasks which together achieve the desired result. The reasoning behind this is that the human brain can only take in and process so much information at one time. To get a real grasp of the project, one have to think about it in pieces rather than trying to process the complexity of its entire details all at once. Thus each level of the project can be understood as the amalgamation of a few simply described smaller units.

The first step in preparing a project WBS is to identify the major sets of activities. Consider a typical systems development project that also requires selection of hardware or software. Table 2.4. gives one possible list of major activities.

Table 2.4: *Typical Major Activity Groups*

- Activities that provide management, coordination, and control
- Activities to select and acquire hardware or software
- Activities to build and unit test the system
- Activities to integrate and systems test the system
- Activities that involve the users
- Activities to implement the system

In planning any project, it is needed to follow the same simple steps: if an item is too complicated to manage, it becomes a list of simpler items. People call this producing a ***work breakdown structure*** to make it sound more formal and impressive. Without following this formal approach one is unlikely to remember all the niggling little details; with this procedure, the details are simply displayed on the final lists. One common fault is to produce too much detail at the initial planning stage. You should be stop when you have a sufficient description of the activity to provide a clear instruction for the person who will actually do the work, and to have a reasonable estimate for the total time/effort involved. It is needed the former to allocate (or delegate) the task.

2.8.2. Task Allocation

The next stage is a little complicated, because of allocation the tasks to different people in the team and, at the same time, order these tasks so that they are performed in a sensible sequence.

Task allocation is not simply a case of handing out the various tasks on your final lists to the people you have available; it is far more subtle (and powerful) than that. As a manager you have to look far beyond the single project; indeed any individual project can be seen as merely a single step in your team's development. The allocation of tasks should thus be seen as a means of increasing the skills and experience of your team - when the project is done, the team should have gained. The tasks you allocate are *not* the ones on your finals lists, they are adapted to better suit the needs of your team's development; *tasks are mounded to fit people*, which is far more effective than the other way around.

Sometimes tasks can be grouped and allocated together. For instance, some tasks which are seemingly independent may benefit from being done together since they use common ideas, information, talents. One person doing them both removes the start-up time for one of them; two people (one on each) will be able to help each other.

2.8.3. Guesstimation

At the initial planning stage the main objective is to get a *realistic* estimate of the time involved in the project. Establishing this not only to assist higher management with their planning, but also to protect team from being expected to do the impossible. The most important technique for achieving this is known as: *guesstimation*.

The corollary to this is keeping records in an easily accessible form of all projects as you do them. Part of final project review should be to update personal data base of how long various activities take. Managing this planning phase is vital to be successful as a manager.

There are two practical problems in guesstimation. First, is about being too optimistic. It is human nature at the beginning of a new project to ignore the difficulties and assume best case scenario - in producing estimates (and using those of others) one must inject a little realism. In practice, one should also build-in a little slack to allow yourself some tolerance against mistakes. This is known as *defensive scheduling*. Also, in a case of eventually deliver ahead of the agreed schedule, one will be loved. Second, one will be under pressure from senior management to deliver quickly, especially if the project is being sold competitively.

2.9. Establishing Control

When the planning phase is over (and agreed), the "doing" phase begins. Once it is in motion, a project acquires a direction and momentum which is totally independent of anything predicted. To gain some hope, however, you need to establish at the start (within the plan) the means to monitor and to influence the project's progress.

There are two key elements to the control of a project

- ***milestones*** (clear, unambiguous targets of what, by when)
- established ***means of communication***

For the leader, the milestones are a mechanism to monitor progress; for the team, they are short-term goals which are far more tangible than the foggy, distant completion of the entire project. The milestones maintain the momentum and encourage effort; they allow the team to judge their own progress and to celebrate achievement throughout the project rather than just at its end.

The simplest way to construct milestones is to take the timing information from the work breakdown structure and sequence diagram. When you have guesstimated how long each sub-task will take and have strung them together, you can identify by when each of these tasks will actually be completed. This is simple and effective; however, it lacks creativity.

A second method is to construct more significant milestones. These can be found by identify stages in the development of a project which are recognizable as steps towards the final product. Sometimes these are simply the higher levels of your structure; for instance, the completion of a market-evaluation phase. Sometimes, they cut across many parallel activities; for instance, a prototype of the eventual product or a mock-up of the new brochure format.

Communication is everything. To monitor progress, to receive early warning of danger, to promote cooperation, to motivate through team involvement, all of these rely upon communication. Regular reports are invaluable - if you clearly define what information is needed and if teach your team how to provided it in a rapidly accessible form. Often these reports merely say "progressing according to schedule". These you send back, for while the message is desired the evidence is missing: you need to insist that your team monitor their own progress with concrete, tangible, measurements and if this is done, the figures should be included in the report. However, the real value of this practice comes when progress is not according to schedule - then your communication system is worth all the effort you invested in its planning. Table 2.5. gives a sample description of the activities as a communication tool in planning the project.

Activity Description

Project:	Project name	Page 1 of 1
Activity:	5.5.20.5 Evaluate Written Proposals	
Description:	Evaluate written proposals received from vendors in response to the RFP.	
Inputs:	▪ Requirements definition (5.5.5) ▪ Request for proposal (5.5.15) ▪ Written proposals from vendors	
Effort:	▪ Review vendor proposals ▪ Reject proposals that do not meet mandatory requirements ▪ Weight proposals for degree of compliance to optional requirements ▪ Prepare recommendations for short list	
Resources:	▪ Project manager (20%) ▪ Hardware analyst (80%)	
Outputs:	▪ Evaluation results consisting of: ▪ Short list of qualified vendors or ▪ Rejection of all proposals ▪ Letters to vendors informing them of evaluation results	

Table 2.5: *Sample Activity Description*

2.10. Planning phase

At the planning stage, you can deal with far more than the mere project at hand. You can also shape the overall pattern of your team's working using the division and type of activities you assign.

The team must be involved in the planning of projects, especially in the lower levels of the work breakdown structure. Not only will they provide information and ideas, but also they will feel ownership in the final plan. This does not mean that your projects should be planned by committee - rather that you, as manager, plan the project based upon all the available experience and creative ideas. As an initial approach, you could attempt the first level(s) of the work breakdown structure to help you communicate the project to the team and then ask for comments. Then, using these, the final levels could be refined by the people to whom the tasks will be allocated. However, since the specification is so vital, *all* the team should vet the penultimate draft.

With planning, projects can run on time and interact effectively with both customers and suppliers. Everyone involved understands what is wanted and emerging problems are seen (and dealt with) long before they cause damage. If one wants project to run this way - then one’s must invest time in planning.

2.11. Testing and Quality

No plan is complete without explicit provision for testing and quality. A wise manager will know that this should be part of each individual phase of the project. This means that no activity is completed until it has passed the (objectively) defined criteria which establishes its quality, and these are best defined (objectively) at the beginning as part of the planning.

When devising the schedule therefore you must include allocated time for this part of each activity. Thus your question is not only: "how long will it take", but also: "how long will the testing take". By asking both questions together you raise the issue of "how do we know we have done it right" at the very beginning and so the testing is more likely to be done in parallel with the implementation.

Another reason for stating the testing criteria at the beginning is that you can avoid futile quests for perfection. If you have motivated your team well, they will each take pride in their work and want to do the best job possible. The same is also true when choosing the tools or building-blocks of your project. While it might be nice to have use of the most modern versions, or to develop an exact match to your needs; often there is an old/existing version which will serve almost as well (sufficient for the purpose), and the difference is not worth the time you would need to invest in obtaining or developing the new one. A related idea is that you should discourage too much effort on aspects of the project which are idiosyncratic to that one job. In the specification phase, you might try to eliminate these through negotiation with the customer; in the implementation phase you might leave these parts until last. The reason for this advice is that a *general* piece of work can be tailored to many specific instances; thus, if the work is in a general form, you will be able to rapidly re-use it for other projects.

On the other hand, if you produce something which is cut to fit exactly one specific case, you may have to repeat the work entirely even though the next project is fairly similar. At the planning phase, a manager should bare in mind the future and the long-term development of the team as well as the requirements of the current project.

2.12. “Fighting” for time

As a project manager regulating the pressure and working load which is imposed upon team; he/she must protect them from the unreasonable demands of the rest of the Institution working in. Once have arrived at what manager considers being a realistic schedule, fighting for it. He/she never let the outside world deflect from what he/she knows to be practical. If they impose a deadline which is impossible, one will need to give some room for compromise, however, since a flat **NO** will be seen as obstructive. Since one wants to help the Institution, one should look for alternative positions, offer a prototype service or product at an earlier date. This might, in some cases, be sufficient for the customer to start the next stage of his/her own project on the understanding that your project would be completed at a later date and the final version would then replace the prototype.

In power electronics projects the complexity of the product, or the total number of units, might be reduced. This might, in some cases, be sufficient for the customer's immediate needs. Future enhancements or more units would then be the subject of a subsequent negotiation which, you feel, would be likely to succeed since you will have already demonstrate your ability to deliver on time. You can show on an alternative schedule that the project could be delivered by the deadline if certain (specified) resources are given to you or if other projects are rescheduled. Thus, you provide a clear picture of the situation and a possible solution; it is up to your manager then how he/she proceeds.

2.13. Planning for error

Recognizing that errors will occur is the reason for implementing a monitoring strategy on the project. Thus when the inevitable does happen, one can react and adapt the plan to compensate. However, being carefully in considering errors in advance can make changes to the original plan to enhance its tolerance. Quite simply, planning should include time where one stand back from the design and ask: "*what can go wrong?*"; indeed, this is an excellent way of asking team for their analysis of the plan.

In power electronics projects, if properly structured, mistakes can be avoided if there is reserved plan (plan B). Very often each design have several alternatives, and if something goes wrong with the first component it is always easy to switch on another one.

2.14. Closing out and deploying a Power Electronics projects

One of the characteristics that distinguish a project from other forms of business activity is that a project ends. Once its purpose has been satisfied, it is closed and becomes part of organizational history. Unfortunately, too many projects seem to drag on forever, coming to a grudging conclusion more by attrition than by design.

At the end of any project, time allocation should be done, in order to review the lessons and information on both the work itself and the management of that work: an open meeting, with open discussion, with the whole team and all customers and suppliers. If one thinks that this might be thought a waste of time by own manager, it is need to think of the effect it will have on future communications with customers and suppliers. With all these considerations in merely the "planning" stage of a project, it is perhaps surprising that projects get done at all. In fact projects do get done, but seldom in the predicted manner and often as much by brute force as by careful planning. The point, however, is that this method is non-optimal. Customers feel let down by late delivery, staff are demotivated by constant pressure for impossible goals, corners get cut which harm your reputation, and each project has to overcome the same problems as the last.

Just as there are proper ways to define, plan, and execute projects, so there is a right way to end them. Closing a project involves three major steps: gaining client concurrence that the project is over, capturing lessons learned during the project, and completing administrative closeout.

Power electronics projects are finished when the prototype is finished, together with technical documentation, final report, but practical manual as well. The conference papers are a second effect on power electronics projects, so each project brings several innovations that can be presented through conferences, but later upgraded in other new projects.

3. The role of Project Managers and Team Leaders in a project

Richard Pascale:
Managers do things right,
While leaders do the right thing

Leadership is just one of the many assets a successful manager must possess. Care must be taken in distinguishing between the two concepts. The main aim of a manager is to maximize the output of the organization through administrative implementation. To achieve this, managers must undertake the following functions: organization, planning, staffing, directing, controlling…

Leadership is just one important component of the directing function. A manager cannot just be a leader, he also needs formal authority to be effective. *"For any quality initiative to take hold, senior management must be involved and act as a role model. This involvement cannot be delegated."* [1] Managers think incrementally, while leaders think radically.

This means that managers do things by the book and follow company policy, while leaders follow their own intuition, which may in turn be of more benefit to the company. A leader is more emotional than a manager. *"Men are governed by their emotions rather than their intelligence."* [3] This quotation illustrates why teams choose to follow leaders. *"Leaders stand out by being different. They question assumption and are suspicious of tradition. They seek out the truth and make decisions based on fact, not prejudice. They have a preference for innovation."* [4]

In some circumstances, leadership is not required. For example, self motivated groups may not require a single leader and may find leaders dominating. The fact that a leader is not always required proves that leadership is just an asset and is not essential. Each of the projects needs both, managers and leaders. Project managers can be found in all industries. Their numbers have grown rapidly as industry and commerce has realized that much of what it does is project work. And as project-based organizations have started to emerge, project management is becoming established as both a professional career path.

3.1. Power Electronics Engineer as a Manager

Before starting any activity it is necessary to stop and think about it: what is the objective, how can it be achieved, what are the alternatives, who need to be involved, what will it cost, is it worth doing? When you have a ***plan*** it is necessary to stop and think about how to ensure that your plan is working. You must find ways of ***monitoring*** your progress, even if it is just setting deadlines for intermediate stages, or counting customer replies, whatever: choose something which displays progress and establish a procedure to ensure that happens. But before you start, set a date on which it is necessary to stop and **rethink** your plan in the light of the evidence gathered from the monitoring.

Whenever you have something to do consider not only the task but first the method. Thus if there is a meeting to decide the cover for the new product you should initially ignore anything to do with marketing slogans and decide:

1) how should the meeting be held,
2) who can usefully contribute,
3) how will ideas be best generated,
4) what criteria are involved in the decision,
5) is there a better way of achieving the same end.

Many of these decisions do not have a single "right" answer, the point is that they need to have "an" answer so that the task is accomplished efficiently. Once the questions are posed, you can be creative. The manger of a small team has three major roles to play: to be a planner, provider and a protector.

3.1.1. Manager as a Planner

A Manager has to take a long-term view; indeed, the higher you rise, the further you will have to look. While a team member will be working towards known and established goals, the manager must look further ahead so that these goals are selected wisely. By thinking about the eventual consequences of different plans, the manager selects the optimal plan for the team and implements it. By taking account of the needs not only of the next project but the project after that, the manager ensures that work is not repeated nor problems tackled too late, and that the necessary resources are allocated and arranged.

In electrical engineering it is important always to think of entire project, and to try to locate the current activity in a long term plan. For example, a testing phase is at the beginning of every big activity, so estimating the length of testing is necessary to take into account all the time, and if someone is not doing it well, there is a time to replace the member of the testing team.

3.1.2. Manager as a Provider

The Manager has access to information and materials which the team needs. Often he/she has the authority or influence to acquire things which no one else in the team could. This role for the manager is important simply because no one else can do the job; there is some authority which the manager holds uniquely within the team, and the manager must exercise this to help the team to work.

Not only authority, but experience is quite important in engineering projects, so the directions set-up by manager is usually the right one. Manager is one that gives the support in additional literature, specialized papers or software that will help other members on the project to respond to the project requirements.

3.1.3. Manager as a Protector

The team needs security from the vagaries of less enlightened managers. In any company, there are short-term excitements which can deflect the work-force from the important issues. The manager should be there to guard against these and to protect the team. If a new project emerges which is to be given to your team, you are responsible for costing it (especially in terms of time) so that your team is not given an impossible deadline. If someone in your team brings forward a good plan, you must ensure that it receives a fair hearing and that your team knows and understands the outcome. If someone is in your team has a problem at work, you have to deal with it.

3.2. Manager’s role in the Power Electronics project

When you are struggling with a deadline or dealing with delicate decisions, the last thing you want to deal with is "people". When the work is really on and the struggle is undecided, you want your team to act co-operatively, quickly, rationally, you do not want a worker who avoids work, you do not want your key engineer being tired all day. But this is what happens, and as a manager it is necessary to deal with it. Few "people problems" can be solved quickly, some are totally beyond your control and can only be contained; but you do have influence over many factors which affect your people and so it is your responsibility to ensure that your influence is a positive one.

You can only underestimate the impact which you personally have upon the habits and effectiveness of your group. As the leader of a team, you have the authority to sanction, encourage or restrict most aspects of their working day, and this places you in a position of power - and responsibility.

3.2.1. Motivation

When thinking about motivation it is important to take the long-term view. What is needed is a sustainable approach to maintain enthusiasm and commitment from your team. This is not easy; but it is essential to effectiveness. What can influence is the local environment and particularly the way in which you interact with your team. The positive motivators are: achievement, recognition, the work itself, responsibility, and advancement. These are what your team needs; loads-o-money is nice but not nearly as good as being valued and trusted.

As the manager, you set the targets - and in selecting these targets, you have a dramatic effect upon your team's sense of ***achievement***. If you make them too hard, the team will feel failure; if too easy, the team feels little. Ideally, you should provide a series of targets which are easily recognized as stages towards the ultimate completion of the task. Thus progress is punctuated and celebrated with small but marked achievements. If you stretch your staff, they know you know they can meet that challenge.

Recognition is about feeling appreciated. It is knowing that what you do is seen and noted, and preferably by the whole team as well as by you, the manager. In opposite terms, if people do something well and then feel it is ignored - they will not bother to do it so well next time (because "no one cares").

The feedback you give your team about their work is fundamental to their motivation. They should know what they do well (be positive), what needs improving (be constructive) and what is expected of them in the future (something to aim at). And while this is common sense, ask yourself how many on your team know these things, right now? Perhaps more importantly, for which of your team could you write these down now (try it)?

Your staff need to know where they stand, and how they are performing against your (reasonable) expectations. You can achieve this through a structured review system, but such systems often become banal formalities with little or no communication. The best time to give feedback is when the event occurs. Since it can impact greatly, the feedback should be honest, simple, and always constructive. If in doubt, follow the simple formula of:

1. highlight something good
2. point out what needs improving
3. suggest how to improve

You must always look for something positive to say, if only to offer some recognition of the effort which has been put into the work. When talking about improvements, be specific: this is what is wrong, this is what I want/need, this is how you should work towards it. Never say anything as unhelpful or uninformative as "do better" or "shape up" - if you cannot be specific and say how, then keep quiet. While your team will soon realize that this IS a formula, they will still enjoy the benefits of the information (and training). You must not stint in praising good work. If you do not acknowledge it, it may not be repeated simply because no one knew you approved.

The work itself should be interesting and challenging. Interesting because this makes staff actually engage their attention; challenging because this maintains the interest and provides a sense of personal achievement when the job is done. But few managers have only interesting, challenging work to distribute: there is always the boring and mundane to be done. You must actually consider how interesting are the tasks you assign and how to deal with the boring ones.

3.2.2. Defining Problems

We are going to look at a simple system for addressing people-problems. It is a step-by-step procedure which avoids complex psychological models (which few managers can/should handle) and which focuses upon tangible (and so controllable) quantities. In any group of people there are bound to be problems - as a manager, you have to solve or at least contain them. You ignore them at your peril.

Before proceeding, it is worth checking that the problem is real - some "problems" are more appearance than substance, some are not worth you time and effort. So, stage 1 is to monitor the identified problem to check that it is real and to seek simple explanations.

Stage 2 is often missed. This sort of interview can be quite difficult because you run the danger of making personal criticism. Now you may feel that problem-maker deserves criticism, but does it actually help? Your objective is to get problem-maker to work well, not to indulge in personal tyranny. If you make it personal, problem-maker will be defensive. He/she will either deny the problem, blame someone else, blame the weather, tell you that he/she knows best or some combination of the above. If, on the other hand, you present the situation in terms of the specific events, you can focus upon problem-maker 's own view of the problem (why is this happening?) and his/her own solution (what can problem-maker do about it - can you help?).

Stage 2 will sometimes be sufficient. If problem-maker had not realised there was a problem, he/she might act quickly to solve it. If he/she had thought his/her behaviour would pass unnoticed, he/she now knows differently. By giving the responsibility for solving his own problem, you can actually motivate him/her beyond the specific problem: he/she may suggest on improved reporting system, or a short training course to deal with a technical short-coming. Finally, the demonstration alone that you are interested in problem-maker 's work may be enough to make him/her improve. Never assume that you know better, always ask first - then if no solution is forthcoming, proceed to ...

Stage 3 is the analysis stage and is based upon a simple model of behaviour: every action is preceded by a trigger, and is followed by a consequence or payoff. Sometimes, good behaviour is blocked by negative payoffs.

Once you have analysed the problem, stage 4 is to find a solution. With most people-problems at work, you will find that the "bad" behaviour is reinforced by a payoff which that person finds attractive. There are two solutions: 1) modify the payoff either by blocking it, or by adding another consequence which is negative, or 2) create a positive payoff for the alternative, desired "good" behaviour. In the long term, the latter is preferable since it is better for motivation to offer encouragement rather than reprimand; optimally you should implement both.

This is where manager need to be creative, providing the solution. It is best to work on one problem at a time because this simplifies the analysis. Further, by addressing one, other related problems are often affected also.

Stage 5 is necessary because such plans do not always work. You must continue to monitor the problem and after a trial period, review your progress. If the plan is working, continue; if the plan has failed, devise a new one; if the plan has worked, look for a new problem to solve.

3.2.3. Seeking the Solutions

The range of problems is so large, that it is impossible to offer more than generalities as advise. Each person is different, each situation is different, so each solution must be carefully crafted. This being said, here are a few ideas. Look for aspects of motivation - any problem which stems from lack of commitment or interest can only successfully be addressed by providing motivation, and any of the motivators described earlier can be applied.

Be flexible with regards to personal problems. When circumstances and the human factor impinge upon your ordered plans, adapt; since you cannot change it, work with it. Focus upon the problem (say, schedule slippage) and deal with that in the existing situation. On a larger scale, look carefully at the "systems" which exist in your team, at those work practices which you and they follow through habit. Some of these can work against you, and the team. For instance, the way you hold team meetings may suppress contributions (at 4 o'clock on a Friday, say); the way you reward the exceptional may demotivate those responsible for the mundane.

Take a long term view. Constant pressure will eventually destroy your team members. If you acknowledge that a relaxed yet engaged workforce is (say) 10% more efficient than one which is over-stressed and fretful, then you should realize that this amounts to half-a-day per week. So why not devote half-a-day to: peer-group teaching, brainstorming on enhanced efficiency, visits to customers (internal and external), guest lectures on work tools, or all four on a four-weekly cycle. You lose nothing if you gain a skilled, committed, enthusiastic team.

Finally, look carefully at how you behave and whether the current situation is due to your previous inattention to the human factor: you might be the problem, and the solution.

3.3. Manager’s problem of delegation

Delegation is a skill of which all of us heard - but which few understand. It can be used either as an excuse for dumping failure onto the shoulders of subordinates, or as a dynamic tool for motivating and training your team to realize their full potential. Delegation underpins a style of management which allows your staff to use and develop their skills and knowledge to the full potential. Without delegation, you lose their full value.

Delegation is primarily about entrusting your authority to others. This means that they can act and initiate independently; and that they assume responsibility *with you* for certain tasks. If something goes wrong, you remain responsible since you are the manager; the trick is to delegate in such a way that things get done but do not go (badly) wrong.

3.3.1. The objective of delegation

The objective of delegation is to get the job done by someone else. Not just the simple tasks of reading instructions and turning a lever, but also the decision making and changes which depend upon new information. With delegation, your staff have the authority to react to situations without referring back to you. To enable someone else to do the job for you, you must ensure that:

- they know what you want

- they have the authority to achieve it
- they know how to do it.

These all depend upon communicating clearly the nature of the task, the extent of their discretion, and the sources of relevant information and knowledge.

3.3.2. Delegation - Information

Such a system can only operate successfully if the decision-makers (your staff) have full and rapid access to the relevant information. This means that you must establish a system to enable the flow of information. This must at least include regular exchanges between your staff so that each is aware of what the others are doing. It should also include briefings by you on the information which you have received in your role as manager; since if you need to know this information to do your job, your staff will need to know also if they are to do your (delegated) job for you.

One of the main claims being made for computerized information distribution is that it facilitates the rapid dissemination of information. You may not believe this vision, but you should understand the premise. If a manager restricts access to information, then only he/she is able to make decisions which rely upon that information; once that access is opened to many others, they can make decisions too - and challenge those of the manager according to additional criteria.

3.3.3. Effective control of delegation

One of the main phobias about delegation is that by giving others authority, a manager loses control. This need not be the case. If you train your staff to apply the same criteria as you would yourself (by example and full explanations) then they will be exercising your control on your behalf. And since they will witness many more situations over which control may be exercised (you can't be in several places at once) then that control is exercised more diversely and more rapidly than you could exercise it by yourself. In engineering terms: if maintaining control is truly your concern, then you should distribute the control mechanisms to enable parallel and autonomous processing.

3.3.4. Staggered Development in delegation

To understand delegation, you really have to think about people. Delegation cannot be viewed as an abstract technique, it depends upon individuals and individual needs. Let us take a lowly member of staff who has little or no knowledge about the job which needs to be done.

The key is to delegate gradually. If you present someone with a task which is daunting, one with which he/she does not feel able to cope, then the task will not be done and your staff will be severely demotivated. Instead you should build-up gradually; first a small task leading to a little development, then another small task which builds upon the first; when that is achieved, add another stage; and so on. This is the difference between asking people to scale a sheer wall, and providing them with a staircase. Each task delegated should have enough complexity to stretch that member of staff - but only a little.

3.3.5. Outcomes and Failures in Delegating

Let consider undoubtedly high standards. When delegate a job, it does not have to be done as well as you could do it (given time), but only as well as necessary: never judge the outcome by what you expect you would do (it is difficult to be objective about that), but rather by fitness for purpose. When you delegate a task, agree then upon the criteria and standards by which the outcome will be judged. You must enable failure. With appropriate monitoring, you should be able to catch mistakes before they are catastrophic; if not, then the failure is yours.

3.3.6. What to delegate

There is always the question of what to delegate and what to do yourself, and you must take a long term view on this: you want to delegate as much as possible to develop you staff to be as good as you are now. The starting point is to consider the activities you used to do before you were promoted. You used to do them when you were more junior, so someone junior can do them now. Tasks in which you have experience are the easiest for you to explain to others and so to train them to take over. You thus use your experience to ensure that the task is done well, rather than to actually perform the task yourself. In this way you gain time for your other duties and someone else becomes as good as your once were (increasing the strength of the group).

Tasks in which your staff have more experience must be delegated to them. This does not mean that you relinquish responsibility because they are expert, but it does mean that the default decision should be theirs. To be a good manager though, you should ensure that they spend some time in explaining these decisions to you so that you learn their criteria. Decisions are a normal managerial function: these too should be delegated - especially if they are important to the staff. In practice, you will need to establish the boundaries of these decisions so that you can live with the outcome, but this will only take you a little time while the delegation of the remainder of the task will save you much more.

In terms of motivation for your staff, you should distribute the more mundane tasks as evenly as possible; and sprinkle the more exciting onces as widely. In general, but especially with the boring tasks, you should be careful to delegate not only the performance of the task but also its ownership. Task delegation, rather than task assignment, enables innovation. The point you need to get across is that the task may be changed, developed, upgraded, if necessary or desirable. So someone who collates the monthly figures should not feel obliged to blindly type them in every first-Monday; but should feel empowered to introduce a more effective reporting format, to use Computer Software to enhance the data processing, to suggest and implement changes to the task itself.

3.3.7. Delegation - When all is done for the Manager

Once the Manager has delegated everything, what does he do then? He/she still need to monitor the tasks he/she has delegated and to continue the development of staff to help them exercise their authority well. There are managerial functions which you should never delegate - these are the personal/personnel ones which are often the most obvious additions to your responsibilities as you assume a managerial role. Specifically, they include: motivation, training, team-building, organization, praising, reprimanding, performance reviews, promotion.

As a manager, you have a responsibility to represent and to develop the effectiveness of your group within the company; these are tasks you can expand to fill your available time - delegation is a mechanism for creating that opportunity.

3.4. Power Electronics Engineer as a Leader

Leadership is a way of focusing and motivating a group to enable them to achieve their aims. It also involves being accountable and responsible for the group as a whole. A leader should: provide continuity and momentum and to be flexible in allowing changes of direction. Ideally, a leader should be a few steps ahead of their team, but not too far for the team to be able to understand and follow them. Leaders must have a wide range of skills, techniques and strategies. These include:

- Planning
- Communication skills
- Organization
- Awareness of the wider environment in which the team operates.

There is a debate about whether leadership should be concentrated in one person or distributed among members of the team. Traditionally, a permanent team leader would be appointed by more senior levels of management or elected by the group. This technique relies on the assumption that one single person has all the strengths required. However, it has been argued that "*on the best teams, different individuals provide occasional leadership, taking charge in areas where they have particular strengths, so no one is the permanent leader, because that person would then cease to be a peer and the team interaction would begin to break down*" [1].

If speaking about engineer as a leader, it is a person that clearly understands the final prototype, knows most of the steps, even several steps further more. A leader - an obsessed engineer will be the one who brings ideas and solving potential problems on the project, but spending not as much time as managers do with a team.

This approach would eliminate the problem of a leader being isolated from group. It must be emphasized, however, that continuity and focus of the group must not be lost. Thus, in our opinion, the best compromise may be to have a permanent leader who is flexible enough not only to delegate responsibility for individual tasks, but also to let others take leadership of the team as required. A leader is someone who people naturally follow through their own choice, whereas a manager **must** be obeyed. A manager may only have obtained his position of authority through time and loyalty given to the company, not as a result of his leadership qualities. A leader may have no organizational skills, but his vision unites people behind him.

3.4.1. Leadership Attitudes

One way of looking at different leadership styles is in terms of **task orientation** versus **employee orientation**.

- Task Orientation or Directive Behaviour. This reflects how much a leader is concerned with the actual task at hand and ensuring that those following him complete it.
- Employee Orientation or Supportive Behaviour. This reflects how much a leader is concerned for the people around him, providing support and encouragement for them.

The combination of these two effects lead to the following diagram:

1. Country Club Management 2. SUPPORTING	**1. Team Management 2. COACHING**
1. Impoverished Management 2. DELEGATING	**1. Authority/Obedience Management 2. DIRECTING**

This diagram can be used in two ways:

- As a guide to how effective your leadership style is. Your general attitude to the leadership of the group will fall into one of these categories.
- As a guide to how best to lead different individuals using different styles to make the most efficient use of both their, and your, time and talents.

If you have a group of widely differing levels of ability, confidence and commitment, you may want to lead them each with a different style.

Directing. A team member who has a lot of enthusiasm for the job but not much actual ability, for example a new start, will need to be directed. You will not need to spend much time giving encouragement or coaxing them along. You will however have to tell them what to do next after they complete every task, and how to do the tasks set.

Coaching. After being in the group for a while, somebody might begin to lose confidence and therefore motivation, as they still can't seem to do the work they want to do. At this stage you will need to coach them along. You will still need to tell them what to do at virtually every point along the way, while taking care to encourage them and praise them at every turn.

Supporting. Gradually the team member's technical ability will increase until they are at a stage where they can actually do everything required of them, however they may still lack the confidence to actually do it off their own backs. You should no longer have to tell them what to do, although they may think otherwise. You should seek their opinions on the next stage, and be seen to take notice of their ideas.

Delegating. A technically competent person's confidence will gradually grow until they feel able to work completely on their own. You should now be able to delegate specific areas of work to them and feel little need to tell them either what to do or to praise them as frequently for doing it. The time that you don't have to spend "leading" these members of the group can be spent with the less experienced group members, or on the work that you need to do.

3.4.2. Leadership Styles

The role of leadership in management is largely determined by the organisational culture of the one team. It has been argued that managers' beliefs, values and assumptions are of critical importance to the overall style of leadership that they adopt.There are several different leadership styles that can be identified within each of the following Management techniques. Each technique has its own set of good and not-so-good characteristics, and each uses leadership in a different way.

The autocratic leader dominates team-members, using unilateralism to achieve a singular objective. This approach to leadership generally results in passive resistance from team-members and requires continual pressure and direction from the leader in order to get things done. Generally, an authoritarian approach is not a good way to get the best performance from a team.There are, however, some instances where an autocratic style of leadership may not be inappropriate. Some situations may call for urgent action, and in these cases an autocratic style of leadership may be best. In addition, most people are familiar with autocratic leadership and therefore have less trouble adopting that style. Furthermore, in some situations, sub-ordinates may actually prefer an autocratic style.

The democratic leader makes decisions by consulting his team, whilst still maintaining control of the group. The democratic leader allows his team to decide how the task will be tackled and who will perform which task. A good democratic leader encourages participation and delegates wisely, but never loses sight of the fact that he bears the crucial responsibility of leadership. He values group discussion and input from his team and can be seen as drawing from a pool of his team members' strong points in order to obtain the best performance from his team. He motivates his team by empowering them to direct themselves, and guides them with a loose reign.However, the democrat can also be seen as being so unsure of himself and his relationship with his sub-ordinates that **everything** is a matter for group discussion and decision. Clearly, this type of "leader" is not really leading at all.

3.4.3. Becoming a Leader

A leader may not always be a manager, and one day you may see an opportunity to lead a project or team within your group, but when do decide the time is right and how do you go about becoming the leader? Here are the steps to become an effective leader:

1. Identify team members and resources willing to support your leadership. Clearly, change may be resisted by some people or organisations, but if you can find enough support this resistance can be overcome. Note that the support of your team may not be enough if you do not have the support of authority (the boss for example) or the physical/financial resources to accomplish your goals.
2. A crucial step is to empathise with others and assess their understanding of the situation. This will help you understand how to influence these people. Many ways of doing this are available: memos, phone calls and informal chats are a few examples.
3. Now you should open a discussion which the members. Clearly, without open discussion some people may feel neglected or excluded. By getting everyone's views it is more likely that you will be able to alter them and get what you want. Now you must convince the others that your view is the one most likely to achieve a favourable outcome for everyone. This may be easy if everyone shares the same goals, or it may be difficult. In the end some form of 'payment' may be required, such as a promise of a favour, to convince certain members. This is easy if you are in a position of power, if not, make sure the cost to yourself is not too high.
4. Having convinced the team of your leadership, encourage team communication to build a team identity. You should also try to motivate the team appropriately.
5. Plan and organise the team by setting realistic goals. However do not give too much or too little guidance, experienced workers may resent you treating them like new-recruits, and this can undermine your leadership.
6. When goals are achieved recognise and reward the team. Do not expect the team to exceed them - this will undermine your leadership and the team will lose trust in you. Of course you may decide that the goals are unachievable or insufficient, but any re-definition of these goals should be done carefully and with team co-operation.

3.5. The image of the Leader in Engineering

The leader is a multicultural person, that develops own cultural sensitivity by observing and understanding cultural differences. But also appreciates the wide variety of people who fit under the diversity umbrella, such as recognizing that workers differ from one another. The leader recognizes differences in cultural attitudes and values in such dimensions as formality versus informality and attitude toward time, and also establishes a good strategy for motivating people from different cultures including identifying their motivation.

Engineer can be a leader if can understand the need of variety of engineers on the same project working with the same value of motivation gaining the same objective. One of the most important characteristic is an experience, which will help an engineer-leader to estimate number of engineers, time, finance and make a functional communication among team members.

Here are presented some main characteristics of an effective leader:

Guiding vision. Effective leaders know what they want to do, and have the strength of character to pursue their objectives in the face of opposition and in spite of failures.

Goals. The effective leader establishes achievable goals.

Integrity. Because they know who they are, effective leaders are also aware of their weaknesses. They only make promises they can follow through on.

Honesty. Leaders convey an aura of honesty in both their professional and their personal lives. Effective leaders earn the trust of their followers and act on behalf of their followers.

Self-Confidence. How can you build up your self-confidence? **Thinking positive** thoughts about yourself or **writing down** your good points to boost your self-confidence, maybe **visualizing** a more powerful you, or maybe **following** a few easy victories with bigger challenges, sometimes is good to try with **dealling** creatively with the emotional turmoil associated with adversity

Communication. Leaders use heavy-impact, embellishing language full of metaphors, analogies, and anecdotes for inspiring group members. They rather use skillfully body language or power-oriented language style for a comprehensive approach. Leaders often avoid detractors such as junk words, vocalized pauses, insipid clichés threadbare anecdotes, and turning to many nouns into verbs.

Curiosity. Leaders are learners. They wonder about every aspect of their charge. They find out what they need to know in order to pursue their goals.

Risk. Effective leaders take calculated risks when necessary to achieve their objectives. If a mistake is made, the effective leader will learn from the mistake and use it as an opportunity to explore other avenues.

Thinking. Leaders pay attention to their intuition in order to recognize the importance of being a big thinker for effective leadership. They are not afraid to ask tough questions, and enhance their ability to read people whenever possible.

Dedication. The effective leader is dedicated to his or her charge, and will work assiduously on behalf of those following. The leader gives himself or herself entirely to the task when it is necessary.

Charisma. This may be the one attribute that is the most difficult to cultivate. It conveys maturity, respect for your followers, compassion, a fine sense of humor, and a love of humanity. The result is that leaders have the capability to motivate people to excel. **Charisma** is recognized as a major leadership quality, because to lead others without charisma puts the leader at a disadvantage. Many of the qualities associated with charisma can be developed and most effective method of developing or enhancing charisma include learning to express the feelings more assertively and becoming more enthusiastic, optimistic and energetic.

Listening. Leaders Listen! This is the most important attribute of all, listen to your followers.

Passion. Effective leaders believe passionately in their goals. They have a positive outlook on who they are, and they love what they do. Their passion for life is a guiding star for others to follow, because they radiate promise!

The image of the leader is present in any occation. **The way leader stand or sit** indicates whether he/she is an open person, easily approachable, also says whether is friendly. Sometimes that can tells others about ability to be a good team player or maybe suggests about being frank and honest, also tells others what the person (the leader) really thinks of them shows whether he/she is part of the team. Also **The way leader dresses** indicates whether person has conventional ideas or whether he/she is “a radical”, that can shows his/her neatness, or just suggests whether person (leader) will fit in with the company's image. Sometimes dressing makes a statement about whether or not person cares enough to find out about the company, its image and its objectives and shows indirectly whether person is confident, whether or not believes in himself/herself. **The way of writing conveys** can indicate whether person is warm and friendly or appear cool and reserved, whether is dynamic and energetic or are lethargic and procrastinate. An image of someone as either intuitive in solving problems, or logical, solving problems step by step, whether or not he/she wants to communicate with others, whether is trying to avoid conflict or seek it, and at least whether is materialistic or idealistic.

3.6. Time management for Managers and Leaders

Time Management is about controlling the use of most valuable (and undervalued) resource. The absence of Time Management is characterized by last minute rushes to meet dead-lines, meetings which are either double booked or achieve nothing, days which seem somehow to slip unproductively by, crises which loom unexpected from nowhere. This sort of environment leads to inordinate stress and degradation of performance: it must be stopped.

Poor time management is often a symptom of over confidence: techniques which used to work with small projects and workloads are simply reused with large ones. But inefficiencies which were insignificant in the small role are ludicrous in the large. The demands, the problems and the payoffs for increased efficiency are all larger as your responsibility grows; you must learn to apply proper techniques or be bettered by those who do. Possibly, the reason Time Management is poorly practised is that it so seldom forms a measured part of appraisal and performance review; what many fail to foresee, however, is how intimately it is connected to aspects which do.

3.6.1. Personal time Management

Personal Time Management has many facets also. Most managers recognize a few, but few recognize them all. There is the simple concept of keeping a well ordered diary and the related idea of planned activity. But beyond these, it is a tool for the systematic ordering of your influence on events, it underpins many other managerial skills such as Effective Delegation and Project Planning.

Personal Time Management is a set of tools which allow you to:

- eliminate wastage

- be prepared for meetings
- refuse excessive workloads
- monitor project progress
- allocate resource (time) appropriate to a task's importance
- ensure that long term projects are not neglected
- plan each day efficiently
- plan each week effectively

and to do so simply with a little self-discipline.

Since Personal Time Management is a management process just like any other, it must be planned, monitored and regularly reviewed. Before we start on the future, it is worth considering the present. This involves the simplistic task of keeping a note of how manager or leader spend time for a suitably long period of time (say a week).

3.6.2. Waste Disposal

There are various sources of waste. The most common are social: telephone calls, friends dropping by, conversations around the coffee machine. It would be foolish to eliminate all non-work related activity (we all need a break) but if it's a choice between chatting to Harry in the afternoon and meeting the next pay-related deadline ... Your time log will show you if this is a problem and you might like to do something about it before your boss does.

Time is often wasted in changing between activities. For this reason it is useful to group similar tasks together thus avoiding the start-up delay of each. The time log will show you where these savings can be made. You may want then to initiate a routine which deals with these on a fixed but regular basis.

3.6.3. Deadlines

The most daunting external appointments are deadlines: often, the handover of deliverables. The basic idea is that management of deadlines should be achieved with exactly techniques of any project:

- check the specification - being sure that everything is agree on what is to be delivered
- break the task down into small sections so that can estimate the time needed for each, and monitor progress

- schedule reviews of progress (e.g. after each sub-task) so that can respond quickly to difficulties

Like most management ideas, this is common sense. Some people, however, refute it because in practise they find that it merely shows the lack of time for a project which must be done anyway. This is simply daft! If simple project planning and time management show that the task can not be done, then it will not be done - but by knowing at the start, you have a chance to do something about it.

An impossible deadline affects not only your success but also that of others. Suppose a product is scheduled for release too soon because you agree to deliver too early. By practising time management, you will always have a clear understanding of how you spend your time and what time is unallocated. If a new task is thrust upon you, you can estimate whether it is practical. The project planning tells you how much time is needed and the time management tells you how much time is available.

There are four ways to deal with impossible deadlines:

- Get the deadline extended
- Scream for more resources
- Get the Deliverable redefined to something practical
- State the position clearly so that leader have fair warning

If this simple approach seems unrealistic, consider the alternative. If you have an imposed, but unobtainable, deadline and you accept it; then the outcome is *your* assured failure. One defence tactic is to present your superior with a current list of your obligations indicating what impact the new task will have on these current ones.

Finally, for each activity you should estimate how much time it is worth and allocate only that amount. This critical appraisal may even suggest a different approach or method so that the time matches the task's importance. Beware of perfection, it takes too long - allocate time for "fitness for purpose", then stop.

3.6.4. Monitoring Staff

Time Management also effects other people, particularly subordinates. Planning projects means not only allocating time but also the distribution of tasks; and this should be done in the same planned, monitored and reviewed manner as your own scheduling. Any delegated task should be specified with an (agreed) end date. As a Manager, you are responsible for ensuring that the tasks allocated to your subordinates are completed successfully. Thus you should ensure that each task is concluded with a deliverable (for instance, a memo to confirm completion) - you make an entry in your diary to check that this has arrived. Thus, if you agree the task for Tuesday, Wednesday should have an entry in your diary to check the deliverable. This simple device allows you to monitor progress and to initiate action as necessary.

3.6.5. Long term Objectives

There are many long term objectives which the good Manager must achieve, particularly with regard to the development, support and motivation of his/her work-team. Long term objectives have the problem of being important but not urgent; they do not have deadlines, they are distant and remote. For this reason, it is all too easy to ignore them in favour of the urgent and immediate. Clearly a balance must be struck.

The beauty of Time Management is that the balance can be decided objectively (without influence from immediate deadlines) and self-imposed through the use of the diary. Simply, a manager might decide that one hour a week should be devoted to personnel issues and would then allocate a regular block of time to that activity. Time may be allocated to staff development and training. The actual time spent in managing this sort of long term objective is small, but without that deliberate planning it will not be achieved.

3.7. Forming the team

Teams are like relationships - you have to work at them. In the work place, they constitute an important unit of activity but one whose support needs are only recently becoming understood. By making the group itself responsible for its own support, the responsibility becomes an accelerator for the group process. What is vital, is that these needs are recognized and explicitly dealt with by the team. Time and resources must be allocated to this by the group and by Management, and the group process must be planned, monitored and reviewed just like any other managed process.

Groups form a basic unit of work activity throughout engineering and yet the underlying process is poorly managed. In the beginning, When people work in groups, there are two quite separate issues involved. The first is the ***task*** and the problems involved in getting the job done. Frequently this is the only issue which the group considers. The second is the ***process*** of the group work itself: the mechanisms by which the group acts as a unit and not as a loose rabble. However, without due attention to this process the value of the group can be diminished or even destroyed; yet with a little explicit management of the process, it can enhance the worth of the group to be many times the sum of the worth of its individuals. It is this *synergy* which makes group work attractive in corporate organization despite the possible problems (and time spent) in group formation.

3.7.1. Definition of the team

Team presents a group of people working in the same room, or even on a common project, does not necessarily invoke the group process. If the group is managed in a totally autocratic manner, there may be little opportunity for interaction relating to the work; if there is fractioning within the group, the process may never evolve. On the other hand, the group process may be utilized by normally distant individuals working on different projects; for instance, at IEE colloquia.

In simple terms, the team process leads to a spirit of cooperation, coordination and commonly understood procedures and mores. If this is present within a group of people, then their performance will be enhanced by their mutual support (both practical and moral). If you think this is a nebulous concept when applied to the world of industry, consider the opposite effect that a self-opinionated, cantankerous loud-mouth would have on your performance and then contrast that to working with a friendly, open, helpful associate. Teams are particularly good at combining talents and providing innovative solutions to possible unfamiliar problems; in cases where there is no well established approach/procedure, the wider skill and knowledge set of the group has a distinct advantage over that of the individual.

In general, however, there is an overriding advantage in a team-based work force which makes it attractive to Management: that it engenders a fuller utilization of the work force. A team can be seen as a self managing unit. The range of skills provided by its members and the self monitoring which each group performs makes it a reasonably safe recipient for delegated responsibility. Even if a problem could be decided by a single person, there are two main benefits in involving the people who will carry out the decision. Firstly, the motivational aspect of participating in the decision will clearly enhance its implementation. Secondly, there may well be factors which the implementer understands better than the single person who could supposedly have decided alone.

3.7.2. Team Development

It is common to view the development of a team as having four stages:

Forming is the stage when the group first comes together. Everybody is very polite and very dull. Conflict is seldom voiced directly, mainly personal and definitely destructive. Since the grouping is new, the individuals will be guarded in their own opinions and generally reserved. This is particularly so in terms of the more nervous and/or subordinate members who may never recover. The group tends to defer to a large extent to those who emerge as leaders (poor fools!).

Storming is the next stage, when all Hell breaks loose and the leaders are lynched. Factions form, personalities clash, no-one concedes a single point without first fighting tooth and nail. Most importantly, very little communication occurs since no one is listening and some are still unwilling to talk openly. True, this battle ground may seem a little extreme for the groups to which you belong - but if you look beneath the veil of civility at the seething sarcasm, invective and innuendo, perhaps the picture come more into focus.

Then comes the ***Norming***. At this stage the sub-groups begin to recognize the merits of working together and the in-fighting subsides. Since a new spirit of co-operation is evident, every member begins to feel secure in expressing their own view points and these are discussed openly with the whole group. The most significant improvement is that people start to listen to each other. Work methods become established and recognized by the group as a whole.

And finally: ***Performing***. This is the culmination, when the group has settled on a system which allows free and frank exchange of views and a high degree of support by the group for each other and its own decisions.

In terms of performance, the team starts at a level slightly below the sum of the individuals' levels and then drops abruptly to its nadir until it climbs during Norming to a new level of Performing which is (hopefully) well above the start. It is this elevated level of performance which is the main justification for using the group process rather than a simple group of staff.

3.8. Building Quality into the Team

In current management writings "Quality" has come to refer to a whole gambit of practices which themselves have resulted in beneficial side-effects; a Team Leader will want to take advantage of these benefits also. In simple terms, attaining Quality has something to do with satisfying the expectations of *the customer*. Concern for the wishes and needs of customers becomes the focus for every decision. Through careful education by competitors, the customer has begun to exercise spending power in favour of quality goods and services; and while quality is not the sole criterion in selecting a particular supplier, it has become an important differentiator. In the case where the product is a service, Quality is equated with how well the job is done and especially with whether the customer is made to *feel good* about the whole operation. In this respect Quality often does cost more, but the loss is recouped in the price customers are prepared to pay.

The clearest manifestation of Quality is in a product's *reliability*: that the product simply works. To prevent problems from arising after the product is shipped, the quality must be checked before-hand - and the best time to check quality is throughout the *whole* design and manufacturing cycle. The old method of quality control was to test the completed product and then to rework to remove the problems. The new approach to quality simply asserts that if testing becomes an integral part of each stage of production, the production time may increase but the rework time will disappear.

In seeking to improve the quality of the product, manufacturers have found that the people best placed to make substantial contributions are the workforce: ***people are the most valuable resource***. It is this shift in perspective from the management to the workforce which is the most significant consequence of the search for quality. From it has arisen a new managerial philosophy aimed at the empowerment of the workforce, decision-making by the front line, active worker involvement in the company's advancement; and from this new perspective, new organizational structures have evolved, exemplified in "Quality Circles".

One outcome of the search for Quality in Japan is the system of Just-In-Time flow control. In this system, goods arrive at each stage of the manufacturing process just before they are needed and are not made until they are needed by the next stage. This reduces storage requirements and inventory costs of surplus stock. Another outcome has been the increased flexibility of the production line. Time to change from one product run to the next was identified as a major obstacle in providing the customer with the desired range of products and quantities, and so the whole workforce became engaged in changing existant practices and even in redesigning the machinery.

3.8.1. Team Leader and Team Quality

While the salvation of an entire corporation may rest primarily with Senior Management, the fate of a team rests with the Team Leader. The Team Leader has the authority, the power to define the micro-culture of the work team. It is by the deliberate application of the principles of Quality that the Team Leader can gain for the team the same benefits which Quality can provide for a corporation. The best ideas for any particular team are likely to come from them - the aim of the Team Leader must be to act as a catalyst through prompts and by example; the following are possible suggestions.

There will be no overnight success. To be lasting, Quality must become a habit and a habit is accustomed practise. This takes time and training - although not necessarily formal training but possibly the sort of reinforcement you might give to any aspect of good practise. To habituate staff to Quality, leader must first make it an issue.

The initial phases are delicate. The team will be feeling greater responsibility without extra confidence. Thus leader must concentrate on supporting their development. Essentially he/she will be their trainer in management skills. Leader could get outside help with this but by undertaking the job him/herself, he/she retain control: mould the team so that they will reflect his/her own approach and use his/her own criteria. Later they will develop themselves, but even then they will understand leader’s thinking and so leader ‘s decisions.

As with all team work, the main problem is clarity. Leader should provide the team with a notice board and flip-charts specifically for Quality problems. These can then be left on display as a permanent record of what was agreed. If one can, steer the group first to some problem which has a simple solution and with obvious (measurable) benefits. A quick, sharp success will motivate.

3.8.2. Team Building

To succeed, a Quality push must engage the enthusiasm of the entire team; so Team Leader, must create the right atmosphere for this to happen. Many aspects of team building can be addressed while Quality remains the focus.

Leader must create the environment where each team member feels totally free to express an idea or concern and this can only be done if there is no stigma attached to being incorrect. No idea is wrong - merely non-optimal. In each suggestion there is at least a thread of gold and someone should point it out and, if possible, build upon it. Any behaviour which seeks laughter at the expense of others must be swiftly reprimanded.

Most importantly, leader must enable failure. If the team is unable to try out ideas without rebuke for errors, then the scope of their solutions will be severely limited. Instead, a failure should be an opportunity to gain knowledge and to praise any safe-guards which were included in the plan.

One of the central tenets of Quality programmes is the idea of monitoring the problem being addressed: *Statistical Quality Control*. Quite simply, if you can't measure an improvement, it probably isn't there. Gathering statistics has several benefits in applying Quality:

- it identifies (the extent of) the problem
- it allows progress to be monitored
- it provides an objective criterion for the abandonment of an idea
- it can justify perceived expense in terms of observed savings/improvements
- it motivates staff by providing a display of achievement

and, of course, some problems simply disappear when you try to watch them. The statistics must be gathered in an objective and empirical manner, the outcome should be a simple table or graph regularly updated to indicate progress, and these results *must be displayed* where all the team can watch. For example, if your team provides product support, then you might monitor and graph the number of repeat enquiries or the average response time. Or if you are in product development, you might want to monitor the number of bugs discovered (i.e. improvement opportunities).

In the long term, it may be suitable to implement the automatic gathering of statistics on a wide range of issues such as complaints, bug reports, machine down-time, etc. Eventually these may either provide early warning of unexpected problems, or comparative data for new quality improvement projects. It is vital, however, that they focus upon an agreed problem and not upon an individual's performance or else all the positive motivation of staff involvement will be lost.

3.8.3. Building Quality into Projects

Clarity of purpose - this is the key to success. What is needed is a simple, stated objective which everybody understands and which everybody can see achieved. Any plan to improve the quality or effectiveness of the group must contain:

- the objective
- the method
- the statistical display for monitoring the outcome
- the agreed criteria for completion or curtailment

By insisting on this format, you provide the plan-owners with a simple mechanism for peer recognition (through the displayed notice board) and yet enable them to manage their own failure with grace. A simple innovation might be for a member of your team to actually talk to someone from each of these internal customer groups and to ask about problems. The interfaces are usually the best place to look for simply solved problems. The immediate benefit may be to the customer, but in the long run better communications will lead to fewer misunderstandings and so less rework.

Quality costs less than its lack. To build a quality product, you must do two things:

- worry the design and the procedures
- include features to aid quality checking

If one of the team spots a modification in the design or the procedures which will have a long term benefit, then that must be given priority over the immediate schedule. The design is never quite right; you should allocate time specifically to discussing improvement.

One of the least-used sources of quality in design and production in the engineering world is ***documentation***. This is frequently seen as the final inconvenience at product release, sometimes even delegated to another (non-technical) group - yet the writing of such documentation can be used as an important vehicle for the clarification of ideas. It also protects the group from the loss of any single individual.

The hardest part, as with all delegation, is in accepting the group decision even though you disagree. You must never countermand a marginal decision. If you have to over-rule the team, it is imperative that you explain your reasons very clearly so that they understand the criteria; this will both justify your intervention and couch the team in (hopefully) good decision-making practices.

Another role which leaders often assume is that of both buffer and interface between the team and the rest of the company: a buffer in that leader protects the team from the vagaries of less enlightened managers; an interface in that leader keeps the team informed about factors relevant to their decisions. Ultimately, the team will be delegating to leader (!) tasks which only him/she, acting as manager, can perform on its behalf.

3.9. Communication and Team Meetings

Most conversations sort of drift along; as a manager, you seek communication rather than chatter. To ensure an efficient and effective conversation, there are three considerations:

- you must make your message understood
- you must receive/understand the intended message sent to you
- you should exert some control over the flow of the communication

Thus *you must learn to listen as well as to speak*. Those who dismis this as a mere platitude are already demonstrating an indisposition to listening: the phrase may be trite, but the message is hugely significant to your effectiveness as a manager. If you do not explicitly develop the skill of listening, you may not hear the suggestion/information which should launch you to fame and fortune.

As a manager (concerned with getting things done) your view of words should be pragmatic rather than philosophical. Thus, words mean not what the dictionary says they do but rather what the speaker intended.. In everything you say or hear, you must look out for possible misunderstanding *and clarify* the ambiguity. The greatest source of difficulty is that words often have different meanings depending upon context and/or culture. If you recognize that there is a potential misunderstanding, you must stop the conversation and ask for the valid interpretation.

So, the problem is this: the word has multiple meanings, it might not be the one intended, and you may have misheard it in the first place - how do you know what the speaker meant? What are suggestions for avoiding communication problems:

Playback for confirmation. Simple, you ask for confirmation. You say "let me see if I have understood correctly, you are saying that ..." and you *rephrase* what the speaker said. If this "play back" version is acknowledged as being correct by the original speaker, then you have a greater degree of confidence in you own understanding. For any viewpoint/message/decision, there should be a clear, concise and verified statement of what was said; without this someone will get it wrong.

Write back for confidence. But do not stop there. If your time and effort depend upon it, you should write it down and send it to everyone involved as a double check. This has several advantages:

- Further clarification - is this what you thought we agreed?
- Consistency check - the act of writing may highlight defects/omissions

- A formal stage - a statement of the accepted position provides a spring board from which to proceed
- Evidence - hindsight often blurs previous ignorance and people often fail to recall their previous errors

Give background for context. When speaking yourself, you can often counter for possible problems by adding information, and so providing a broader context in which your words can be understood. Thus, there is less scope for alternative interpretations since fewer are consistent. When others are speaking, you should deliberately ask questions yourself to establish the context in which they are thinking. When others are speaking, you should deliberately ask questions yourself to establish the context in which they are thinking.

3.9.1. Practical points in communication

As with all effective communication, you should decide (in advance) on the purpose of the conversation and the plan for achieving it. There is no alternative to this. Some people are proficient at "thinking on their feet" - but this is generally because they already have clear understanding of the context and their own goals. You have to plan; however, the following are a few techniques to help the conversation along.

Assertiveness. The definition of *to assert* is: "to declare; state clearly". This is your aim. If someone argues against you, even loses their temper, you should be quietly assertive. Much has been written to preach this simple fact and commonly the final message is a three-fold plan of action:

- acknowledge what is being said by showing an understanding of the position, or by simply replaying it (a polite way of saying "I heard you already")
- state your own point of view clearly and concisely with perhaps a little supporting evidence
- state what you want to happen next (move it forward)

Confrontations. When you have a difficult encounter, be professional, do not lose your self-control because, simply, it is of no use. Some managers believe that it is useful for "discipline" to keep staff a little nervous. Thus, these managers are slightly volatile and will be willing "to let them have it" when the situation demands. If you do this, you must be consistent *and fair* so that you staff know where they stand. If you deliberately lose your temper for effect, then that is your decision - however, you must never lose control.

3.9.2. Meeting Management - preparation

In any organization, "meetings" are a vital part of the organization of work and the flow of information. They act as a mechanism for gathering together resources from many sources and pooling then towards a common objective. They are disliked and mocked because they are usually futile, boring, time-wasting, dull, and inconvenient with nothing for most people to do except doodle while some opinionated has-been extols the virtues of his/her last great (misunderstood) idea. Your challenge is to break this mould and to make your meetings effective. As with every other managed activity, meetings should be planned beforehand, monitored during for effectiveness, and reviewed afterwards for improving their management.

A meeting is the ultimate form of managed conversation; as a manager, you can organize the information and structure of the meeting to support the effective communication of the participants. Some of the ideas below may seem a little too precise for an easy going, relaxed, semi-informal team atmosphere - but if you manage to gain a reputation for holding decisive, effective meetings, then people will value this efficiency and to prepare professionally so that their contribution will be heard.

Should you cancel? As with all conversations, you must first ask: is it worth your time? If the meeting involves the interchange of views and the communication of the current status of related projects, then you should be generous with your time. But you should always consider canceling a meeting which has little tangible value.

Who should attend? You must be strict. A meeting loses its effectiveness if too many people are involved: so if someone has no useful function, explain this and suggest that they do not come. Notice, they may disagree with your assessment, in which case they should attend (since they may know something you do not); however, most people are only too happy to be released from yet another meeting.

How long? It may seem difficult to predict the length of a discussion - but you must. Discussions tend to fill the available time which means that if the meeting is open-ended, it will drift on forever. You should stipulate a time for the end of the meeting so that everyone knows, and everyone can plan the rest of their day with confidence.

It is wise to make this expectation known to everyone involved well in advance and to remind them at the beginning of the meeting. There is often a tendency to view meetings as a little relaxation since no one person has to be active throughout. You can redress this view by stressing the time-scale and thus forcing the pace of the discussion: "this is what we have to achieve, this is how long we have to get it done".

Agenda. The purpose of an agen da is to inform participants of the subject of the meeting in advance, and to structure the discussion at the meeting itself. To inform people beforehand, and to solicit ideas, you should circulate a draft agenda and ask for notice of any other business. Still before the meeting, you should then send the revised agenda with enough time for people to prepare their contributions. If you know in advance that a particular participant either needs information or will be providing information, then make this *explicitly* clear so that there is no confusion.

The agenda states the purpose of each section of the meeting. There will be an outcome from each section. If that outcome is so complex that it can not be summarized in a few points, then it was probably too complex to be assimilated by the participants. The understanding of the meeting should be sufficiently precise that it can be summarized in short form - so display that summary for all other interested parties to see. This form of display will emphasize to all that meetings are about achieving defined goals - this will help you to continue running efficient meetings in the future.

Typical phasses in Planning a Meeting:

1. Determine overall goal, plan sequence
    - Right balance, off-line, in-meeting work
    - Decide agenda items for this meeting
2. Determine outcomes for each meeting
    - visible
    - invisible
3. Invite right people
    - Determine who should attend, roles
4. Use right process
    - Design the meeting: structure the content, select the processes, create the agenda
5. Get people prepared

  - Distribute other material
  - Send agenda to participants
  - Pre-sell if necessary

3.9.3. Meeting Management - conducting

Whether you actually sit as the Chair or simply lead from the side-lines, as the manager you must provide the necessary support to coordinate the contributions of the participants. The degree of control which you exercise over the meeting will vary throughout; if you get the structure right at the beginning, a meeting can effectively run itself especially if the participants know each other well. In a team, your role may be partially undertaken by others; but if not, you must manage. Manager’s most important tools are:

- Clarification - always clarify: the purpose of the meeting, the time allowed, the rules to be observed (if agreed) by everyone.
- Summary - at each stage of the proceedings, you should summarize the current position and progress: this is what we have achieved/agreed, this is where we have reached.
- Focus on stated goals - at each divergence or pause, re-focus the proceedings on the original goals.

Code of conduct. In any meeting, it is possible to begin the proceedings by establishing a code of conduct, often by merely stating it and asking for any objections (which will only be accepted if a demonstrably better system is proposed). Thus if the group contains opinionated wind-bags, you might all agree at the onset that all contributions should be limited to two minutes (which focuses the mind admirably). You can then impose this with the full backing of the whole group.

The (stated) purpose of a meeting may suggest to you a specific way of conducting the event, and each section might be conducted differently. For instance, if the purpose is:

- to convey information, the meeting might begin with a formal presentation followed by questions
- to seek information, the meeting would start with a short (clear) statement of the topic/problem and then an open discussion supported by notes on a display, or a formal brainstorming session
- to make a decision, the meeting might review the background and options, *establish the criteria* to be applied, agree who should make the decision and how, and then do it
- to ratify/explain decisions, etc etc

As always, once you have paused to ask yourself the questions: what is the purpose of the meeting and how can it be most effectively achieved; your common sense will then suggest a working method to expedite the proceedings. You just have to deliberately pause. Manage the process of the meeting and the meeting will work.

Support. The success of a meeting will often depend upon the confidence with which the individuals will participate. Thus all ideas should be welcome. No one should be laughed at or dismissed ("laughed with" is good, "laughed at" is destructive). This means that even bad ideas should be treated seriously - and at least merit a specific reason for not being pursued further. Not only is this supportive to the speaker, it could also be that a good idea has been misunderstood and would be lost if merely rejected. But basically people should be able to make naive contributions without being made to feel stupid, otherwise you may never hear the best ideas of all.

Avoid direct criticism of any person. For instance, if someone has not come prepared then that fault is obvious to all. If you leave the criticism as being simply that implicit in the peer pressure, then it is diffuse and general; if you explicitly rebuke that person, then it is personal and from you (which may raise unnecessary conflict). You should merely seek an undertaking for the missing preparation to be done: we need to know this before we can proceed, could you circulate it to us by tomorrow lunch?

What Does a Good Meeting Look Like?

- Starts on time
- Ends on time, subjects covered
- Team works well, solves problems
- Group feels its time was well spent
- Goals of the meeting are met

3.9.4. Meeting Roles

Leader. A person who calls the meeting and also owns the content. Usually he/she owns responsibility for outcome and will often need to participate in the discussions but also will make decisions. A good leader invests time in the planning of the meeting, so he/she establishes content and desired outcomes and with facilitator determines meeting processes and correct attendees, assign roles. Preparing, gathering and distributing material is another responsibility of the leader. Maybe the most important is handling logistics and issuing agenda.

Facilitator. Makes sure the group is using the most efficient methods for accomplishing their goals in the shortest period of time. Responsible for all meeting procedures, to allow meeting leader to concentrate on content: discussion, issues, and decisions. Also controls the process but not content and listens to what group is saying remaining neutral and building trust. A facilitator makes sure success conditions are there. Facilitator responsibilities during the meeting are to maintain direction witj keeping everyone in one discussion. One of the major responsibilities is to maintain time limits on agenda items, and sometimes to move the group toward conclusion, if needed.

In some special occasions facilitators solicit input from quiet people and protect the weak, watch for suggestion squashing, acknowledge competence with taking minority discussions off-line trying to keep emotional level low.

Recorder. A person dealing with documents, action items, catching key decisions and key issues. Also trying to keep recorded other meeting information: attendees, key topics summary and provides data to leader for publishing. A good recorder captures necessary information without disrupting or slowing down the meeting, also captures information with “fidelity” to preserve.

Participant. A role of participant is to keep information at the right level of detail for the goals of the meeting, or to contribute leader’s information. Help the group work together well, he/she is sometimes::

Harmonizer - Bring calm when things are tense...
Motivator - help deal with frustration...
Gatekeeper - helping silent people speak…
Summarizer - help focus, clarity of progress

4. Project Methodology

4.1. About project methodology

A ***methodology*** is a set of guidelines or principles that can be tailored and applied to a specific situation. In a project environment, these guidelines might be a list of things to do. A methodology could also be a specific approach, templates, forms, and even checklists used over the project life cycle.

A formal project methodology should lead the work of all team members throughout the life cycle of a project. All members of a team should be familiar with and use the chosen methodology throughout their projects.

Project managers should realize that any repetitive continuous process is not a project. They should be focusing on a one-time event. Project manager must ensure that the project actually fits into the project plan that was built. Executives (team members) or clients then routinely scrutinize this plan to check for variances and request the necessary corrections or deviations. Project management thus has an important role to play. Project changes and new requirements will always be present because of regulatory, technological, or new strategic initiatives.

We need to be aware of the key tasks that a project manager performs on any project (see Table 1.1). These are not all the objectives that might be on a specific project, but the list gives a basic feeling for what objectives are to be met. Throughout the life of any project, project managers are responsible for the key areas. Some of these responsibilities, which tie in directly with any project methodology, follow:

- Obtain approval for the project to proceed.
- Determine the project scope and its feasibility to the overall business.
- Ensure the necessary project resources are identified and allocated.
- Plan the project to the relevant detail it requires.
- Ensure that the project methodology and associated processes are adhered to.

- Monitor the project in terms of cost, quality, and schedule.
- Identify and monitor project issues and risks.
- Provide updated reports and summaries to key stakeholders.
- Provide leadership to the project team.

Table 4.1: Project objectives

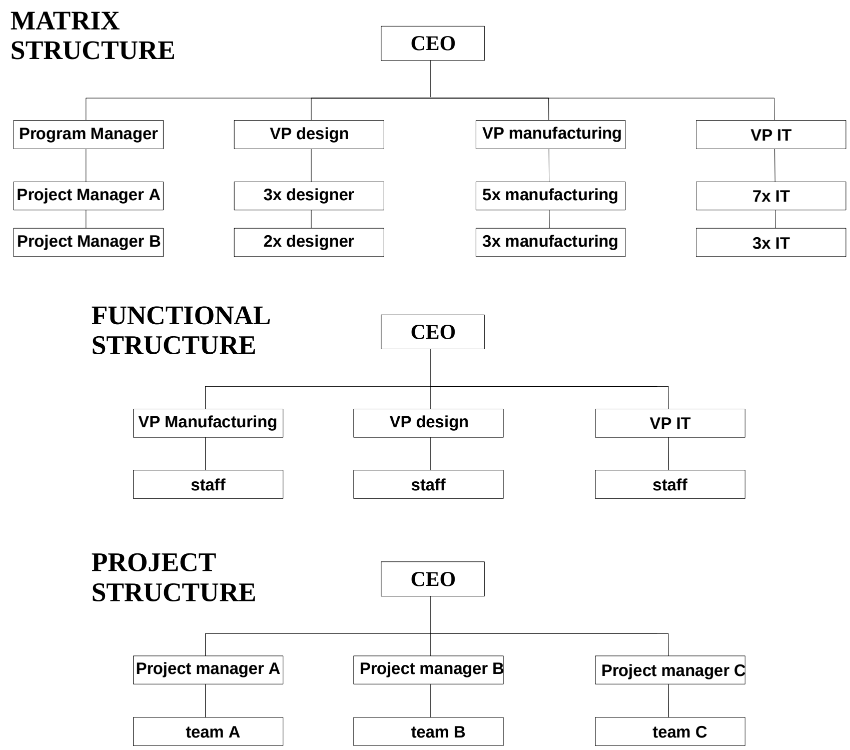
Objectives	**Responsibility**	**How**
Obtain the user requirements	Analyst/PM, client	Interviews
Define the project	PM, Client	Definition report, Business case, Feasibility study
Plan the project	PM	Gantt
Negotiate for resources	PM, Sponsor	Resource plan
Create the project team to perform the work	PM	Team contract
Execute the project, including changes	PM	Implementation plan, Change requests
Control and monitor the actual versus planned	PM	Status reports, Issue and Risk logs
Close the project and release the resources	PM, Client	Closure report
Review project and support postproject	PM, Client	Questionnaire review

4.2. Why do Projects Fail?

Projects fail mainly because of two reasons: (1) a failure of estimation and (2) a failure of implementation. The following are reasons projects fail:

- Initial cost and schedule estimates are not revised when more information becomes available as the project progresses.
- Plans are not used correctly or used to guide the project forward.
- The project scope changes.
- Requirements have major changes.
- Communications are poor.

There are various structures when managing the project. Executives and project managers who need to understand how projects are going to be managed in the organization, should first understand the company structure. Figure 2 shows three main types of organizational structures you might encounter when managing projects. First is a ***matrix*** structure, which is extremely difficult to work in, where project coordination and follow-up is mandatory. Second is the ***functional*** structure, which relies on the functional managers to manage their projects. Third is the ***projectized*** structure, or the project approach, which has the ability to rapidly formulate the project team and move forward.



Picture 4.1: *Three main types of organizational structures*

Project management is not about deadlines; it is about tracking, controlling, and improving the process of change. Lack of time may be the excuse, but why isn't the initiative planned more carefully?

4.3. Importance of strategy

Strategy always comes before any tactics. It's similar to thinking before doing. The strategy must be correct before we select a project or development methodology. In other words, you must be doing the right thing and only then can the necessary tactics support that newfound strategy. Strategy—as it has always been and will always remain—is the perpetual struggle for advantage. The objective of strategy is to take actions that build, sustain, and compound advantage. The purpose of strategy is to provide rapid direction and concentration of effort as organizations continually strive to improve their position or gain the upper hand in the marketplace. Speed is the ultimate factor here.

Both project managers and executives need to understand the impact that new developments in technology are having on business from the project, operational, and risk points of view. It is possible to split the responsibilities of methodologies into three broad areas:

2. Managing project performance.
3. Managing the project life cycle.
4. Managing the resources and communications aspects.

Projects of varied size and complexity require different project management skills and techniques to effectively and economically manage project risks. Project management stands out as the enabler to make this happen. The challenge for most project environments, however, is to tailor or scale the methodology so it makes sense for projects of lesser size, risk, and complexity. Additionally, project management methodologies can be thought of as a set of principles and techniques for controlling project risks, quality, change requests, and for capturing any opportunities as projects are brought to fruition. Because of economics and common sense, project management techniques need to be tailored to the specific risks and opportunities of each project. The methodology provides a means for selecting the degree of project management attention appropriate for your particular project.

The traditional ways of thinking about strategy and how to build advantage are no longer working. Executives need a fresh strategic imagery and analysis of how to cope with the virulent hyper competition and a prescription of how to build advantage in this new environment.

It is not a problem to buy many things—technology, advice, assets, and, often, even time. What you cannot buy is ***commitment***. Commitment is something that is earned and must be won. It is something that must be planned for and managed. The absence of commitment, not the poor selection of technology, is often the primary cause of strategy failure on a project. As hyper competition defines the competitive landscape into the new millennium, the basis of advantage will be the agility of project management methodologies. This important insight must be acted on. This insight ultimately separates the winners from the losers and the successes from the failures.

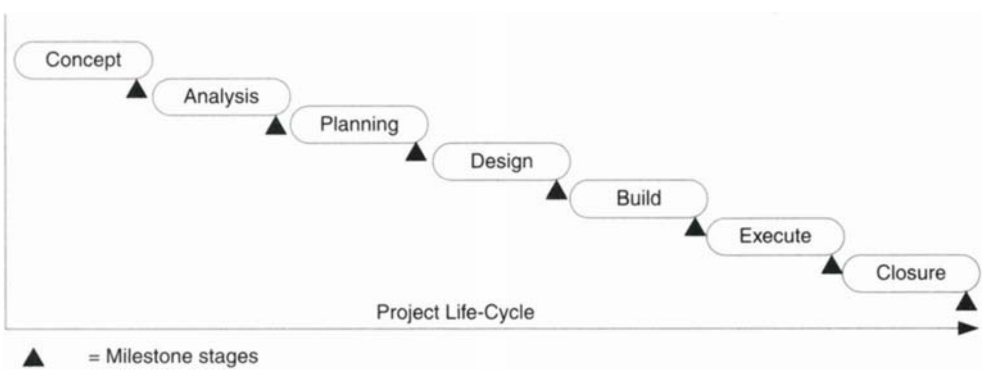
4.4. Project Methodology Overview

Key decision makers must often determine whether a universalized project life-cycle methodology is sufficient for all their projects. By simply assessing those project methodologies that exist today, we see that a universal project approach simply won't work. A project life cycle is, therefore, a collection of project phases. Project phases vary by project or industry, but some general phases include:

- **Concept**
- **Development**
- **Implementation**
- **Support**

It is good to remember that products also have life cycles. Many companies have project managers or executives who are unwilling to follow systematic project methodologies all of the time. Instead, they tend to rely on standard business activities to get them through the project. They are simply trying to keep up with all this talk of project methodologies and associated processes and techniques. Questions such as "Why are there so many methodologies?" and "Which one do we use?" often arise. Over the years, even those involved in managing projects have observed that projects have common characteristics that can be formalized into a structural process, which allows them to manage projects more effectively.

Each phase can typically be brought to closure in some logical way before the next project phase begins; and each phase results in discrete milestones or deliverables, which provide the starting point for the next phase. Project methodologies should be structured to take advantage of the natural phases that occur as work progresses. The phases should be defined in terms of schedule and specific accomplishments. Define how you will know when you have finished each phase and what you will have to show for it.



Picture 4.2: *Depiction of general project methodology phases.*

Cost and schedule estimates, plans, requirements, and specifications should be updated and evaluated at the end of each phase, sometimes before deciding whether to continue with the project. At times, you may want to hold off or cancel the project. Large projects are usually structured to have major program reviews at the conclusion of significant project phases. These decision points in the life of a project are called *major milestones.* Picture X shows how project phases are somehow linked to one another. This is the basis of how project phases, once incorporated, form a typical project development methodology.

Milestone decisions are made after conducting a major program review in which the project manager presents the approved statement of requirements, acquisition strategy, design progress, test results, updated cost and schedule estimates, and risk assessments, together with a request for authorization to proceed to the next phase. The early project phases tend to shape the direction for all further efforts on the project. They provide requirement definitions, evaluation of alternative approaches, assessment of maturity of technologies, review of cost, schedule and staffing estimates, and development of specifications.

On small projects, if no formal agreements are written, the project manager should deal with clients and executives in an informal, yet somewhat structured and logical, manner. This means managing expectations and making clear agreements about what will be produced and when.

On long-term projects, you may find project phases take place over many months or even years, and, in this case, it is vital to provide interim deliverables to give the clients and executives a sense that work is being accomplished, to provide an opportunity for feedback, and to capture project successes in documented form. This is exactly why a project methodology works. It is wise that the project processes be built around the specific project methodology. Particular care should be given to defining the work to be accomplished in each phase. This should include definition of the deliverables to be produced, identifying testing and demonstrations to be completed, preparing updates of cost and schedule estimates, reassessing risks, and conducting formal technical and management reviews.

4.5. Background to Project Methodologies

Project management has grown from the early initiatives in the U.S. defense and aerospace sectors in the late 1950s and 1960s. The U.S. Department of Defense and NASA achieved early project management successes—mainly promulgated through their internal policies, procedures, and lessons learned. From this flowed numerous white papers, articles, seminars, and training programs that expanded the project management genre, although much of the theory centered around the use of tools and techniques, such as:

- PERT/Gantt charts.
- Critical path.
- Scheduling techniques.
- Organizational issues.
- Conflict management and others.

In the pioneering days of project management, it was common practice for project staff or managers to devise their own methods of moving through the life cycles of their projects, which were often influenced by information technology, engineering challenges, or financial constraints. It was a time when a project was driven by the events that occurred while on the job. This was fine for certain projects, but it led to the failure and delay of many projects because of problems that started to show (1) poor or inconsistent project designs, (2) poor project analysis, and (3) ineffective project communications. It seemed projects lacked the rigor and key ingredients to make them more effective. Sometimes, it takes a complete outsider to show how to expedite projects more quickly than before, in innovative futuristic ways.

It is essential that the management of any organization identify and articulate its critical success factors (CSFs). These are the ground rules that determine the appropriateness of the environment in which the organization operates. The CSFs set out the culture, behavior, and actions for management to take to achieve its objectives relating to project methodologies.

Most projects share a common life cycle. This is not to say that these projects are all designed and executed the same way, but they remain universal, as they pass similar phases during the life cycle of the project. When dealing with any methodology, ask the following questions:

1. How do we ensure that our projects develop and deliver successful products? Is the methodology able to accurately capture requirements and effectively manage the project against those requirements?
2. How can we deploy projects more quickly, avoiding overruns and poor performance, and for better value, lower cost, and better functionality?

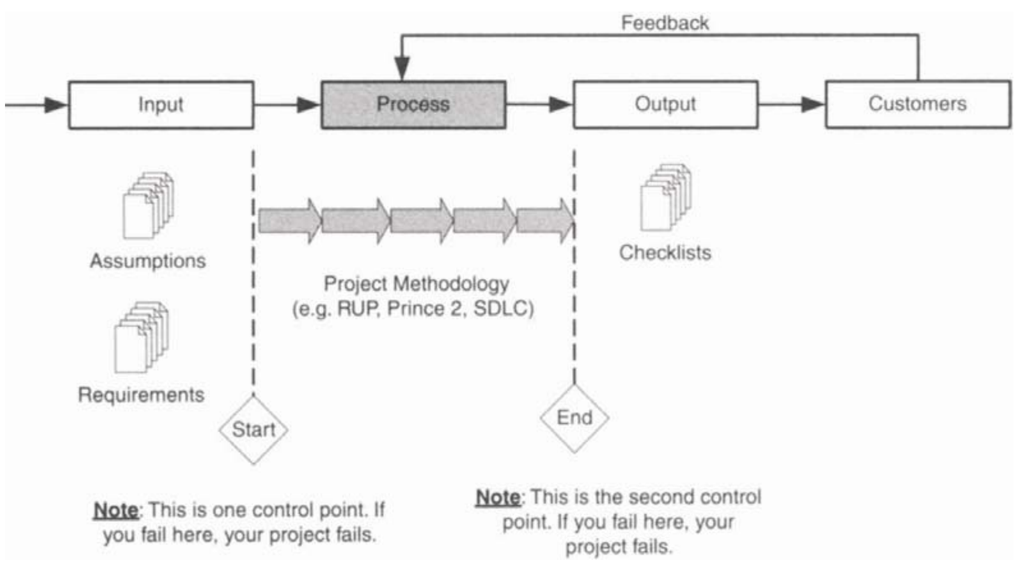
When looking at organizational project methodologies available today, we realize that certain methodologies work well and some do not. Some are more proactive than reactive. For those that are not well planned, the organizations will simply not have success with those methodologies.

Competitors will overpower them and deliver products faster to the market, and the organization will face competitor lockout. After the project life cycle is defined, the project budget and technical aspects must be managed together. And this is important. Can you imagine delivering a project within cost and schedule but that the project does not meet its technical specifications? Of course not—a project life cycle must be efficiently managed if the project is to be successful.

An ***iteration*** is defined as a distinct sequence of activities with an established plan and evaluation criteria resulting in an executable release. If we examine the set of illustrations describing the waterfall approach, we can see that an iterative approach does have advantages over a straightforward waterfall approach. This analogy should help reveal other ways to manage projects.

4.6. CIPOC—A Conceptual Approach

When trying to place any project life cycle or methodology into perspective, it is always going back to the Client, Input, Process, Output, Clients (**CIPOC**) approach, a slight deviation from the "supplier" concept. It is one of the greatest examples of a primer that gives a high-level conceptual view of the way all project methodologies fit into the grand scheme of things (Picture 4.2).



Picture 4.2: ***CIPOC technique to reflect methodology usage.***

CIPOC works like this. A client has certain requirements for which he or she needs a certain solution. This can be a new skyscraper, submarine, spacecraft, software, or even a rock concert. It doesn't matter what kind of project. These client requirements are formed into inputs, which in turn serve as the defining moments or starting point for the process. The project manager uses his/her chosen methodology and proceeds to design, build, test, and deploy the solution. These are the control points. When complete, an output has been generated that is then accepted by the client. The client can be involved anywhere in the **CIPOC** approach; the client readily provides feedback at any stage.

All assumptions must be made upfront at the onset of the project process start. This is one of the control points. If the project manager cannot control the assumptions, the project may come back and bite, irrespective of methodology employed.

4.7. Understanding Project Model Terminology

Project Feasibility and Justification. The project manager's first task is to become familiar with the feasibility of the project. He or she should reaffirm to his or her own satisfaction the findings of the original study, which may have been some time ago, certainly before he or she accepted the job. Thus, reaffirming the feasibility and justification of the project is crucial.

User Requirements. The most important phase in any project is to find out what is actually needed. Without proper establishment of the requirements, no one is certain what is really required. This is not covered fully in the Project Service Request (PSR); therefore, work and effort are needed at the start of the project. Subsequent time may be wasted if the user requirements are not established and understood.

System Design. After establishing and agreeing on the requirements, a high-level design of the main functions of the system can be produced. This is followed by considering the development of each of these main functions in more detail.

Detailed Design and Buy or Build. These follow the established meanings found in most development models. Each activity in the work breakdown structure (WBS) is given sufficient individual attention so that it is designed in detail ready for building. These phases apply equally to the design and creation of documentation as well as software. They also apply to hardware, except that items needed to run the software will be ordered from suppliers instead of building the items. The hardware design is determined by the software requirements.

Acceptance. The acceptance phase is the running of integration tests at system level to prove all documentation, software, hardware, and other equipment. These tests must be designed carefully and not left to the suppliers (of equipment, software, and documentation) to construct. Otherwise, we find that suppliers may test only the parts that work and may deliberately not consider the whole system, which may lead to problems for the end users. Notice that testing occurs throughout the project—not delayed until a single testing phase when and where it would be too late to rectify faults efficiently. This phase is about testing to accept the whole system, not testing to see if it works.

Commissioning. Every component is built, tested and integrated. *Commissioning* is the setting to work of the proven and integrated system. This is the time to introduce the end users to their relevant parts of the working system and then cut over to the live system. During this stage (or even before in some projects), user training takes place and the help desk is set up.

Completion and Post-Implementation Audit – PIA. When all stages are completed to the satisfaction and agreement of all parties, it is important that the project be recognized as complete. At this stage, it is crucial that the project manager document the following before starting another project:

- Job descriptions for operations staff.
- Job descriptions for systems staff.
- Working practices for operations and systems teams agreed on by management, operations manager, and systems manager.
- Rolling plan for update, upgrade, and replacement of equipment over the next two to five years.
- A plan to ensure that all documentation is complete and signed off.
- A plan to ensure that all contractors, subcontractors, and self are paid up-to-date.
- A postimplementation audit date for three to six months after project close-down.

In the postimplementation audit (PIA), the project manager returns a few months after responsibility for the new system has been assumed by the client (i.e., steady—state). The actual audit procedures should be determined initially, indicating that a team will return to see whether the system is working as designed. Most of this audit consists of ensuring that the project team is adhering to established working practices. It is quite surprising how people misinterpret documented procedures and invent ways around problems. These issues of documentation standards are beyond the scope of this book. The PIA has rarely been carried out in the past and is only now gaining a reputation for its usefulness.

4.8. Methodology Design

The focus is how project methodologies can be developed to support projects in a team. Developing a project methodology and adapting it to the situation often deal with changes on many levels—changes in culture, processes, and information systems. A ***culture*** can provide project teams with a shared frame of reference and facilitate communication. The ***processes*** can provide a structure of activities in the projects, which helps new employees and can provide a common language. ***Information systems*** may be linked to the process and provide the tools that influence the daily work.

The research is based on active participation during the development of a methodology for product development. The case illustrates the tendency to focus on the process level and underestimate the importance of influencing the culture and adapting the current system to the new envisaged processes. The results are analyzed to provide increased understanding of the success factors when new project methodology is to be developed. The aim is to create a framework that can be used by the team that want to develop a project methodology or improve their existing project methodology.

With any new process, the way an organization works—and its entire culture—changes. Hence, it becomes crucial that the project manager not only develop the project management processes themselves but also create:

- Support plans.
- Communications plans.
- Deployment plans.

We now examine the relationship between methodology size, project size, and problem size. This discussion can be tricky because there is a tendency to think that more people must solve larger problems.

Project size and methodology are connected by a positive feedback loop. With relatively few people, relatively little methodology is needed. With less "weight," they work more productively. With greater productivity, they can address a larger problem with their smaller team and lighter methodology. On the other hand, when more people are assigned to a project, they need more coordination (i.e., more methodology). The heavier methodology lowers their productivity; therefore, more people are needed to accomplish the same work. Methodology grows more slowly than project size, so eventually they get to a point where they can solve the problem and manage the coordination activities (assuming sensible management). Therefore, for a given problem, you need fewer people if you use a lighter methodology and more people if you use a heavier methodology. However, there is a limit to the size of problem that can be solved with a given number of people, and that limit is higher for a large team using a heavier methodology than for a small team using a lighter methodology (i.e., at some point, you will need both a large team and a heavier methodology). The difficulty is that there is no reliable way to determine the problem size at the start of a project and no way to know the minimum number of people needed to solve it. The number of people varies with the people in question. Finally, as the project grows in size, a different combination of methodology and project size becomes optimal.

To begin to consider what constitutes a ***good*** and ***effective project management*** or development methodology, you need to clearly understand what phases are available to use, within all the project and development methodologies that face you as a project manager. The most common phases you would likely encounter when discussing or designing a methodology are discussed in the following sections:

1. **Discovery/Concept/Idea**

A well-conceived idea is the creative stuff that makes everything important. It's why the project started in the first place. There is no launch if there is no acceptable initial idea. Brainstorming is an effective technique to help you develop a prime idea. Be aware of the effect that the external environment (customers, competitors, market, etc.) has on the idea. In the concept stage, the exact definition of the idea and strategy is derived. The objective is to develop a protocol with defined target markets, product concepts, and attributes.

2. **Engagement/Concept**

Because each project is unique and must be approached very differently from the next because of client requirements and demands, in the engagement or concept phase, the project manager and sales executive actually meet with the client and discuss possibilities and begin to extend the communications process between the parties involved. This is often the most important phase as it sets the standard going forward. This can initially be a single occurrence or a series of meetings that brings the stakeholders together. It identifies key role players in the project and starts setting responsibilities.

3. **Analysis/Feasibility**

The analysis or feasibility phase determines that the project has been thoroughly assessed and deemed economically or strategically feasible to continue. If the analysis weighs against the project's success, the project is discontinued or returned to executives for further discussions. It is highly recommended that projects be analyzed before commencing to the next phase of the project life cycle or methodology.

4. Strategy Planning

Every company needs to have a system for deciding on and formulating the necessity and priority of launching any project or product. Whether a new design or new release of software, the strategists need to plan within the framework of the business model. The strategy planning would allow decisions about launching additional projects to support a priority project or delaying certain projects to favor a more important project's getting to market.

5. Feasibility Assessment

Before committing time and resources to any development, it may be necessary to establish the *need* for the project. Sometimes, it's not feasible to commit the organization to even attempt the project because it simply duplicates another effort or costs too much to gain a successful foothold in the marketplace. Additionally, the technical feasibility of the project may be unknown, and without performing a proper feasibility study of the technology, the project would result in negative cost and schedule delays.

6. System Analysis

After the project is launched, it becomes vitally important to establish client requirements to start designing the eventual system or product. At this stage, the project team should use techniques to fully understand what the project should deliver.

7. Design/Development

On any project methodology, one of the key phases is the design or development phase. The phase represents the solution build. Key staff—such as designers, architects, or engineers—develop a solution based on either partial or full user requirements. This design will form the basic building blocks from which the project team will work.

8. Deployment/Execution

After the project has been built, tested, and proven to work as designed and specified, the project is ready for installation or rollout. It is during this phase that the product or system is finally assembled and installed. In addition to simply implementing a system, users must be trained.

9. Testing

This phase indicates the formal testing of the solution. Testing can be done either incrementally or at the end of a development phase if following a waterfall approach.

10. Quality Assurance

In the quality assurance phase, the solution is validated and tested against the initial specifications of the project.

11. Training/Education

Before any system or project is fully deployed, users need to be identified and trained. This phase may involve establishing the training requirements for the project and generating either the necessary training courses or documentation.

12. Rollout/Implementation/Deployment

This phase is the delivery of the solution within the client organization. The rollout takes effect when the system is ready to be installed either in a series of small increments or as a fullblown deployment. During this phase, it is crucial to have an implementation plan and schedule to assist with the details of rolling out the project to the client.

13. Maintenance/Support/Operations

After the project has been finalized and the product launched, it is considered operational or in production. Therefore, the product must now be maintained. Many products need constant updates or changes. For example, after a new software is launched, it is likely that some updates will be needed. Therefore, the project needs to address exactly how postproject changes will be handled and executed. Considerations such as how incremental changes will be implemented must be resolved. On many other projects, fulfillment and restocking of vital spare parts—including the vendors' support—are crucial in making this project a success. In this phase, the organization or client introduces operational support for the project once completed. Tasks such as arranging help desk support, service level agreements, and monitoring and diagnostics are performed in this phase.

4.9. Using the Mind-Mapping Concept

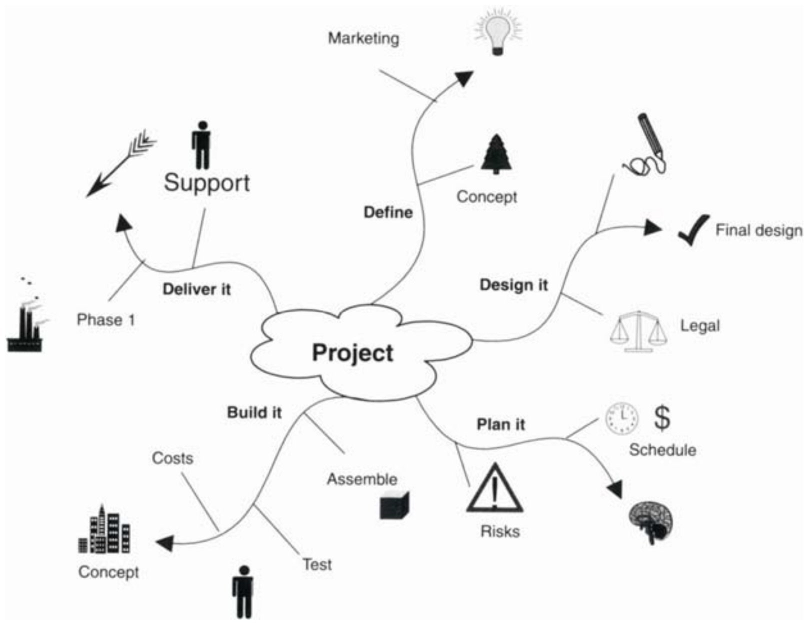
The one effective way to lay out the envisaged framework of a project methodology is to illustrate or mind map it on paper first, thereby addressing all areas of the organization. Picture 4.3. shows a typical mind-map framework. You can easily start developing a framework in this manner. Look at the way the things are organized - as this is very relevant to thinking about methodologies. If you cannot map out a process, it is futile.

However, the human brain is so sophisticated that the mind-mapping method guides the methodology development process. Your brain initially encounters biochemical or electromagnetic resistance along its pathway, where thoughts are reduced. The first time is a struggle, as you have to fight your way through the undergrowth. The second time you travel that way, it is easier because of the clearing you made on the first pass. Frequent repetitive events make it easier for you. Likewise, creating mind maps and documenting them in creative graphical formats assist the human brain in receiving, holding, analyzing output, and control.

What happens in your brain when you want to design a project methodology? The answer is both simple and amazingly complex. Every thought or bit of information entering the brain—experiences and memory (template, code, word) can be represented as a central sphere that radiates tens, hundreds, thousands, millions of hooks—which represent associations—that in turn have their own links and connections. The number of associations you have can be thought of as your memory or database. The mind-mapping technique offers us the following approach:

- It has a central theme.
- It has branches of themes, which radiate from this central core.
- These branches contain keywords and are connected.
- This together creates a "picture" of the solution or idea you need.

A mind-mapping method can be extended easily to designing or conceptualizing any project methodology in existence in a graphical manner. From this, anything is possible, and because of that this method is often used for engineering projects in industry.



Picture 4.3: *Mind-mapping methodology*

4.10. Implementing Project Methodologies

Successful implementation of any project methodology is a project itself. The hard part is to roll it out and make it part of the everyday culture. You cannot get everyone to start using the new methodology by simply attaching a few wall charts of the project methodology to cubicle walls and expect results. It could in fact take many months to implement a full-blown project methodology. Many project life cycles require the following:

- Automation and workflow.
- Ease of use.
- Proper methodology documentation.
- Acceptance by the entire organization.

Some modesty is necessary before attempting any methodology implementation. Who can speak authoritatively on *all* the issues that are of concern in the implementation of project methodologies? The only thing that really distinguishes projects from non-projects is the project life cycle. To develop a broad understanding of the generic discipline of the management of projects, both project managers and executives should address the broad range of issues affecting all stages of the life cycle in all kinds of projects. This is certainly a tough challenge: It requires a substantial breadth of analysis and understanding.

4.10.1. How to Get Started with Methodology

One of the first things to do is to establish a methodology project team. This team will be responsible for implementing the overall methodology or framework that will be used. The methodology is tweaked and adjusted to fit the organization. Next, document and start expanding the methodology. Feedback should be encouraged and used to correct critical issues omitted. After the corrections are made, a pilot project to test the methodology, using a real project, is launched. The following steps should be taken to execute this pilot:

- Pilot the implementation processes using a series of workshops.
- Establish appropriate project office, portfolio management, and other support functions to enable the new pilot methodology.
- Incorporate a process feedback system into the pilot rollout.
- Develop a communication plan for the organization.
- Measure results continually throughout the pilot implementation.

Many participants do not know what they want when determining project scope, risk, and execution of projects, nor do they realize the intricacies of project/development methodologies. Therefore, the project manager should introduce everyone to the basics of project management or development best practices. After they understand these project/development concepts, show them the need to introduce a framework. Then start extending your efforts by adding project templates, tools, and techniques.

4.10.2. How to Implement the Methodology

The methodology should be introduced gradually—it does not help to have a massive deployment to company departments, and possibly operating companies, without first gaining some prior success on a small scale. Implementing the methodology on a step-by-step basis demonstrates early successes and allows you the opportunity to adjust things you may not have had time to do in a single deployment. As the project lead for the implementation of the methodology, you could decide to conduct a pilot project to prove that the methodology works. You could be faced with a scenario in which a process does not work well, or you might need to tweak a phase of the new methodology. If the project fails because the methodology is too complex or is drawn out because of administrative work, it is time to meet with the project sponsor, who is the champion for the new methodology. Minor issues can be refined based on the pilot project experience. The second project will go more smoothly if you implement what you learned from the pilot project. There has to be some feedback loop built into "tweaking" the methodology.

The introduction of any project methodology to an organization/team impacts:

- The people.
- Their roles and responsibilities.
- The processes.
- The technology being used.

This level of impact must be assessed and managed accordingly. A useful checklist of the issues and concerns should be prepared; it should cover the organization, its culture, the people, and, possibly, attitudes that need to change.

4.10.3. How Long Is a Typical Implementation?

Each project methodology has its own unique set of challenges and advantages. Certain methodologies are simply straightforward deployments, whereas others designed from scratch may take longer to deploy. Project methodology implementation durations can range from 8 to 12 weeks for a standard ones. For a tailored approach, six months is the minimum period needed. A more complex deployment could take substantially longer (e.g., deploying a project methodology in 20 offices globally). Immediate results of implementation of your methodology become evident after a few projects have been completed, but the metrics should be established as soon as possible (i.e., you want to measure the number of projects that succeed in reducing cost or schedule overruns because of the chosen methodology).

4.11. The use of Gantt Chart

Gantt Charts are useful tools for analyzing and planning complex projects, because they:

- Help you to plan out the tasks that need to be completed
- Give you a basis for scheduling when these tasks will be carried out
- Allow you to plan the allocation of resources needed to complete the project, and
- Help you to work out the critical path for a project where you must complete it by a particular date.

When a project is under way, Gantt charts help you to monitor whether the project is on schedule. If it is not, it allows you to pinpoint the remedial action necessary to put it back on schedule. An essential concept behind project planning (and Critical Path Analysis) is that some activities are dependent on other activities being completed first. As a shallow example, it is not a good idea to start building a bridge before you have designed it!

These dependent activities need to be completed in a sequence, with each stage being more-or-less completed before the next activity can begin. We can call dependent activities 'sequential'. Other activities are not dependent on completion of any other tasks. These may be done at any time before or after a particular stage is reached. These are nondependent or 'parallel' tasks.

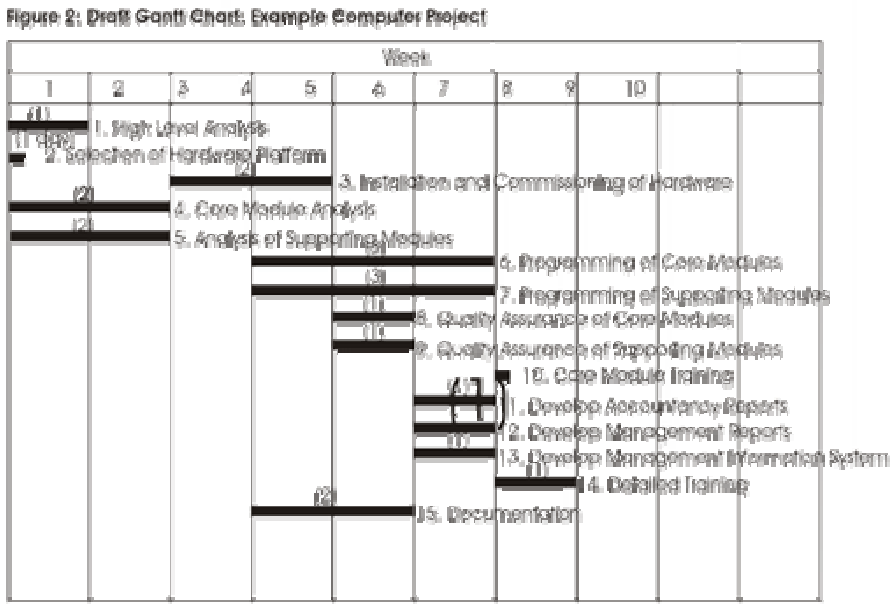
Steps to form a Gantt Chart:

1. List all activities in the plan
For each task, show the earliest start date, estimated length of time it will take, and whether it is parallel or sequential. If tasks are sequential, show which stages they depend on.

2. Head up graph paper with the days or weeks through to task completion

3. Plot the tasks onto the graph paper
Next draw up a rough draft of the Gantt Chart. Plot each task on the graph paper, showing it starting on the earliest possible date. Draw it as a bar, with the length of the bar being the length of the task. Above the task bars, mark the time taken to complete them. Do not worry about task scheduling yet. All you are doing is setting up the first draft of the analysis.

This will produce an untidy diagram like the one below:



Picture 4.4: *Gantt chart example*

4. Schedule Activities

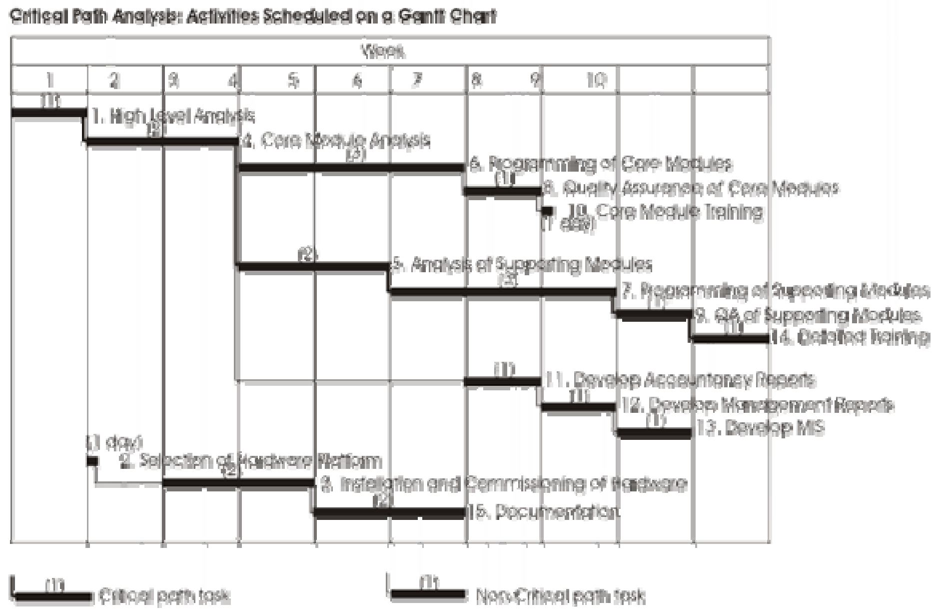
Now take the draft Gantt Chart, and use it to schedule actions. Schedule them in such a way that sequential actions are carried out in the required sequence. Ensure that dependent activities do not start until the activities they depend on have been completed.

Where possible, schedule parallel tasks so that they do not interfere with sequential actions on the critical path. While scheduling, ensure that you make best use of the resources you have available, and do not over-commit resource. Also allow some slack time in the schedule for holdups, overruns, quality rejections, failures in delivery, etc.

5. Presenting the Analysis

The final stage in this process is to prepare a final version of the Gantt Chart. This should combine the draft analysis (see above) with your scheduling and analysis of resources. This chart will show when you anticipate that jobs should start and finish.

A redrawn and scheduled version of the example project is shown below:



Picture 4.5: *Critical Path analysis*

By drawing this example Gantt chart, it is possible to see that:

- If all goes well, the project can be completed in 10 weeks
- If you want to complete the task as rapidly as possible, you need:
  - 1 analyst for the first 5 weeks
  - 1 programmer for 6 weeks starting week 4
  - 1 programmer for 3 weeks starting week 6
  - Quality assurance resource for weeks 7 and 9
  - Hardware to be installed by the end of week 7
- Analysis, development and installation of supporting modules are essential activities that must be completed on time.
- Hardware installation is a low priority task as long as it is completed by the end of week 7

While this section describes how to draw a Gantt Chart manually, in practice project managers tend to use software tools like Microsoft Project to create Gantt Charts. Not only do these ease the drawing of Gantt Charts, they also make modification of plans easier and provide facilities for monitoring progress against plans. Microsoft Project is reviewed at the top of the left hand sidebar.

Key points:

Gantt charts are useful tools for planning and scheduling projects. They allow you to assess how long a project should take, determine the resources needed, and lay out the order in which tasks need to be carried out. They are useful in managing the dependencies between tasks. When a project is under way, Gantt charts are useful for monitoring its progress. You can immediately see what should have been achieved at a point in time, and can therefore take remedial action to bring the project back on course. This can be essential for the successful and profitable implementation of the project.

5. **Managing Power Electronics Project for IEEE Contest**

Project system is a set of different elements,
so connected or related as to perform a unique function
not performable by the elements alone.

Each two years 4 basic *IEEE* [1]sections in the field of power engineering make an open call for Competition for all of the Universities throughout the world expecting the students to develop new energy solutions through their work and innovation.

Students World Contest: **Future Energy Challenge** (http://www.energychallenge.org) is organized in order to bring innovations in the field of Energy Science and to attract more and more students to think on the way of saving the energy.

Energy saving is a modern trend in electrical engineering, experiencing a great boom in the last decades. Reasons are constant rise of energy prices and awareness of limited energy resources on Earth. Saving electrical energy is of outmost importance since it is the purest form of energy that can be easily converted to any other form. According to some data, electrical drives in the developed world consume between 60% and 70% of all the electric energy produced in these countries [1, 2]. Some of these motors are in houses of each one of us, in our blenders, vacuum cleaners, washing machines, air-conditioners and usually we pass by them without even noticing them. Everyone household has at least one these appliances, so just imagine what amount of energy they consume and what amount of money as well.

Frost & Sullivan Market Intelligence report that motors with power under 7,5 kW present 40% of USA market, those of powers of 7.5kW to 75kW represent 31% and those over 75kW are 29% of the market. The next well-known fact is that over 90% of all the motors produced in the USA have less than one horse power and overall value of this market share is more than 7 billion US dollars annually.

[1] [illegible]

The vision of the Challenge was to encourage development of technologies and to bring dramatic improvements to low-cost single-phase motor systems for home use, to incorporate practicality, manufacturability and affordability into competition process, improve education through development of innovative team innovative team-based solutions to complex based solutions to problems. The technical goal was to construct adjustable speed motor system Construct adjustable speed motor system costing less than US $40 for a 500 W unit, achieving maximum efficiency and operating requirements while maintaining acceptable levels of performance, reliability, and safety.

The direct requirement on Students World Contest was to develop a final product - single-phase adjustable speed drive with 500W rated power and 1500rpm rated speed, which would allow continuous speed control in 150-5000 rpm range with efficiency higher than 70%. The **MiniDrive team** was fully developed in Laboratory for Digital Control of Electrical Drives at the Faculty of Electrical Engineering, by undergraduate students from the Power Engineering, Electronics and Automation and Control departments of this faculty. The prototype is based on a three-phase induction motor (Tesla's motor), with complete electronics integrated in the motor box; sensor less control algorithm performed on a low cost RISC microcontroller; digital display for speed and error code information and IrDA communication with a Pocket PC.

These advanced solutions, suggested by MiniDrive team, include the implementation of microcontroller logic with power electronics and highly sophisticated control algorithms. Great improvements were made in power electronics area since the beginning of their implementation in the late 60s thus making drive control much more flexible and the price of these drives similar or less than those of DC motor drives.

This presents one real research project with a strict requirements, criteria, time, final product valued on the market, team members, and of course leaders and managers, whose role is the most important here.

Steps in leading the MiniDrive project:

5.1 Project objective – Establishing the Project

5.2 Breaking-down structure, structuring the project

5.3 Task description and distribution

5.4 Organizing the team

5.5 Planning phase - Setting the Milestones

5.6 Running the Project: Progress – Control – Monitoring

5.7 Reports – Documentation – Closing.

5.1. Project objective – Making the Project

At the very beginning, the idea to participate at the International Future Energy Challenge occurred, so, after several consultations with professor Vukosavić – head of Department for Digital Control of Electrical Drives, we made a strong decision to take part.

Our vision was to make a motor prototype - final product that will satisfy requirements set by the organizers. We were strongly committed to organize to whole process of making the prototype, leading and managing the group of young and not so experienced students and at the very end to take the first prize in Students' World Contest.

The first step of a project was to make an objective (goal) in one or two sentences that describes what the project is intended to accomplish. As team leaders, our attempt was to establish the project objective. Normally, this won't be a problem because we know the general purpose of the project. An objective statement for our project was:

The MiniDrive prototype is an upgraded digitally controlled single phase 500W unit asynchronous motor-drive with innovations in easy control and energy efficiency.

The next step was to make a project proposal with all necessary details. We included all needed specifications: software, additional equipment and literature, so we made a projection how many students we need because there was a deadline, so, at the end of the Contest, we have to send our prototype to United States (the Finals is decided to be there) to be tested. The Project proposal presents the whole structure of a project we made, and it was consist of four main aims:

5.1.1. <u>Supporting students to work in innovative way</u>

The basic knowledge gained through the faculty is a good foundation for further designing work. By working on this International competitive project, students get an opportunity to feel all the phases has to go through in order to reach a solution. At the same spot a number of students from various departments of School of Electrical Engineering are gathered around the same assignment to act as a team.

Each one of the students has his area of work on the project and can realize the necessity of each other member, and understand that without mutual cooperation the goals cannot be reached.

By working on a project of this kind, students can present their own creativity and also get the opportunity to improve their knowledge of the particular subject. Since the problems we are dealing with are very up-to-date in electrical engineering, partial project results can be used as a basis for graduation works, as well as for papers for some seminars, conferences or workshops. Another project result is student's introduction to development of all the needed project documentation as well as introduction to writing conference papers because it is something they haven't come up to in the regular course of their studies.

5.1.2. Design of integrated drive as a practical application

Design of the motor-drive is more than useful for it can solve the problem of efficient motor speed regulation. Such a device could be applied in all sorts of home appliances that can be driven by asynchronous motor (mixers, laundry-machines, vacuum-cleaners, hair-dryers, air-conditioners...), small compressors and pumps used both at home and in industry, as well as in all sorts of drives limited to the power of *500 W*. The speed reference signal would be set either manually through linear analog signal or remotely by computer. Another possibility of remote speed setting would be available, namely by palm-top computer via IR communication.

Considering today's common practice to use (that contain a lot of lead inside) where the speed regulation is needed, growing trend in the EU member states is to substitute this devices with asynchronous motors for the reasons of ecology. Our device driven by asynchronous motors would be also able to work in a wider speed range than collector motors, running on speeds exceeding nominal more than three times, while accomplishing significant energy saving and improving overall energy efficiency. Besides the design of the whole integrated drive, representing around two thirds of the amount of work, it has become a common knowledge that there would be a lot of work left considering standardization and adjustment of the final product to the costumers. All the big companies having an research and development section are facing the problem of responsibility in such a dynamic work. For the reasons given above, one of the goals is making the students be aware that this work carries a burden of responsibility.

5.1.3. Promotion of the faculty and the power engineering

Many universities from around the world took part in this competition, but beside three universities from USA, our team was the only European representative reached the finals. During one of the previous *IEEE* conferences in Seattle where the accomplished results were presented by each team, we were marked as the one with best perspective and thus motivated even more to proceed and bring this project to its end. This fact has pushed up significantly our faculty's rating among *IEEE* members present at the conference and shown that we keep up the pace with today's scientific trends.

In the past few years student's interest in studying power engineering is ever smaller, on our faculty as well as throughout the world. Perhaps the reason is lack of information of what power engineering and power electronics can offer. This project can certainly promote possibilities in this area in a very good manner while being a very good base for further research.

5.1.4. <u>Educational impact</u>

Working on this innovative project, students will meet with a very new way of thinking. They will develop a new solution for requirements set by the organizers, generating ideas that will gather in a very new product that will have a market value. All knowledge they've got at the Faculty, they can practically use in the complex project. Deep analyzing, responsibility, making decisions, communication among team members, initiative are main parts of this project, so this is a great opportunity for all of them to feel how big engineering projects looks like.

Writing the papers for Conferences, reports and technical documentation are new aspect of engineering, which students couldn't find during the basic studies, but being on this project. Later on, four papers were presented at the International Conferences, and several articles were published in IEEE Region 8 Magazine.

So, the structure of the project was set, and we could start with procedure of breaking-down in order to see how many activities will be on the project, and to see how many students, and which profile we need. This first phase of leading the project need sometime, and can not be done very fast, because that is a base for further planning. So one final project is consists of starting point, detailly explained procedure and a well defined result that need to be achieved. Also, project need to have milestones, which are clear and unambiguous targets.

5.2. Breaking-down structure, establishing the structuring

After describing the whole process and procedures to achieve the appropriate prototype, it is possible to divide a project onto less difficult *activities*. If any of these are still too complex to easily organize, it is necessary to break them down also into another level of simpler descriptions, and so on until make them possible to manage everything. Thus our one complex project is organized as a set of simple tasks which together achieve the desired result - a functional prototype.

In planning this project, we were trying to follow the well known simple steps: if an item is too complicated to manage, it becomes a list of simpler items - ***work breakdown structure***. Planning is the act of determining what needs to be done when. The simplest plan is "We will have the project finished by August the 1st." Unfortunately, unless the project starts after August the 1st, such a "plan" is doomed because, until the completion date, there is no way to tell whether the project is on track.

The purpose of our planning is to permit us to run the project—to take whatever actions are needed to ensure that it will complete on time. Planning has no other purpose or intrinsic value. Once the project is complete, the plan's job is done. Other than for project review or to guide future planning, it may be discarded.

To track progress, the project must be broken down into small, manageable activities. The piecemeal approach is simply to begin listing activities and hope that the ones you miss don't sink you. There is an alternative, a systematic approach known as *hierarchical decomposition.*

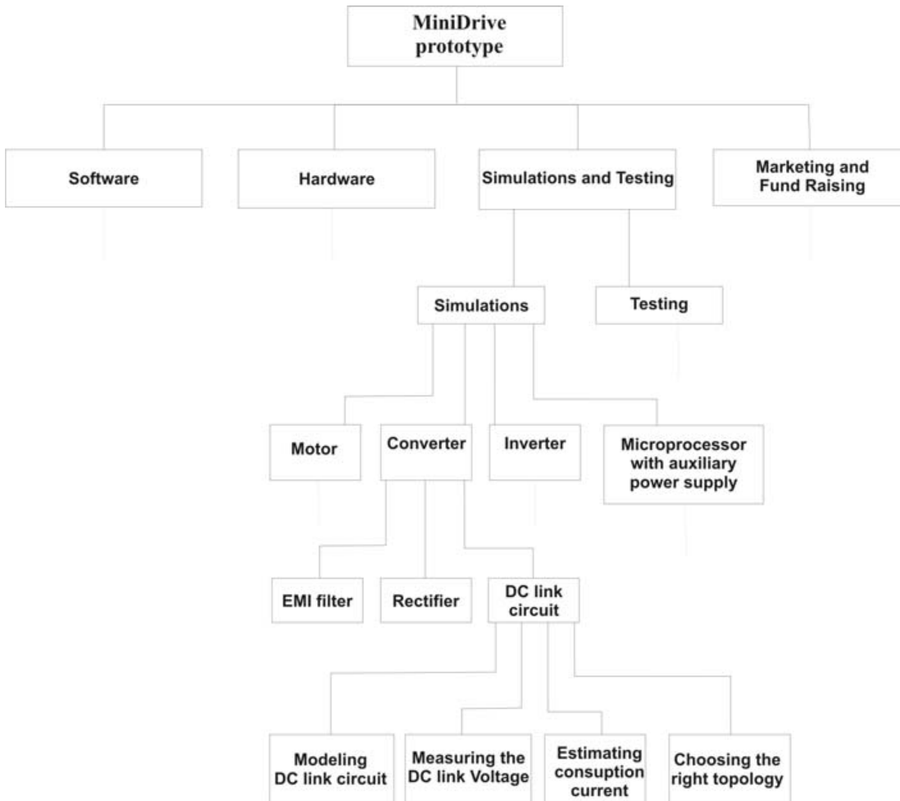
Decomposition is the process of breaking down an activity into smaller chunks. *Hierarchical* means that the decomposition proceeds top-down by defining the major components of the project, then breaking each component into smaller pieces. The process continues through successively lower levels until the activities are "small enough." With some practice, this top-down approach ensures that all activities will be identified. The result is the work breakdown structure.

The MiniDrive project was a great mixture of Powers, Electronics, Automation, Programming and Communication, so technically we need to make lots of research in several directions, but also to make work break-down and list all the manageable activities. Because of that complex research, firstly we divided the whole project into four big activities:

1. **Simulations and testing**
2. **Hardware research**
3. **Software research**
4. **Marketing with Fund Raising.**

Simulations are used to predict the expected problems and to check functionality of the whole concept, but also to try to set the main principles of control algorithm. So, the drive had to be very precisely modeled, with the least neglects possible, in order to obtain parameters of the control algorithm that would ensure the requirements of the project are met. Simulations bring first preliminary results upon which is possible to make other steps. The drive prototype is separated into following sections: motor, converter (EMI filter, rectifier and DC link circuit), inverter and microprocessor with auxiliary power supply. The simulation model has roughly the same structure. Matlab Simulink was used for all simulations, so the simulation results gave us certain response and we could choose the right topology in choosing the electrical components.

Also, simulation was used in generating the printing circuit. The OrCAD software was used as a tool to make a precise description of the main electric board, where all passive and active components will be implemented.



Picture 5.1: *An example of Breaking-down the structure*

Hardware research activity includes process of issues which resulted by original hardware setup that was the basic part of the whole drive system. List of simple passive components, comparation of different components, different producers, technical sheets, implementation, assignment, functionality are activities needed to be proceed.

Hardware research was maybe the most difficult activity, with a lot of separate tasks – subtasks like: generating Auxiliary power Supply, Inverter, DC link, Rectifier and EMI filter, implementing the Power Factor Control (PFC), designing the Control circuit with all the protections, do the termic design... And at the end choosing the components, making the printing electrical circuit and assembling the elements onto the board.

Software research activity mainly includes process of programming the control algorithm, A/D conversion and protection, PWM signals that drive the inverter, communication among devices and necessary protections. But also, there was a great doubt about choosing the right processor, so, apart of programming, members of software group should present advantages and disadvantages of proposed devices in order to make a decision which to use later on.

Marketing with Fund Raising brings a great responsibility in giving publicity to the team and attracting the financial institutions and companies for sponsorships. First step is to make a proper Project Proposal that consists of project goals, principles, rough description and financial plan. An internal system for communication among the entire group is the second step, so, all MiniDrive members can send and accept necessary information about the project: news, tasks progress, eventually changing the plan, questions, descriptions…

Explaining and adopting the technical innovations of the MiniDrive team, and showing them to the public, as well as progress and results, is the responsibility of **Marketing with Fund Raising** group. Some important tasks of the group were to make a project proposal, make financial plan and constantly care about communication on the project.

Here is the break-down structure with all tasks and sub-tasks hierarchically presented the whole Project and steps for each of groups to make.

1. DRIVE
- 1.1. SIMULATION RESEARCH
  - 1.1.1. Motor Simulation
  - 1.1.2. Converter simulation
  - 1.1.3. Simulation of microprocessor with auxiliary power supply
  - 1.1.4. Inverter simulation
- 1.2. MOTOR TESTING
- 1.3. SIMULATION RESULTS
- 1.4. DRIVE TESTING

2. HARDWARE
- 2.1. AUXILIARY POWER SUPPLY (APS)
  - 2.1.1. Flyback converter analysis
  - 2.1.2. Buck converter analysis
  - 2.1.3. Generating the final Schematic for APS
- 2.2. INVERTER
- 2.3. PFC
  - 2.3.1. Examine the Standards
  - 2.3.2. Generating PFC
- 2.4. DC LINK CIRCUIT
- 2.5. RECTIFIER & EMI FILTER
  - 2.5.1. Rectifier
  - 2.5.2. EMI filter
- 2.6. CONTROL CIRCUIT & PROTECTION
- 2.7. TERMIC DESIGN

2.8. CHOOSING THE COMPONENTS
2.9. PRINTING BOARD
2.10. ASSEMBLING THE ELEMENTS ONTO THE PRINTING BOARD

3. SOFTWARE
3.1. PROGRAMMING
3.1.1. Control algorithm
3.1.2. A/D conversion and protection
3.1.3. PWM signals
3.1.4. LED Display
3.1.5. Digital Communication
3.1.6. Protections
3.2. REALIZATION OF OBJECT ORIENTED INTERFACE

4. MARKETING WITH FUND RAISING
4.1. MAKING THE PROJECT
4.2. WEB PRESENTATION
4.2.1. Internal
4.2.2. External
4.3. PUBLIC RELATIONS
4.4. FUND RAISING

When recognized the list of all project activities, arranged hierarchically in levels, it is much easier now to describe them. The activities are used to prepare estimates, assign resources, and track progress. They also include charges for the team members, which, with the costs, constitute the project budget. One of the major uses for WBS numbers is time reporting. Team members will complete time sheets, charging their time to specific activities identified by WBS number. The number will also be used to identify activities in the schedule. Once the project has started to gather statistics by activity, the activities cannot easily be renumbered, so it is wise to use a number scheme that allows new activities to be inserted.

5.3. Task description

According to the realization of the MiniDrive prototype presented, the entire project has been divided to 20 tasks grouped in four group activities. All the tasks need to be described and sorted to each of the groups. Very important is a starting point for each task, the literature, or a model – material that will help group member(s) to start work on the activity. Also, very important is definition of task result expected when task is finished.

Task description:

Task ID	Task description	Task result
Group A – DRIVE		
Drive 1	**Simulation research.** Simulation of asyncronous motor in rotor field reference frame, converter and control	1. SIMULINK drive model 2. Report that describes the model and gives parameters needed
Drive 2	**Motor testing.** Experimental verification of motor performance and parameters	1. Report that proves motors rated values and parameters
Drive 3	**Simulation results.** Simulation of the whole drive	1. The complete SIMULINK drive model 2. Report with diagrams that shows simulation drive performance specified by the proposal specifications
Drive 4	**Drive testing.** Experimental verification of the drive performance	1. Report with diagrams that shows drive performance specified by the proposal specifications
Group B – HARDWARE		
Hardware1	**Auxiliary power supply.** Do the analyzis of buck and flyback converters; chose the right one and generating the schematic.	1. Deatil report of comparation of two analyzed converters 2. Auxiliary power supply schematic
Hardware2	**Rectifier.** Choosing rectifier diodes based upon thermal characteristics	1. Report that shows thermal calculations and gives diodes name, characterics and ordering number
Hardware3	**DC link.** Choosing DC link capacitor based upon thermal characteristics	1. Report that shows thermal calculations and gives capacitor name, characterics and ordering number
Hardware4	**Inverter.** Choosing inverter transistors and diodes based upon thermal characteristics	1. Report that shows thermal calculations and gives transistor and diodes names, characterics and ordering numbers
Hardware5	**Choosing the components.** Choose the right components needed to satisfy prototype requirements.	1. Make a list of neccessary components 2. Contact big components' producers for prices: Farnell... 3. Compare the components from different producers 4. Make a final list of choosed components with: component name, producer, price

Hardware6	**Assembling the components to the printing board.** Make a final printed board that is functional.	1. Check the funcionality of the printing board and check the components 2. Do the Assembling in order to get funcual printing board
Hardware7	**EMI filter.** Choosing EMI filter parameters based upon experience	1. Report that gives EMI filter description and parameters
Hardware8	**Printed board.** Design of printed boards for various testings (e.g. software) and design of the final printed board	1. Printed board for each testing with ORCAD file 2. The final printed board with ORCAD file
Hardware9	**PFC.** Studing the IEC standards given by organizers and give the PFC characteristics.	1. List of main hints given by IEC standards 2. Main characteristics for proposed PFC
Hardware10	**Control circuit with protections.** Make the schematic of control circuit withmicroprocessor and all passive components.	1. Give the proposed OrCAD schematic for control circuit
Group C – SOFTWARE		
Software1	**Programming.** Programming the control algorithm, A/D conversion and protection, PWM signals, Digital Communication and Protections.	1. Program of Control algorithm 2. Program of PWM signals 3. Program of Digital Communication 4. Software verification of all three programs
Software2	**Object oriented interface.** Realization of object oriented interface.	1. An idea for object oriented interface 2. Program of object oriented interface
Group D – MARKETING		
Marketing1	**Internal web site.** Making a safe and secure internal network for exchanging ideas, news, attachments...	1. Defining the number of users 2. Make a pilot version of internal web site and check the functionality 3. Do the final functional internal web site
Marketing2	**External web site.** Making functional web site to inform public about MiniDrive goals, progress and attempts.	1. Suggest the web site map 2. Suggest the web site design

Marketing3	**Fund raising.** Generating the financial plan, that includes all the project expences.	1. Calculate all the expences for additional equipement 2. Make an overal financial plan for each group 3. Locate the main potential sponsors and prepare the complete Project Preview with Financial plan
Marketing4	**Public relations.** Making the reports for newspapers, TV meadia and updateing the web site news.	1. Make the Media map of desired TV and newspaper representatives 2. Do the strategy and template of keywords for reports

Name of all the tasks, their timelines and links among each other are given in form of a Gantt chart in Appendix I. The real success of the management team lies in the fact that most of the work is done according to the plan made at the very beginning of the project in June 2004. Slight changes occurred mostly due to extremely huge difficulties experienced with the purchase of various components that mainly came from USA producers that do not have representatives in the region of South Eastern Europe, or due to temporary lack of funds. This problem was usually solved by changing both component and calculation, or by patience. During May, according to the Gantt chart, the new task that included power factor control design has started. The need for this improvement came out of the performance drive test, which was not satisfactory.

5.4. Forming the team - Team organization

Activities are carried out by individuals, but planning usually starts with classifications. To complete an estimated plan, it is needed to know what types of skills each activity needs and what staff classifications have those skills. The leaders have to put names to each activity, but, it is important to know how many of which type of staff is need. Distributed activities sometimes involve one person (project management) or a number of people—up to and including the entire project team (reviews).

On this MiniDrive project, we clearly understood that we do not build systems; teams do. There is a vast difference between a team and a bunch of people, not the least of which is performance. Building a team is therefore the most important aspect of running a project.

A team is a group of people who are *committed* to a *common goal*. The common goal for a project should be easy to define: It is the successful completion of the project.

It was not easy at all to choose the team, even the core team. We knew all the tasks need to be done, but we didn't know if students could finish the required activities, nor quality, nor on scheduled and planned time. So, we decided to make several presentations, kind of short lectures (workshops) for students from Departments of Electronics, Powers and Automation. Our aim was to present the whole project, the goal of the project, but also the phases, deadlines, tasks and activities that need to be done by students, so in that way to try to attract and involve them into the project.

When 20 of students desired to join the MiniDrive team, we need to sort them in the groups we made before. Very important was to make a short-term training for each of student, in order to be aware of team spirit, implementing the innovations during working on the project, and of course of responsibility.

All the engineering work on the project was performed in first four groups whose members were undergraduate students. Each task within the group was undertaken by at least two students, since teamwork was one of the organization priorities.

After two months it was easy to choose a leader of each group. The main responsibility of the person was to control the progress in the group, implement the communication among team members and prepare and moderate weekly group meetings.

The communication within the groups has been realized through weekly meetings and discussion lists posted at the internal website and e-mailing groups. The meetings are organized in two levels: within one group only and between all the groups. The purpose of the weekly meetings was live information and discussion on progress results including actions to be performed in the future. Internal website and e-mailing groups were also design in order to make communication easier and more effective. The purpose of internal website was to post all the documentation needed for our team members to perform their tasks, and for the short discussion that needed fast decisions.

Team meetings are an essential part of team building. Properly run, they help develop a true, committed team spirit. Improperly run, they provide public validation of the attitude that it's them against you. The purpose of a team meeting is to gather and disseminate information, not to discipline, solve problems, or identify the guilty.

During the team meetings the main aspect was MiniDrive members' **motivation** and spreading the overall commitment. Motivation we were running was based on the knowledge students get during working on the MiniDrive project, working in a group with the same aim.

5.5. Planning phase – Setting the Milestones

Planning phase is coming after we divided the project onto tasks and describe all the tasks, assign the results and sort them into the four groups. A plan is more than a schedule or Gantt chart, so we are aware what most people call "the plan" is really "the schedule." It is important to know that task owners must buy into their assigned tasks, dates, and dependencies but also the plan focuses on the results the project team was engaged to achieve.

Planning Process Objectives are when we confident that the plan covers all requirements and that the plan has buy-in from the team and group leaders, but also when realize that it is possible to manage the project with the plan.

Most important, the right plan is one that ultimately comes from us, so that our work reflects our critical path accurately and truthfully, and is the roadmap we use to make sure we do not get lost, even if the team contends they know better than us, leaders, where the project is going. In order to make an accurate and functional plan we have to be sure that we:

- Understand requirements completely.
- Write an implementation strategy for each key requirement.
- Roll those strategies into our master plan.
- Ensure that the critical path is the backbone of our schedule.
- Make the plan to be as detailed as required to effectively manage the project.

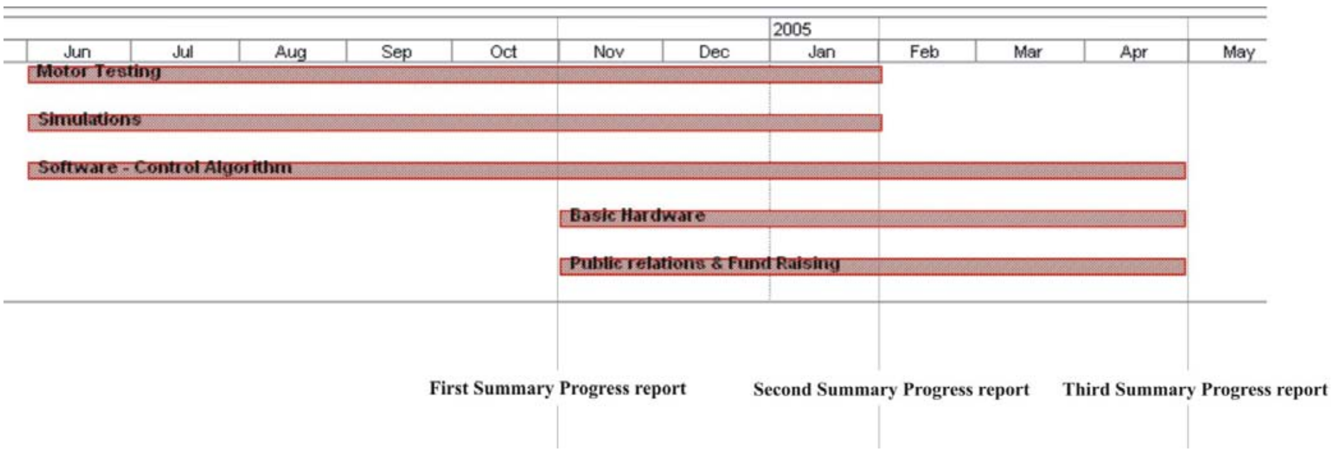
We were aware that it is not uncommon for project managers and team leaders to essentially rush straight to the work, no matter what managed to find its way onto paper. To do that, we need to be okay with the process ourselves. We developed our requirements and specifications while the technology solution was designed and validated. Also we wrote an implementation strategy for each solution and accounted for all identifiable risk.

What we took into account were the dead-lines and progress reports we were obligated to make. Organizers gave us 4 dead-lines: the 1st of November – First Summary Progress report, than the 1st of February - Second Summary Progress report and the 1st of May – Third Summary Progress report. We had to organize the group in a way of making the quality technical documentation while doing any research on a Project, so that can be used for Progress reports. The idea was to have enough material to make proper progress report before deadline, because due to report some teams will be eliminated.

Very first step in planning phase we bring an idea to take main components and lay them out with only one or two levels of detail. Critical dates are assigned to these plan segments, and any key relationships, such as dependencies or linked task dates, are identified at this time. At this point, we only have a plan with a few dozen "tasks." That is most desirable in that the relative dearth of tasks makes it easier to maneuver major deliverables and dates without the encumbrance of all that detail.

For the main activities we chose: Motor testing (to see if it fits in the requirements gave by organizers), Drive Simulations (modeling the whole drive concept and make changes on time, if necessary), Software (programming the most important Control algorithm), Basic hardware (generate

Auxiliary Power Supply as well as Power electronics and surroundings for Micro Processor) and at a very end - Public Relation and Fund Raising (needed to announce the aims of the team and to try to get some funds).



Picture 5.2: *Gantt chart for global activities and progress reports*

On picture above we presented main activities that need to be done in showed period of time. We projected five main activities in timeline and put three date for progress reports just to make a general plan which groups need to start to work on activities firstly.

Now that we have gotten a much better handle on the schedule, it is time to review it with team leads to ensure that everyone else agrees with the scheduling logic. These conversations may be difficult for a couple of reasons. Team leads may very well insist that their views of the schedule are better than our big picture, even though we are looking at all aspects of the project compared with their parochial views. We were way ahead of them in terms of thinking this through. It is also possible that people push back because they do not understand what we planned to do.

But we were patient, trying to understand that getting everyone on the same page is critical. So, our plan was to give the group tasks to each group and to see how they will organize time for completion of these activities. After they put the activities with all dependencies to the timeline, we gathered all the students with a purpose of making the overall project interdependencies so the Gantt Chart was almost ready.

Milestones are needed in order to control the progress on a project. It is not such easy to define milestones, so it is necessary to care about deadlines, priorities, procedures on a project so the milestones are the right ones.

A milestone is a specific date in the project when some clearly defined work will have been done. Many project plans have just two milestones, start and end, which means that the project manager will not know how the project is doing until it should have finished.

The purpose of milestones is to identify problems of two types: schedule slippages and functional deviations. A late milestone indicates a schedule slippage; a functional deviation occurs when the client says, “That’s not what I wanted.” Milestones provide a formal mechanism for the project manager to become aware of both kinds of problem in time to fix them.

Milestones come in two flavors: **external** and **internal**. External milestones involve the client and some form of approval, whereas internal milestones are restricted to the project team. There is usually an external milestone for each deliverable or set of deliverables. Internal milestones mark such points as the completion of a program or the planning for a workshop, where the outputs will not be formally delivered to the client. To ensure that you can judge when milestones have been met, they must require the delivery, in final form, of some concrete project output. A milestone that requires, for example, that a document be 50 percent complete is useless; nobody can judge percentage completion.

According to the progress reports required by the organizers, we made several milestones, the key points of our project. Because the whole project was complex we decided to set the internal milestones with our professor, and for external milestones to put deadlines that were given by organizers. So, internal milestones were some moments on our project where we presented the progress to the professor. He could test the made progress and criticize it, checking if we were on the track.

For example, our first milestone check was the entire Drive Simulation. The professor took several hours to test and examine the functionality of the Simulation, and at the end gave us critics and several ways to fix the faults on the simulation.

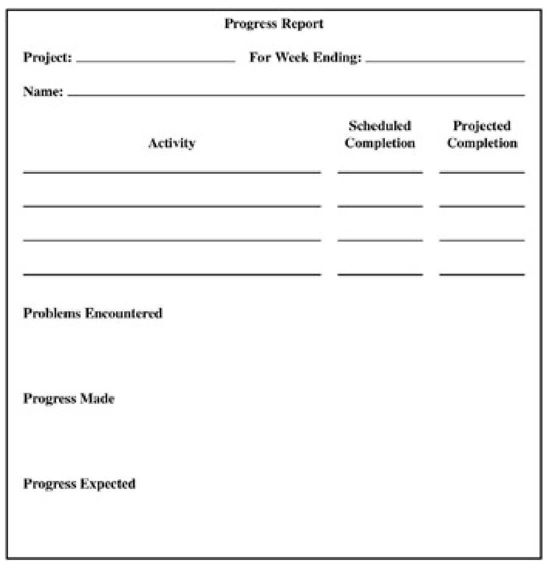
External milestones were the dates given by IEEE organizers. The first deadline was in October the 1st, 2004 where we presented Project organization and team members, Technical status, Project timeline, Safety regulations established and first Simulation results. Main point was to organize the critical group among MiniDrive members that will care about the Reports. 10 days before deadline, they stop with their project activities and started to prepare the report concept, than animating others to give the proper results in a proper way, so it can be presented the best in a report. They were handling the whole report, which was monitored by two leaders, and finally checked by professor.

5.6. Running the Project: Progress – Control – Monitoring

Running a project is simple: Meet all activity completion dates, and the project is on track; miss one, and you are in trouble. Keeping the project on schedule, therefore, means ensuring that all activities finish on time and that all milestones are met.

Regardless of how we tracked progress, we were trying to keep on some principles that make MiniDrive team more effective:

- **Being formal.** When wanted to find out how people are doing, we never asked casually and never depend on an oral response. We knew that there is nothing wrong with casual conversation, but when we really want to find out what is happening with the activity progress, there is only one effective way: To ask all team members for a formal weekly status report. Picture 5.3 presents the example of usual progress report need to be filled, so the progress could be measured.



Progress Report

Project: ____________ For Week Ending: ____________

Name: ____________

Activity	Scheduled Completion	Projected Completion

Problems Encountered

Progress Made

Progress Expected

Picture 5.3: *Example of weekly progress report*

- **Being specific.** We made sure all team members understood that when they say an activity is complete, it is complete. No further time may be booked against it, no more work may be done on it, its product advances to the next stage of the project.

Being formal and specific was a bit problem for us leaders, at a beginning, because we were almost the same age as the students were, so firstly we attract them on the project with a leisure and friendly atmosphere, and at one moment everything started to be formal. So, our idea was to motivate their work, so that they could understand that only serious work and commitment on a project can lead us to the top.

Internal website was a great instrument for measuring the progress, because whenever any of tasks were complete, team member put it on a internal website with the highest priority, so that all the team could see it. This was a great motivation for all to see the entire progress, but also to push harder in order to do the same.

One of the problem and challenges during running the project was making decisions. This occurred as a problem because we, leaders, could not know all the answers on plenty of technical questions made by project members. So, one situation can explain our doubts during managing the project:

There were 3 members in a Software group which were choosing the right microprocessor to implement into the drive. So, each of them proposed different type of processor: Atmel, DSP and PIC. In order to solve the situation, we decided to make a workshop where everybody could take part, with an aim to give equal chance for all three proposals and software members to present pros and cons. One afternoon was set up the workshop, not more than ten of us came, and blackboard was divided into three parts, for each of three microprocessors.

First step was to give software members 10 minutes each to present advantages and personal thoughts why should we use that processor, to try to persuade us. After that half an hour we gave each of them 10 minutes again to put on a blackboard all disadvantages of opposite proposals. So, all of us, including three software guys, could see all advantages and disadvantages for all three proposals. Then, several questions came from members of hardware group, they were carrying for electronics that will support the processor. After that, another set of questions started with a purpose to check the availability mentioned processors on the market and their price. So, after almost 3 hours the problem was solved, we choose the Atmel microprocessor, due to its characteristics, price, dimensions and easy to download the code and change it from time to time.

5.7. Documentation

The activity description gives an overview of the activity for those who will be carrying it out. However, its most important function is to help you ensure that no activities have been missed. It does this by requiring that you **document the inputs and outputs** for each activity.

All activities have inputs, which are usually documents, forms, standards, or code. All inputs must be either external to the project or provided by an activity within it. Similarly, all activities have outputs, usually documents or code. All outputs must be project deliverables or inputs to other activities.

Hence, documenting the activities with their inputs and outputs allows you to determine that all inputs are accounted for, either by external sources or by other project activities, and that all outputs have a destination, either as project deliverables or as inputs to other activities. Once we have established the source for all inputs and the destination for all outputs and we have determined that no activity has a mystery input or a hanging output, we can be confident that have not missed any of activities.

Documenting the activities is important because later, anybody can do the same activity just using the existing documentation. So, there are rules how one should do the technical documentation in Power Electronics projects. There are differences in coding and assembling, but rule of making proper documentation is to e clear and specify all necessary steps that help activity's completion. Most of documents bring some cautions and hints that can make documenting easier.

5.8. Measured Progress - Required Progress Reports and Results

In order to measure progress on a project we were asked for 3 progress reports during our work on a MiniDrive prototype. The required progress reports make strong influence over the jury to decide which team will keep competing in Contest.

All reports were presenting project progress in several ways:

- Progress in simulating and testing the drive
- Progress in hardware
- Progress in software
- Progress in establishing safety regulations

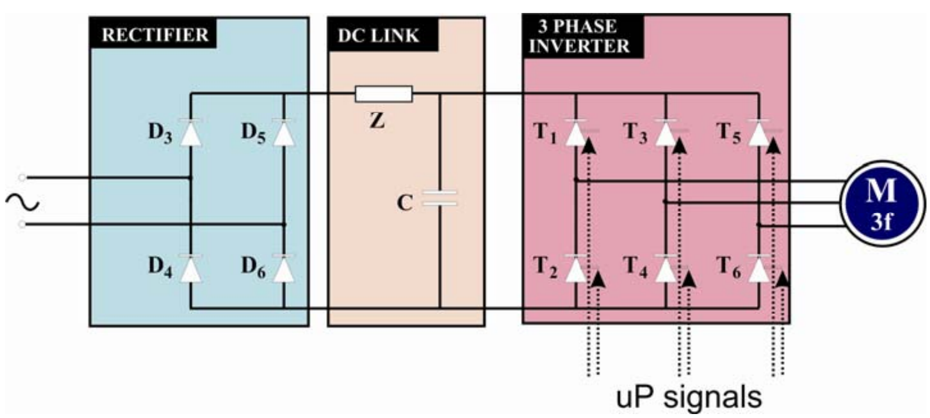
5.8.1. Progress in simulating and testing the drive

At a very beginning of the project the organizers set up ***the requirements for final prototype*** which have to be tested. It is requested that a convenient shape with volume less than 4 L, total mass less than 8 kg for the complete system. Power factor measured at the electrical input should be at least 80% when tested under a 500 W shaft load at 1500 RPM. Current waveform should conform to requirements in IEC1000-3-2 standards. Speed is to be controlled from start to the full 5000 RPM with a linear 0-10 V analog signal, referenced to the unit case. Except for starting, no testing will be performed below 150 RPM.

Results of Simulating and testing the drive in the First Progress report. Firstly it was started with simulation of a typical drive system, which will be used to determine the optimum parameters of the control algorithm; testing of the motor in order to obtain the parameters needed for the simulation; and testing of the finished prototype to confirm that it meets the requirements set by the project proposal.

The actual operating speed should remain within ±5% of the voltage command setting (2 V/1000 RPM) from no-load to full-load, while operating current shall not exceed 150% of the nominal full-load current under any conditions, including power-on inrush and motor starts. The input power source is single phase. There are *no restrictions* on the motor technology or motor phase count as long as the system operates from single-phase power.

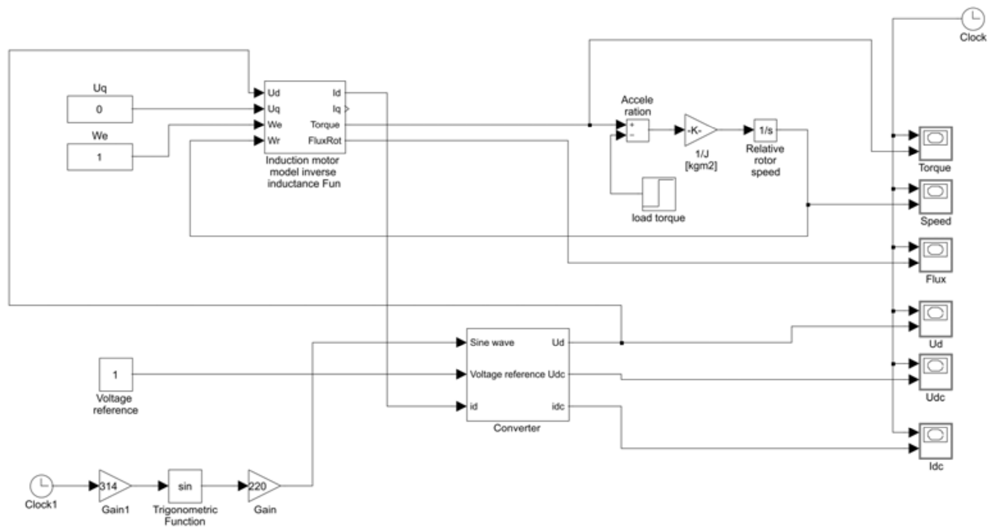
In order to meet the required speed regulation and accuracy set by the specification of the project, we have decided to apply the U/f regulation on our speed motor drive. We believe that this is the best solution considering the small amount of space available for electronics (the size of the printed board is only 10x10cm), and limited microprocessor time resources. Another advantage of this type of control is that only one current sensor is needed (it will be placed in the DC link where it will measure the total input current of the motor), while if we were using the current control we would need three current sensors - one for each phase of the motor.



Picture 5.4: *Typical topology of Digital Control Drive system*

Results of Simulating and testing the drive in the Second Progress report. The U/f regulation allows the mechanical characteristic of the motor to be shifted along the ω-axes in the M-ω plain (M-torque, ω-rotating speed) in order to achieve the maximum torque for any operating speed. This causes the incline of the mechanical characteristic to appear constant throughout the entire operating range of the rotating speed.

After calculating this mathematical model, we have simulated it using the Matlab Simulink. We will use this simulation throughout the project to determine an optimum control algorithm, in order to meet the specifications of the project. The applied transformations resulted in reducing the order of the model by two (it is now a 5th order model – two equations for the rotor, two for the stator and Newton's mechanical equation). The simulink model of digital control drive system is presented on Picture 5.5.



Picture 5.5: *Simulink Model of Digital Control Drive system*

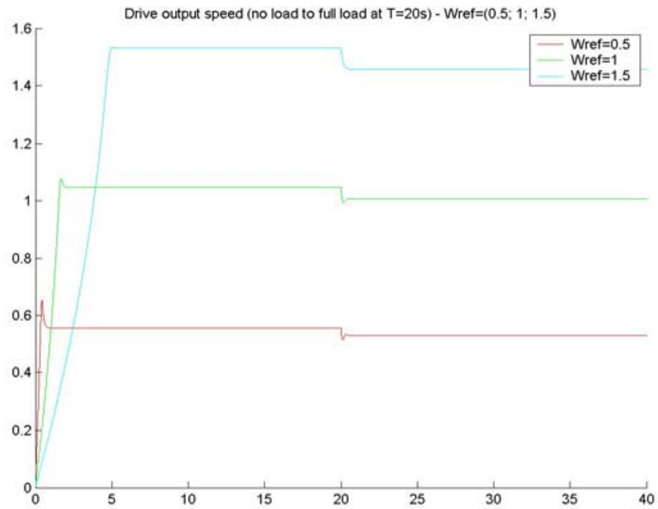
The Simulink simulation is derived with four presumptions:

- The magnetic circuit is linear
- The parasitic capacities are negligible
- The skin effect is negligible
- The motor is a *concentrated parameters network*

These presumptions cause an error of less than *3%*, which can be tolerated in the implementation of the model.

By applying the rotating reference frame model, we have adapted the motor to the application of the U/f regulation. This will make the control algorithm as simple as possible, thereby minimizing the microprocessor resources needed for the algorithm to be processed.

The tests of the motors have been finished, so the results showed the necessary parameters of the control algorithm that have been determined for speeds ranging from 0.5 up to 1.5 [p.u.]. The graph of motor speeds for 0.5, 1 and 1.5 rated speed is given in Picture 5.6. The one may notice that the speed signal is within 5% boundary, but we are still not satisfied with no-load to full-load response. Currently we are improving control algorithm to meet the required speed range and achieve better no-load to full-load response.



Picture 5.6: *Graph of Motor speeds for 0.5, 1 and 1,5 of rated speed*

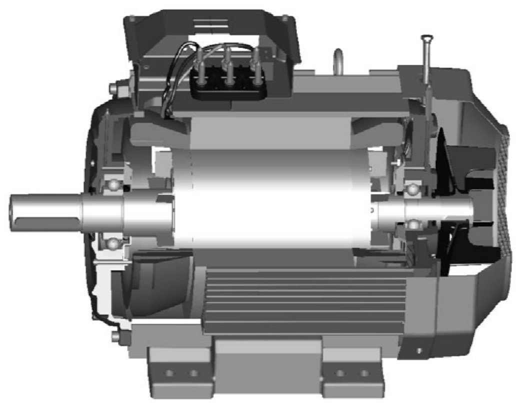
Results of Simulating and testing the drive in the Final Progress report. For realization of the MiniDrive, the team had three different three-phase induction motors (donated by *Sever-Subotica*, *Siemens* and *ABB*). The intention was to measure the characteristics of the three-phase motors in order to determine which best meets the project requirements, or if none of these three has satisfying performances rewind the single-phase motor to obtain the necessary characteristics. The comparison of electrical (efficiency, rated slip, nominal speed, nominal current) and physical characteristics (mass, volume) and price, revealed that one of the three three-phase motors meets the project requirements, so this motor was selected for the actuator in MiniDrive prototype. The opinion was that rewinding the single-phase motor would not yeld much better characteristics than those of the selected three-phase motor, but would consume a large amount of time. The main reasons for this dicision are low price, simple maintenance, cheap exploitation and possibillity of utilization in hazardous and sterile industrial environments.

Our final choise was based on relevant factors shown in the following table (the table includes manufacturer data and measured results).

Table 5.1: Comparison of three-phase motor's characteristics

Parameter	Motor Sever	Motor Siemens	Motor ABB
Rated Power [W]	550	550	550
Efficiency factor [%]	69	71	71
Power factor [%]	76	78	78
Rated Current [A]	1.59	1.32	1.5
Rated Slip [%]	8.34	6	6
Mass [kg]	9.8	10	7.9

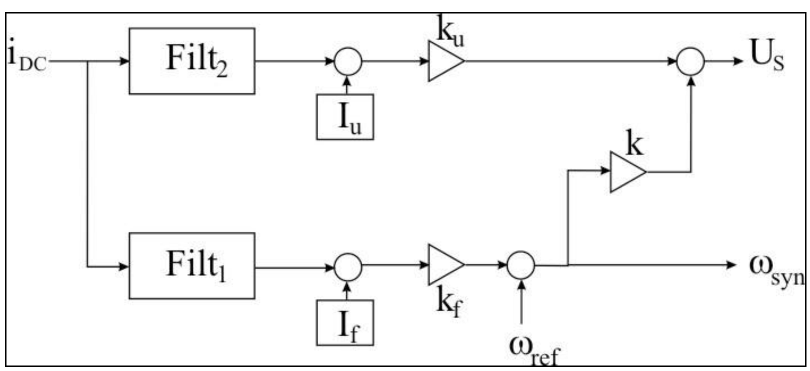
We decided to choose the ABB motor because of bigger efficiency factor than Sever motor, bigger rated current and less mass than Siemens motor. So. we started to measure all parameters needed for Simulation in order to get valid results, necessary for software algorithm.



Picture 5.8: ABB induction motor

The speed regulation algorithm implemented in MiniDrive, ensures better drive characteristics when compared to the conventional scalar control algorithms, but still without complicated calculations required by standard vector control algorithms. The system uses only one current sensor placed within the DC-link circuit to obtain constant flux and regulate the shaft speed by accurate slip compensation.

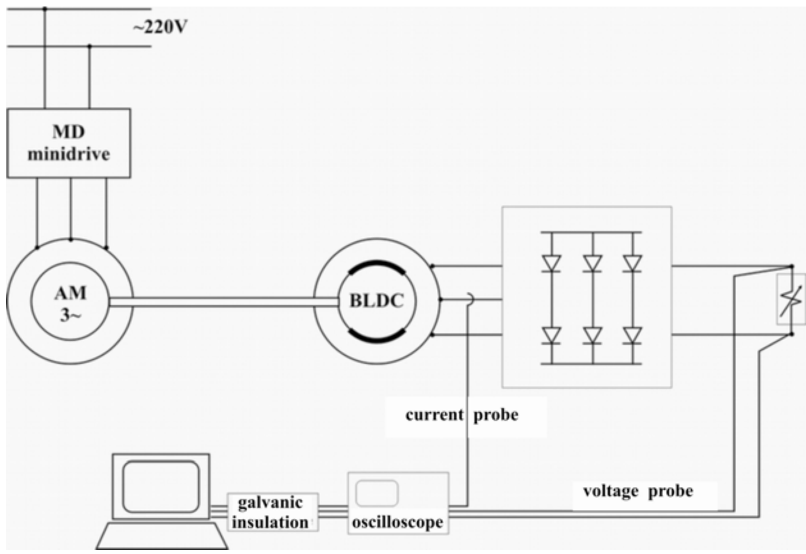
The proposed structure of control algorithm is shown in Picture 5.8.



Picture 5.9: The diagram of control algorithm

Filter $Filt_1$ in the frequency control loop is a simple first order lag with time constant $\tau = 50ms$. It has the role of determining the character and response time of the speed loop. Filter $Filt_2$ in the flux control loop is realized as a 3rd order Butterworth filter with 1kHz break frequency. Its role is to filter out the PWM noise in the DC-link current signal.

We are currently revising the possibility of an improvement to our control algorithm. We believe that we could minimize iron losses by optimizing the flux, thus improving the power consumption of the drive. We have prepared the setup for final tests of the drive prototype. We will use a brushless DC motor as load for our prototype. The speed of the drive will be measured using a digital laser, while the input power will be measured on a digital wattmeter. The picture of this setup is shown below.



Picture 5.10: Final setup for testing the prototype

After choosing the right motor and right control algorithm, software group need to code the control algorithm and implement it into the Microprocessor, while hardware group will project Auxiliary power supply for proper work of Microprocessor and drive can be tested.

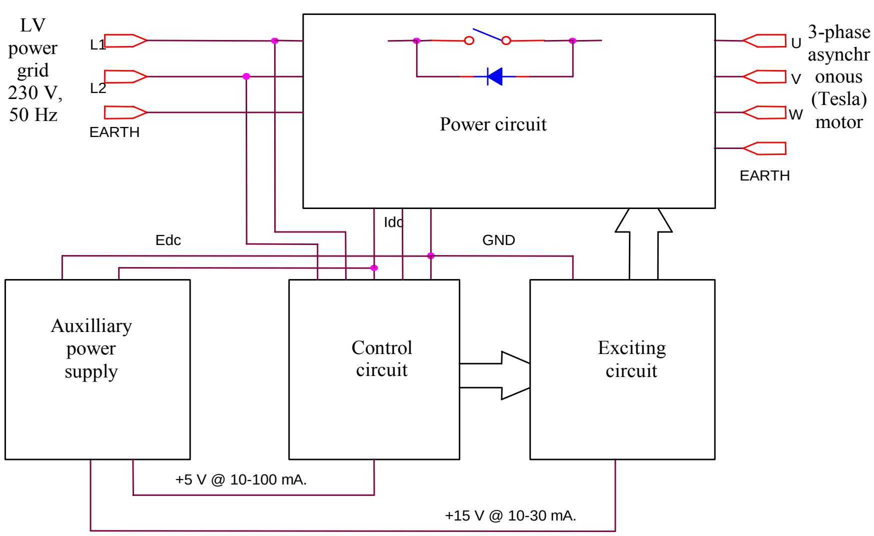
5.8.2. Progress in Hardware

The ***hardware requirements*** given by the organizers concerned about power factor measured said that at the electrical input it should be at least 80% when tested under a 500 W shaft load at 1500 RPM. Current waveform should conform to requirements in IEC1000-3-2 standards. Speed is to be controlled from start to the full 5000 RPM with a linear 0-10 V analog signal, referenced to the unit case. Except for starting, no testing will be performed below 150 RPM.

Very important when choosing the components is manufacturing cost - should not be more than US$40 when scaled to high-volume production (scaled for 1 million units/year). The complete unit is to be provided with an IEC 320 input connection, with a clear label stating the voltage requirement. Access to the speed control voltage signal is to be provided either through a conventional BNC jack or a pair of screw terminals. The input should be protected against accidental polarity reversal. The speed must return to zero if no signal is connected.

Results of Hardware group in the First Progress report. At the beginning of the hardware research we divided all hardware activities on: Power Electronics activity, Auxiliary Power Supply activity, Control circuit activity and choosing the components activity. Because of previous research in Power Electronics, we've already got a case study for components of inverter, DC link capacitors and rectifier. So, it was much easy for us to make a list of mentioned components and make a thermal design to check the feasibility that showed us which components will be critical from thermic point of view. The suggested structure of drive converter is standard one, but because of small space on printing board we tried to gather as many components as be possible to say togehter without making so much heat inside the drive.

Another big thing in hardware was to choose the right drive structure, so we agreed about the proposed structure which is presented in Picture 5.11.



Picture 5.11: Proposed structure of miniature drive converter

Results of Hardware group in the Second Progress report. Schematic and layout of the test board are competed. The test board will contain following sections: power, control, auxiliary power supply, IR communication and digital display. The power section includes the main switch, fuse, rectifier, electrolytic DC link capacitors and inverter. For the time being the test board will not include an EMI filter. Also, the design of autonomous auxiliary power supply is completed, and it is presented on a Picture 5.12. We have also considered using a BUCK converter due to its low price and simple design. Buck converter could be suitable if no galvanic insulation is needed.

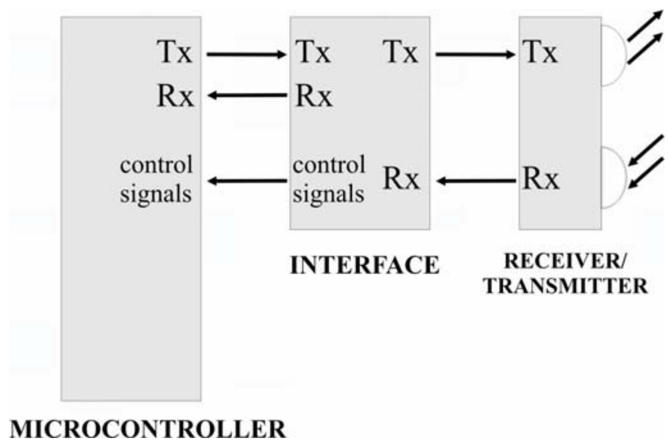
The purpose of auxiliary power supply is to adapt the DC link voltage to the level required for the on board electronics supply. For proper operation of the MiniDrive prototype, the auxiliary power supply has to output: 5V/50mA with galvanic insulation from the rest of the outputs, and 5V/300mA and 15V/100mA stabilized voltages. According to these requirements, the output power should not exceed 6W. The best performance can be achieved using a switching power converter. According to the ATmega168 and IRAMS datasheets, the ripple of power supply voltage must not exceed 50mV. The big question was whether to use flyback or buck converter, so we made one simple comparation, presented in Table 5.2. We have decided to implement the Flyback converter. This is a more xpensive, but much more flexible solution, and is a real innovation, which is very bringing more testings than ususal, standard converter scheme.

Table 1.2: *Comparison of Buck and Flyback converters*

Characteristics	Modified BUCK	FLYBACK
Galvanic insulation	BUCK converter does not have galvanic insulated output. It has to be modified.	Intention for galvanic insulated applications.
Control	Insulated output has no control; non-insulated output is easy to control	Simple control
Dimension	Smaller	Usually bigger
Transformer	Needed only for modified output	Necessary
Construction	Easier	Complicated transformer design
Practicality	Untypical solution	Typical solution
Price	Lower	Usually Higher

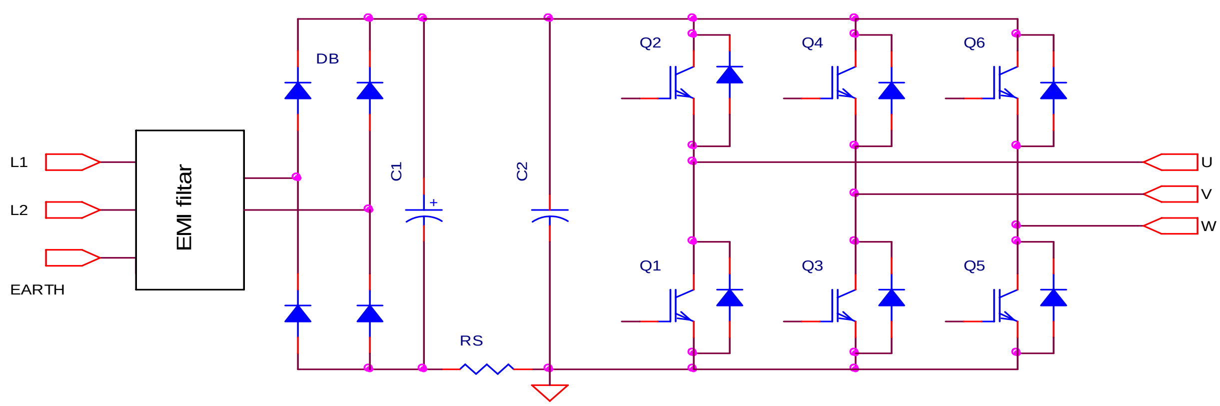
The low cost RISC microcontroller (20 MIPS) has been chosen. This microcontroller will perform AD conversion of following signals: linear 0-10V analog speed reference signal (as defined in the project proposal), DC link voltage, DC link current and the temperature of the most critical component. The speed reference signal and DC link current signal will be used as the input signals for control algorithm, while DC link voltage and temperature signals will be used to realize safety protections.

The thermal design is finished. The inverter circuit has been defined as the most critical component. According to the IR communication case study, mentioned in the first progress report, the optimal electrical components for the realization of IR communication are chosen, so Picture 5.12. presents the structure of IC circuits for proper IR communication. There is a microcontroller for IR sommunication, as well as interface and receiver/transmitter integrated circuit.



Picture 5.12: S*tructure of IC circuits for realization of IR communication*

Results of Hardware group in the Final Progress report. The adopted topology of power electronics is shown in Picture 5.13. At the input terminals of power electronics section is a single-phase 230Vrms; 50/60Hz AC signal. This signal is processed through the Rectifier and then boosted to 380VDC by the Power Factor Correction (PFC) circuit and DC-Link capacitor. Within the DC-Link circuit is also a shunt resistor used for measuring the consumption current of the drive. The boosted DC voltage is later used to generate three-phase voltage of varying amplitude and frequency, which power the motor terminals.

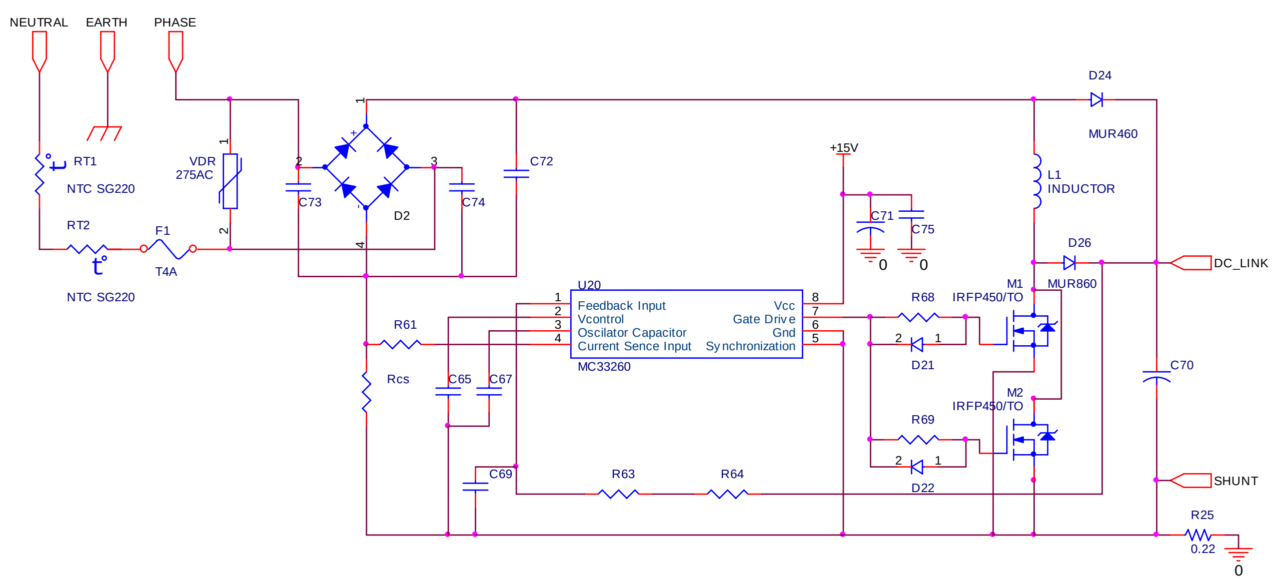


Picture 5.13: *Power circuit of proposed miniature drive converter*

EMI filter at the input side is used to reduce the level of electromagnetic noise produced by the converter and sent back to the distribution network to that required by standards. Shunt resistor in this scheme is used for measuring DC link current and therefore device protection and speed regulation. Capacitor C1 is the main electrolytic capacitor, which can be replaced by parallel connection of two in some implementations.

Due to necessity of complying with IEEE standards, a Power Factor Control (PFC) circuit is introduced. Its role is to decrease amount of higher harmonics in input current and maximizes real power available from the mains. A novel solution called Follower Boost PFC was applied. Power factor (PF) is defined as real power to apparent power ratio. When current and voltage are sine functions, PF=cosine of the phase angle between them, and if they are also in phase, PF=1.

The main goal in PFC designing is to reduce the harmonics enough to meet the regulations. Electrical equipment in Europe must comply with the European Norm EN61000-3-2, which specifies the maximum amplitude of line-frequency harmonic up to and including the 39th harmonic for electrical appliances with input power of 75W or greater. This can be achieved by placing the inductor between the input rectifier and the storage capacitor. This type of PFC is called the passive PFC. Passive PFC circuit suffers from a few disadvantages despite its inherent simplicity. The size and weight of the inductor (core) become unpopular for the power supplies above 250W; the higher current harmonics are not repressed enough; and finally, the voltage rail is not regulated.



Picture 5.14: *Schematic of PFC implementation in Mini Drive*

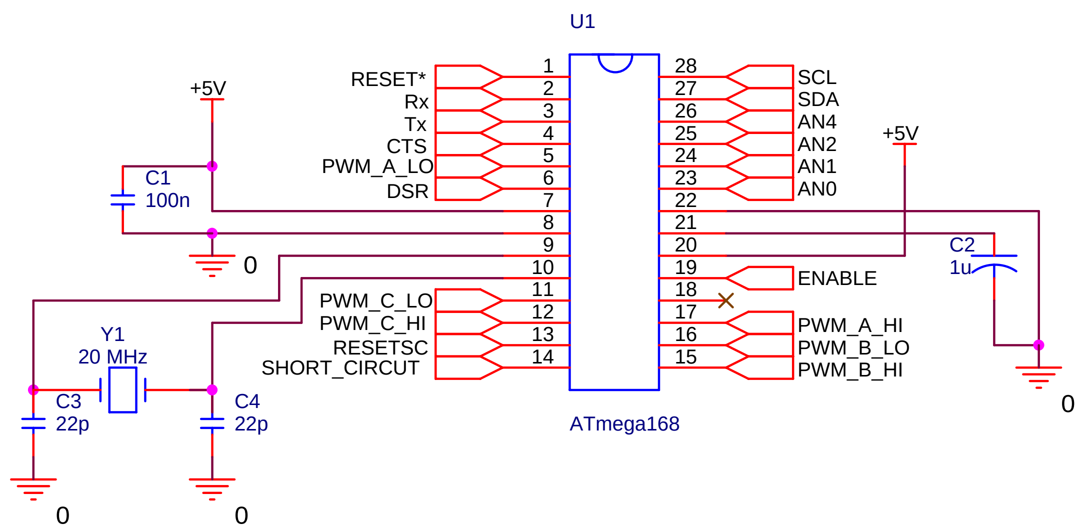
Control circuit should perform the following operations: calculations for SVPWM algorithm, precise control algorithm with slip compensation based on DC link current, protection of motor and converter during irregular operating conditions, digital communication with LED display and IrDA standard wireless connectivity device for bilateral communication between user and the drive.

SVPWM algorithm is used for generation of three signals that control the state of inverter bridge transistors. Slip compensation method is used for maintaining referenced shaft speed within appropriate limits without using a speed sensor. The slip is estimated based on DC link current and voltage measurements.

The control circuit is based on a low cost RISK microcontroller (20mips) ATmega168. This microcontroller has six AD converter inputs, and possibility of three-phase Pulse Width Modulation emulation. The main tasks of the microcontroller are: the emulation of PWM; AD conversion of NTC resistor signal (the Irams module temperature signal), DC link voltage, DC link circuit (voltage of the DC link shunt resistor) and analogue speed reference signal; control algorithm computation and communication with the LED display and IrDA module. The pin-out of the ATmega168 is shown in Picture 5.15.

The LED display is controlled by the SAA1064 chip. This circuit is especially designed to drive four 7-segment LED displays with decimal point by means of multiplexing between two pairs of digits. It communicates with the main controller via the I^2C serial interface.

The IrDa is controlled by the MCP2140 interface circuit. This circuit implements IrDA standard connectivity. The serial and IR interface baud rate is fixed at 9600 baud. The MCP2140 encodes an asynchronous serial data stream converting each data bit to the corresponding infrared (IR) formatted pulse. IR pulses received are decoded and then handled by the protocol handler state machine. The protocol handler sends the appropriate data bytes to the Host Controller in UART formatted serial data. Infrared communication is a wireless, two-way data connection using infrared light generated by low-cost transceiver signaling technology. This provides reliable communication between two devices.



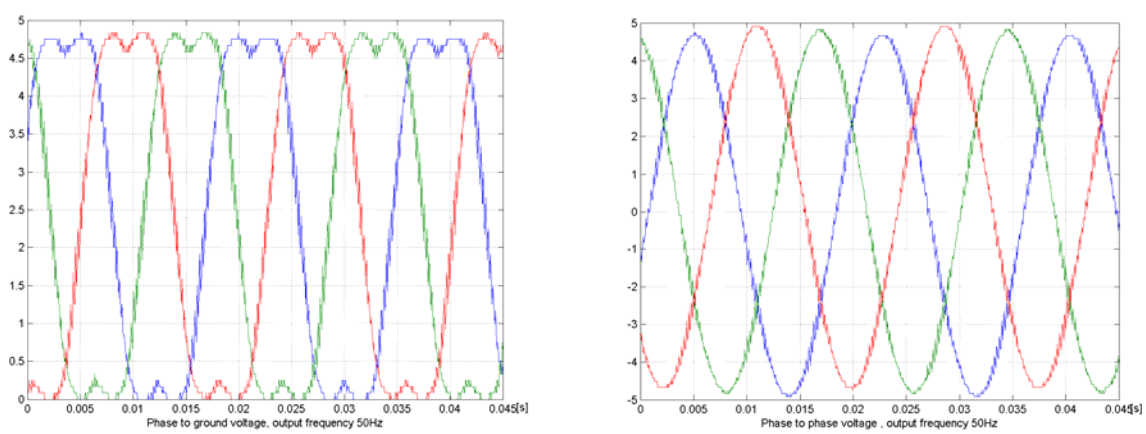
Picture 5.15: *ATmega168 Pin-Out*

5.8.3. Progress in Software

Software group has a great responsibility because of gathering attempts of drive and hardware groups. All simulations and test made by drive group and components and set-ups made by hardware group need to be functional. One example is required self-protection against continuous stall conditions, over temperature, or loss of input source with no damage caused by any of these (up to the maximum storage temperature), which is coded into the software of ATMEL microprocessor, but also done and operated by hardware components.

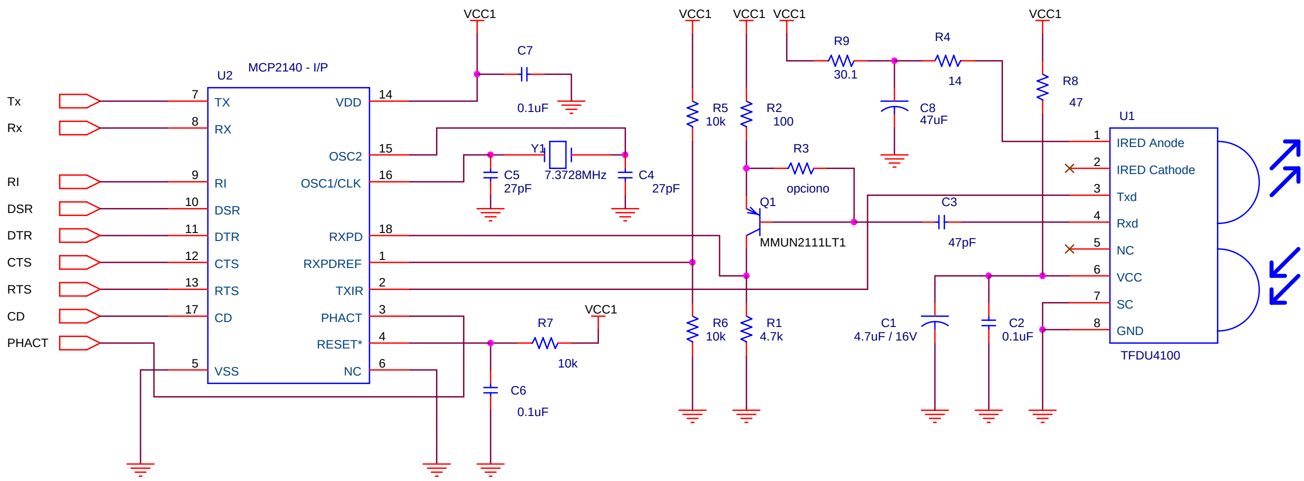
Program coding was done separately. The control algorithm was coded first, and after that safety regulations together with Infra Red communication. But Space Vector Puls Width Modulation (PWM) was firstly checked in FPGA device, to check the right pattern, and then implement into the main program.

Results of software group established in the First Progress report. Software group has very strict aims in their work. First aim was to code Space Vector Modulation and to do testing in order to make perfect sine wave. So, in first progress report the programming of space-vector PWM is finished. Picture 5.16 presents filtered voltage command signals on two output frequencies.



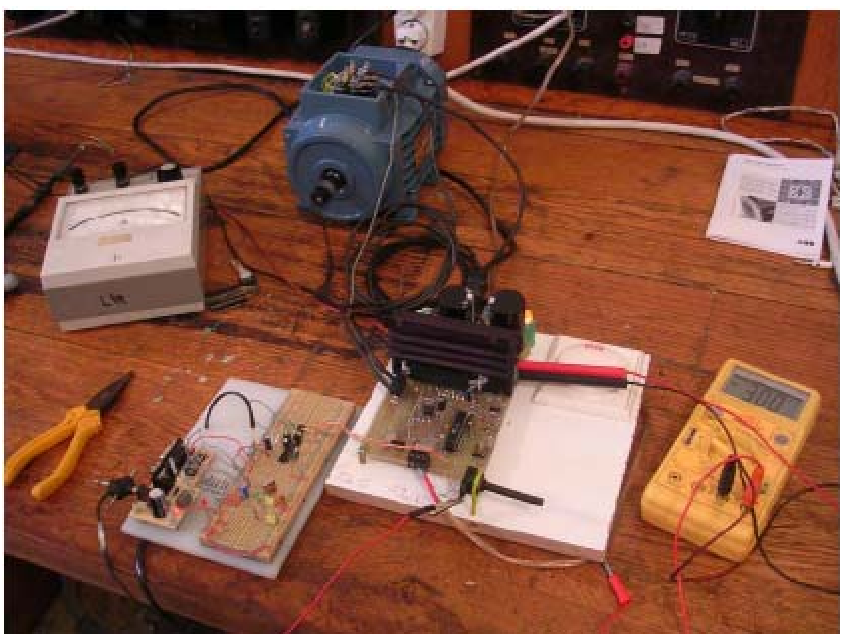
Picture 5.16: *Phase to ground and phase to phase voltage, output frequency 50Hz*

Case study of IR communication is finished, and it represents the bases for the future work on digital communication. Picture 5.17. presents the proposed schematic for IR communication, and is tested and confirmed in ***Pspice*** Application Software.



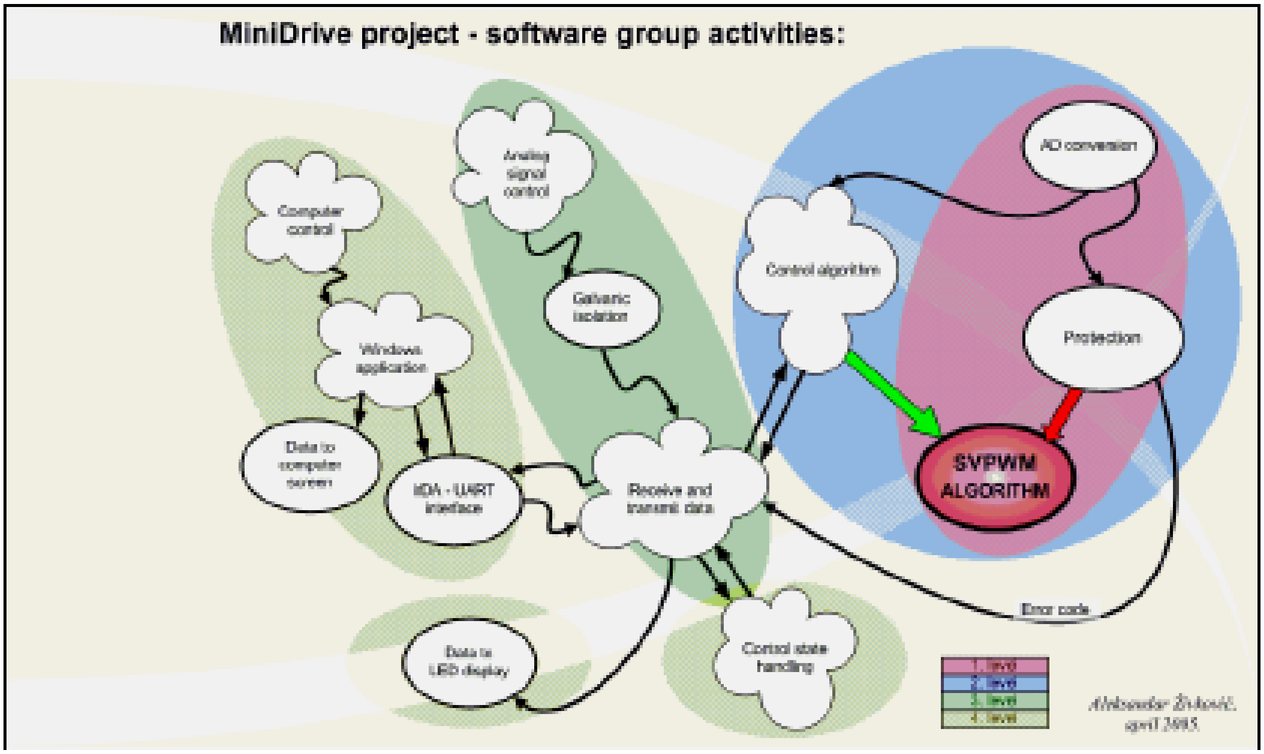
Picture 5.17: *Schematic of realization of IR communication*

Results of software group established in the Second Progress report. Later, the members of software group mainly work on implementation of coded Space PWM into the ATMEL microcontroller, but also prepared MD Workstation in the computer center – Picture 5.18. A proto board with power supply and various LED indicators is designed for this purpose, and one computer has been connected to the proto board and equipped with necessary software (based on C and assembler codes) for microcontroller programming. This workstation allows programming and direct upload of program code to the microcontroller.



Picture 5.18: *Testing setup for Test Board*

Apart from a number of tasks that have been finished, we have made improvements to the organization of our group. All the tasks performed by this group will be finished according to the structure shown in Picture 5.19. The distinction of this structure is that the tasks are not sequentially arranged; rather they can be accomplished independently. The group was organized in this manner because of the difficulties in the procurement of certain components and tight links to other groups working on this project, whose work is done at a different pace. This allows our group to keep working on those tasks that can be accomplished at a given time.



Picture 5.19: *The software group activities*

To make it possible for our group to function within the time boundaries of the entire project, it was necessary to define the functional levels, which will allow experiments on the drive at different stages of the design. There are four functional levels:

- Level 1: the controller can be mounted on the motor and is able to drive it. At this moment all the protections must be active (finished) and they prevent any damage of the motor. At this point it is also necessary that the information from the outside are properly processed – AD conversion. This level can't be broken into lesser factors.

- Level 2: besides the elements of the first level, it contains the control algorithm that provides proper operation of the drive under different conditions – regulation of the rotating speed.

- Level 3: together with the first two levels it assures that the drive satisfies all the requirements of the project – proper interaction with the user, that is the possibility of setting the speed voltage reference via the control 0-10V signal.

- Level 4: After the basic requirements of the project have been met it is possible to enhance the interaction of the user with the drive. At this level beside the analogue 0-10V signal, the reference can be set using a pocket PC via IR communication. Also the user can read the necessary information on the LED display situated on the drive itself.

Results of software group established in the Third – Final Progress report. Finally we realized that the microcontroller with algorithms implemented inside represents the most important node between other electrical components within MiniDrive system. It must deal with signals in different priority levels: from SVPWM and control algorithm signals to LED display and infrared communication. When choosing the microcontroller, the decisive factor was its ability to generate a three-phase PWM signal. The chosen microcontroller, the *ATMega168* [37], is capable of generating a *space vector* PWM signal. The output (PWM) commutation frequency depends on the *clk* (the system clock) frequency and the resolution of the internal PWM counter. If the counter resolution is N (an N-bit counter), and the clock frequency f_{clk}, then the commutation frequency is given by the following equation:

$$f_{PWM} = \frac{f_{clk}}{2 \cdot 2^N}$$

In our system for the parameters N=8 and f_{clk}=2.5MHz, the above equation derives f_{PWM} = 4.9kHz. Three timers inside *ATMega168* mentioned above represents a digital-analogue converter with three inputs and three outputs (each per one phase). The SVPWM algorithm placed within the microcontroller controls this DA converter.

The control algorithm is the part of the code with the most mathematical operations executed. The end of this section will show that this part of code consumes the most of the CPU processing time. On the other side we had cheap 8 bit RISC microcontroller with fixed point arithmetic. We had to do some extra work in order to move from simulations of control algorithm made with continual signals to fixed-point algorithm that is possible to implement into C code.

Table 5.3: ATmega168 Resources

RESOURCE	MAXIMUM	TAKEN
Program memory	16kB	97%
SRAM	1kB	25%
Cycles	4080 (per one PWM cycle)	95%

OPERATION	CYCLES	TAKEN
SVPWM algorithm	284	7%
AD conversion	98	3%
Protection	467	12%
Control algorithm	2275	56%
UART communication	376	10%
LED display	676	17%

The first step is to scale variables to higher level in order to keep calculations without fractional part with enough high resolution. In order to keep maximal length of the word to 16 bits we have choused 14bit precision – that is 14 bits plus one bit for sign and one for problematic overflow operations. In order to scale variables inside algorithm we had to know the maximum level for each of them with input variables set to the worst case.

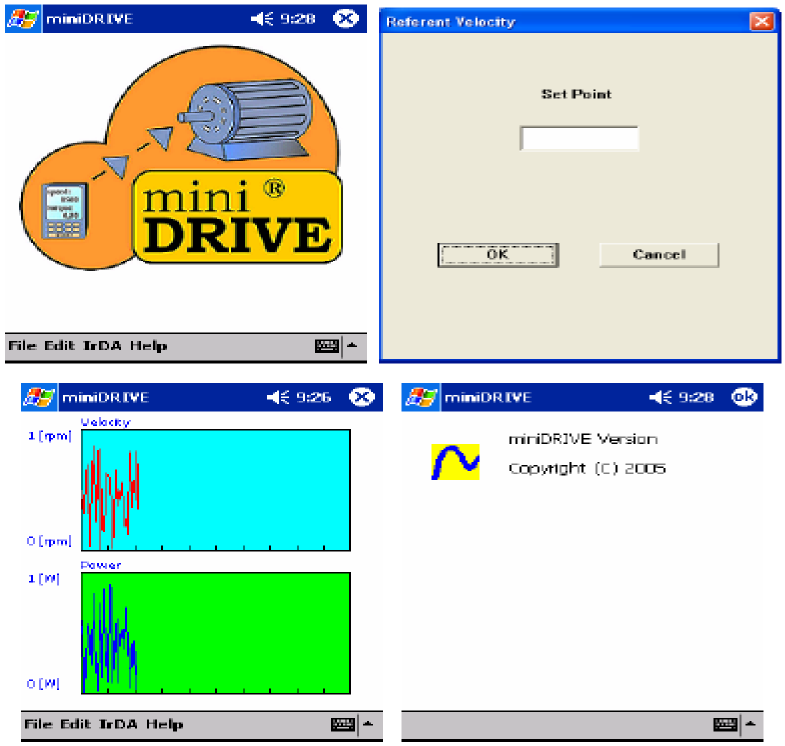
While scaling control algorithm variables we were aware that after multiplying two scaled variables you have do divide it with their maximum. Since dividing in chosen microcontroller is not possible we had to choose numbers with power of two. In that case, dividing is logical shift right.

After implementing control algorithm in this way we realized that the time for its calculations is still too long. With detail analyze of what C compiler does [40], we found out that the 16 bit variables multiplication in our case could be optimized to approximately three times faster execution. Therefore we had to use inline assembler in C code which gave us good results.

When speaking of *SW realization of Drive Protections,* MiniDrive prototype is protected from irregular states at both hardware and software levels. Protections are:

1. The DC link over voltage protection - software level
2. The DC link under voltage protection - software level
3. The IRAMS module temperature protection - software level
4. The over current protection - hardware level, doubled

Software inside the main microcontroller checks if an irregular condition occurred every *204µs*. It checks voltage levels via an AD converter. These levels represent the DC link voltage, the DC link current and IRAMS module temperature. The main microcontroller also checks if any errors occurred in communication with analog input circuit and LED display driver. If irregular condition happens, software sets the appropriate bits in variable called *error_code* and calls the function that stops the drive. In order to restart the drive it has to be shut down and turned on again. If, at the moment the error occurred, communication with the Pocket PC was active, the error can be read and the drive turned on via the Pocket PC – Picture 5.20.



Picture 5.20: *Graphical User Interface on Pocket PC*

As an additional option, our team has decided to implement another type of drive speed control. We have introduced the option of digital communication to our prototype – wireless serial connection, realized according to IrDA standard protocol. This decision brought up problems concerning the realization of hardware needed for this type of communication, but also question related to handling critical situations which may occur as a result of two types of control: “Which type of control has priority: analog or digital signal?”

We should notice that this drive could be found in two different states:

- State A: analogue speed control
- State B: digital speed control

State A implies that microcontroller reads the information from the analog input. The *ATTiny15* microcontroller scales the analogue signal and inserts it into control algorithm that generates the SVPWM signal.

State B implies that our drive has established communication with the computer and that the speed reference has been past onto it in form of a digital signal. The value of the analog input is ignored and the information arrived via the UART interface is utilized in the SVPWM algorithm.

5.8.4. Progress in establishing safety regulations

At a very beginning of the project the organizers set up the requirements for final prototype which have to be tested. So, the drive system is intended for safe use in a home appliance or household HVAC system, which means that it has self-protection against continuous stall conditions, over temperature, or loss of input source with no damage caused by any of these (up to the maximum storage temperature). Operating current shall not exceed 150% of the nominal full-load current under any conditions, including power-on inrush and motor starts. The final rules will contain detailed safety information. No live electrical elements are to be exposed when the system is fully configured.

Due to these requirements, safety regulations we were trying to reach during the progress can be showed through progress reports.

Safety regulations established in the First Progress report. During this practical work all students involved in MiniDrive project have acquired knowledge necessary to operate with laboratory equipment safely. However, at the beginning of this project each of them was again introduced to the safety regulations.

Nevertheless, we have decided that all the tests on motor and drive will be performed by teams consisting of at least two undergraduate students, and one of the student leaders, which have considerable experience when it comes to operating the equipment in our laboratory.

Safety regulations established in the Second Progress report. *Overload protection* was set up, which means that the motor current was monitored at all times, if it rises above critical limit the device will be shut down. This protection was software implemented. *Overvoltage protection* was also set up, while supply voltage was limited with adequate component. *Undervoltage protection* is important as well because it monitors DC link voltage, and if it falls below critical limit the device will be shut down. We were considering the importance of *Thermal protection*, so the temperature of inverter device will be monitored. In case overheating is detected the device will be shut down. *Program execution* will be protected with on chip brown-out and watchdog circuits.

In case any of the protections is activated, the corresponding message will be indicated on the digital display.

The start point for establishing safety regulations for our project were IEC 60335-1 standard (Household and similar electrical appliances – Safety – Part 1: General requirements) and "Request for Proposal" document. Our goal is to make this device safe to use and operate, and to meet as much requirements stated in mentioned documents as possible.

Components for test board were chosen to be as reliable as possible for the given price range, and to comply with IEC 60335-1 standards.

During the PCB design, special attention was given to the design of those parts of the board that are under high voltage. Special oscilloscope access points will be mounted on the testing prototype to provide easy and safe monitoring and measuring of the device.

Safety regulations established in the Final Progress report.

1. The drive has overcurrent protection. If in some case a short circuit happens a fast analog circuit shuts down the inverter and signals the processor. Analog circuit that detects overcurrent works like a flip-flop; to reactivate the inverter it has to be reset by the controller. Overcurrent protection triggers at 6.2A. This will protect the prototype against continuous stall.

2. Chosen inverter has a built in NTC element that gives the information on its temperature. This temperature is monitored by the controller and in case of overheating the inverter is shut down. Overheating protection is set to trigger at 85°C.

3. The controller measures the DC voltage of the input bulk capacitor. In case of overvoltage the inverter is shut down. In this way the device is protected from destruction that may occur when motor enters the generator mode. Upper limit for DC voltage is set at 350V. For normal operation of the drive, the DC voltage must be greater than 250V. If the voltage drops below this limit the controller will not run the motor. This will protect the prototype against the loss of input source.

4. The controller program execution is protected by the programmable on chip watchdog timer. The implemented controller also has an on chip programmable brown out circuit that will reset the controller in case of a voltage drop on the auxiliary power supply.

5. We have chosen a flyback based switch mode power supply as the auxiliary power supply. One of the secondary windings will be used to decouple the analog speed control input signal, which has to be referenced to the unit case. The transformer is made manually; our effort is to make as best isolation as possible considering the dimensions of the transformer. Speed control input is protected against accidental polarity reversal.

6. Special attention during the PCB design was given to the clearances and creeapage distances. All the components are chosen to comply with IEC 60335-1. Our device has a main switch, a voltage selector switch and a reset button that will comply with the IEC 60335-1 standard. It is provided with an IEC 320 input connection and has appropriate fuse.

7. Separate PCB was designed for the LED and IR communication circuits. It will be connected with the main board using an appropriate cable.

8. We have begun the design of a special casing, which will host all the printed circuitry and will be mounted on the motor and properly labeled. The casing will be attached to the motor; it will be attached so that it can't be loosened by the vibrations of the motor. The casing will have an opening that connects motor wiring with the board, a window for LCD and IRDA and special holes for switches and connectors. A labeled BNC connector will be provided for the speed control input. The entire casing will be properly grounded, without any live electrical elements and it will be designed to comply with the IEC 60335-1 regulations for a class I appliance (IEC 60335-1 §3.3.9).

The main power switch will be mounted so that it can be easily noticed and it will be marked with a rated voltage. The device will be provided with a voltage selector switch that will also be clearly labeled. Since we will use the casing as a heat sink, it will be properly isolated in order to keep the maximum temperature of the casing below 60ºC as stated in IEC 60335-1. We will use iron or aluminum in casing construction. The casing will be closed and it will not be possible to open it without a specialized technician and the manual provided.

5.9. Closing out the Project

Just as there are proper ways to define, plan, and execute projects, so there is a right way to end them. Closing a project involves two major steps: capturing lessons learned during the project and completing administrative closeout.

The purpose of ***capturing lessons*** learned is to help the organization benefit from its errors and advance to a higher level of project management. Projects produce two types of lessons learned: the lessons relating to how the project was conducted and the lessons relating to the effectiveness of the product. It is easy to identify these lessons with two separate procedures that follow a project: the post-project review and the post-implementation review.

A post-project review is concerned with how effectively the project was executed. How well did we manage scope? Risk? Communications? Quality? The budget and schedule? A post-project review is conducted in a meeting of the project team, excluding the client, and is held as soon as possible after the completion of the project. A post-project review may even be held before the formal completion, after the end of some major step, such as integration, before most of the team moves on to other projects.

A post-implementation review is concerned with the effectiveness of the project's product and its implementation. It deals with questions such as whether the product fulfilled its purpose and whether the organization realized the benefits that it expected when it authorized the project. The purpose of the review is to help project managers and technical teams determine how they can better build products that fulfill user needs. It may seem unjust to criticize a project team for building a product that does not meet its purpose if they followed the client's specifications, but projects are not simply automated "do what the client says" agents; their job is to satisfy some real business need. If that means challenging what the client asks for, such a challenge is legitimate.

Lessons are valuable only when they are available for the next situation to which they apply. For this reason, many organizations have adopted a lessons learned repository, a database that contains lessons learned from previous projects and that project managers can use to help them avoid making the mistakes of their predecessors.

There are several lessons we learned during working on MiniDrive IEEE project. The main one is about communications. Communication among team members is valuable thing, so we should give more importance to team communication, because several times some misunderstandings occurred because of absence of right communication. Another lesson is connected with dependencies among technical activities in this Engineering project. For example, we should be strict that none activity that didn't pass through Simulation process can not be implemented in software/hardware. In that case we could save lots of time, because it happened to us that some control logic was software implemented without simulated, so later we realized the fault. Luckily, we have enough time to fix the problem, but it is important to make a procedure for each activity and give great responsibility to team members who will run it.

Another great lesson was in generating final prototype. We should make two prototypes, not only one, so that different groups can test different innovations in the same time. Another advantage of two or more prototypes could be realization of two different control algorithm (software coding), because implementing software into the hardware takes some time. Having two prototypes makes things easy, so it is not a problem to change some parts if damages happened, but also while fixing the problem, to continue with testing using other prototype.

Completing administrative closeout is another major step in closing out the project. Projects attract a wealth of administrative details that need to be taken care of when they finish. Charge codes must be closed, equipment handed over to another project or to a general pool, and project information archived. Picture 5.21. is a checklist of items that you may need to take care of in order to ensure that the project is complete. One of the key activities in project closeout is archiving project materials. We gathered the key project management documents of the project and bundle them into a file, either paper or electronic, depending upon our organization's standard. At a minimum, the archives should include the project proposal, the contract or other authorization to proceed, the project plan with any scope changes, project status reports, meeting minutes, the issues log, scope change requests, formal acceptance, lessons learned, and any memos, letters, or reports that dealt with substantive matters. The project archive should be indexed with details such as the project type, technology architecture, customer or customer industry, and application area so that future projects can open the archive and reuse some of its material.

Project Closeout Checklist

Project: ______________________ **Date:** ________

Manager: ______________________

Handoffs

- The project has been handed off to and accepted by operations. ___
- The project has been handed off to and accepted by maintenance. ___
- The project has been handed off to and accepted by server support. ___
- The project has been handed off to and accepted by database support. ___
- The project has been handed off to and accepted by the help desk. ___
- The project has been handed off to and accepted by the client. ___

Reviews

- A post-project review has been conducted. ___
- A post-implementation review has been scheduled. ___

Administration and Security

- The project information has been archived. ___
- All project charge codes have been closed. ___
- All borrowed resources have been returned. ___
- All project-specific network accounts and privileges have been terminated. ___
- Project folders and files have been closed. ___
- All project-specific vendor security accesses have been terminated. ___
- All project-specific hardware has been disposed of. ___
- All confidential information has been collected and safely stored. ___
- The project sites have been cleaned and material disposed of. ___
- Team member supervisors have been notified. ___

Picture 5.21: *Project Closeout Checklist*

The Project closeout list helped us not to forget main steps in closing out project, but one of the requirements that was set-up by the organizers was to make Users' Manual (Picture 5.22). Users' Manual is sort of a guide through easy handling the product. It should be written in formal but strict language explaining the user how certain product is working, and what are possibilities for using.

So, our idea was after making one, to bring one undergraduate student and see if he/she is able to use the prototype just guided by the Users' Manual description of our prototype. That showed us if the Manual was designed well. The Manual is presented in the Appendix II at the end of the Thesis, so it is possible to check if we done the job right.

Picture 5.22: *Users' Manual and detail from inside*

6. Conclusion and Suggestions

Success comes from wisdom.
Wisdom comes from experience.
Experience comes from mistakes.

One of the characteristics that distinguishes a project from other forms of business activity is that a project ends. Once its purpose has been satisfied, it is closed and becomes part of organizational history.

We realized that strong communication among team members, and functional communicational hierarchy in one group are the most valuable for the entire team. It is important to set the whole team structure, make work break-down structure and deliver responsibilities to start with a communication. The communication will help the team effectiveness. We have had a week meeting for each of the groups, but maybe we need at least 2 meetings in last month and a half working on the project. In parallel we communicate via internet, using Internal Website, but face-to-face meetings were much more effective.

It is hard enough to keep a project on track in those disciplines where the road has been traveled before, the activities are familiar, and the pitfalls are clearly marked. Modern systems projects, with evolving development technologies, changing methodologies, and novel applications, have created an environment in which each project is an exploration; not only is the plan difficult to follow, it is even harder to create with any degree of confidence.

If our industry is to mature to the point where it can routinely deliver what is required of it, one of the issues we must resolve is the shortage of qualified, experienced, professional, career project managers. We need to find and develop people who can work with the special ambiguities of project life, who can master the intricacies needed in project planning and execution, and who are powerful managers of themselves and their teams.

Such people are not common. Computer systems careers lead more readily to advanced technical expertise or line management. Project management is too often seen as a stepping-stone to “real” management or as a useful ancillary set of skills for technical leaders. Neither view is likely to produce people who are eager to make project management a lifetime career.

Another important thing that should be done after the completion of the project is a project review. It is often held few months to a year after the completion of implementation, when the product has had a chance to settle down. Any new process or system will generate resistance, errors caused by unfamiliarity, pining for the predecessor, or caustic comments on how the product should have been designed, built, or implemented. The reason for waiting before conducting the post-implementation review is to allow opposition to the product to disappear so that its evaluation can be conducted apart from the heat that accompanies change.

MiniDrive prototype is product that meet certain requirements gave by IEEE Contest organizers, but in a case it was done for global market, it is sure that the project review need to be focus on four very important areas:

1. **The scope of the product:**
   - Does the product satisfy the original scope? If not, where does it depart? What lessons for future projects can we learn about identifying and managing departures from scope?
   - Does the product do what the client expected? If not, where is it deficient? What lessons for future projects can we learn about determining and satisfying the client's expectations and needs? Be careful to ensure that any "deficiencies" are departures from the original scope and not improvements that users have identified because they have become familiar with the product.
2. **Implementation:**
   - Was user training adequate? If not, where was it deficient? What lessons for future projects can we learn to ensure that training is adequate in the future?
   - Was implementation more disruptive than expected? If so, what were the causes of the disruptions? Could they have been reasonably avoided? What lessons for future projects can we learn about making our implementations smoother?
3. **Documentation and support facilities:**
   - Is the user documentation, written and online, adequate? If not, where is it deficient? What lessons for future projects can we learn to ensure that user documentation is adequate?

- Is the technical documentation adequate? If not, where is it deficient? What lessons for future projects can we learn to ensure that technical documentation is adequate?
- Are the support facilities, including the help desk, adequate? If not, where are they deficient? Could these deficiencies have reasonably been avoided by the project? If so, what lessons for future projects can we learn about establishing adequate support facilities?

4. **Benefits analysis:**
    - Did the product produce the benefits that the client expected? If not, where are they deficient? Could these deficiencies have reasonably been avoided by the project? If so, what lessons for future projects can we learn about defining and satisfying benefits?

APENDIX I: MiniDrive team Gantt Chart

ID	Task Name	Duration	Start	Finish	Predecessors	Resource Names
1	**1. DRIVE**	**305 days**	**Tue 6/1/04**	**Mon 8/1/05**		
2	**SIMULATION RESEARCH**	**78 days**	**Tue 6/1/04**	**Thu 9/16/04**		A2,A1
3	Motor Simulation	34 days	Mon 8/2/04	Thu 9/16/04	7	A1
4	converter simulation	33 days	Tue 6/1/04	Thu 7/15/04		A2
5	simulation of microprocessor with auxiliary power supply	23 days	Mon 8/2/04	Wed 9/1/04		A1
6	inverter simulation	30 days	Mon 6/21/04	Fri 7/30/04		A1
7	**MOTOR TESTING**	44 days	Tue 6/1/04	Fri 7/30/04		A3
8	**SIMULATION RESULTS**	22 days	Fri 9/17/04	Mon 10/18/04	3,4,5,6	A4
9	**DRIVE TESTING**	33 days	Thu 6/16/05	Mon 8/1/05	10,29	A3,A1
10	**2. HARDWARE**	**272 days**	**Tue 6/1/04**	**Wed 6/15/05**		
11	**AUXILIARY POWER SUPPLY (APS)**	**154 days**	**Thu 7/1/04**	**Tue 2/1/05**		**B1,B2**
12	Flyback converter analyzis	55 days	Thu 7/1/04	Wed 9/15/04		B1
13	Buck converter analyzis	55 days	Thu 7/1/04	Wed 9/15/04		B2
14	Generating the final Schematic for APS	88 days	Fri 10/1/04	Tue 2/1/05	13,12	B1,B2
15	**INVERTER**	60 days	Wed 9/15/04	Tue 12/7/04	19	B3,B4
16	**PFC**	**110 days**	**Wed 9/1/04**	**Tue 2/1/05**		**B5**
17	Examine the Standards	28 days	Wed 9/1/04	Fri 10/8/04		B5
18	Generating PFC	78 days	Fri 10/15/04	Tue 2/1/05	17	B5
19	**DC LINK CIRCUIT**	35 days	Thu 7/15/04	Wed 9/1/04		B6
20	**RECTIFIER & EMI FILTER**	**206 days**	**Tue 6/1/04**	**Tue 3/15/05**		**B5,B4**
21	rectifier	44 days	Tue 6/1/04	Fri 7/30/04		B5
22	EMI filter	42 days	Mon 1/17/05	Tue 3/15/05		B4
23	**CONTROL CIRCUIT & PROTECTION**	54 days	Mon 1/17/05	Thu 3/31/05		B5
24	**TERMIC DESIGN**	15 days	Mon 5/2/05	Fri 5/20/05	16,19,15,11	B4
25	**CHOOSING THE COMPONENTS**	43 days	Fri 4/1/05	Tue 5/31/05		B4
26	**PRINTING BOARD**	11 days	Wed 6/1/05	Wed 6/15/05		B4
27	**ASSEMBLING THE ELEMENTS ONTO THE PRINTING BOARD**	11 days	Wed 6/16/04	Wed 6/30/04		B6
28	**3. SOFTWARE**	**259 days**	**Tue 6/15/04**	**Fri 6/10/05**		
29	**PROGRAMMING**	**259 days**	**Tue 6/15/04**	**Fri 6/10/05**		
30	control algorithm	259 days	Tue 6/15/04	Fri 6/10/05		C1,C2,C3
31	A/D conversion and protection	56 days	Mon 8/16/04	Mon 11/1/04		C1,C2
32	PWM signali	45 days	Thu 7/1/04	Wed 9/1/04		C3
33	LED Display	24 days	Tue 3/15/05	Fri 4/15/05		C1,C2
34	Digital Communication	54 days	Tue 2/15/05	Fri 4/29/05		C1
35	Protections	64 days	Tue 2/1/05	Fri 4/29/05		C2
36	**REALIZATION OF OBJECT ORIENTED INTERFACE**	54 days	Tue 3/1/05	Fri 5/13/05		C2
37	**4. MARKETING**	**344 days**	**Tue 6/1/04**	**Sun 9/25/05**		
38	**MAKING THE PROJECT**	23 days	Tue 6/1/04	Thu 7/1/04		D1
39	**WEB SITE**	**120 days**	**Tue 6/1/04**	**Mon 11/15/04**		**D2**
40	internal	11 days	Tue 6/1/04	Tue 6/15/04		D2
41	external	34 days	Wed 9/29/04	Mon 11/15/04	38	D2
42	**PUBLIC RELATIONS**	190 days	Mon 1/3/05	Sun 9/25/05		D3
43	**FUND RAISING**	67 days	Mon 5/2/05	Tue 8/2/05	38,41	D4

APENDIX II: User's Manual

1. Features

- Single-phase adjustable speed motor drive is intended for indoor installation and usage in household and industrial applications.
- Wide speed and power range available.
- Drive speed can be viewed at any moment on LED display mounted on top of the drive.
- In case of malfunction error code is displayed on LED display.
- The device can be driven from Mini Drive Windows application on Pocket PC through IR communication from a substantial distance.
- The use of durable, long-lasting components assures maintenance-free performance for many years.

2. Safety considerations

The machine is intended for installation and safe usage by both specialized technicians and common users. Unauthorized personnel should not open converter box.

Earthing must be carried out according to local regulations before the machine is connected to the supply voltage.

Normal ambient temperatures should not exceed 40°C if standard performance is to be achieved. Check that the motor has sufficient airflow. Ensure that no nearby equipment, surfaces or direct sunshine radiate additional heat to the motor.

The constructional maximum speed of the motor must not be exceeded.

The temperature of the outer casing of the machine or the converter box may be hot to the touch during normal operation.

Safety regulations acquired for single-phase adjustable speed motor drive are according to IEC 60335-1 standard (Household and similar electrical appliances Safety Part 1: General requirements).

The machine should always be stored indoors, in dry, vibration free and dust free conditions. It is recommended that shaft be rotated periodically by hand to prevent grease migration.

3. Mini Drive specifications

- Dimensions: 250x120x250mm (LxWxH)
- Weight: ~9kg
- Power supply: single-phase AC 220V, 50/60Hz
- Speed: 100-5000rpm
- Resolution: 5rpm
- Rated power: 500W
- Rated torque: 3.18Nm (at 1500 rpm)
- Display: 1) four 7-segment LED displays with decimal point
  2) Mini Drive Windows application on Pocket PC
- IR communication range: 1.5m
- Operating temperature: -20° to +40°C
- Maximum altitude: 1000m above sea level.
- Standards: IEC 60335-1

4. Drive description

❶ Motor
❷ Converter box
❸ Main power connector
❹ ON/OFF button
❺ Analog control signal (BNC connector)
❻ LED display
❼ IR communication port

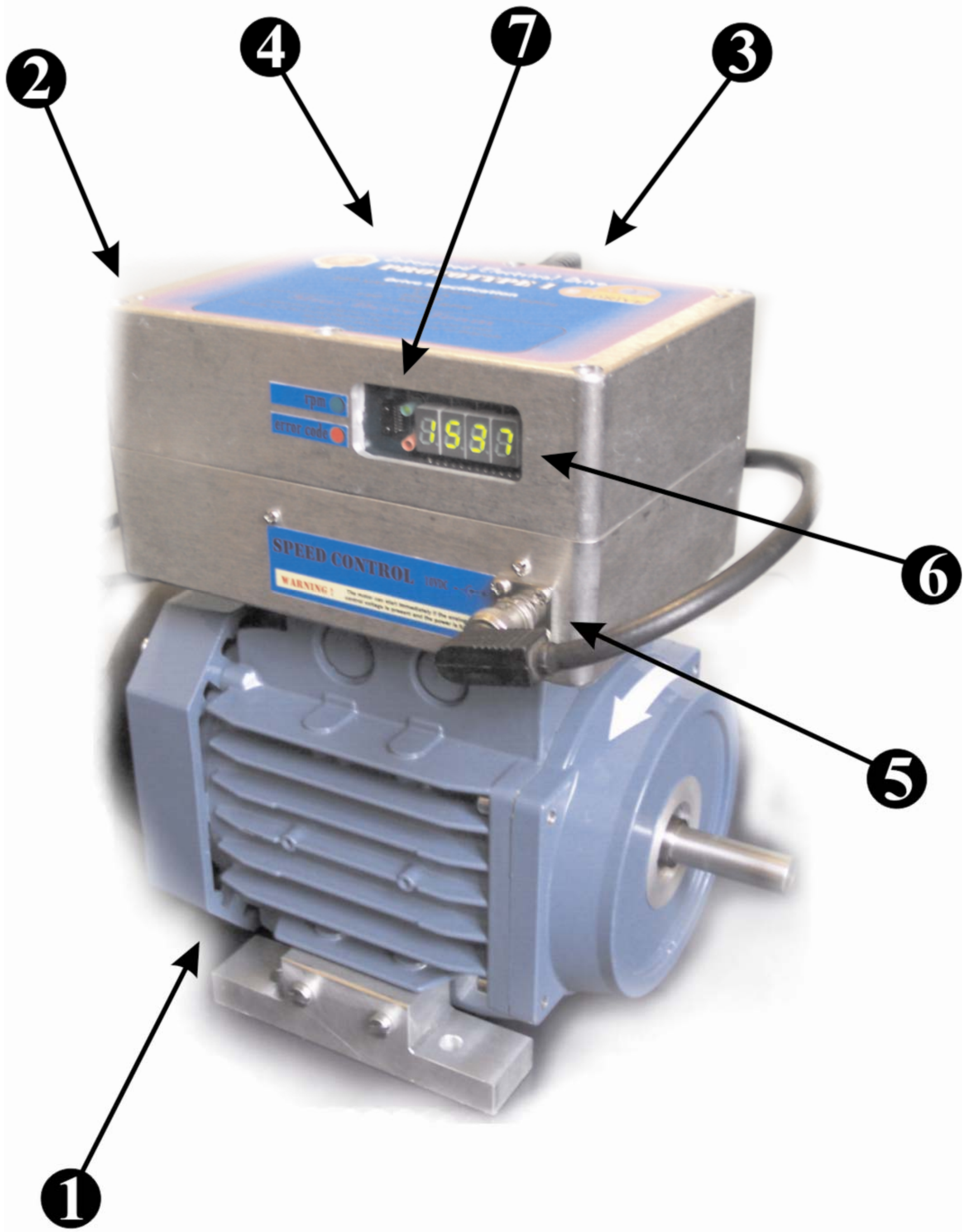


FIGURE: Drive description

5. Installation and working procedure

Direction of rotation is counterclockwise when viewing the shaft face. Turn shaft by hand to check free rotation.

Check if your power supply is according to the MiniDrive specifications. Check the earthing system.

Connect the input voltage cable to the IEC 320 main power connector on the drive. Plug the cable into the power socket (220V/50Hz).

Push the ON/OFF button into ON (1) position.

1) If analog drive control is to be acquired, a DC voltage source is needed. The voltage source is galvanic isolated from the rest of electronics. The value of DC voltage is calculated referenced to earth. This input transforms input DC voltage of 0-10V through BNC connector linearly into speed reference of 0-5000rpm.

2) Digital drive control is achieved with Pocket PC via IR communication. Windows CE application on Pocket PC is capable of speed referencing. When MiniDrive is in IR communication range, it will be shown in MiniDrive IrDA window. User should connect with *Connect* button. When the connection is successful the user is able to set speed reference in range 0   5000 rpm. Control source is changed by switching between options: *Analog control* and *Digital control*. In order to control shaft speed with PocketPC *Digital control* option should be active.

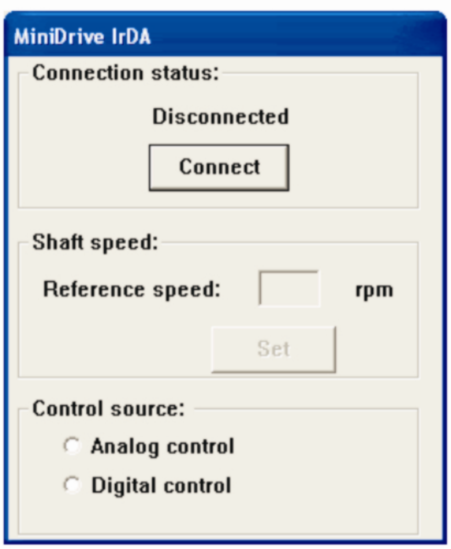


FIGURE 2: Speed referencing

LED display:
The 4 segment LED display is capable of displaying referenced speed and error code. Additional two LEDs are connected with these two modes:

- normal condition: green LED is on the displayed value is the speed reference. If shaft speed reference is being changed too fast, this LED will be turned off until shaft speed reaches reference speed.
- irregular condition: red LED is on displayed value is the error code

NOTE: in case both, red and green LEDs are turned on, the microcontroller has received more than one interrupt request. This option allows MiniDrive qualified technicians to make software checkups.

The following protections are implemented:

- Overcurrent protection: Includes short circuit protection for currents higher than 6A and overload protection.

- Overvoltage protection: DC bus voltage is above critical limit of 440V and the device will be shut down.

- Undervoltage protection: DC bus voltage is below critical limit of 250V and the device will be shut down.

- Thermal protection: Converter device temperature is above critical limit (85ºC) and the device will be shut down.

- Program execution is protected with on chip brown-out and watchdog circuits.

In case any of the protections is activated, the corresponding error code will be indicated on the digital display.

6. Troubleshooting

ERROR CODE	DESCRIPTION
64	DC bus voltage over 440V
32	DC bus voltage below 250V
16	Temperature over 85ºC
8	Short circuit on DC bus
4	LED display communication interruption
2	Malfunction on analog input circuit
1	Reserved

APENDIX III: Costing Spreadsheet

2005 FUTURE ENERGY CHALLENGE

Inverter and Motor Costing Spreadsheet

UNIVERSITY: University of Belgrade

NAME OF MAIN CONTACT: Igor Stamenkovic

PROJECT NAME: Min Drive

DATE: 5-Aug-05

DEVICE	QTY	DESIG	UNIT	MEASURE	VOLT (Vpk)	VOLT (Vrms)	CUR (Avg)	CUR (Arms)	UNIT COST	EXTENDED COST
DIODE	3	D7, D8, D9			600		1		2.12	6.35
DIODE	1	D26			600		8		2.50	2.50
DIODE	1	D24			600		4		2.28	2.28
DIODE	2	D4, D5			1000		1		2.15	4.30
DIODE	2	D21, D22			100		1		2.07	4.14
MOSFET	2	M1, M2			500		9		6.22	12.45
SCR	1	VDR			275		4		0.62	0.62
CAP (ALUM)	1	C30	10	uF	25				0.10	0.10
CAP (ALUM)	3	C32, C35, C38	100	uF	63				0.16	0.47
CAP (ALUM)	3	C20, C22, C24	22	uF	63				0.11	0.34
CAP (ALUM)	3	C28, C71, CD6	100	uF	25				0.11	0.33
CAP (ALUM)	1	C70	560	uF	450				15.80	15.80
CAP (FILM)	1	C72	1	uF	630				2.45	2.45
CAP (FILM)	2	C73, C74	0.000001	uF	1000				0.63	1.26
CAP (FILM)	1	C29	0.01	uF	630				0.65	0.65
POWER RESISTOR	1	R27	5	W					1.20	1.20
Mass Scaled Electromagnetic Devices	**QTY**	**DESIG**			**note**	**Mass (kg)**		**Mass (kg)**	**UNIT COST**	**EXTENDED COST**
MAG (HF Ferrite)					kg of Ferrite		kg copper			
MAG (HF Powdered Iron)					kg of Powdered Iron		kg copper			
MAG (HF Cool Mu)					kg of Cool Mu		kg copper			
MAG (Laminations)					kg of Si-steel		kg copper			
MAG (Soft Mag Material)					kg of SMC		kg copper			
Aluminum Die Castings					kg of Al					
MAGNETS (Ferrite)					kg of Ferrite					
MAGNETS (Neo)					kg of Neo					
Area/Vol Scaled Devices	**QTY**	**DESIG**			**note**	**Area (sq.in.)**		**Area (sq.in.)**	**UNIT COST**	**EXTENDED COST**
Rotor Retaining Shrowd					sq.cm					
CIR. BOARD (1 Layer)					sq.cm					
CIR. BOARD (2 Layer)	1	PCB			sq.cm	205			3.18	3.18
CIR. BOARD (4 Layer)					sq.cm					
Rubber Isolation					cu. cm					
Other Motor Devices	**QTY**	**DESIG**							**UNIT COST**	**EXTENDED COST**
Bearings (Sleave)										
Bearings (Ball Bearings)										
LOSSES (Inverter or Motor)		Motor		W						
CONTROLS, Programming, Layout, Revision Managment										2.92
PACKAGING, Enclosure, Parts Mounting, Parts Management										2.92
OTHER (EXPLAIN)										44.43
TOTAL										108.69

REMARK

The price of the motor is $14 at 1 100 000 pieces
The total price of the electronics)(without the motor) is $ 108,69 for 1-10 pieces quantity. This price is estimated at $20 for 100 000 pieces produktion.
The price of the drive is estimated at $35 for 100 000 pieces production.

OTHER

DEVICE	QTY	DESIG	UNIT	MEASURE	VOLT (Vpk)	VOLT (Vrms)	CUR (Avg)	CUR (Arms)	UNIT COST	EXTENDED COST
CAP (TANTAL)	6	C2, C34, C3 7	1	uF	35				0.14	0.84
CAP (TANTAL)	1	CI8	47	uF	16				0.83	0.83
CAP (TANTAL)	2	CA1, C5	2.2	uF	2.2				0.20	0.40
CAP (TANTAL)	1	CA4	3.3	uF	20				0.15	0.15
25-250 kHz INDUCTOR	1	L1	0.215	UH				5	4.50	4.50
100 kHz TRANSFORMER	1	TX1				400		0.5	1.00	1.00
ATMEGA 168	1	U1	20	MHz					2.70	2.70
Attiny 15	1	IC1							0.73	0.73
MCP2140	1	UI2							1.75	1.75
TFDU 4100	1	UI1							3.20	3.20
SAA1064	1	UD1							3.00	3.00
LED DIGIT	4	UD2, UD3, UD4, UD5							0.76	3.04
NCP 1053	1	U3							0.65	0.65
MCP33260	1	U20							0.45	0.45
LM339	1	U20							0.15	0.15
OPTOCOUPLER	2	U7, UA6							0.27	0.54
7805	3	U6, U5, UD6							0.15	0.45
7815	1	U4							0.15	0.15
78L12	1								0.14	0.14
IRAMS06UP60A	1	IRAMS							17.00	17.00
OSCILATOR	2	Y1, Y2							0.33	0.66
NTC S100	1	RT2							2.10	2.10
TOTAL										44.43