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Working Performance of Synchronous Generators and Grid Photovoltaic in Microgrid

Fredi Prastiyo[1], Mochammad Facta[1], Ngurah Ayu Ketut Umiati[2]

[1]Department of Electrical Engineering, Faculty of Engineering, [2]Department of Physics, Faculty of Science and Mathematics,
Diponegoro University, Semarang Indonesia.

Corresponding Author: Ngurah Ayu Ketut Umiati

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ABSTRACT

This work aims to analyse the working performance of the synchronous generator micro generation system, especially the rotor angle aspect with the comparison of inverter grid photovoltaic feeding in microgrid system. Micro synchronous generators and photovoltaic grid inverters are renewable energy sources that are increasingly popular in integration into the power grid. Experimental methods are used to measure and analyse electrical power proportion parameters such as active power, apparent power, and reactive power in synchronous microgenerators and photovoltaic grid inverters. Tests are performed in various linear load scenarios to evaluate how these two systems behave under different conditions. The results of this study provide a deeper understanding of the effect of synchronous mini generator feeding and photovoltaic grid inverter on the rotor angle that occurs. Analysis of the interaction between these two systems also provides insight into how the combination can affect the overall quality of electrical power. The findings of this research are expected to contribute to the development of renewable generation systems that are more reliable and efficient in maintaining the quality of electrical power.

Keywords: Synchronous Micro Generator, Photovoltaic, Grid Inverter, Microgrid

INTRODUCTION

The development of electricity generation technology has led to using renewable energy sources, such as synchronous micro-generators and photovoltaic grid inverters, as alternatives to reduce dependence on limited and environmentally detrimental fossil fuels. However, along with the adoption of these generation systems, it is necessary to understand in more depth how their behaviour impacts the quality of electrical power [1], [2], [3].

By understanding the impact of the interaction between the two, it is hoped that this study can provide better guidance in designing, operating, and integrating renewable generation systems into existing power grids.

LITERATURE REVIEW

Micro-generating systems of synchronous generators and photovoltaic grid inverters have complex properties and dynamic interaction with the power grid. Therefore, it is important to identify and analyse the impact of these generation systems on the quality of electrical power [4], [5], [6].

The synchronous microgenerator is one type of generator used on a small scale, this system has synchronization characteristics that affect the stability of frequency and voltage in the network. On the other hand, photovoltaic grid inverters convert solar energy into electricity and feed it into the distribution grid. However, fluctuations in energy input from solar sources can affect the quality of electrical power [7], [8].

The effect of excitation current on generator voltage in dynamic loading situations has been identified in previous work [9]. The work made the experiments showing that the voltage of the Mini Hydro *Curug* synchronous generator is strongly influenced by the regulation of excitation current. The results showed that when the excitation current was at a value of 2.2A, the generator output voltage was 6.133kV, while the highest voltage reached 6.479kV at an excitation current of 4.6A, from the study it can be concluded that a lack of understanding of how the quality of electrical power is affected by the interaction between the two systems is still not widely written. Such interactions can include phenomena such as the harmonic influence of synchronous mini generators on total harmonic distortion generated by photovoltaic grid inverters, or the impact of load fluctuations on plant performance and power supply composition [9], [10].

Therefore, this study will analyse the behaviour of synchronous generator microgeneration systems and photovoltaic grid inverters in an integrated manner in the context of the angle of the generator rotor to the proportion of power.

MATERIALS & METHODS

This research begins with a Literature Study which includes references related to the parameters of stability and reliability of electrical systems, harmonic calculations in electrical systems, methods of analysis, calculation, and design of Solar Power Plants (Solar Power Plants), as well as references related to micro-generator calculations. This initial step is important for building a solid understanding of the research context. Furthermore, secondary data retrieval is done by collecting Datasheets from Grid Tie Inverters consisting of three single-phase inverters, DC motors as prime mover of Synchronous Micro Generators, and Photovoltaic (PV). This data becomes the necessary basis for the design and implementation of the system.

Creating and designing Solar and Micro Synchronous Generator Design is the next stage. This design is done using PSIM software, which allows determining the specifications and configuration of solar power plants and adapting them to various possible topologies. In addition, the determination of the specifications of the 1-phase drive motor and synchronous microgenerator is also carried out in this stage. The need for protection design in the system is also considered.

The rig of experiment was set by using micro synchronous generator 400 V in Y connection with maximum power 300 Watts with power factor 0.97 and frequency 50Hz at 1500 rpm. The PV-grid inverter system consists of three PV panel with 120 Watt-peak for each phase. Those two systems supplied the pure resistive electric load 300 Watt as shown in Figure 1.

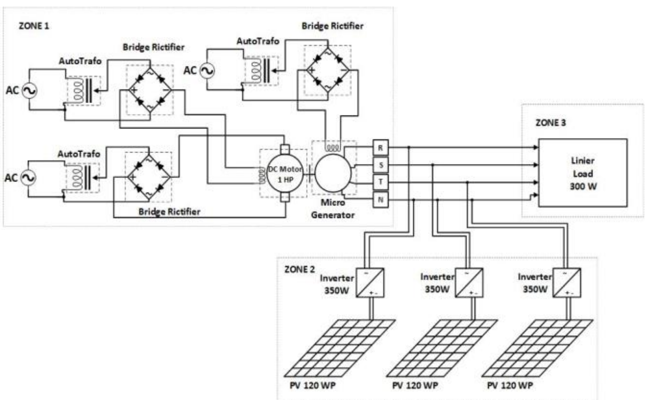

Figure 1. Test Rig

After the design is completed, the implementation of the design is carried out by following the specifications that have been predetermined. Implementation involves setting up photovoltaics according to their specifications, 1-phase DC motors according to their specifications, and micro-generators according to their specifications. Protection systems are also implemented to ensure safe operation.

The next step is to retrieve the linear loading power proportion data on the system. At this stage, the current and voltage on the synchronous microgenerator are identified, and possible disturbances are identified. Simulations are performed under normal conditions and during loading to calculate power flow based on design, as well as current, voltage, and frequency values on the line.

The final step is to perform an analysis of the power proportions and rotor angles of the generator. The results of this analysis are used as a basis for understanding the quality of electrical power generated by the system that has been designed and implemented.

RESULT AND DISCUSSION

The data shown in Figure 2. is the result of measurements accumulated in real-time from 09:00 (9 am) to 15:00 (3 pm). This measurement is carried out using a linear load installed in the form of an incandescent lamp with a total power of 300 watts. The generator speed has been set at a constant speed of 1500 rpm, while the excitation current is set at 0.8A according to the peak capability of the installed generator. In Figure 2 there are six colours representing each phase of current generated from generator and photovoltaic-grid inverter (PV-grid inverter). There are three set of independent PV-grid inverter connected to each phase of generator. The colour blue, orang and dark blue representing the phase R, S, and T of generator subsequently, while the colour orange, light blue and brown representing phase R, S, and T from independent PV-grid inverter. Each phase work independently to make synchronizing work to take the resistive load given for each phase.

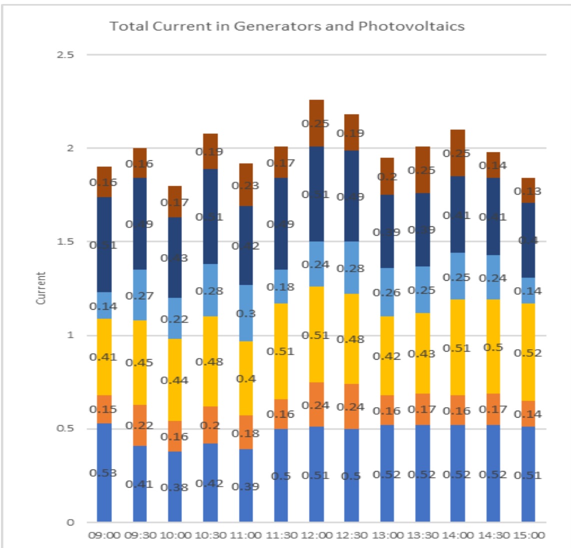

Figure 2. Generator and photovoltaic total current diagram

Figure 3 shows the portion of each phase from generator and PV-grid inverter took every resistive load for each phase independently. Every phase of synchronous generator takes bigger portion in the range of 22.24-24.18%, while each PV-grid inverter in every phase takes the smaller portion i.e. 9.15-11.09%. Based on the experimental results shown in the Figure 1 and 2, the source generate power and deliver current to the load in proportion to the capacity of the source. The 300 Watts synchronous generator has bigger capacity than PV Grid inverter with 120 Watts peak maximum for each phase.

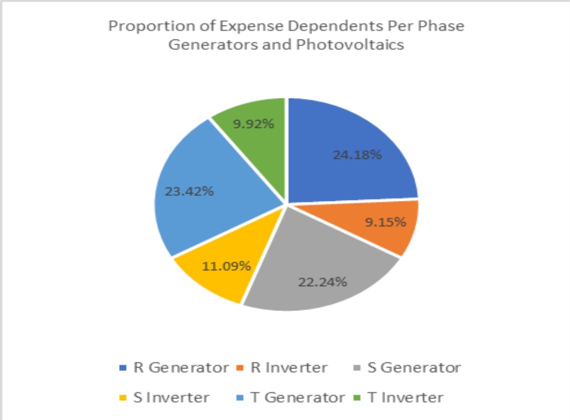

Figure 3. Generator and photovoltaic power dependency diagram

The average results are then presented in the form of graphs in Figure 3. Using graphs, the authors can provide a more visual and easy-to-understand picture of the relative contribution of each component to the total power of a hybrid system. Thus, these data processing steps allow the author to present more comprehensive information.

By looking at the irradiance data, temperature, and humidity, the author tries to formulate the relationship between the lag of the rotor angle and the effect in Figure 4. Especially the influence of irradiance itself. Figure 4 shows that the data collection process is carried out in sunny weather conditions with an average solar radiation is above 1500 Watt/m^2, and humidity levels below 50%. This is considered important because these optimal conditions are expected to produce optimal data. Great care and precision must be applied during the data collection process to ensure that the data obtained is accurate and reliable

The maximum irradiance 1665 Watt/m^2 was achieved at 13.00 (1 pm) in Figure 4, so the PV-grid inverter may deliver up to 11.09 % at phase S as it is shown in Figure 2. The maximum production of electricity from PV-grid inverter will slightly reduce the current from micro synchronous generator, as the phase S of generator produce the smallest amount of current i.e. 22.24 % in Figure 2.

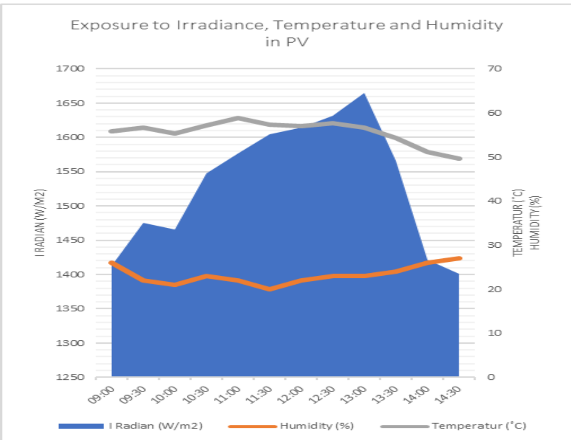

Figure 4. Irradiance, temperature, and humidity at PV side.

The experimental results also shows that each independent phase PV-grid inverter has successfully working in parallel to three phase micro-synchronous generator to deliver power at load side. It can be concluded that synchronous generators and Photovoltaic with the grid tie inverter method can run well in line.

CONCLUSION

Based on the results of work and analysis, the synchronous generators and Photovoltaic with the grid tie inverter method can run well in line and achieve the maximum performance at irradiance of 1665 Watt/m^2 at 13.00 (1 pm) o'clock.

The study also provides a deeper understanding about the interaction between these two systems provides insight into how the combination of the two affects the overall quality of electrical power. It is expected that the findings from this study will make a significant contribution to the development of renewable energy generation systems that are more reliable and efficient, as well as maintaining the quality of electrical power sustainably.

Declaration by Authors

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