Experimental Analysis of DC Shunt Generator Characteristics

Abang Syafiqnurain Bin Haji Abang Shokeran[1]

[1] *Polytechnic Kuching Sarawak*
E-mail: abgsyafiq@poliku.edu.my

Abstract

In this experimental study, the operation of a self-excited DC shunt generator what will happen to it if the load condition changes. This study examines the relationship between load current, output voltage, and power delivery by comparing experimental readings with theoretical expectations. The same experiment was carried out by three independent test sets, showing significant variations in generator performance that indicate real-life challenges in electrical machine testing.

First, although the generator voltage regulation follows the expected sag shape, the magnitude of the voltage drop varies significantly between test sets. Output power measurements show that optimal transfer occurs at medium range loads, but the corresponding operating point varies depending on equipment conditions. The study identified key parameters that affect performance consistency such as equipment aging, measurement accuracy and load selection.

The results have significant implications for electrical engineering laboratory practice and education, and the importance of regular equipment maintenance and standardization of test procedures. Practical recommendations are made to improve experimental reliability and data consistency when conducting experiments with DC shunt generators. This study facilitates the understanding of real-life generator behavior and serves as a guide for academic learning and industrial practice in applications that require accurate voltage regulation.

Keywords **:** *DC shunt generator, voltage regulation, load characteristics, experimental analysis, electrical machines*

I. INTRODUCTION

DC shunt generators are an important component in electrical engineering practice and teaching because of their ability to provide a constant voltage output under varying load conditions. This experimental study examines the performance of a self-excited DC shunt generator through the analysis of voltage regulation and power output characteristics when subjected to the application of various electrical loads. This study aims to bridge the gap between theory and practice applied in the classroom.

This study looked at discrepancies in performance parameters obtained from multiple groups of experiments using the same generator configuration. Although theoretical models expect that the voltage drop characteristics and the optimal power transfer point will be reproducible, experimental test data often display significant deviations. These deviations are significant in the terminal voltage, load current, and output power parameters that form the basis for setting the operating limits and efficiency of the generator.

2 study objectives. First, to demonstrate the practical challenges in achieving consistent operation with DC shunt generators, and second, to establish the main reasons for variations in performance. These findings have significant implications for electrical engineering education. These findings also have implications for industrial practice where older machines can acquire similar deviations in performance. Through the methodical analysis of experimental results, the study forms the basis for the improvement of both laboratory teaching methods and equipment maintenance practices in electrical machine testing.

II. LITERATURE REVIEW

The voltage regulation characteristics of DC shunt generators have been extensively studied in previous studies with particular emphasis on terminal voltage

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drop and load current relationships. According to [1], the natural voltage regulation in a self-excited DC generator is mainly affected by the armature reaction and IR drop, which causes the terminal voltage to drop non-linearly with increasing load current. The same was seen in [2], where experimental data revealed a 15-20% voltage drop at full load operation compared to no load operation. Further research in [3] revealed that the degree of voltage drop is significantly affected by the resistance of the field winding, and higher resistance values worsen the regulation problem. All of these studies confirm the theory of DC shunt generators that exhibit sag voltage characteristics under load changes.

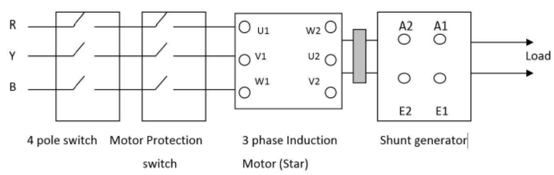
Generator performance needs to be optimized for efficiency under variable load conditions. Research in [4] shows that maximum power transfer for DC shunt generators occurs at about 50-60% of full load, where efficiency decreases due to excessive copper loss. This is supported by [5], which uses dynamic load testing to establish the optimum operating point for different generator configurations. Additionally, [6] developed an improved analytical model that incorporates brush contact resistance and temperature effects for more accurate efficiency predictions. The study shows the complex interaction of electrical and mechanical parameters in determining generator efficiency, especially in practical operating conditions where load changes are common.

Directly, generator maintenance and performance aging has become a hot topic in a study. An experimental investigation by [7] revealed that worn commutators and carbon brushes can increase contact resistance by up to 30%, with severe effects on voltage regulation. Similarly, [8] found that insulation degradation in the field winding reduces the magnetic flux density, resulting in a reduced no-load voltage build-up. A comparative investigation in [9] on new and old generators revealed up to 25% difference in output power capacity under the same loading conditions. This can be seen with the profound effect of equipment condition on generator performance, explaining the differences encountered in student lab experiments with machines with various conditions.

There are several recent and modern techniques that have been created to help strengthen the analysis. In a study, [10] introduced infrared thermography as an effective technique to detect irregular heating patterns in armature windings. Meanwhile, [11] proposed a machine learning-based predictive maintenance method using vibration and current signature analysis. Research in [12] shows the value of real-time monitoring systems in identifying the onset of performance degradation. These advanced diagnostic methods provide valuable tools for maintaining generator efficiency and reliability, but their implementation in educational settings is still hampered by financial issues.

III. RESEARCH METHODOLOGY

This experiment was designed to identify the performance characteristics of DC shunt generators in a systematic manner under various loading conditions. The experiment aims to measure important parameters such as output voltage, load current and power output and compare the results with theoretical expectations. This procedure uses controlled testing protocols, standardized measurement procedures and replicated experimental trials to increase the reliability of the data. By comparing findings from three separate groups, the study also investigated what accounts for the variability in generator performance.



Experimental Block diagram shunt generator

The experimental setup uses a self-excited DC shunt generator with an adjustable resistance load bank, and the measuring instruments used are a digital multimeter, ammeter and voltmeter to take accurate readings. The shunt field circuit is equipped with adjustable resistors to vary the excitation level, and a tachometer is used to take shaft speed readings on the motor. The load resistance is systematically varied from minimum to maximum to observe the response of the generator over its operating range. The same procedure was followed by all groups but with different results, which highlights the influence of equipment conditions and experimental parameters on the results.

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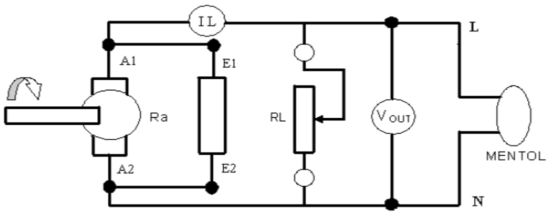

Equivalent circuit of shunt DC generator

Data collection such as load current, terminal voltage and field current at increasing load steps, with output power determined for each measurement point. The process includes calibration checks and protective procedures to minimize errors and protect against equipment damage. The experiment was performed by three different groups to allow comparison of results under the same nominal conditions. This allows the identification of consistent trends as well as anomalous behavior that does not conform to theoretical expectations.

Data analysis from experiments consists of comparing the recorded performance with the expected behavior of the DC shunt generator. Voltage regulation curves and power output graphs were drawn for each group, and there was significant variation in the results. The experimental procedure allows investigation of potential sources of discrepancies, including generator maintenance conditions, measurement accuracy and load selection effects. By using this rigorous experimental protocol, the study was able to demonstrate both the theoretical aspects of generator operation and the practical problems encountered in real-world test settings.

Systematic data collection and repeated trials can increase the reliability of the results. Limitations are potential instrument calibration drift and uncontrolled equipment differences between groups. Future improvements could involve automated data logging systems and generator conditioning routines to further improve experimental consistency. This methodological approach successfully meets the objectives of the study while illustrating important considerations in electrical machine testing and performance analysis.

1. Group A

IL	0.12A	0.11A	0.1A	0.09A	0.07A	0.05A	0.02A	0.02A	0.01A
RL	7Ω	11 Ω	15 Ω	18 Ω	22 Ω	50 Ω	100 Ω	150 Ω	250 Ω
Vout	1.2V	1.4V	1.5V	1.7V	1.8V	2.2V	2.4V	2.4V	2.5V
Pout	0.144W	0.154W	0.15W	0.153W	0.126W	0.11W	0.048W	0.048W	0.05W

2. Group B

IL	0.26A	0.36A	0.52A	0.74A	0.8A	0.9A	1.5A	1.35A	1.30A
RL	1000 Ω	770 Ω	500 Ω	250 Ω	150 Ω	100 Ω	50 Ω	22 Ω	15 Ω
Vout	265V	250V	215V	140V	110V	90V	60V	30V	20V
Pout	67.6W	99.79W	135.2W	136.9W	96W	81W	112.5W	40.1W	25.35W

3. Group C

IL	1.2mA	8.8 mA	7 mA	3.8 mA	22 mA	16.5 mA	12 mA	36 mA	56 mA
RL	7 Ω	15 Ω	22 Ω	50 Ω	100 Ω	150 Ω	250 Ω	500 Ω	770 Ω
Vout	1.6V	1.85V	2V	2.3V	2.35V	2.44V	2.5V	2.5V	2.5V
Pout	1.92mW	0.016 mW	0.014 mW	8.74 mW	0.052 mW	0.04 mW	0.03 mW	0.09 mW	0.14 mW

IV. RESULT AND DISCUSSION

The results of the study from the three groups show little difference in the performance of the DC shunt generator under different load conditions. Group B shows behavior closest to the theoretically expected characteristics, where the output voltage (Vout) decreases as the load current (IL) increases, and the output power (Pout) peaks before decreasing. On the other hand, Group A exhibits abnormally low voltage and power output (1.2V–2.5V and ≤0.154W, respectively), while Group C shows unstable and very low power values (in the milliwatt range) without any flow.

Comparison with Expected Results
A DC shunt generator should theoretically exhibit a decreasing terminal voltage value with increased load current due to internal voltage drop, i.e., armature resistance and reactance. The output power is expected to increase with load current initially, then be at a maximum level, and finally decrease as overload causes inefficiency. Group B data follows this trend, with Vout decreasing from 265V to 20V with increasing IL, and Pout peaking at 136.9W before decreasing. Group A and Group C were against this trend, indicating a weakness of the experimental setup or a defect in the condition of the equipment.

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Possible Causes of Discrepancies

There are several reasons for the differences in study results among groups. First, the condition of the generator plays a big role. An aging or poorly maintained machine may have damaged field windings, worn brushes, or increased armature resistance, leading to inefficiency and erratic readings. This may explain the unstable low voltage power readings of Groups A and C. Further, measurement errors such as mismeasured equipment or loose connections can result in inaccuracies, especially in very low Group C power readings.

Additionally, the selection of load resistance. Group B has chosen a larger resistance (of 1000 Ω), and this allows the generator to operate close to its optimum range. But Group A and Group C have chosen a smaller resistance, and this can lead the generator to operate inefficiently, resulting in poor performance. In addition, incorrect field excitation due to incorrect shunt resistance settings or insufficient residual magnetization can also cause the results to be further distorted, such as Group A.

These experiments serve to highlight the importance of equipment condition, proper procedures, and selecting appropriate loads in obtaining reliable results. Although the results of Group B correspond to theoretical expectations, the errors in Group A and Group C serve to show the effect of real-life variables on the experimental results. To minimize such differences in future studies, it is recommended to use well-maintained generators, verify instrument calibration, and standardize load resistance values. In addition, verification of the integrity of the field winding and a stable excitation supply can help achieve more reproducible and accurate results, unifying the relationship between theoretical concepts and practical applications.

V. CONCLUSION

From the test conducted on the DC shunt generator, it was observed that the terminal voltage (Vout) decreased as the load current (IL) increased. This trend is consistent with the theoretical performance of a self-excited DC generator, where an increase in load causes the output voltage to drop due to increased internal voltage drops across the armature and field windings.

Furthermore, even though the same circuit parameters and procedures were followed by each group, the results varied significantly from group to group. This is because of the physical condition of the generators used. Older or less well-maintained generators had lower output voltage and power, unstable readings, and lower efficiency. Groups that used newer or better-maintained machines, however, were able to produce results closer to theoretical expectations.

This works to highlight the importance of the state of equipment in real experiments and reinforce the understanding that real performance can differ from ideal textbook situations. Overall, the experiment did a good job of demonstrating the working principle, external characteristics, and performance-affecting factors of a DC shunt generator under different load conditions.

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AUTHOR'S INFORMATION

First Author: Abang Syafiqnurain Bin Haji Abang Shokeran 	Department Of Electrical Engineering, Kuching Sarawak Polytechnic, Kuching, Sarawak, Malaysia E-mail: abgsyafiq@poliku.edu.my

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