AN AUTOMATED TECHNIQUE FOR COMPLETE ANALYSIS OF DC MOTORS

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ABSTRACT

This paper provides essential information on an ongoing research aimed to develop a ‘DC Motor test and analysis platform’ which can be used to calculate losses & efficiency, provide motor characteristics and also as a speed controller. Presently there are different tests and methods available to evaluate these parameters but, the concept of motor performance analyzer, which is discussed in this paper, reveals how intelligently integration of all these analysis can be done with user friendly automated setup. Integration has been accomplished by designing a data acquisition & SCR bridge firing hardware. This hardware has the capability to drive the phase controlled rectifiers, acquire current, voltage, temperature & speed. A PC based front end application communicates with the hardware and provide user with different options of evaluating motor performance. It provides data which can benchmark the performance of motor for motor manufacturers and quality sensitive users. With almost successful completion of development of DC motor performance analyzer, authors, through this paper aim to extend an overview on this novel concept.

KEY WORDS: DC Motor test, analysis platform, losses and efficiency, data acquisition, phase controlled rectifiers, dc motor performance analyzer.
1. INTRODUCTION

A dc motor designed to run on dc electric power is a highly flexible and versatile machine. It can satisfy the demands of loads requiring high starting, accelerating and retarding torques. For a dc motor, the main attraction lies in its flexibility and ease of control. Hence, it is easily adaptable for drives with a wide range of speed control and fast reversals. This explains why in spite of its rather heavy initial investment it still retains its charm in strong competitive industrial applications. In the world, today, around 25% of the motors manufactured are dc motors. Also, there are various aspects in which dc drives are superior to ac drives, as mentioned below:

DC motors, because of their characteristics have a long tradition of being used as adjustable and variable speed drives and as such a wide range of options have evolved for this purpose.

DC regenerative drives are available for applications requiring continuous regeneration for overhauling loads. AC drives matching with this capability would surely be more complex and costly.

Properly applied, brush and commutator maintenance is minimal in case of dc motors.

DC motors are capable of providing higher starting and accelerating torques (in excess) as compared to ac motors of same rating.

Some of the ac drives produce audible motor noise which is much undesirable in specific applications.

DC motor controllers are less complex as compared to ac motor controllers, because they require only single power conversion from ac to dc. [1]

Performance evaluation of a DC motor involves complex analytical and numerical computations of data acquired from testing of motor. Whenever the application of any dc machine is considered, its operational performance along
with its economical and technical viability is the essential criteria behind selection. Performance index of a dc motor can be defined by its characteristic curves, efficiency and losses. To derive the same user must acquire various parameters of motor eg speed, torque, armature current, field current, armature voltage, field voltage, winding temp etc.

Various conventional schemes for analyzing the performance of a dc motor are available in literature. However, no specific setup or device has covered a single automated method to acquire all the performance defining parameters of motor like characteristic curve data, efficiency and losses. In the conventional methods, which are meant to carry out different types of analysis (viz for characteristics curves or to find out losses or efficiency or speed control), the experimental setup needs to be modified based on type of test or motor technology. Moreover, there cannot be universal platform for all the dc motors of different type. As a result, if one tries to evaluate the dc motor, a combination of various conventional methods is required; this turns out to be very time-consuming, cumbersome, errors prone and tedious approach [2].

This outcome of above mentioned facts was the starting point and motivation of the research chosen by authors.

DC motor performance analyzer (DCMPA) is an embedded design dedicated for automating the process of evaluating the performance of any given dc motor of any rating and specifications. Various parameters of dc motor e.g. speed, torque, armature current, field current, armature voltage, field voltage, winding temperature variations and dependency of these parameters on each other is closely monitored with help of control hardware and application software. DCMPA controls the motor input DC voltage/s through SCR bridges, electrically load the motor through a generator, collect the motor parameters at each loading condition and manipulate the acquired data in PC based software to arrive at the parameters which will define the motor performance. The setup
includes a DC motor coupled to a DC generator and connected to the PC through data acquisition and control hardware. The setup helps to calculate motor losses, motor efficiency and motor characteristic curves. User is able to drive the motor through controlled bridges through a speed controller utility in the PC software.

Control Hardware is based on AVR RISC Microcontroller which is programmed with firmware taking care of synchronization of different Hardware modules and communicating to the RS232 channel. Microcontroller can be programmed In-System through Programming Connector provided On-Board which makes the hardware more flexible and adaptable to the third party application. The front end application software provides provision for running the dc motor at different speeds and load settings under tests like individual parameters test, step by step loading test or continuous single load test etc. The user with the help of front end software is able to select the type, rating of the motor, input field and armature voltage, maximum and minimum load limits, maximum current limit, target rpm and all other necessary settings for a particular test.

The data collected shall be dynamically plotted in graphs and stored for future reference and comparison. Communication circuit between application software and high speed embedded controller module is provided through RS 232.[3]

DCMPA designed shall have the following objectives:

To automate the process of testing a dc motor for its performance at various loading conditions.

To constitute a single platform for evaluating all types of dc motors (shunt, series and compound) of different ratings and by taking into account all possible critical parameters with a provision of complete digital control in the proposed DCMPA.
To provide flexibility of storing the values of critical parameters monitored during various tests on the DCMPA in a database for future reference and comparison with the help of application software.

To enable engineers/technicians for conducting experiments in all those fields where calculations are required at different loading conditions and at different speeds and hence help them immensely in smoothly carrying out the design job.

To device a bench marking tool for all dc motor manufactures and quality sensitive users through the proposed DCMPA.

2. RESEARCH DESIGN OF DCMPA

In DCMPA, motor under test has interfacing topology as shown in Fig. 1. In this section, a brief detail of author’s concept is given.

Figure 1: DCMPA set-up
Motor – Generator Set: DC motor under test is coupled to a separately excited DC generator. Generator itself is electrically loaded by adding resistance across its armature terminals and generator field is also fed through a controlled dc voltage source. Motor-Generator thus has their shafts mechanically connected using appropriate sized old-ham couplings.

This setup has been used by author as a mean to achieve electrically controlled loading of motor shaft.

Interface Hardware: In order to carry out testing of motor using PC, motor-generator set has to be interfaced to hardware which can carry out various controls and data acquisition on motor and communicate the same to PC. This is achieved by designing a microcontroller based electronic hardware interface, capable of following:

- Control SCR bridges to generate variable dc voltage
- Acquire and process motor current, motor input voltage, generator output voltage, motor speed, motor winding temperature
- Execute sequence of tests to be conducted on motor
- Communication with PC serial port

The various circuits of Interface hardware includes Microcontroller circuit & System Power supply, motor speed controller circuit, data acquisition circuit and communication circuit. Hardware is controlled by an 8-bit, RISC microcontroller, ATMega32 of Atmel AVR family. Associated firmware programming is carried out in embedded-C language.[4]

PC software: DCMPA hardware will communicate with PC via RS232 serial port. A program based on Microsoft Windows has been designed to provide interface to user and also interact with hardware. Visual Basic is chosen as the development platform for application programming. Visual Basic is easy to implement development language which provides rich graphic capabilities to
program, at the same time ensures transparent interface to lower layer of hardware like serial RS232 port.

Application software will address following major responsibilities:

Graphic user interface for DCMPA

Communication with DCMPA hardware and control of operations

Data storage

Editing/updating information regarding motor setup

Choosing different type of tests to be conducted

Processing the data received from hardware.

It is clear from the given brief description that authors’ concept brings data acquisition, dc motor controls, motor testing techniques and PC based analysis all embedded into one platform.

3. MOTOR ANALYSIS USING DCMPA

Analysis 1: Study of dc motor characteristics curves is important for detection of faults, losses and understanding of machine. Concept of PC based automated acquisition of motor characteristics is proposed by author. This requires collection of Speed-Torque, Torque-Armature current and Speed-Armature current curves of dc motor. Acquisition of these curves involves complex controls and calculations and is explained below:

Speed–Torque Characteristics: To obtain this characteristics, mechanical load on the motor shaft (Torque) is increased gradually and corresponding change in motor speed is recorded.

Torque–Armature Current Characteristics: For this test, mechanical loading of motor shaft (Torque) is elevated gradually and corresponding variation in armature current is acquired.
Speed–Armature Current Characteristics: To obtain this characteristics, with increase in speed of motor, change of motor armature current is noted.

Author has introduced concept of automating above mentioned tests using PC. Following key objectives shall be addressed by the same:

Complete PC based control of tests i.e. motor characteristics acquisition
Automated acquisition of motor current, motor voltage, motor torque, motor winding temperature.

Automated sequence for increasing mechanical loading of motor and complete control over dc voltage fed to motor. It should be able to drive SCR bridges to feed controlled DC voltage to motor.

Automated control of keeping speed, armature current or torque constant, as required in the test.

Automated technique introduced by author, acquires characteristics data of dc motor in real-time and provides an insight to motor’s behavior under different operating circumstances. As per the literature survey conducted by author and highlighted in previous chapter, there are no similar techniques available which carries out motor characteristics acquisition in real-time manner. In proposed methodology author extends the scope of application to confirm/verify the practical performance of dc machine to data derived from theoretical calculations and equations [1,5].

Analysis 2: Losses and efficiency data of a dc motor provides useful information, which can help user to understand compatibility of machine to given application. Various losses occur in a dc motor depending upon the load, applied voltage and speed. As a result, the efficiency of a particular machine changes with the amount of input energy lost during the process of electromechanical energy conversion. Therefore determination of efficiency requires calculation of loss. Accuracy in having an account of losses will give a
correct estimate of efficiency of the motor. Though both loading and indirect loading test (viz direct loading test, Swinburne’s test, Hopkinson’s test) are available for determination of efficiency of a dc motor, yet all of them have certain limitations. Moreover, no universal or single process/methodology can be applicable for all types of dc motor (viz series, shunt and compound), and for no-load and full-load conditions. Additionally, the conventional tests are based on certain approximations and require some correction factor to be applied under different conditions. Proposed design by the author is not only automated, but also independent of any such limitations. The same experimental set-up can be used to directly measure the losses of 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:

**Efficiency:** The presence of fixed and variable losses in a machine, continuously changes efficiency of a dc motor and it is seen to continuously increase with the load acquiring a particular value at a particular load related to design of dc motor.

**Losses:** For any dc motor, there are fixed and variable losses. Fixed losses are sum of iron, friction and windage losses and are determined by choice of flux density and volume of iron used. Variable losses are copper losses and take place in windings of the armature and field windings of dc motor. These losses are governed by the choice of current density and volume of copper used.

Following is a brief about the requirements addressed by automated setup proposed by author:

Complete PC based control of tests i.e. motor losses & efficiency calculations.
Automated acquisition of motor current, motor voltage, motor torque, motor winding temperature i.e. the parameters which define losses & efficiency associated with a dc motor.

Automated sequence for acquiring efficiency & losses under different operating circumstances.

Graphical representation of data on PC and storage of same in a file.

Author’s proposal is a novel approach / methodology where process of acquisition of losses & efficiency is simplified and demands less operator’s intervention. On going research work on DCMPA will abstract all complex calculations and equations from user and provide visual representation of processed data[1,5].

**Analysis 3:** To carry out the above mentioned tests and obtain results out of same, different motor parameters has to be controlled like motor speed, motor armature current and mechanical load on motor shaft. DCMPA is supposed to address following requirements for same:

Speed of motor can be controlled by DCMPA. A controlled dc voltage source like a fully controlled SCR bridge and its corresponding driver hardware-software will be required. By varying the dc voltage fed to motor, speed can be adjusted.

Similar to above mentioned control, 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.

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

It was therefore essential to implement a PID control algorithm for above mentioned parameters and to ensure correct evaluation of motor. With control of these parameters in DCMPA, manual intervention & monitoring during testing can be eliminated [2,5].

**Analysis 4:** A key requirement of the author’s concept is graphical and interactive way of presenting data which is acquired from different automated tests and processed. Keeping same in view, following specifications must be met in the final product:

- It is established in the previous problem statements that tests can be conducted in automated fashion using PC, at the same time data acquired from motor should be represented in a graphical way and user should be given provision to start- stop, modify different tests and test types.

- In addition to graphical representation, user is 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 software’s like word, excel etc.

- Complete control of automated tests has been provided to user through a GUI driven software.

- PC based software with above mentioned features ensures that tests conducted are hassle free and user will be able to focus on analysis of data collected from motor, rather then getting into details of motor testing[3].

**Analysis 5:** DC motors being the most versatile, flexible and easily controllable energy conversion device will always remain in demand in various industries, domestic sector as well as educational institutes. This is the reason that in today’s world around 25% of 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 various conventional methods is required; this turns out to be very time-consuming and cumbersome. This product of the author after completion will be a single platform for automating the process of testing and evaluating dc motor should serve as benchmarking tool for all dc motor manufactures[1,5].

4. RESULTS AND DISCUSSION

This paper has highlighted authors’ concept to develop a hardware-software package capable of evaluating performance of a dc motor in an automated manner and thus the concept of ‘DC motor performance analyzer’ has been introduced. Authors have briefly asserted how latest techniques, effective controls and efficient approaches can be integrated for performance analysis of all dc motors. The research technique being implemented by authors make use of electrical loading of dc motor and PC based analysis involving collection of numerical values of important electrical parameters of motor behavior under different operational conditions. In parallel, this technique clearly enlightens the development of a hardware-cum-software package which can provide an easy to use and interactive interface to user and also conduct various tests on motor.

Authors anticipate that the research work conducted by them will provide immense benefits in the following ways:

DCMPA will enable the user to acquire the key parameters of a dc motor in an automated way, which will define its performance & capabilities, like motor characteristics, motor efficiency and motor losses. Various methods of getting motor characteristics and calculating efficiency / losses have been presented in previous section but none has automated this process. In DCMPA, complete process will be controlled by a PC based application and a universal data acquisition & control hardware.
DCMPA will consist of microcontroller based hardware capable of data acquisition and control of key parameters of DC motor. Same hardware could be used to carry out testing and evaluation of different type of dc motors like separately excited, shunt, series or compound.

User will be able to carry out performance testing and record test data for future reference. DCMPA will have a user friendly PC based Graphical Interface for control of various operations.

DCMPA, after its completion, will be a universal platform for evaluating performance of dc motor of any type and wide range of rating, by utilizing PC based windows Application software and microcontroller based hardware.

REFERENCES