THE ENGINEER STORY

e-ISSN: 3009 - 0792 Volume 9, 2024, 6-9

CORRELATION BETWEEN ROTOR BLADE AERODYNAMICS AND PERMANENT MAGNET GENERATOR FOR MATCHED OFF-GRID WIND TURBINE SYSTEM

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ABSTRACT

Due to Malaysia's typically low and fluctuating wind speeds, it is crucial to carefully select and match appropriate wind turbine generators to ensure efficient power production. However, the data provided by manufacturers for wind turbine generators often differs from actual operational performance. This study aims to use the developed test rig as a verification and post-processing tool for analyzing the matching effects and characterize the generator constant. The verification testing involved validating a 1kW generator with rated voltages of 48V and 120V under both unloaded and loaded power systems. The results showed that the calculated generator constant (Kv) for the 1kW 48V generator was 4.56 rpm/V and for the 120V generator was 1.50 rpm/V when the system was unloaded. The 120V system exhibited a lower cut-in RPM of 161 RPM compared to the 48V system that start charging at 227 RPM. According to the results, the maximum charging power attainable at the generator's rated RPM of 380 was 608W. This test result contradicts the manufacturer's claim that at a rated RPM of 380, the power output is 1kW.

KEYWORD

Wind turbine, low wind speed, generator, verification testing, generator constant

INTRODUCTION

Wind power is one of the renewable energy sources capable of generating electricity. It is still being researched and studied in various countries, including Malaysia. This is because Malaysia's annual average wind speed is approximately 2 m/s, categorizing it as a low wind speed region. However, wind speeds across Malaysia are not uniform and vary by region and month. According to studies by Masseran et al. (2012) and (Albani & Ibrahim, 2017), the average wind speed in Malaysia is below 3 m/s, which is insufficient for generating electricity. Nonetheless, Masseran et al. (2012) found that at certain times and locations, the wind speed can reach between 6 m/s and 12 m/s, which is sufficient for electricity generation. Ho (2016) underscores the reliance on poor data and inaccurate estimations of wind potential in Malaysian wind turbine research. An investigation on wind speeds in Tawau by Koh & Lim (2010) reported a wind speed of 4.82 m/s, but the height of the anemometer tower used was not disclosed.

MATERIAL AND METHODOLOGY

The rig setup for verifying the generator is based on a generator-motor experimental setup in the laboratory. To verify the loaded generation system of the wind turbine, a 1kW generator setup is used for the verification testing. Figure 1 shows the block diagram of the power generation setup at the Wind Turbine Laboratory, UTM.

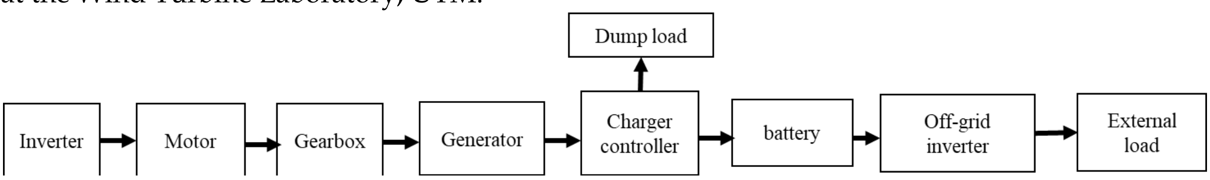

Figure 1: Block diagram

The inverter is used to regulate the motor's torque and speed, driving the system. The testing utilizes 1kW generators with a rated RPM of 380 and rated voltages of 48V and 120V. The motor is connected to the generator, and the experimental setup includes a weighing scale to measure generator torque. The motor operates the generator, as illustrated in Figure 2. The motor and generator shafts are interconnected through shaft couplings with shock and vibration absorbers to dampen effects during operation. Lead-acid batteries with specifications of 12V and 25Ah are used in the experiment. A charge controller regulates the voltage sent to the battery and includes a dump load to prevent overcharging. Additionally, an off-grid inverter is used to integrate the storage system with an external load.

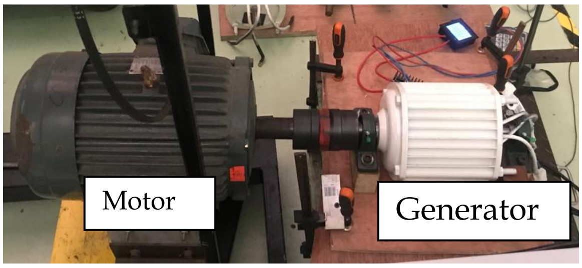

Figure 2: Motor to generator test rig.

After the mechanical and electrical setup is completed, the testing phase will begin to gather the specified parameters according to the designed experiment. Specifically, for the generator testing, the parameters to be measured include motor speed (RPM), torque (N.m), DC voltage from the generator (V), output current generator (A), charging power (W), state of charge (%) and voltage battery (V).

RESULT AND DISCUSSION

This section presents the experimental results, focusing on four main analyses which is the impact of State of Charge (SoC), external load effects, and the generator constant Kv. The study encompasses two generators with different rated voltages 48V setups with 1.2kWh and 4.8kWh, and a 120V setup with 3kWh battery configurations. Both loaded and unloaded conditions were examined. The generators were tested under varying motor speeds with initial battery percentages of 19%, 25%, and 40% for the 48V system. Additionally, experiments were conducted with an increased energy storage capacity of 4.8kWh, starting with a battery percentage of 47.5%.

Figure 3 illustrates the test results of RPM versus voltage for the 48V system. From the graph, the Kv for the generator under no-load conditions is 4.57 rpm/V. When using the 4.8kWh ESC, the slope of the graph, representing the generator constant, measures 62.104, which is notably higher compared to the system with a 1.2kWh ESC. In that configuration, the slope is 12.954, observed at SoC levels ranging from approximately 40% to 47.5%.

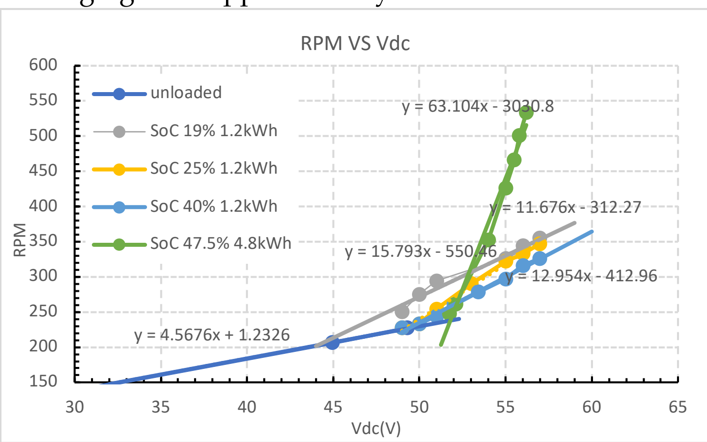

Figure 3: Graph of RPM versus voltage for 1kW generator,48V system.

The testing then repeated by using 120V generators with 3kWh battery configuration. The generators were tested under varying motor speeds with initial battery percentages of 9%, 23%, and 90% for 120V system. Kv for the generator with rated voltage 120V at no load condition is 1.49rpm/V. It is observed that the 120V system exhibits a lower cut-in speed, with the minimum cut-in speed recorded at 146 RPM and SoC of 9%, compared to the 48V system is 227 RPM at SoC 25%. This advantage in achieving lower cut-in RPMs can be beneficial under low wind speed conditions. However, it is noted that the 120V system generates a lower maximum charging power compared to the 48V system.

From the test, the power curve has been plotted as shown in Figure 4. At a rated RPM of 380, the system generates a charging power of 608.75W. This finding contradicts the manufacturer's data, which states that at 380 RPM, the generator should produce 1000W. Therefore, these tests are crucial for verifying the actual performance of the generator before its deployment in a real wind turbine application.

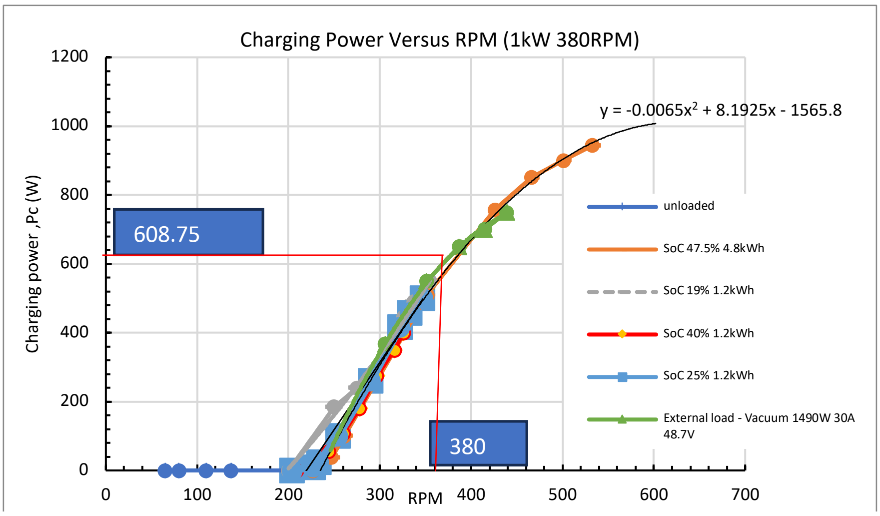

Figure 4: Power curve of 1kW generators

CONCLUSION

The experimental findings reveal a considerable difference between the manufacturer's stated performance and the actual output of the generator. The manufacturer claims that the generator can produce 1kW at 380 RPM, but the experiment shows only 608W is generated at this speed, indicating an efficiency of 60.8%. Additionally, the 4.8 kWh setup reaches a higher peak charging power of 944W, while the 1.2 kWh setup only achieves 519.24W. These results emphasize the necessity of verification testing to confirm manufacturer specifications and to develop a matched system. Further research into the variables affecting generator efficiency and performance under different conditions is suggested.

ACKNOWLEDGEMENT

This research is fully supported by University Teknologi Malaysia, UTMFR, Q.J130000.3824.22H61. The authors fully acknowledged Ministry of Higher Education (MOHE) and Universiti Teknologi Malaysia for the approved fund which makes this important research viable and effective.

REFERENCE

Albani, A., & Ibrahim, M. Z. (2017). Wind energy potential and power law indexes assessment for selected near-coastal sites in Malaysia. *Energies*, *10*(3). https://doi.org/10.3390/en10030307

Ho, L. W. (2016). Wind energy in Malaysia: Past, present and future. *Renewable and Sustainable Energy Reviews*, *53*, 279–295. https://doi.org/10.1016/j.rser.2015.08.054

Koh, S. L., & Lim, Y. S. (2010). Meeting energy demand in a developing economy without damaging the environment-A case study in Sabah, Malaysia, from technical, environmental and economic perspectives. *Energy Policy*, *38*(8), 4719–4728. https://doi.org/10.1016/j.enpol.2010.04.044

Masseran, N., Razali, A. M., Ibrahim, K., & Wan Zin, W. Z. (2012). Evaluating the wind speed persistence for several wind stations in Peninsular Malaysia. *Energy*, *37*(1), 649–656. https://doi.org/10.1016/j.energy.2011.10.035