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Development of DC smart grid model for voltage stability disturbance

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Abstract. DC smart grid and distributed generation have evolved rapidly as the integration of renewable energy. The robustness parameter of DC smart grid can be defined by the ability of the system to maintain stability under normal or perturbed conditions and provide fast restoration after faults. This research aims to design DC smart grid to simulate the voltage stability again disturbance. A model of DC smart grid was tested by key parameters in power station such as voltage stability. Voltage stability is the ability of power system to maintain steady voltage within permissible range at all buses in reasonable condition and after having been subjected a perturbation, such as an incremental change in load. The obtained duration time for a system to recovered voltage stability problem was approximately two seconds until three seconds. It was concluded that designed DC smart grid could simulate the voltage stability disturbance.

1. Introduction

A smart grid has many renewable energy sources and connects into the power transmission. A smart grid also composed of a distribution system as an integral component [1]. The smart grid concept provides the possibility to detect, analyze and respond to various voltage stability disturbance. A smart grid used for improving efficiency, sustainability, flexibility, reliability, and security of the electrical system [2].

Since the 1920s, the stability of the power system against operational security has become a severe problem. The diversity of disturbances and instability in the power system can cause damage to the generator which causes the system to die (black-outs), so that stability analysis on the smart grid becomes very important in planning, designing and operating. The toughness parameter of a DC smart grid is defined by the system's ability to recover quickly when a fault occurs [3]. Research on the DC smart grid has been carried out in the form of an analysis of voltage stability without interruption and with the presence of interference by Amty Ma'rufah [4]. In that study, a relay has been used as a power supplier actuator and caused recovery time around 4th to 6th seconds.



In this research, a smart DC grid model was developed to simulate the voltage stability again disturbance. Voltage stability is the ability of power system to maintain steady voltage within permissible range at all buses in normal condition and after having been subjected to a severe system perturbation, such as a simulation of an increase of load or create an overloaded condition. MOSFET was used as actuators for controlling their power allowed to work at high frequencies. In addition, the DNP3 protocols were utilized as protocols of the communication.

2. DC smart grid model

The general smart DC grid system in Figure 1 consists of a smart-grid master (SG-M), smart-grid 1 (SG-1) and smart-grid 2 (SG-2). SG-M have a function as the main grid with stable resources using 12V 10A batteries. The SG-M can supply power to another grid if there is an increase in load and loss of resources power on a distributed grid. The distributed grid consists of SG-1 and SG-2. The SG-1 using 12V 5A battery whereas the SG-2 using the 12V 3.5A battery. Rechargeable batteries (Accu) are considered as storage from the renewable energy source.

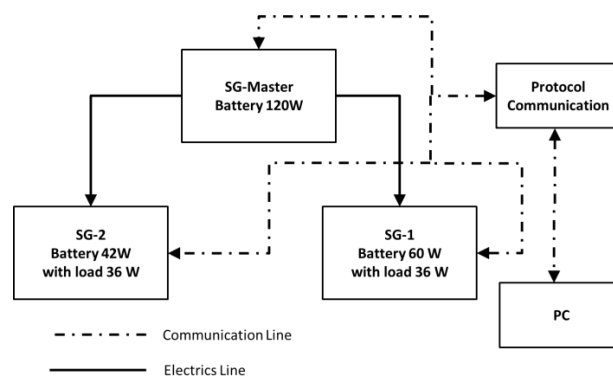


Figure 1. The general DC smart grid system.

The developed DC smart grid system equipped with two-way communication using RS-485 protocol allows operating data management systems in a Personal Computer (PC). Based on the information from the distributed grid, if the distributed grid needs more power, PC will launch command to SG-M to give power to the distributed grid. PC displayed a table data and online measurement and monitoring graph from each smart grid. Thus the status of the system was under control. The DNP3 protocol was employed for the communication between subsystems as shown in Figure 2. The DNP3 protocol is a data communication standard for the DC smart grid as outlined in IEEE P1815-2010.

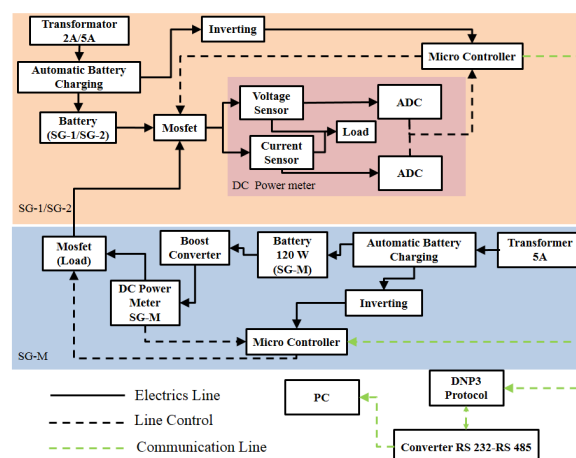


Figure 2. The DC smart grid subsystem

The DC smart grid subsystem comprises of the battery as stable power source, an ATmega 8535 controller, a personal computer (PC), a Mosfet as a power supply actuator, an automatic battery charger circuit that keeps the power of battery, DC power meter, boost converter, max 485 circuit and max 232 as a serial communication line. We are used boost converter only in SG-M wherein for maintained possibility reverse current flow to SG-M. In the previous research [4], analysis stability was evaluated from voltage response against a disturbance. They used a simple relay as actuator power distribution. In this developed-DC smart grid, we employed a Mosfet, which fast response was expected well to recover the system against disturbances than a simple relay.

This system was applied to simulate disturbance by using 2 DC lamp (12V/35watt) with 2 scenarios. The first scenario was SG-M without a used boost converter and the second scenario was SG-M with a used boost converter. Both scenarios were simulated on SG-1 and SG-2. Each scenario had 3 steps. The first step, the SG-1 or SG-2 would not be loaded from the lamp. The second step, the SG-1 or SG-2 would be loaded with a reasonable load from the lamp (12V/35watt). Then the third step, the SG-1 or SG-2 received an extra load from 1 more lamp (12V/35watt). In the third step, the distributed grid received burdened status and requested assistance from SG-M. The SG-M received the information from PC to open Mosfet gate and give the power. The SG-M checked own battery state of charge (SOC) status first, before SG-M open Mosfet gate. When SG-M battery was under 50% SOC, the SG-M give no power to the distributed grid. During the simulation, the distributed grid cannot help each other.

3. Result and discussion

The integrated smart DC grid system was tested their performance by sending data to the PC via RS-485 and RS-232 using the DNP3 protocol.

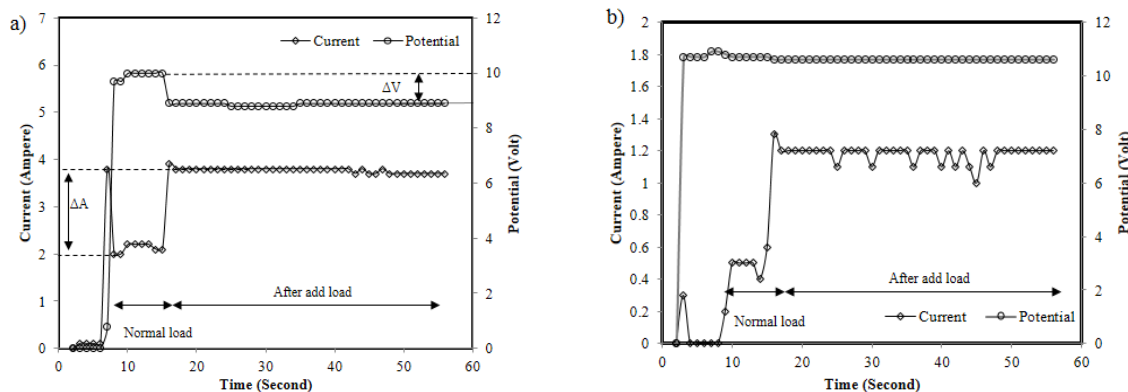


Figure 3. Current and potential profile of a) SG-2 with assisted of SG-M and b) SG-M without using a boost converter.

Figure 3a showed the voltage stability under disturbed load without using the boost converter for the grid SG-2. Initially, SG-2 was operated with a normal load (lights with a power of 12V/35W (3A)) which was noted as normal in the figure. The voltage was stable at 10 Volt and current raised to 2.2 A. Then in 16th seconds, the SG-2 load was purposely added with 35W power lamp in parallel to simulate load to the system indicated by the rise of the current to 4A. In this situation, SG-2 delivered an aiding signal to SG-M because the battery specifications on SG-2 could only drain a maximum current of 3.5A. SG-M responded to the received signal by providing power supply aid (Figure 3b). Utilized the power aid from SG-M, the current flow to a maximum value of 3.8 A, however, the voltage did not return to stable values i.e., 10 Volt. The system could not resolve the voltage on SG-2 to initial stable condition (10 Volt) even though the power at SG-M was greater than SG-2. Furthermore, additional effort need to be applied to resolve this problem.

Furthermore, in the second test, the scenario was carried out with similar treatment as a previous test (SG-M using boost converter). In this scenario, the distributed grid under test was SG-1. Initially, SG-1 was operated without load and then the system added a normal load of a lamp with a power of 12V / 35W (3A).). When the load was added to the SG-1 with 35W power lamp in parallel, the current reached a maximum current of 4.5A. As shown in Figure 4a, before the SG-1 got assisted from SG-M, the voltage drop to 8.2 volts. Whereas when the SG-1 got assisted from SG-M, the voltage back to 9.4 volts.

By applying a smart system when the voltage dropped, SG-1 automatically send a signal to the PC that SG-1 required additional power. The PC delivered a signal to SG-M then transmitted additional power to SG-1. Figure 4b showed the current increased on SG-M after SG-1 had received additional power supply. The SG-M checked the SOC of SG-M battery first before sending additional power. If SOC of SG-M battery under 50% so the SG-M would not open the Mosfet. The recovery time of this system was around 2 seconds. Utilization of boost converter at SG-M produced the voltage of SG-M became 12 V and helped SG-1 voltage returned to initial voltage. It was highlighted, the SG-M have supplied to a maximum current to the SG-1, and maintained voltage over 11 V.

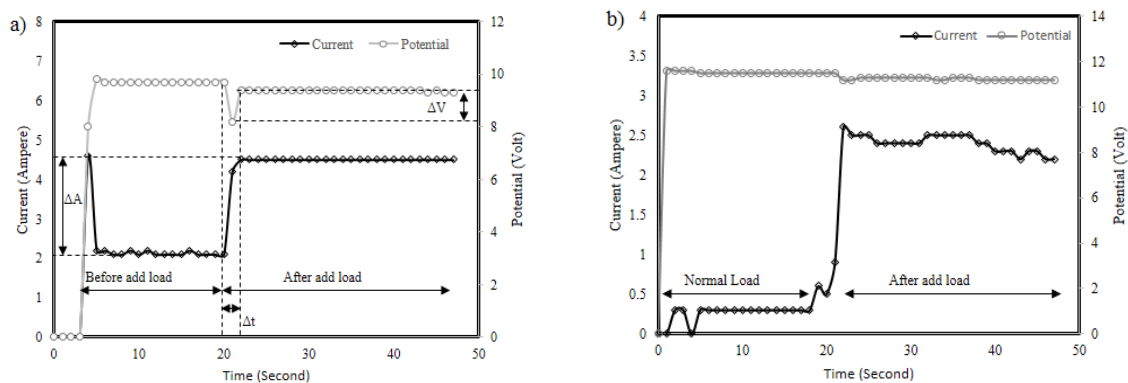


Figure 4. Current and potential profile of a) SG-1 with assisted of SG-M, b) SG-M using boost converter.

Similarly occurred on SG-2 when this grid was added to to simulate overloaded this grid was unable to reach maximum current (Figure 5). It was highlighted that when a smart system via a PC automatically controls by delivering additional power from SG-M to SG-2. It was clearly showed in Figure 5a the voltage raised soon after getting the power supply aid from SG-M and yielding a recovery time of 3 seconds.

The conditions that occurred in the SG-M before and after being loaded are shown in Figure 5b. Smaller resources on SG-2 (12V 3.5A) cause the power transmitted to SG-2 was greater than the power transmitted to SG-1. This clearly in turned that the magnitude of the current flowing to SG-2 (3.5A) which was greater than the current flowing to SG-1 (2A).

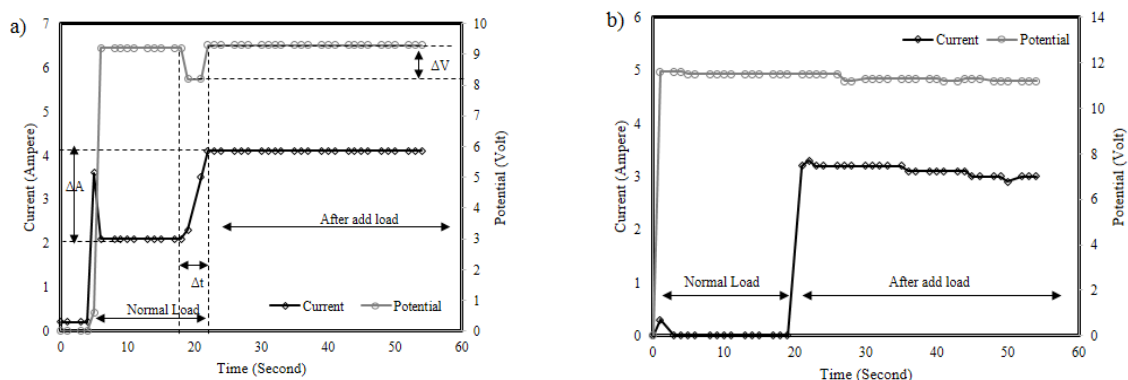


Figure 5. Current and potential profile of a) SG-2 with assisted of SG-M., b) SG-M using a boost converter.

4. Conclusion

The developed smart DC grid model successfully simulated the performance of a smart DC grid when the disturbance occurred and the system responded by controlling the distribution of DC power to achieve voltage stability. It was highlighted that the response time to resolve the voltage stability was approximately two seconds until three seconds

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