3. SCOPE OF WORK AND PROBLEM DEFINATION

3.1 Introduction
This chapter establishes the scope for the assignment to be undertaken by the investigator in the present thesis. This explains in detail how the assignment has been derived out of the previous works already carried out in this area of research by various other authors. This also defines the problem to be addressed as the research work and the guidelines for taking up the problem.

The Chapter starts with a brief discussion of the inferences drawn out from the literature review; scope for further which lists the gaps identified by the investigator which establish the problem statement in this area. It is followed by objectives of the present work and then a research design section which brings forward the investigator’s idea to develop a suitable product for addressing the problem statements. This chapter also establishes detailed specifications and expectations from the final product. In the last section of the chapter, a product development roadmap has been provided, in which explanations about the various steps involved in executing the product design and its development have been provided.

3.2 Background
The previous chapter has highlighted some existing gaps in the dc motor performance analysis methodologies, as inferred from the literature review carried out on the earlier research works undertaken on dc motors. A brief summary of the inferences drawn out of the literature review is again produced below:

- Motor characteristics and their analysis have been established as an important means for detection of faults, losses and improvement in the efficiency of dc drives.
- Data related to motor efficiency and losses provides key information to understand suitability of a dc motor for a given application.
DC MOTOR PERFORMANCE ANALYSER

- There is no single test or methodology available, which can provide all informations about parameters effecting the motor performance. User has to perform multiple tests and create different setups for acquisition of parameters.
- In recent years, PC based analysis of motor parameters has been widely accepted in research community to carry out detailed study of motor behaviours.
- Graphical representation of data helps understand the problems easily and infer the root cause of problem. It can also suggest improvements in product design.
- An automated way of carrying out motor performance analysis is much needed to ensure proper diagnosis of the motor performance defining the motor parameters correctly. Automation will also help in minimizing the operator intervention to change setups in order to carry out different tests on one motor. Complex calculations, derivations and controls will get off loaded from the operator and can be integrated in automated tests.
- Advancements in the field of power electronics and microcontroller based embedded systems have enabled development of complex and interactive controls for motor applications.
- A single hardware-software package capable of communicating with PC, is essentially required which can control the motor and obtain its major performance characteristics by acquiring the necessary parameters properly.

Based on the above mentioned gist of inferences, scope of the work has been established and also a problem definition for the proposed work has been clearly defined in the following sections of this chapter.

3.3 Scope for the Present Work
The investigator in this section has elaborated the scope for the present work as inferred from the literature review carried out on earlier research works. The points are mentioned below:
3. SCOPE OF WORK AND PROBLEM DEFINITION

i. Publications reported in [6-28] focus on the analysis of motor parameters, behaviours and the improvements incorporated in the product, based on observations and investigations. Motivated by the facts obtained from the publications, the investigator has envisaged establishing the base for the present area of research i.e. performance evaluation of dc motors.

ii. Importance of graphical data analysis has been highlighted in the publications [29-37]. This has been the major motivation for the investigator to decide that graphical way of representation of data will be highly appreciated by the user. Similarly, relevant data acquisition and processing in case of dc motors can provide insight for understanding the related problem.

iii. The research article in [38] has discussed motor performance analysis utilizing power electronics technologies. The investigator envisages to work on similar lines and improved this approach by fully automating the process of dc motor performance evaluation. In the given publication, mechanical loading of motor and analysis of motor currents, voltages have been mentioned. The investigator however intends to extend the analysis to acquisition of motor characteristics, losses and efficiency. Also the loading technique has been changed to electrical loading instead of mechanical braking.

iv. The publications reported in [39-74] again have stressed on different ways to evaluate motor performance. Based on the investigation reports mentioned in these literatures, the author's intention is to develop similar but improved techniques as analysis tool for dc motors.

v. Reviewing the research documents mentioned in [75, 76] and after conducting survey, on already exciting software-hardware data acquisition packages in the market, the investigator has identified need for a single hardware-software package which can provide all electrical interfaces required to evaluate a dc motor like – SCR bridge control, speed acquisition, voltage, current, temperature acquisition, graphical
representation of motor parameters, data-storage, speed Control, PC based motor loading control etc. The investigator aims to bridge this gap by carrying out the proposed research work.

vi. Different methods of speed control for a dc motor on neural networks, fuzzy logic, microprocessor and microcontrollers have been presented in articles reported in [77-126]. One can read about various types of PID controllers for dc motors mentioned in articles reported in [127-130]. Inspired from these articles, the investigator aims to incorporate PID control for different parameters of the dc motor in this work.

vii. As explained in recent research publications [131-144], it becomes clear that introduction of microcontrollers with high on-chip peripheral integration and processing speeds has enabled designing of complex control systems and products in a small form factor and cost effective way. Based on the claims and the testing results of the above mentioned publications, the investigator envisaged to select Atmel AVR family microcontroller to develop the dc motor performance analyser (DCMPA). In DCMPA, the CPU load and processing requirements may be similar to the applications mentioned in the above listed publications.

viii. Research papers reported in [145-158] reveal how compatibility of a dc motor for any type of application can only be best understood by analyzing the speed-torque characteristics of dc motors for their applications. Thus, the importance to capture information to obtain characteristic curves of a dc motor became clear to the investigator.

ix. Articles mentioned in [159-204] depict different methods for calculation of efficiency and losses and their importance. The investigator thus, envisaged to integrate losses and efficiency calculations in her approach of performance evaluation of a dc motor.

x. Another significant field where knowledge of predetermined parameters of dc motor is essential is the fault detection. The failure of machines could cost lot of money; hence in most of the industries, a very expensive scheduled maintenance is performed before they can result in
3. SCOPE OF WORK AND PROBLEM DEFINITION

... catastrophic failures. Articles mentioned in [205-227] depict different methods for fault detection in a dc motor. Based on these articles, the investigator has envisaged how operating characteristics of a dc motor which is also considered as performance index for any given dc motor, can be very helpful in detecting faults if a given dc motor is seen to divert from its expected performance.

3.4 Problem Statement

Based on the scope for the present work established by the investigator, definition of the problem statement leading to the development of the product called dc motor performance analyser (DCMPA) has been defined in this section. The problem is divided in five parts as mentioned below:

Part 1 Detailed study and critical analysis of dc motor characteristics for the purpose of detection of faults, losses and understanding of the machine performance.

Concept of PC based automated acquisition of motor characteristics forms a good proposition. This requires collection of Speed-Torque, Torque-Armature current and Speed-Armature current characteristics of a dc motor. Obtaining these characteristics involves complex controls and calculations which are explained below:

i. **Speed-Torque Characteristics**

   This curve is plotted between motor armature current and torque. During the test Mechanical load on the motor shaft (Torque) is increased gradually and corresponding change in motor speed is recorded.

ii. **Torque-Armature Current Characteristics**

   In this test the major parameter under observation is motor armature current variation under the effect of Motor shaft loading. Torque generated by the motor to drive the shaft is plotted against the corresponding change in armature current.
DC MOTOR PERFORMANCE ANALYSER

iii. Speed-Armature Current Characteristics

Above mentioned test when conducted to record the relationship between speed and armature current with variation in motor shaft loading, provides Speed-Current characteristics of a dc motor.

In the present proposal it is intended to introduce the concept of automating the above mentioned tests using PC for the purpose of achieving the following major objectives:

i. Complete PC based control of tests for motor characteristics acquisition

ii. Automated acquisition of motor parameters such as current, voltage, torque, winding temperature etc.

iii. Automated sequence for increasing mechanical loading of the motor and incorporating complete control over dc voltage fed to motor through SCR bridges.

iv. Automated control for maintaining parameters such as speed, armature current, torque etc at constant values as per requirement of the test.

It is envisaged by the investigator that the automated technique introduced in the present thesis work will be able to acquire the characteristics data of dc motor in real-time and will provide an insight to motor’s behaviour under different operating conditions. As per the literature review carried out by the investigator which was highlighted in the previous chapter, there are no such techniques available which can carry out the motor characteristics acquisition in real-time. In the proposed methodology the investigator extends the scope of application to confirm/verify the practical performance of dc machine to data derived from theoretical calculations and equations.

Part 2 Data of a dc motor regarding losses and efficiency, provides useful information, which can help the user understand compatibility of a machine to the given application.
Various losses occur in a dc motor depending upon the load, applied voltage and speed of the motor. As a result, the efficiency of a particular machine deteriorates with the amount of input energy lost during the process of electromechanical energy conversion. Determination of efficiency therefore, requires calculation of the total losses. Accuracy in having an account of losses will give a correct estimate of efficiency of the motor. Although both the direct loading and the indirect loading test (Swinburne’s test, Hopkinson’s test etc) are available for determining the efficiency of a dc motor, all the tests have certain limitations which have been discussed in detail in sub-sections 1.2.5 and 1.2.6 of chapter 1. Moreover, no universal or unique process/methodology can be devised for all types of dc motor (viz series, shunt and compound etc), and for no-load and full-load conditions. Additionally, the conventional tests are based on certain approximations and very much require some correction factor to be applied under different conditions.

The proposed design will not only take care of automation, but will also be independent of any such limitations mentioned above. The same experimental set-up will be capable of directly measuring the losses of a given dc motor as it will have the capability to read various currents, voltages and speed of the motor as and when required.

Following are the details regarding losses and efficiency of dc motors:

i. **Losses**

For any dc motor, there are fixed and variable losses. Fixed losses are calculated by summing iron, friction and windage losses. These losses remain constant unless there is an appreciable variation in speed and are dependent on a) flux density, b) specific density and c) volume of iron used in a machine. Variable losses are copper losses which occur in the windings of the armature and the field of the motor. These losses are proportional to the square of the load current and are dependent on a) current density, b) specific resistance and c) volume of the conductor material used in the machine.
ii. Efficiency

The presence of fixed and variable losses together in the dc motor continuously tends to change the efficiency of the dc motor. A given percentage of error in the measurement of losses causes about one tenth of that percentage error in the computation of efficiency. So, when a machine is to be selected from a large number of available machines, then their methods of loss measurement should necessarily be the same.

The investigator envisages the following salient features which need to be built in the proposed setup:

i. Complete PC based control of tests i.e. motor losses and efficiency calculations.

ii. Automated acquisition of motor parameters viz current, voltage, torque, winding temperature etc which define losses and efficiency of a dc motor.

iii. Automated method for acquiring efficiency and losses under different operating circumstances.

iv. Graphical representation of the total data on PC and its storage.

The present proposal is a novel approach / methodology where process of acquisition of losses and efficiency has been simplified and demands less operator's intervention. The proposed setup named DC Motor performance Analyser (DCMPA) will abstract all complex calculations and equations from the user and after the process is over, will provide the visual representation of the processed data.

Part 3 To perform the above mentioned tests and obtain results out of them. The process includes control of various motor parameters like speed, armature current and mechanical load on the motor shaft. DCMPA is proposed to address the following requirements:

i. Speed of the motor must be controlled by the DCMPA. A controlled dc voltage source like a full-wave fully controlled SCR bridge and its
corresponding driver hardware-software will be required for this purpose. Motor speed can be adjusted by varying the armature voltage.

ii. Motor armature current is another important parameter which needs manipulation during testing and has to be controlled by varying motor shaft loading and input dc supply.

iii. Controlled Mechanical loading of motor shaft should be achieved in the DCMPA. A loading mechanism for dc motor by coupling it with a separately excited dc generator of higher rating has been introduced. Control of the generator field while electrical load is connected to the armature of the motor, can achieve controlled mechanical loading of the motor. Generator field can be fed from an SCR bridge to achieve a smooth control of motor loading.

It is essential to implement a PID control algorithm for the above mentioned parameters and to ensure correct evaluation of the motor performance characteristics. Incorrect manual monitoring and intervention during testing can be eliminated by controlling the various motor parameters with the help of DCMPA.

Part 4 A major requirement for the implementation of the proposed concept and for execution of investigator’s concept is a graphical and interactive way of presenting data which is acquired from different automated tests and processed thereby. Keeping the same in view, following specifications must be met in the final product:

i. It is established in the previous part of the problem that tests will be performed following automotive process using PC, and at the same time data acquired from the motor will be represented in a graphical way and the user will have the provision to start/stop, modify different tests and test types as per the need.
DC MOTOR PERFORMANCE ANALYSER

ii. In addition to graphical representation, user will be able to record the data in a file. Format of data file should be such that it can be viewed and analyzed in other word processing softwares (like word, excel etc) also.

iii. Complete control of the automated tests will be provided to the user through a GUI driven software.

PC based software with above mentioned features will ensure that tests will be performed hassle free and the user will be able to focus on the analysis of the data collected from the motor, rather then getting into details of motor testing.

Part 5 DC motor being the most versatile, flexible and easily controllable energy conversion device will always remain in demand in various industries, domestic sectors as well as educational institutes.

This is the reason that in today’s world around 25% of the total manufactured motors are dc motors. The applications of dc motors being very specific, manufactures need to evaluate dc motors at different loading conditions and speeds for different parameters. For this purpose, a combination of different conventional methods is required; which turns out to be very time-consuming and cumbersome.

The present product proposed by the investigator with a single platform for automating the process of testing and evaluating dc motor performance should serve as a benchmarking tool for all dc motor manufactures.

3.5 Objectives of the Present Work

Considerable areas of improvement have been identified in the field of automated performance analysis of dc motors, on the basis of literature review carried out by the investigator, which has been discussed in detail in the 2nd Chapter. The investigator, influenced and motivated by this point, has chosen the performance analysis of dc motors as the area of research in her PhD programme. Keeping in view, the problem statement defined in the previous section, the investigator in this report, proposes to design and develop a
3. SCOPE OF WORK AND PROBLEM DEFINITION

A hardware-software package called **DC Motor Performance Analyser (DCMPA)**, which is believed to be capable of evaluating performance of a dc motor of any type and any rating in an automated manner.

An automated dc motor performance analyser will be designed to accomplish the following objectives:

- The device will automate the process of testing a dc motor of any type and any rating for its performance at various loading conditions.
- The device will open a universal platform for evaluating performance of a dc motor of any type and of wide range of rating, by utilizing PC based windows application software and microcontroller based hardware.
- DCMPA will be a benchmarking tool for all dc motor manufacturers and quality sensitive users.
- This will enable the user to acquire major parameters of a dc motor in an automated way, which will define its performance and capabilities, like motor characteristics, motor efficiency and motor losses. Various methods of obtaining motor characteristics and calculating efficiency / losses have been presented in the section 1.2 of chapter 1. None of these methods has automated the process of testing. In DCMPA, the complete process will be controlled by a PC based technique through a universal data acquisition and control hardware.
- DCMPA will consist of microcontroller based hardware capable of data acquisition and controlling the major parameters of a dc motor. Same hardware could be used to carry out testing and evaluation of different types of dc motors like separately excited, shunt, series or compound etc.
- User will be able to carry out performance testing and record the test data for future reference. The device will have a user friendly PC based Graphical Interface for control of various operations.
DC MOTOR PERFORMANCE ANALYSER

An automated dc motor performance analyser will have at least following advantages over existing techniques/methods for this purpose:

- Number of experimental set-ups is available to carry out different types of analysis related to dc motors. Most of them are unique to the kind of work expected from them; hence, most of them almost remain unused depending upon the demand of analysis required in the market. The proposed DCMPA will provide a single set-up which can be used for any type of evaluation required for any type and any size of a dc motor, thus can always be utilized effectively and efficiently.

- In order to carry out various tests smoothly and to reduce chances of human errors, highly trained engineers/technicians are required for performing any experiment on dc motor. The current methods are quite complex and involve considerable amount of manual efforts. On the other hand operation of the proposed DCMPA, only needs a person familiar with PC, who should be clear about the objective of the experiment to be performed on a dc motor. Neither highly trained nor professional engineers will be required for this job.

- The existing conventional experimental set-ups require constant maintenance and checking at regular intervals as they are constituted by lot of exposed hardware and circuitry. The design of proposed DCMPA will be such that it would be a single enclosure with all the control hardware incorporated inside it. One will only have to interface it with PC through serial port provided on its back and connect it to the bridges. No regular checks will be required in this case.

- Purchase of any experimental set-up is by some organization involves considerable expenses. But, as environment changes and some additional feature is required for the same kit, expansion plan cannot be executed immediately. Proposed DCMPA will provide adequate flexibility in software which will be able to take care of small additional features if required by the user for future expansion.
An automated dc motor performance analyser would offer at least the following possibilities for the product analysis:

- **Detection of faults**
  The Study of operating characteristics is a measure of how final output of a given motor will fit in for use of any such tasks, hence, it is considered as *performance index* for any given motor. The transition from manual to automated tracing of operating characteristics of any motor being faster, more accurate and less prone to errors can be very helpful in detection of faults if a given motor is seen to divert from its expected performance.

- **Comparison of different dc motors**
  An automated examination of dc motors will provide the flexibility of storing the values of critical parameters monitored during various tests in a data-base for comparison among different dc motors. Thus, any number of dc motors can be compared with one another under different categories and choice for the best suitable one for any application can be made easily.

### 3.6 Research design

In view of the problem statement discussed in section 3.4, the investigator envisages to design a hardware-cum-software package to achieve the requirements of the details laid down in the previous section. Preliminary details of the product have been discussed in this section.

#### 3.6.1 DC Motor Performance Analyser (DCMPA) – An overview

In the proposed DCMPA, the dc motor under test will be incorporated with an interfacing topology as shown in Fig.3.1. A brief detail of the concept envisaged by the investigator has been incorporated in this section. Elaborated description of the product specifications will follow in the next sections of this chapter.
Following are the main blocks of the proposed DCMPA setup:

i. Motor – Generator Unit

DC motor under test, needs to be coupled to a separately excited dc generator. The generator itself may be electrically loaded by connecting a 200 ohm, 50W resistance across its armature terminals and the field may be fed through a controlled dc voltage source. Motor-Generator necessarily should have their shafts mechanically connected using appropriate sized old-ham couplings. This setup is envisaged to be used by the investigator as a mean to achieve electrically controlled loading of the motor shaft.

ii. Interface Hardware

In order to carry out the detailed performance test of a motor using PC, the motor-generator set needs to be interfaced to a hardware which can device various data acquisition and controls on the motor and communicate the same to
3. SCOPE OF WORK AND PROBLEM DEFINITION

the PC. This can be achieved by designing a microcontroller based electronic hardware interface, capable of attaining the following salient features:

i. Control of SCR based full-wave fully controlled bridges to generate variable dc voltage
ii. Acquiring and processing motor parameters such as current, input voltage, generator output voltage, speed, winding temperature etc
iii. Execution of sequence of tests to be performed on the motor
iv. Communication with the PC serial port

Hardware has been envisaged to be controlled by an 8-bit, RISC microcontroller of Atmel AVR family. Associated firmware programming may quite effectively be carried out in embedded-C language.

iii. PC software
DCMPA hardware is supposed to communicate with the PC via RS-232 serial port. A program based on Microsoft Windows will be designed to provide the necessary interface to the user and also interact with the hardware.

Visual Basic has been chosen as the development platform for application programming. Visual Basic is easy to implement development language which incorporates rich graphic capabilities into the program, at the same time ensures transparent interface to the lower layer of the hardware like serial RS-232 port. Application software built in the DCMPA is supposed to address following major responsibilities:

i. Graphic user interface for DCMPA
ii. Communication with DCMPA hardware and control of the operations
iii. Data storage
iv. Editing/updating information regarding the motor setup
v. Choosing different types of tests to be performed
vi. Processing the data received from the hardware
It is quite clear from the brief description of the DCMPA, that the proposed system will be capable of data acquisition, bringing in dc motor controls, motor testing techniques and PC based analysis all embedded into a single platform.

3.6.2 DCMPA Product Specifications
DCMPA from development stand point of view, can be categorized into two major areas of work – i) Hardware design and ii) Software development. This section will cover the detailed specifications of the product and the scope of the work in implementing the same.

A. Detailed Hardware specifications
DCMPA hardware will be an interface between the PC and the motor under test. It should therefore be able to provide data acquisition and control capability for testing dc motors.

The present system has been considered for handling any type of dc motor up to rating of 5HP. At the same time, flexibility must be built in the system such that the hardware be capable of accommodating higher capacity dc motors with minimal change in the interfacing circuitry. In other words, it must be capable of being called a universal hardware which can carry out the performance analysis for all types and ratings of dc motors. Based on the requirements set by the problem statement defined earlier, following specifications have been derived for the DCMPA hardware:

i. DC voltage measurement interface
   Voltage measurement range is assumed to be from 0 to 300V dc. This specification is based on the operating voltage range of commonly deployed dc motors; an extra overhead may be added to accommodate any deviations from the range. This is accomplished by using appropriate resistive divider circuit. At least two measurement interfaces should be provided with a measurement resolution of 1V.
ii. **DC measurement interface**

One direct current, measurement interface is required to acquire input current to the dc motor. To accommodate dc motors up to 5 hp, 0 to 25 ampere measurement capability with resolution of 0.1 Ampere will be sufficient. Hardware should be simple to bring in modifications for higher current ranges.

iii. **DC voltage terminal**

One fixed dc voltage terminal with 230V dc / 1 Ampere capability should be provided. This may be used for providing field voltage to the separately excited dc motor and for helping to check the motor/generator before actual testing starts.

iv. **Temperature sensor interface terminals**

Temperature sensor should have a range of 0 to 100 degree Celsius and a resolution of atleast 1 degree Celsius. This will be used to measure the temperature rise in the motor winding.

v. **Speed measurement**

Interface capable of acquiring speeds in excess of normal operating speed of 1500 rpm must be provided. A range of 0 to 1800 rpm with a resolution of 5 rpm should be sufficient to device different controls on the motor.

vi. **SCR based bridges**

DCMPA should be capable of controlling at least two SCR based bridges. This control circuit requires two identical interfaces which can produce firing pulses to control 4 SCRs in each bridge. SCR bridges should be provided externally to the DCMPA hardware such that they can be modified as per the current requirements of the motor (i.e. the motor rating). Voltage control resolution of minimum 2V must be achieved over the complete 0 to 180 degree firing angle span.

vii. **Communication interface**

The system should have a communication interface with RS-232 voltage levels.
viii. Indications
DCMPA must have status indication LEDs and a power switch which should be able to operate the DCMPA from 230V ac/50Hz power supply.

ix. Compliance standards
DCMPA must comply with industrial standards for Electrostatic Discharge (ESD), Electrical Fast transients (EFT), Power Supply Dip Surge (PSDS), Conducted Emissions (CE), Radiated Emissions (RE), Conducted Susceptibility (CS) and Radiated Susceptibility (RS) testing. The product must be capable of continuously working without compromising with its quality of performance over a temperature range of 0 to 55°C.

x. Microcontroller based solution deployment
DCMPA functionalities should primarily be controlled by a microcontroller and its firmware. This will provide a flexible way to develop and deploy DCMPA product operations. To accommodate the functionalities of the DCMPA (as established in the previous sections) the microcontroller should have the following features:

- On Chip Integrated Flash and SRAM memory. 32 kilobytes of Flash and 2k SRAM will suffice for application.
- On Chip integrated ADC (minimum 6 channels) with 10 bit resolution and at least 1ksps sampling-rate.
- Timers – at least two with 16 bit counter.
- On chip 20 or more usable GPIO pins
- UART communication port.
- Flash Programming/debug port.
- Watchdog timer to reset the system in case of malfunctions.
- Atleast two interrupt capable digital input pins.
- ESD protection and tri-state capability for all GPIO pins.
- Preferably a RISC architecture based microcontroller to accommodate processing requirements of this application. It is preferred that instructions should take minimum machine cycles for execution. 1 MIPS per MHz of clock is the target expectation.
from microcontroller. This ensures that any future upgradation to firmware or product capabilities will not demand hardware modifications.

B. Detailed software specifications
DCMPA software interface will be a PC application, responsible for the control of the DCMPA hardware, Data processing and analysis and user interaction. Based on the facts established earlier regarding expectations from DCMPA software, following specifications may be derived:

i. Software developed should necessarily be compatible with the commonly used PC operating systems. Compatibility with Microsoft windows is a must.

ii. PC application (Software) should be able to provide a graphical interface to the user and the navigation should be maintained simple, so that the software can be used by a user without any prior training.

iii. User should be capable of entering motor setup details and selecting communication channel to connect with the DCMPA hardware.

iv. Software should provide with a list of tests and their analyses which can be carried out on the motor. An option for selecting the same should also be built in. Few of the tests and their analyses are mentioned below which may be included:
   - Speed-Torque characteristics
   - Torque-Armature current characteristics
   - Speed-Armature current characteristics
   - Copper losses and motor efficiency
   - Motor performance evaluation at different speeds and torque, under complete user control.

v. DCMPA status should be indicated on the screen at all point of times. In case test is being carried out, current values of parameters (in appropriate units) being acquired should be displayed on the screen.
vi. Motor analysis should be represented in graphical form in real time. Axes of the graph should have auto-scale of the test as per requirements.

vii. User should be able to capture the acquired test data in a file. User should also be able to open or import data file in commonly used text processing software like MS Excel etc.

viii. Acquired data should be processed and converted into the desired format/unit automatically by the software.

ix. All operations provided in the software should be accessible through ‘Icons’ and ‘Drop-down Menus’.

x. Once a test/analysis is started by the user, PC software should be able to complete the same without any intervention from the user.

xi. There should be a provision to calibrate the test setup before a motor is connected for testing.

### 3.7 Product Development Roadmap

This section has discussed about the activities to be carried out by the investigator in order to develop the proposed DCMPA complying with the product specifications mentioned in the previous section. DCMPA consists of a Hardware platform along with a PC based application. The development roadmap for the said product can be broadly categorized as discussed in the following subsections:

#### 3.6.1 Hardware development

A well executed design and development cycle for an electronic product requires travel through many stages before arriving at a successful conclusive end. Flow of hardware development life cycle is shown in Fig.3.2 in the form of a block diagram.
3. SCOPE OF WORK AND PROBLEM DEFINITION

DCMPA hardware process will be concluded in two development steps. First step will comprise the development of the prototype product and second step will consist of the final development of DCMPA.

Hardware development process steps are listed below in a sequential manner:

i. **High level design**
   A Block level concept has been derived from the hardware specifications and then an overview is provided in the form of a block diagram, known as High level design (HLD). Major decisions to be made in high level design are listed below:
   a) A block level topology of complete hardware to be finalized
   b) Microcontroller selection to be finalized
   c) Microcontroller firmware development roadmap to be defined
   d) Hardware development requirements like ECAD tools, Test equipment, SPICE simulation tools needs to be defined.
   e) PCB technology identification has to be implemented which includes Number of layers, component type, PTH/Non PTH, minimum track width, minimum drill size etc.
ii. Detailed level design
Followed by the HLD, a detailed level Design (DLD) of the hardware will be developed, and will further lead to accomplishment of the following steps:

a) Pre-design calculation and component finalization
b) Circuit entry in ECAD tool
c) Circuit simulation
d) PCB design
e) Gerber data (PCB fabrication data file format) generation and verification

iii. Hardware build
After Layout creation for all sections of the hardware, PCBs will be fabricated for all modules of DCMA hardware and components will be populated on it through manual soldering. Steps are summarized below:

a) PCB Fabrication
b) Component procurement
c) Component population/assembly

iv. Hardware testing
Prior to usage of hardware, a testing session has to be conducted, which assures the suitability of the hardware for the intended applications. In case of DCMPA hardware, one round of testing will be performed before starting firmware development as listed below:

a) Cold testing of hardware
b) Power up testing
c) Module level testing

v. Firmware development
Firmware design like DCMPA hardware, also requires a specific approach. This sub section presents an overview of the various steps involved in the embedded firmware design and development. The steps are as mentioned below:
3. SCOPE OF WORK AND PROBLEM DEFINATION

a) System requirements and specifications
Embedded firmware development process starts with finalization of functional requirements, which are derived from product specifications.

b) High level design
The finalized firmware functions are converted into a programme model using modeling tools or flow-chart based representation, to give a diagrammatic representation of the decision items to be taken and the tasks to be performed.

c) Pre-design calculations and module level design
Module level design deals with the details and design strategy for subsections of the total software eg Communication driver, ADC driver, firing-angle control sub routine etc.

d) Microcontroller initialization design routine
This part of the code needs to be executed before any other software operation takes place. This section of software makes sure that the microcontroller has all its pins set in the correct mode (input or/and output) so that it does not give adverse effect on external circuitry connected to it.

e) On chip peripheral driver coding
This is part of the programme which initializes the on-chip peripherals of the AVR microcontroller by configuring the control registers.

f) Applications subroutines
These are functions added to the firmware which accomplish application tasks by using low level driver functions like firing angle routine, acquisition of ADC functions etc. These functions are more application centric and perform tasks like carrying out motor characteristics acquisition tests etc. Detailed description of the same has been provided in the following chapters.

g) Integrated build
Integrated build is the usage of all the functions (application level and driver functions) to work in synchronism so as to achieve the desired
DC MOTOR PERFORMANCE ANALYSER

functionality of the product. It is basically integration of all application level functions and their driver functions.

**h) Test plan**

Creation of test plans is essential in order to ensure that all aspects of the software have been addressed for any product and must be carried out keeping in view high level and low level product requirements.

**vi. Integrated testing**

Integrated testing stands for testing of Hardware and microcontroller firmware. This in any ways should not be confused with integrated testing of DCMPA hardware and PC application software. Following are the two main steps involved in this test:

a) Hardware-firmware integrated development and testing
b) Firmware optimization

**3.6.2 PC Software development**

The present section presents an overview of the various steps involved in the design and development of the PC Application Software. This is depicted diagrammatically in Fig. 3.3.

![Flow of software development life cycle](image_url)

*Fig. 3.3 Flow of software development life cycle*
3. SCOPE OF WORK AND PROBLEM DEFINATION

The steps are explained below:

i. **High level design (HLD)**

   Architecture of the software organization has to be derived from the product specifications established in the previous sections. This will guide the software development path. A list of major activities to be accomplished in the HLD phase of the software development is given below:
   
   a. Software architecture design.
   
   b. Finalization of development platform. For instance the investigator has preferred MS Visual Basic as development language for PC application design.
   
   c. Brief details of all the sub modules / sub routines required to accomplish the application.
   
   d. Flow-chart representing the flow of the software

ii. **Low level design (LLD)**

   Each module represented by the HLD is narrowed down to subroutine level and detailed design has been created. Subroutines like - Communication module, Graphical user Interface, Print module, Report generation and data storage module etc. Algorithm flow chart has to be designed for all the major functions.

iii. **Coding and Interface design**

   Based on the HLD and LLD, coding of application has been carried out. Graphical user interface is designed prior to coding which is supposed to drive the flow of the programme.

iv. **Integrated build**

   Integrated build is the usage of all the subroutines (Graphical interface and Events) to work in synchronism so as to achieve the desired functionality of the product.

81
v. Test plan
Creation of test plans for ensuring that all aspects of software are properly addressed is essential for any product and should be carried out keeping in view high level and low level product requirements.

3.6.3 Integration testing of the product
Finally developed hardware and software need to be tested together to identify any gaps in achieving the desired product functionality.

Following main steps are involved in integrated testing of the product:
   i. Integrated test plan development
   ii. Identification of Jigs and fixtures required for testing
   iii. Mapping of all test results matching with the product specifications.
   iv. Identification of scope of modifications for improvement in the product.

Conclusion
It is clear from the details provided in this chapter that the investigator will be going through the complete electronic product design lifecycle during the product development. Also, specifications and development roadmap established in this chapter will be followed in the next chapters. It has also been discussed in this chapter how the proposed work in this thesis is an integration of latest techniques, effective controls and efficient approaches for performance analysis as mentioned in the literature survey section.

The next chapter will discuss the design and development of DCMPA Hardware. The chapter will provide complete details about various blocks of interface Hardware, various tests and analyses conducted leading to its validation and finalization.