Simulation of Microgrid and Study of its Operation

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***Abstract*— Distributed generators using renewable energy play an important role in electricity production in the current times, with the rise in global warming and pollution level. Microgrid is a renewable distribution network which is connected to the main utility grid. It consists of a group of loads and distributed generators that collectively operate as a single system. Microgrid concept has been introduced as a fix to various electrical grid challenges such as the rapid increase of energy demand, obtaining energy from renewable energy sources, and stable and reliable energy supply. On the basis of the supply source, microgrids are classified as ac and dc microgrids. This paper presents a comprehensive review on microgrid, especially AC microgrid. A small scale microgrid system is simulated and its operation on a typical day is analyzed, using the MATLAB/Simulink environment.**

***Index Terms*—Distributed generation, Microgrid, MATLAB, Renewable energy.**

I. INTRODUCTION

Efficient generation of energy that are eco-friendly, is significant for sustainable development. Conventional energy sources will be exhausted due to its irrational utilization by humanity. Renewable energy offers a very promising alternative. It plays a major role in the global energy sector. Renewable energy is the energy that gets continuously replenished by natural processes. Due to the increasing day-to-day power demand, non-renewable energy sources like natural gases, coal and petroleum are diminishing, hence after a few years, their reserve would be vacant. Hence, the importance of renewable energy sources is also increasing. The major benefits of renewable generation are environmental. They are clean energy, hence reducing greenhouse gases emissions.

Recently, distributed generation technologies have gained popularity due to its various benefits such as high reliability, quality energy and power supply, environment friendly and reduced operating costs. However, an increased number of distributed generators will also introduce difficulties in terms of its control and management. To make use of the full potential of distributed generation, the generation and loads can be treated as a single system. Microgrids come into play so as to improve the performance of the power system.

Microgrid has two modes of operation: islanded mode or grid-connected mode. Microgrids help to increase the reliability of supply of energy by detaching from the grid when any network fault occurs. A major challenge faced today is to implement renewable energy into the existing power systems. Microgrid provides great flexibility and reliability in this regard. Microgrid is based on the assumption that many numbers of micro generators are connected to the network, so as to lower the requirement of transmission and high-voltage distribution systems. It is the most effective form of distributed generation.

This paper is organized as follows: Section II provides the description of microgrid and its operation and control. Section III explains about AC microgrids. Section IV highlights the MATLAB/Simulink simulation done. Followed by section IV, that contains results of the simulation. Finally, the conclusions are drawn in Section V.

II. MICROGRID

Microgrid is one of the best alternatives to traditional energy generation and distribution. Microgrid is a power system that consists of loads, distributed generation, energy storage and various control systems that can be operated as an isolated system or connected to the main grid. To the utility, a microgrid can be considered as a controlled cell of the entire power system. It is a distribution network of low voltage. In a microgrid, distributed generators (DGs) must be capable of carrying most of the loads those are connected to the microgrid. DGs are located at strategic points, at the distribution level, in close proximity to load centres. They are mainly used for capacity and voltage support and regulation, and reduction of line loss.

A. Operational Modes of Microgrid

There are two operating modes of a Microgrid power system. Islanding mode and grid connected mode. Grid Connected Mode: When connected to the utility grid, the static switch will be closed. On clearing the fault in the main grid, this mode is activated. Voltage of the microgrid is re-synchronized with the voltage of the main grid before closing the static transfer switch. At the Point of Common Coupling, the voltage and frequency are controlled from the main grid. Islanding Mode: Power will not be supplied by the utility once the static switch opens. The main grid is lost and hence the voltages and frequency are not controlled externally. The point where the entire microgrid system is connected to the utility grid is Point of Common coupling. Islanding mode has two working conditions: intentional and unintentional islanding.

B. Microgrid Control

The power between the microgrid and the main grid has to be controlled in the grid-connected mode. Microgrids should have the ability to last even when the main grid is disconnected. To reduce any issue in the microgrid, choosing the proper control technique is important. Control system maintains frequency and the voltage level in island control of the operation. Droop control is the main method used to maintain the stability in microgrids, and is classified as active power frequency and reactive power-voltage. These controllers can enable multiple machine; rotating synchronously, to control the power sharing and to maintain the stability of frequency and voltage.

There are three major hierarchical levels that can be applied to a microgrid network:

1) Primary Control

Primary control is designed to satisfy the requirement, given below: To stabilize the voltage and frequency of the microgrid- During the islanding mode, the microgrid might lose its stability in its voltage and frequency, if any mismatch happens between the demand and generated power. It also provides the voltage and current control loops reference points of the Distributed Energy Resources. Primary control usually gives differences to the frequency and voltage set points. Secondary control can be opted so as to correct this.

2) Secondary Control

This ensures that the electrical levels going into the microgrid are always within the required value. This controller has slower dynamic response than the primary, which hence justifies the decoupled dynamics of both the primary and secondary control loops, and simplifies their designs. Secondary control also satisfies the power quality requirements to an extent.

3) Tertiary Control

Tertiary control is the highest control level which considers the economic concerns in the optimal microgrid operation. This control is helps to achieve the power flow by frequency and voltage control while the microgrid is in grid connected mode. The active power and reactive power of the network's grids can be compared besides the desired reference by measuring real and reactive power through the PCC. Hence by adjusting the microgrid reference frequency, the active power at the grid can be controlled.

Droop Control: This control method is used to maintain the load current sharing, which can be done by changing the output voltage under both current and voltage droop characteristics. It measures the distributed generation terminal voltages and currents to compute its active and reactive power outputs. The active and reactive powers are expressed as following two equations:

$$P = \frac{V_S{}^2}{Z} COS\theta - \frac{V_S V_L}{Z} COS(\theta + \delta) \qquad (1)$$

$$Q = \frac{V_S{}^2}{Z} Sin\theta - \frac{V_S V_L}{Z} COS(\theta + \delta) \qquad (2)$$

III. AC MICROGRID

An AC microgrid has an AC bus, and all the sources with variable frequency and voltages, that are connected to the bus through converters (AC/AC or DC/AC). DC/AC inverters are important so as to convert the DC sources outputs. Sources with AC output are connected with AC/AC converters. AC to DC converters are installed in order to supply the DC loads. Due to the usage of a number of power electronics devices and power output conversions from both DC to AC or AC to DC, AC microgrids have higher losses. Whereas, due to the variable nature of different distributed power sources and the need of a large number of power electronic devices, and also the magnitude of available power from different sources at varied periods, a smart load system for controlling and management is required. In this regard, AC microgrids are suitable for the existing power system infrastructure.

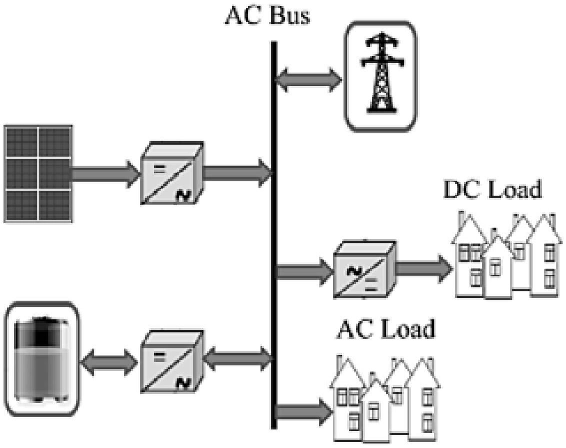

Fig.1. AC Microgrid

IV. SIMULATION OF AC MICROGRID

The microgrid system was developed and simulated in MATLAB Simulink SimPowerSystems. PV system, battery storage, battery controller, loads, distribution network, and power grid are six major components in the microgrid model. The simulation diagram is given in Fig.2. A phasor model was used to simulate 24-hour scenarios in a short amount of time. Power electronics components, on the other hand, are not modelled.

The PV array contributes to the microgrid, which is a PV-battery system that has a capacity of 50 kW.

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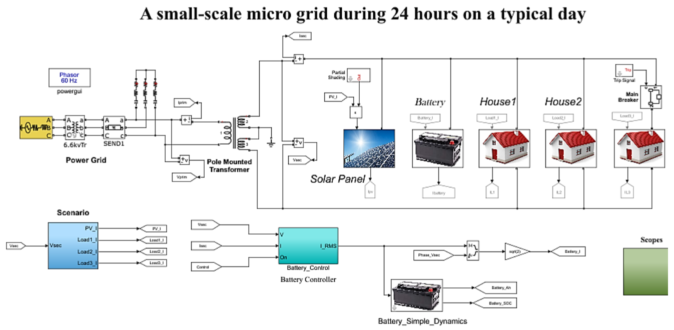

Fig. 2. Simulation Model

The battery controller employs a load dispatch mechanism, which charges the battery with excess renewable energy generation. The main grid will be used to supply electricity to the loads if the renewable energy configuration is unable to feed the load. The electrical system is a single-phase network with a voltage of 230 V and frequency of 50 Hz. The PV system is modelled as follows:

$$P_{Out} = GFAe$$

where Pout is the output power from PV array in kW, F is the partial shading factor (0-1), G is solar irradiance (W/m2), A is PV area size in m2, e is the efficiency of the PV panel (0-1). The battery storage system is modelled as follows:

$$SOC = 100\left[1 - \left(\frac{1}{Q}\int_0^t i(t)\,dt\right)\right] \qquad B_{AH} = \frac{1}{3600}\int_0^t i(t)\,dt$$

where Q is the rated capacity in Ah, SOC is percentage of battery capacity, i is the battery current, and BAH is the battery ampere-hour. The load comprises residential load. There are three residential loads modelled in the microgrid system so as to simulate the energy demand in a rural area. The loads are also used to simulate the performance of the energy management system in variety of load conditions.

V. RESULTS

Solar radiation and a load profile are used as inputs in this model. Fig.3. depicts the solar radiation and load profile input. The y-axis and x-axis of the graphs depict the Power(watts) and the time(seconds). From 20h to 4h, solar electricity generation is not observed. The load follows a typical distant location profile, with peaks at 9h, 19h, and 22 h, with demand of 6.5 kW, 7.5 kW, and 7.5 kW, respectively. From 0 to 12 hours, and from 18 to 24 hours, the battery controller is controlled by a controller. The pole-mounted transformer's active power is set to zero. As a result, the battery controller monitors current to ensure that the grid's active power is always zero.

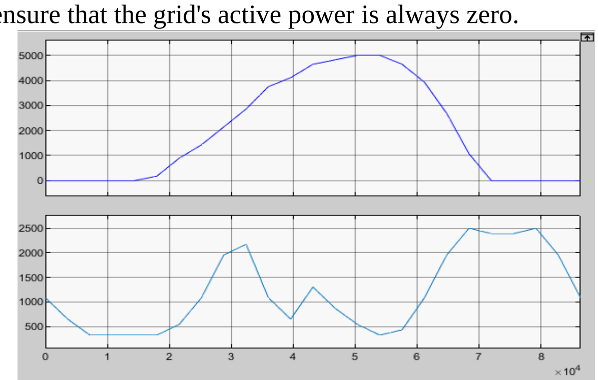

Fig. 3. Inputs: Solar radiation and load profile

Simulations outputs are given below.

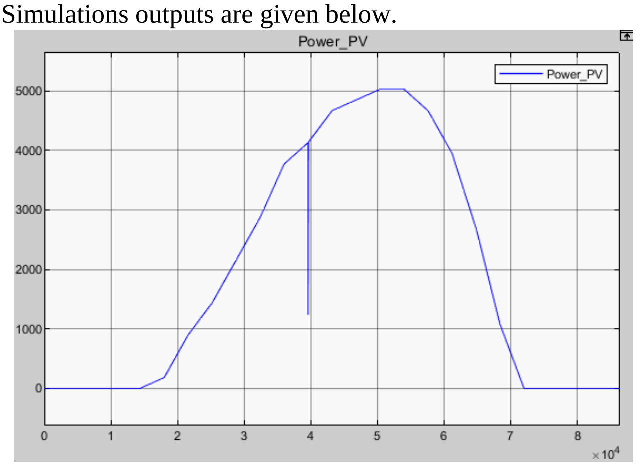

Fig. 4. PV Generation

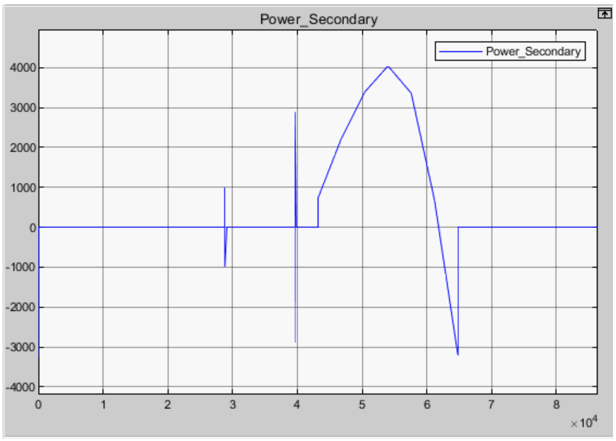

Fig. 5. Power Secondary

When the microgrid's total generation is insufficient to fulfil the load demand, the battery storage system kicks in. When the load demand is less, the storage absorbs additional power from the microgrid. From 12 to 18 hours, there is no battery control. As a result, the battery state-of-charge (SOC) remains constant, and the controller does not charge or discharge. In the event of a power outage, the controller will discharge the battery to meet the demand. Surplus generation will be used to charge the battery if there is any.

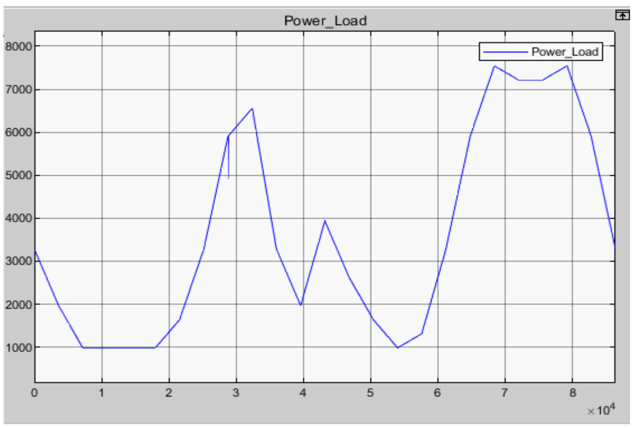

Fig. 6. Power Load

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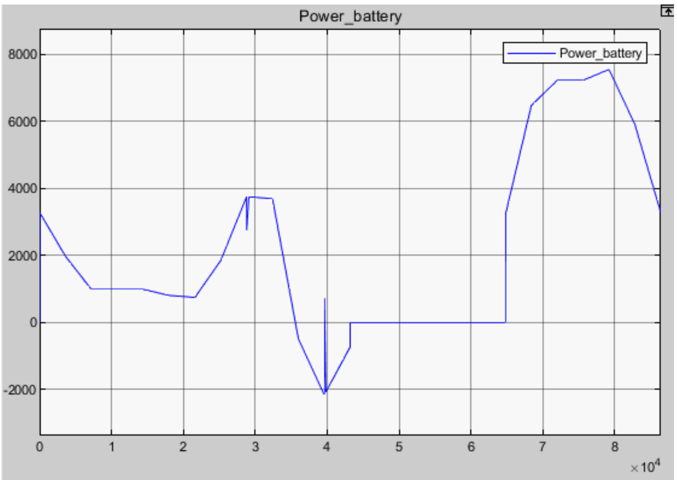

Fig. 7. Battery Power Output

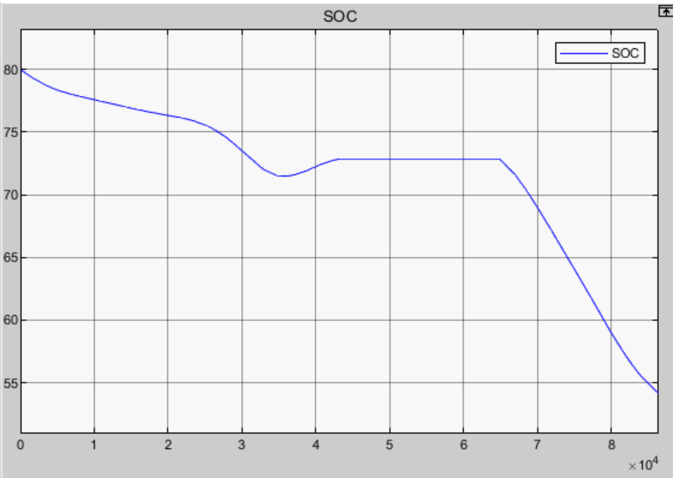

Fig. 8. Battery SOC

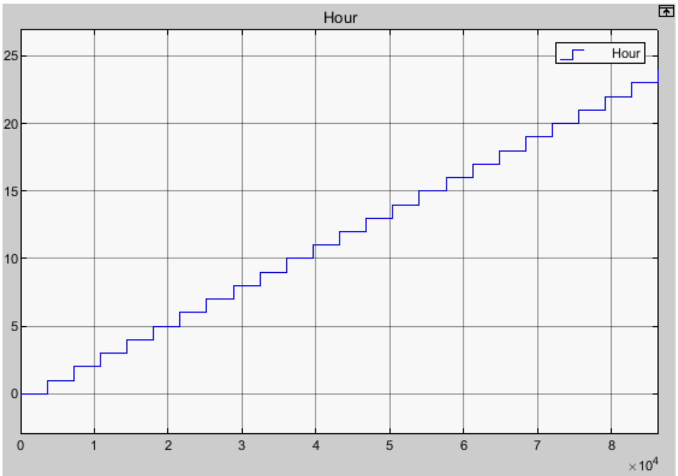

Fig. 9. Hours in a Day

VI. Conclusion

A. In this paper, a detailed study on microgrid, and its operation and control has been performed, and operation of AC microgrid has been specially looked into. MATLAB/Simulink environment is used to simulate a small-scale microgrid, and its performance on a typical day was observed, and the necessary outputs were obtained. The dynamic behavior in every subsystem is studied. The beneficial characters and novelty of this microgrid design enable it to be used in a variety small-scale power distribution application.

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