COMPUTER–BASED NOVEL SYSTEM FOR OBTAINING THE CHARACTERISTICS OF DC SHUNT MOTORS

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Abstract: *Experimental determination of characteristics of dc motors is quite important for their accurate performance prediction. Exhaustive literature review reveals experimental procedures that have been used to obtain these characteristics. Every practiced method has its own limitations and constraints. This paper describes a computer based novel system for measuring the characteristics (speed versus torque ,torque versus armature current, speed versus armature current) of a dc motor and automatic post-experimental data processing. Experimentally measured results of a 0.5HP dc shunt motor using the discussed scheme are presented in the paper. Also, a comparison of methodology of this system with conventional techniques for computing speed-torque curves has been elaborated to show the effectiveness of the system. Furthermore, it is asserted that the automated system described in this paper can be used to obtain the characteristics of other types and rating of dc motors also.*

Key words: *speed-torque characteristics, performance-index of dc motor, data acquisition, electrical loading of dc motor, motor torque.*

1. Introduction

An essential criterion for deciding the performance-index for dc motors is the knowledge of their speed-torque characteristics. Also, 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 .Idealization of the speed-torque characteristics will result in a model which cannot predict the performance of the machine with sufficient accuracy. It is necessary therefore to determine speed-torque characteristics as closely as possible.

Though different techniques have been investigated to acquire the accurate characteristics of dc motor, but it has been surveyed that no single test or methodology already available or published can provide all informations about parameters affecting the motor performance. Moreover, due to considerable human involvement, the current methods are less likely to give accurate results.

In this paper, an automated method of obtaining the speed-torque characteristics of dc motor is explained. The embedded scheme has been developed using an external interface hardware based on AVR microcontroller, a data acquisition circuit, and a graphical programming environment (visual basic). The graphical programming method allows a high degree of software modularity and automated presentation of results, whereas capabilities of AVR microcontroller are utilized for data acquisition, SCR bridge control and RS232 serial communication [1-3].

2. Methodology of conventional techniques to obtain speed-torque characteristics of dc shunt motor

It was surveyed that conventional set-ups make use of two types of methodologies for performing load-tests on dc motors [4-7]. One set-up involves use of mechanically coupling ‘a brake drum’ (i.e. pulley-belt arrangement) with spring balance on both sides as shown in Fig 1. To increase the load torque, the tension on the two belt portions is adjusted for an increased difference. The dc shunt motor is started with help of starter and brought to its rated speed. By adjusting the spring tensions, the motor is loaded from its no-load to full-load and reading of the measuring devices are noted down for further calculations of torque and other necessary parameters.

The other method of loading involves use of dc generator coupled with test dc shunt motor, along with other essential electrical measuring devices as shown in Fig. 2. The dc shunt motor is started with the help of starter, and brought to its rated speed with help of field-current-rheostat of motor. The coupled dc generator is run to obtain its terminal voltage with help of field rheostat of generator. DC generator is then loaded with help of its loading rheostat, keeping its terminal voltage constant. Reading of measuring devices is observed while entire range of no-load to full-load of motor are covered. Different sets of readings can be taken for different speeds of dc shunt motor.

In both of the methodologies, in order to collect the final results, lot of manual computations/calculations of observed parameters is required. Not only this, multiple tests at different loads and different speeds of dc shunt motor is essential to cover the complete operating range of the dc motor with use of such conventional techniques. As the measuring instruments used in the set-up are chosen according to the rating of dc shunt motor, for testing higher (or lower) rating of dc shunt motor, the entire set-up needs to be modified. Similarly, modification in the set-up will also be required for testing different types of dc motors. As a result, if one tries to evaluate a dc motor for its characteristics with the current available techniques, the process becomes time-consuming, cumbersome, error prone and tedious.

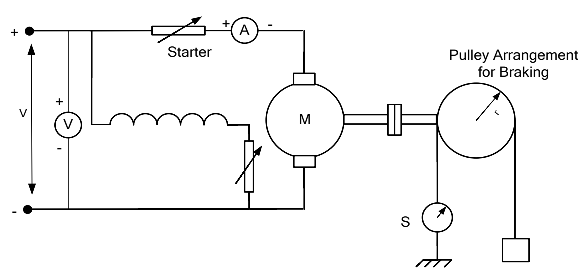

Fig. 1. Conventional Loading Methodology 1 for DC Shunt Motor

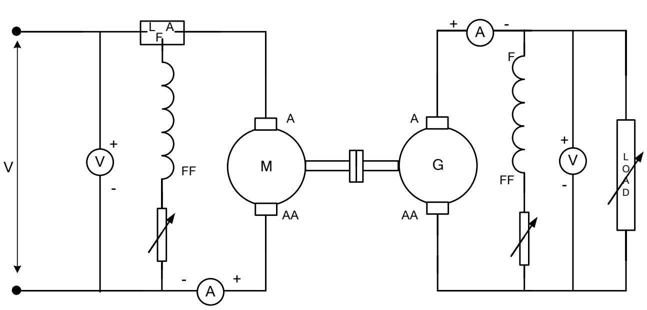

Fig. 2. Conventional Loading Methodology 2 for DC Shunt Motor

3. Automated technique to determine dc shunt motor characteristics

The previous section establishes the scope for the work undertaken by the investigators in the present paper. This also explains how the presented work has been derived out of the previous works already carried out in this area of research. Automation helps in minimizing the operator intervention to change setups in order to carry out different tests on one motor. Complex calculations, derivations and controls get off loaded from the operator and are integrated in the automated tests. User after carrying out performance testing will be able to record the test data for future reference. The platform has a user friendly PC based graphical interface for control of various operations.

The platform for automating the process of testing of any given dc shunt motor consists of dc shunt motor (under test) coupled with a separately excited dc generator, which is interfaced with the control hardware and PC. The generator itself is electrically loaded by connecting suitable fixed resistance at its terminals. The interconnection topology of the discussed automated test platform is shown in Fig.3.

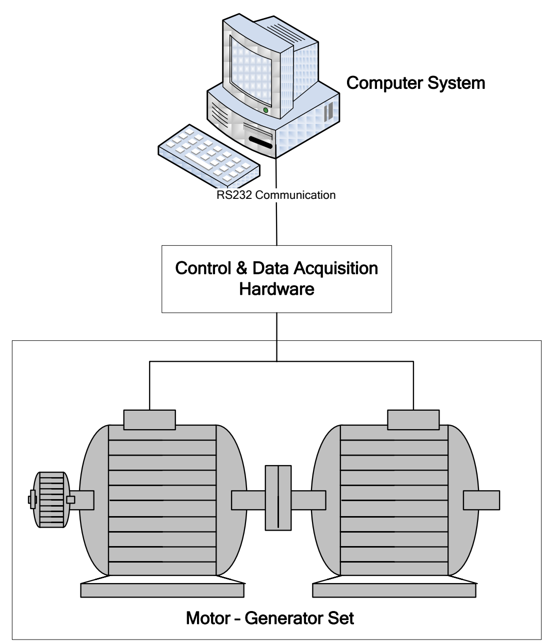

Fig. 3. Automated test platform for testing DC Shunt Motor

The control hardware platform for this system is designed around AVR series microcontroller ATMega32 [8], whose various on-chip peripherals are utilized for purpose of data acquisition, motor controls and communication with PC.

Different motor parameters like motor current, motor voltage, generator field voltage, speed and winding temperature are acquired by analog to digital converter (ADC) port of microcontroller after being filtered and conditioned by signal conditioning section. These analog signals are acquired from different sensors like Hall Effect Current Transducer (2.5 V full scale output for 25 A current) to acquire motor current, tachogenerator(30V full scale voltage output for 1500 r/min) to acquire motor shaft speed and an NTC Thermistor(operating temperature range -30 to 120^0C) to acquire temperature of dc motor winding. For acquiring dc motor and dc generator voltage signals, resistive voltage divider circuits are used.(ATMega 32 has integrated analog to digital converter with 8 multiplexed analog input channels, 10-bit resolution and 15Ksps maximum sampling rate).

Output signals obtained from the various sensors are conditioned by signal conditioning section to make them compatible with the ADC inputs of the microcontroller. Current and voltage signals have been filtered by using a low pass second order active filter whereas the temperature sensor output has been filtered using passive low pass filter. Speed signal is received from tachogenerator, so electrical signal is first rectified using diode and capacitor before filtering the same.

Microcontroller based hardware is also configured to provide digital inputs and outputs. Digital inputs are used to acquire signal coming from zero crossing detector (to detect the phase of incoming AC voltage), limit switches, proximity switches or push buttons. Digital outputs in this hardware are primarily meant to drive the SCRs and hence are interfaced to pulse transformers using power transistors. Digital output pins can be optionally used to generate PWM and relay control signals also.

Microcontroller UART is configured for 115200 bits per second baud rate to communicate with PC RS232 port. A voltage level shifter IC is used to convert 0-5V signal levels of microcontroller to RS232 voltage levels and vice-versa.

The firmware of microcontroller is designed in AVR Studio 4 development environment utilizing AVR-GCC compiler. Firmware is responsible for performing all control and data acquisition tasks, which include generation of correctly timed firing pulses for SCRs, data acquisition via analog to digital converter channels, digital filtering of analog data, serial UART communication, PID control algorithm execution to control generator field etc[9].

Since, the control hardware communicates with the PC via RS-232 serial port, a PC program based on Microsoft Visual Basic is designed to provide the necessary interface to the user and also interaction with the hardware. This PC based application software gives provision for choosing different type of tests to be performed, editing/updating information regarding motor set-up, data storage and processing the data received from control card/hardware.

During the test, the data is acquired from the microcontroller hardware via serial RS232 port using 'MSComm component' from 'Microsoft windows comm controls 6.0' library available in Visual basic 6.0.This data is used to compute the values of motor parameters and converted to desired units. Processed output is written and saved automatically in a data file in ASCII text format and be read by user in any text editor software including MS-Excel. For visual graphical display of the results obtained from the tests, 'Chart plotting' feature of 'Microsoft windows chart control 6.0' library in Visual Basic 6.0 is utilized. The application software designed for the presented scheme also provides the provision for the user to enter motor–generator setup details (e.g. rating of machines, rated speed, rated voltage, rated current, armature resistance, field resistance, etc) which is used to calculate the dc motor copper losses and efficiency.

Methodology involved in this automated technique revolves around the fact that generator output voltage (voltage at generator armature terminals) is proportional to shaft speed, magnetic field strength and number of conductor loops in armature. Since last parameter stays constant for a test, it is clear that any change in motor shaft loading caused by reduction in speed can be compensated by increase in generator field voltage (magnetic field strength) and vice versa.

When generator armature is connected to electrical load, it applies a mechanical opposition to the rotation of shaft. This shaft loading is utilized to test the behavior of motor under different loading conditions.

As discussed in previous section, in conventional methods, dc motor (under test) is loaded by adding electrical load to the generator output and keeping the generator field excitation voltage constant. During the motor performance testing, there is a requirement to achieve the constant mechanical loading of motor shaft. The fact that mechanical loading of motor shaft is dependent on speed makes it difficult and impractical to achieve the same.

Authors have utilized the microcontroller's processing power to achieve a precise PID control of motor shaft loading by manipulating the generator field voltage. In this case, electrical load on the generator armature is fixed whereas the field voltage of generator is varied by a fully controlled SCR Bridge.

In order to acquire speed-torque characteristics of the dc shunt motor, the motor is run at the rated speed and loading of motor shaft is increased gradually in a controlled manner (as mentioned in previous paragraphs).Other than the start and the stop commands sent by the PC, all the other operations are executed at regular intervals by the microcontroller timer interrupt service subroutine.

During the performance of these tests motor parameters like speed, line current, motor voltage etc are read by the microcontroller and the digital data is sent to the PC. The PC software calculates from this information the complex parameters like torque, armature current, back emf, power input, power output etc. PC software calculations are based on the motor specifications entered by the user.

Block diagram for the automated scheme [10] to obtain speed-torque characteristics of dc motor is illustrated in Fig. 4.

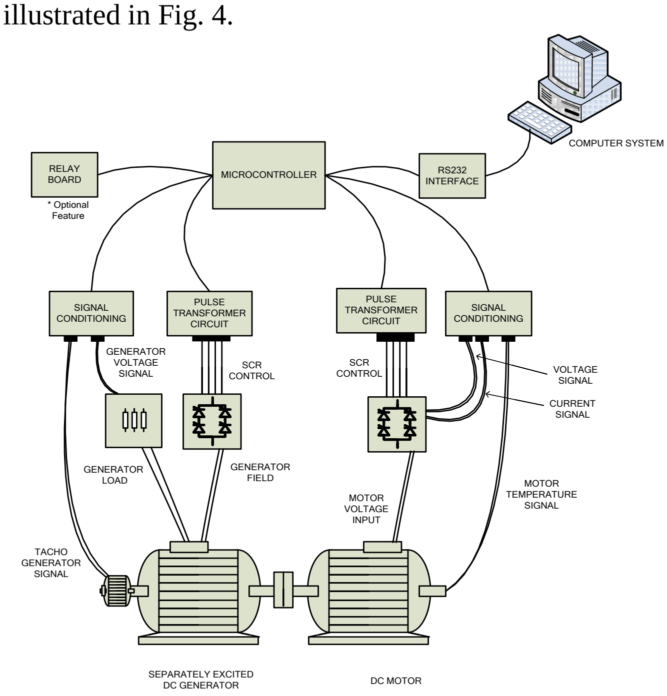

Fig. 4. Methodology to acquire Speed-torque Characteristics of DC Shunt Motor

4. Automated test results

The system presented in the paper after fabrication was tested and validated using 0.5 HP dc shunt motor-generator (MG) set (as shown in Fig. 5). Characteristics of dc shunt motor (viz. to obtain speed-current, torque-current and speed-torque characteristics curves) were automatically captured on PC using Visual Basic Application software in form of curves as well as in tabular form.

Fig. 5. Practical set-up of DC Shunt Motor under Test

For illustration of the results, the three characteristics have been presented in form of screen shots shown from Fig. 6 to Fig. 8 and values of parameters generated and recorded in PC application software are shown in Table 1 to Table 3.

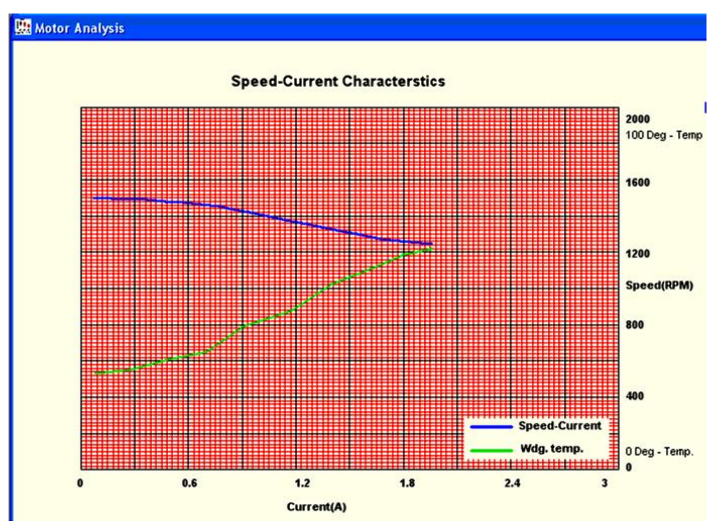

Fig. 6. Screen-shot of Speed-Current Characteristic of DC Shunt Motor

It can be observed in the graph (in Fig. 6) that initially motor speed change is minimal and then it drops linearly till the armature current reaches near 1A. Overall deviation in the speed is approximately 5%. This is indicative of shunt type behaviour of motor which has good speed regulation. After wards, due to increased drop of voltage inside the motor armature (due to armature resistance and increased value of armature current), motor speed starts to fall and finally reaches 1244 r/min at near rated current.

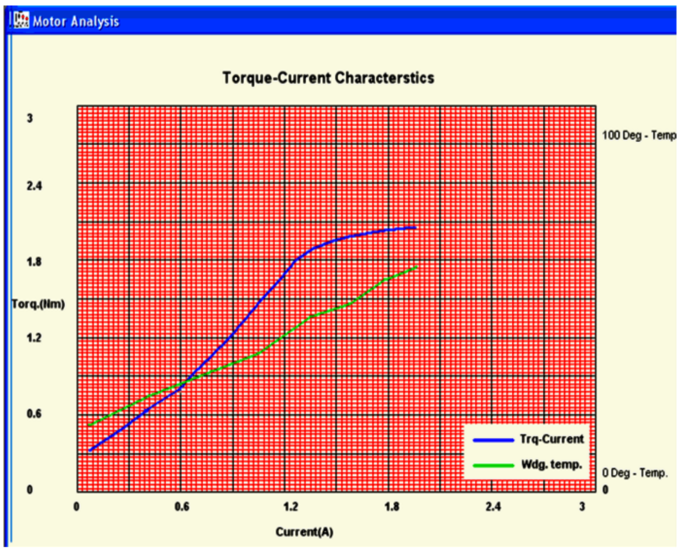

Fig. 7. Screen-shot of Torque-Current Characteristic of DC Shunt Motor

It can be observed in Fig. 7, that torque of the motor increases almost linearly till its value of 1.9 N·m with corresponding change of 75% in armature current. Afterwards the incremental torque variation with armature current reduces.

Speed of motor can be seen falling slowly from 1498 r/min to 1244 r/min with increase of torque from 0.32 N·m to 2.06 N·m in Fig. 8. Initially the speed stays near constant but as the armature current increases to deliver the higher torque requirements, ohmic drop inside the armature increases and finally speed decreases.

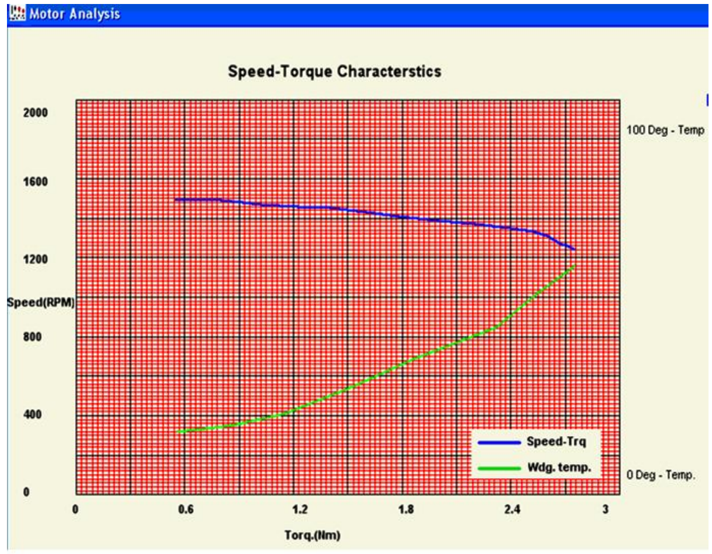

Fig. 8. Screen-shot of Speed-Torque Characteristic of DC Shunt Motor

Table 1.Values of Parameters Generated for Plotting Speed-Current Characteristic

Motor Voltage (V)	Field Current (A)	Armature Current (A)	Speed (r/min)	Winding Temperature (^{o}C)
205	0.43	0.07	1498	27
206	0.43	0.17	1495	28
204	0.42	0.27	1490	28
208	0.43	0.37	1490	29
208	0.43	0.47	1481	29
204	0.42	0.57	1472	30
208	0.43	0.67	1463	31
206	0.43	0.77	1452	36
204	0.42	0.97	1412	42
206	0.43	1.07	1392	45
208	0.43	1.17	1373	48
208	0.43	1.27	1354	51
206	0.43	1.37	1331	54
204	0.42	1.48	1312	57
207	0.43	1.57	1292	58
205	0.43	1.67	1271	58
206	0.43	1.96	1244	60

Table 2. Values of Parameters Generated for Plotting Torque Current Characteristic

Motor Voltage (V)	Field Current (A)	Torque (N·m)	Armature Current (A)	Winding Temperature (°C)
205	0.43	0.32	0.07	18
206	0.43	0.41	0.17	18
204	0.42	0.5	0.27	18
208	0.43	0.6	0.37	19
208	0.43	0.69	0.47	19
204	0.42	0.76	0.57	19
208	0.43	0.92	0.67	19
202	0.42	1.2	0.88	21
204	0.42	1.34	0.97	23
206	0.43	1.5	1.07	27
208	0.43	1.65	1.17	31
208	0.43	1.8	1.27	33
206	0.43	1.89	1.37	35
207	0.43	1.98	1.57	38
205	0.43	2.01	1.67	39
202	0.42	2.03	1.78	40
206	0.43	2.06	1.96	42

Table 3. Values of Parameters Generated for Plotting Speed-Torque Characteristic

Motor Voltage (V)	Field Current (A)	Speed (r/min)	Torque (N·m)	Armature Current (A)	Winding Temperature (°C)
205	0.43	1498	0.32	0.07	18
206	0.43	1495	0.41	0.17	18
204	0.42	1490	0.5	0.27	18
208	0.43	1490	0.6	0.37	19
208	0.43	1481	0.69	0.47	19
204	0.42	1472	0.76	0.57	19
208	0.43	1463	0.92	0.67	19
206	0.43	1452	1.05	0.77	20
202	0.42	1431	1.2	0.88	21
204	0.42	1412	1.34	0.97	23
206	0.43	1392	1.5	1.07	27
208	0.43	1354	1.8	1.27	33
206	0.43	1331	1.89	1.37	35
204	0.42	1312	1.95	1.48	37
207	0.43	1292	1.98	1.57	38
205	0.43	1271	2.01	1.67	39
206	0.43	1244	2.06	1.96	42

4. Discussion

The validity of the test results can thus be checked by comparing the speed-torque characteristics obtained from this automated procedure, with experimentally measured speed-torque characteristics obtained by conventional methodology using higher precision measurement equipment. In light of the successful results obtained in testing and validation process, and looking at the methodology of automation process discussed in the paper, it is envisaged that all other types of dc motors can also be tested in same automated way. It is also highlighted that the automated test set-up presented in the paper offer the capability to calculate the copper losses occurring in the dc shunt motor under test and determining efficiency curves of the dc motor. The effectiveness and flexibility of technique stands unmatched with other conventional methodology due to the fact that the same test up can be utilized to automate the process of testing dc shunt motor of higher ratings also.

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