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A MODELLING APPROACH TO THE MANAGEMENT OF DISTRIBUTED ENERGY RESOURCES SYSTEM

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ABSTRACT

A distributed energy resource (DER) system contributes to an improved operation of an electrical power system for better economy and technical efficiency. In several applications, renewable energy sources are becoming more acceptable for powering nodes. Solar energy is an essential energy source, particularly for outdoor wireless sensor systems. This is due to the regularity and dependability of solar energy systems. In recent times, Photovoltaic cells (PV) are considered expensive alternatives to typical demand-limited lithium batteries, to provide a limitless energy source. This study has modelled and simulated a DER-enabled power distribution network with the use of Simulink in MATLAB and Simscape Electrical for switching operations. The switching operation selected a distributed-based approach, as influenced by the factors of availability and efficiency in enhancing the steady and uninterrupted supply of electric power to the load. The simulated results were achieved by subjecting the island and main utility grids to disturbances at specified time intervals in seconds (10, 35 seconds) and an additional 300 kW load was added to the variable load at the specified time intervals in seconds (40, 20 seconds, etc. respectively). The results and interaction between the island and utility grids, which yielded frequency disturbance, distributed resources, and the microgrid responses to the changes made, were analyzed and discussed. The study has provided a modelled solution for a reliable DER system to provide an almost uninterrupted power supply to the load.

Keywords: distributed energy resources, MATLAB, modelling, photovoltaic cells (PV), solar energy.

1. INTRODUCTION

Distributed systems are designed to leverage seemingly uninterrupted energy sources. The energy constraint is a major limitation in most wireless networked systems. In most cases, the base station is a computer connected to a gateway, which is a device that collects data from the sensors. A base station application analyses the data received, does the necessary computations and shows the results on the user's screen. In recent years, wireless sensor networks have been discovered to have numerous uses in a variety of fields, ranging from health care to utilities and remote monitoring [1], [2]. A wireless sensor network comprises several low-power sensor nodes scattered across an area to collect data on a single observable event. In most applications, the node localization and deployment techniques make power rechargeability impossible, thereby requiring a powerful approach to ensure the longevity of the installed units. In several applications, renewable energy sources are becoming more acceptable for powering nodes. Photovoltaic cells (PV) are considered as costly alternatives to typical demand-limited lithium-based batteries, to provide a limitless energy source.

Renewable energy (RE)defines the various energies extracted from various self-renewing resources and sources which include sunshine, flowing water, wind, biomass, industrial waste, and garbage [3]. These resources can generate energy for all economic sectors, transportation fuels, and heat for buildings and industrial processes. Each of the renewable energy technologies is developed and commercialized at a different pace. There are few pollutants being generated by renewable energy sources which contribute to urban smog, acid rain, and health problems. Therefore, there is no necessity for environmental clean-up or trash disposal costs [4], [5].

Globally, the demand for RE is rising. The restraint on the fossil fuels reserve and the ever-increasing environmental pollution is increasing because of the application of conventional means of energy generation, which can further exacerbate certain health challenges that have been noticed in the last decade's development of renewable energy sources (RES). This paper aims to model, control design, and manage a distributed energy resource (DER) system. It has specific objectives to model a solar smart grid system using MATLAB to simplify abstract modelling components; construct a smart grid solar powered system using a voltage regulator circuit, (PWM) charge controller, batteries, central processing unit, microcontroller, and an IoT system; develop an adaptable inventory management system; a devaluate system performances.

The provision of a smart grid system improves power generation and continuity of power supply because of the need for more reliable means of electric energy other than conventional power sources, and the advancement in the management of software applications is embedded in our day-to-day life. The modelling and design of distributed energy systems help to create a small-scale unit of power, and this saves electric energy by moderating the usage of grid energy. It saves oil expenses sustained in using a generator [6]–[10]. The modelling and construction of a distributed energy system, in this case, a solar system, aims at providing an alternative means of power generation, with the aid of Simulink to design and simulate a solar system comprising two solar panels that can be energized individually and supply power to the load through the central processing unit, with the provision of a project switching operation the provision of power supply can move from solar node 1 to solar node 2 when solar node 1 is not energized enough to power the specified load as this improves power generation and supply. The system is efficient, cost-effective and promotes the judicious use of available energy by the load (consumer).

2. RELATED WORKS

Fossil fuel has proven to be extremely harmful to the environment, which has resulted in scientists and engineers researching alternative energy resources that can meet the future energy demand. The dramatic drop in renewable energy costs over the years has not only expedited the use of renewable energy to replace fossil fuels in power generation. Renewable electricity is increasingly beginning to replace fossil fuels in other industries due to its low cost, the reason being that renewable electricity is currently cheaper per unit of energy than oil, about the same price as fossil gas but still higher than coal [5]. As such, in the creation of sustainable development strategies, renewable energy plays an important role. In addition; three primary technological advancements are often included in Sustainable Energy Development Strategies: energy savings on the demand side, energy efficiency gains on the production side, and the replacement of fossil fuels with diverse renewable energy sources. As a result, strategies for integrating renewable sources into coherent energy systems impacted by energy savings and efficiency measures must be included in large-scale renewable energy implementation plans [11].

Realizing the smart grids and market's goal entails a significant shift in electricity systems, involving a wide range of stakeholders and posing a variety of technological, social, economic, political, and environmental issues. These must be fully considered in decision support tools for electricity system agents. Demand response, distributed generation, distribution grid modelling, and efficient market integration are examples of emerging paradigms (models) in the field of smart grids that may be tested using modelling and simulation as a flexible and rich modelling framework (Ringler et al, 2016). Renewable energy can be implemented either through a practical approach (construction) or modelling and simulation.

2.1 Modelling and Simulation of Distributed Energy Resources

A DER (gas-fueled generators, solar panels, electric vehicles, etc.) is a power generation in a small-scale unit to be operated locally and produces energy that is often consumed close to the distributed energy resource. The modelling and simulation of a distributed energy resources distribution network are carried out in this project. In addition to the presentation of the general network performance, a switching operation that selects a distributed energy resource based on factors such as availability and efficiency is also considered and analysed. In the analysis and design of complex systems, modelling, and simulation are becoming increasingly important facilitators. Modelling and simulation research is changing from simulation approaches to modelling methodology and technology to address issues of ever-increasing complexity [13]. Figure-1 shows a Distributed Energy Resources Distribution Network and The Switching Operation.

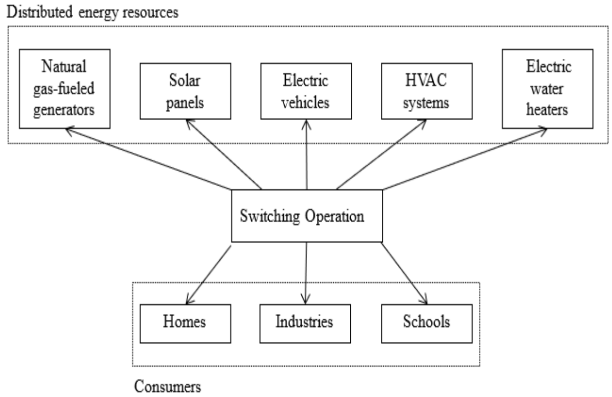

Figure-1. A distributed energy resources distribution network and the switching operation [6].

Modelling is a complicated process that entails a variety of actions, each of which necessitates mastery of specific skills. As a result, any level of competency must be presumed to be acquired gradually. The ability to produce models necessitates the gradual evolution of a series of epistemological commitments: first, to the notion of a separation between phenomena and noumena: being able to appreciate that a representation may be of, but not identical to, that which is being represented; second, to the possibility of producing a representation through the development and deployment of a system of formal elements; and third, to the notion of prediction using simplified representations that enable emergent behaviour to be identified [14].

The simulation model is primarily intended for the examination of renewable energy resource utilisation opportunities, their management throughout the design phase, and the investigation of problems that may arise because of the chosen solution. The accepted solution is concerned with the management options available, as well as the monitoring and control, and the command of renewable energy sources and consumers[15]. This study offers a simulation of a Distributed Energy Resource System: Solar Energy, created with the MATLAB application software Simulink, MATLAB, and Simscape Electrical. A modelling and simulation concept is shown in Figure-2.

3. METHODOLOGY

The modelling and simulation of a distributed energy resource network in which an island and the main utility microgrid will be discussed here, as well as the description of the combination of the components required and how their various functions within the system. The system design involves designing the system and testing the system with different values and taking the variable

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load to control the power supplied from each renewable source.

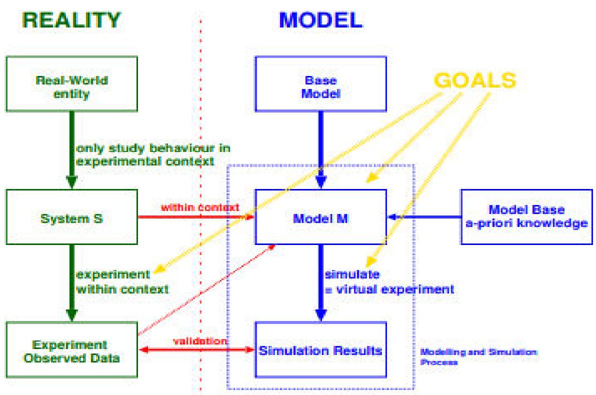

Figure-2. Modelling and simulation concepts [13].

A detailed description of the components utilised throughout the simulation process, a brief description of the circuits used, and a comprehensive evaluation of the system will be discussed. In this project, Matlab, Simulink, and Simscape were the methods used to actualise the modelling and simulation. A block diagram of a Distributed Energy Resources Network is shown in Figure-3.

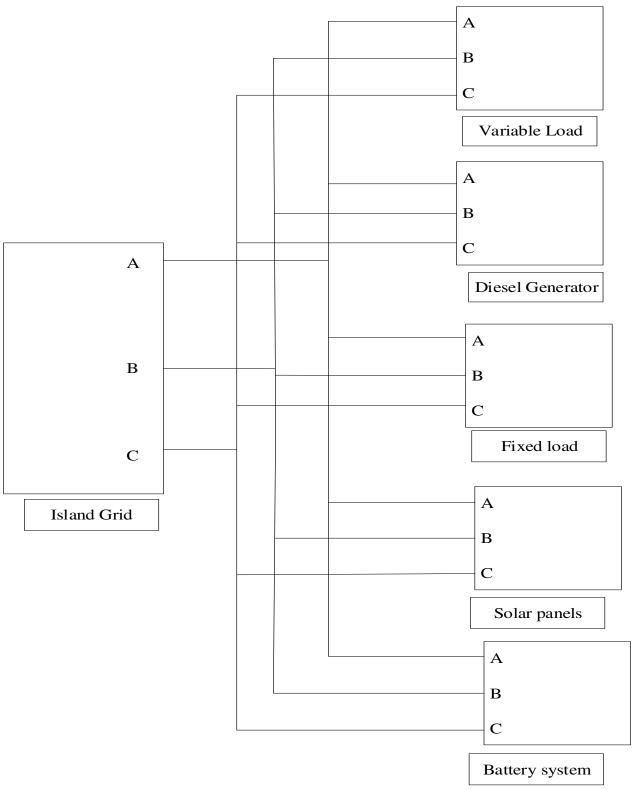

Figure-3. A block diagram of a distributed energy resources network.

3.1 Modelling and Simulation of a Distributed Energy Resources Network

The Simulink model of the island and main utility microgrid is shown in Figure-4. The island grid is connected to the main utility grid by a relay system.

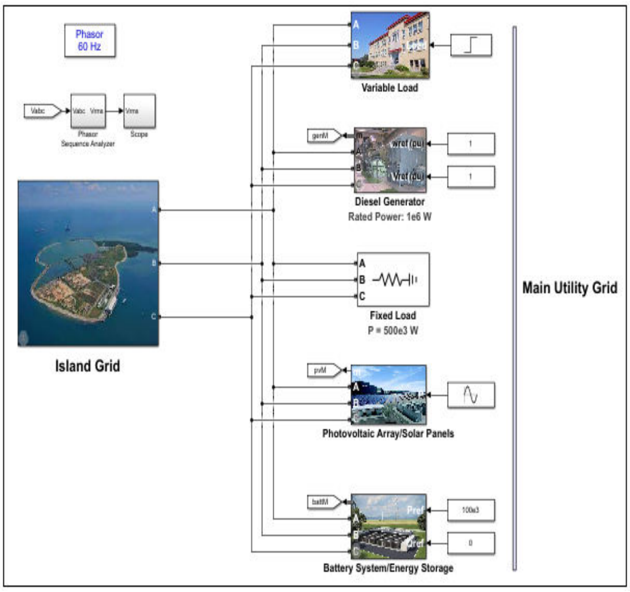

Figure-4. Simulink model of the island and main utility microgrid.

a. The Island Grid

The island grid consists of a command centre, a three-phase source, a three-phase transformer (two windings), and a three-phase breaker, as shown in Figure-5. The three-phase block implements a three-phase circuit breaker where the opening and closing times can be controlled either from an external Simulink signal (external control mode) or from an internal control timer (internal control mode). This block can be used in series with the three-phase element of an element one desires to switch. The arc extinction process of the three-phase fault block is the same as for the breaker block.

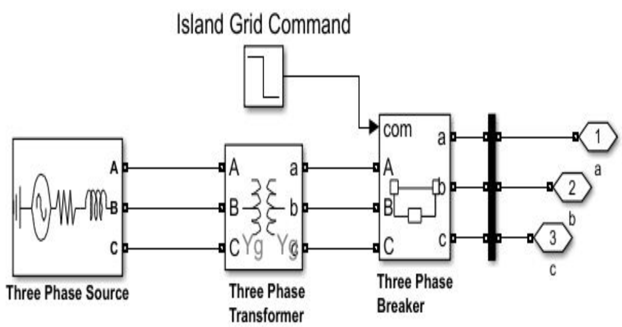

Figure-5. The island grid simulink block components.

b. The Main Utility Grid

The main utility grid consists of three distributed energy resources: a variable and a fixed load. The

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distributed energy resources are a battery system, a photovoltaic array, and a diesel generator.

c. Battery System/Energy Storage

The Battery System/Energy Storage Simulink block models a generic grid-connected energy storage system (ESS) rated at 500 kW, as shown in Figure-6. The inputs to this block are the commanded active and reactive power of the ESS. The ESS is assumed to have four-quadrant operations.

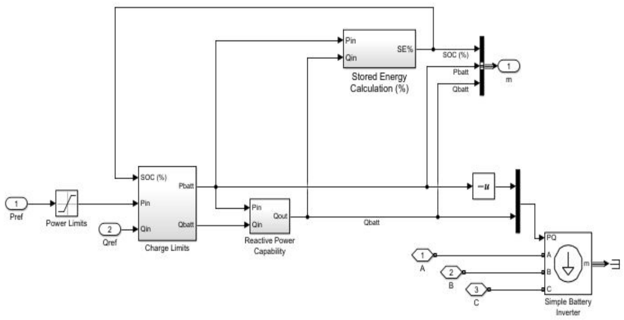

Figure-6. The island grid Simulink block components.

The island and main utility microgrid were subjected to dynamic disturbances by first disconnecting the island grid entirely from the main utility grid, which is done by opening the island grid breaker for 10 seconds. Then, add an additional 300 kW load at 40 seconds on the variable load. To obtain a different result, Subject the island and main utility microgrid to dynamic disturbances by first adding an additional 300 kW load at 20 seconds on the variable load. Then, disconnect the island grid entirely from the main utility grid for 35 seconds.

Similarly, the process was repeated for variable load at 50 seconds. To obtain a different result, the process was repeated at 45 seconds and adding an additional 300 kW load on the variable load at 15 seconds; also, first adding an additional 300 kW load at 50 seconds on the variable load. Then, the island grid was entirely disconnected from the main utility grid for 20 seconds.

d. Photovoltaic Array/Solar Panels

The Photovoltaic Array/Solar Panels Simulink block models a grid-connected solar array rated at 500 kW using the Three-Phase Dynamic Load block, as shown in Figure-7. The input to the block is the power output of the grid-connected PV array.

e. Diesel Generator

The diesel generator Simulink block contains a synchronous generator, diesel governor and excitation system to represent the dynamics of a Genset rated at 1 MW, as shown in Figure-8 The inputs to the basic Diesel generator block are the desired speed reference (in PU) and the desired voltage reference (per unit).

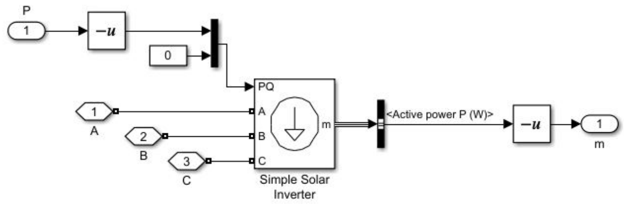

Figure-7. The photovoltaic array/solar panels Simulink block components.

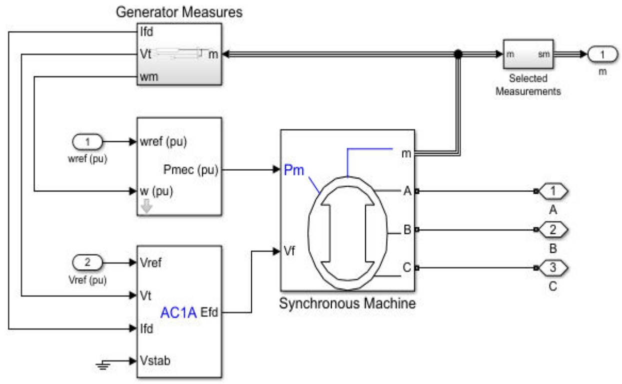

Figure-8. The diesel generator Simulink block components.

f. Variable Load

The variable load Simulink block implements a lumped approximation for a distribution feeder. The input (active power) is scaled accordingly to generate the desired load, as shown in Figure-9.

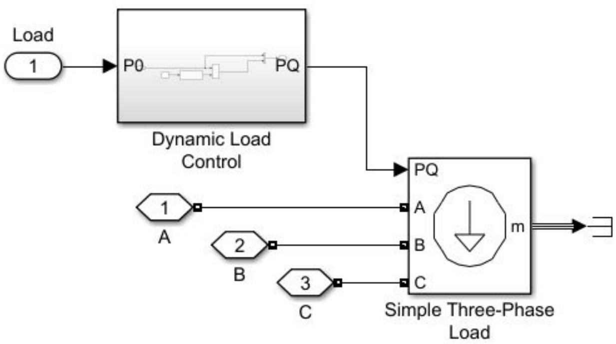

Figure-9. The variable load Simulink block components.

4. RESULTS AND DISCUSSIONS

The results of the simulations of disturbances introduced to the island and the main utility microgrid models is presented and discussed.

As seen in Figure-11, frequency disturbances (Microgrid Frequency graph) occur due to the islanding of the microgrid at 10 seconds, and the additional load added at 40 seconds. The distributed resources also change over time according to how the microgrid is currently operating, as seen in the Distributed Resources graph. The solar array (PV) tracks the irradiance over time. The diesel generator (GenSet) tries to hold everything steady by making up all the additional power output (maintaining

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unity frequency and unity voltage) as islanding occurs at 10 seconds and as the additional load is added at 40 seconds. Also, the energy storage is seen to maintain a 100 KW steady power output. The Microgrid Voltage is a flat or steady line instead of the expectation of a three-phase AC waveform because the simulation used a phasor simulation type as seen on the power grid block.

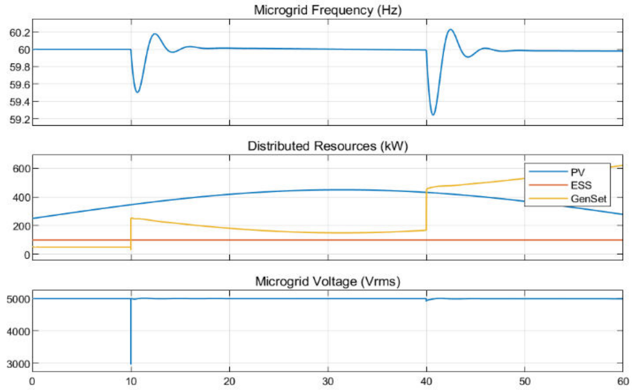

Figure-10. The three-phase circuit breaker is opened at 10 seconds, and power is added at 40 seconds.

The performance of the distributed energy resources network of the simulation is shown in Figure-12. The only difference between this result and the result in Figure-12 is the change in the timing of the disturbances. The disturbances in Simulation 2 are recorded at 35 seconds.

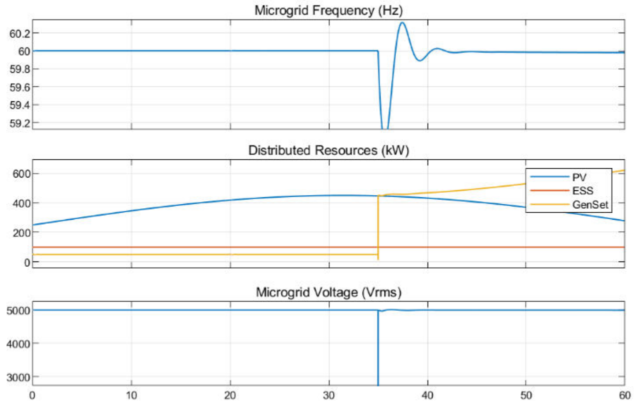

Figure-11. The three-phase circuit breaker is opened at 35 seconds, and power is added at 20 seconds.

The performance of the distributed energy resources network of the simulation is shown in Figure-13 the only difference between the results in Figure-13 and the results in Figures 11 and 12 is the change in the timing of the disturbances. The disturbances in Simulation 3 are recorded at 50 seconds.

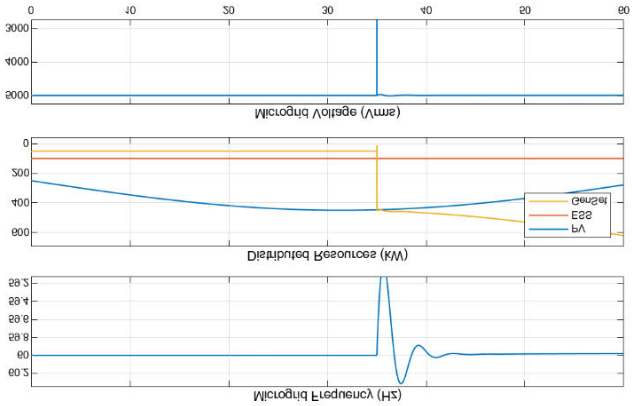

Figure-12. The three-phase circuit breaker is opened entirely, and power is added at 50 seconds.

The performance of the distributed energy resources network of the simulation is shown in Figure-14 the only difference between the results in Figure-14 and the results in Figures 11, 12, and 13 is the change in the timing of the disturbances. The disturbances in Simulation 4 are recorded at 45 seconds.

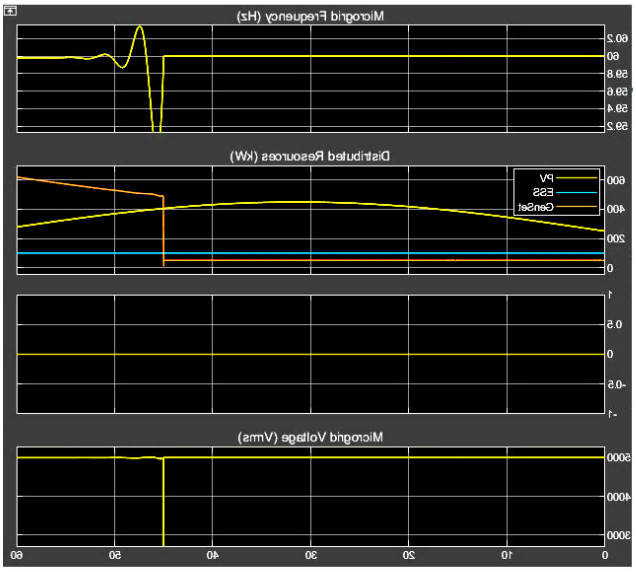

Figure-13. The three-phase circuit breaker is opened at 45 seconds, and power is added at 15 Seconds.

The performance of the distributed energy resources network of the simulation is shown in figure 15. The only difference between the result in Figure 20 and the results in Figures 11, 12, 13, and 14 is the change in the timing of the disturbances. The disturbances in Simulation 5 are recorded at 20 seconds.

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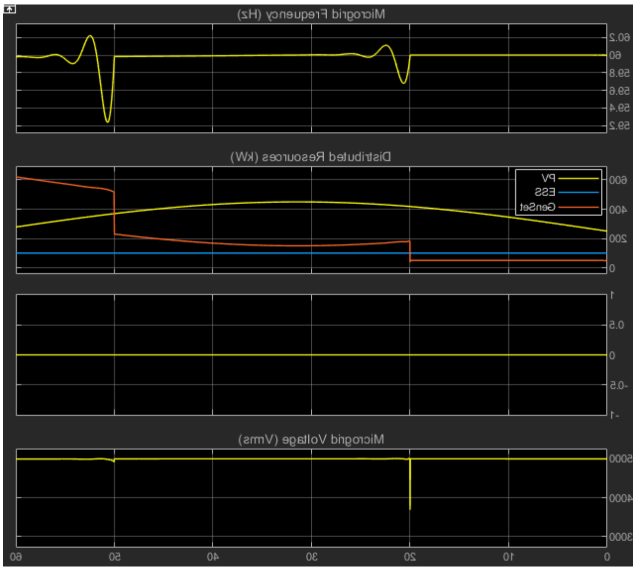

Figure-14. The three-phase circuit breaker is opened at 20 seconds, and power is added at 50 seconds.

5. CONCLUSIONS

Renewable energy generation is replacing conventional means of power generation all over the world. This project presents island and main utility grid analyses, which are designed and operated to ensure the effective use of distributed energy resources as they are interconnected together to improve the power being supplied. The simulation of the micrograds was accomplished with the use of Simulink in Matlab software and Simscape electrical. The graphical results were obtained after the three-phase breaker of the island grid was opened at a specified time in seconds, and a 300kW load was added at a specified time in seconds on the variable load as all specified times are within 60 seconds range set on the simulator. It was discovered that at the time at which the island grid three-phase circuit breaker opens is greater than the time the 300kW load is added; only the time of the island grid disconnection is represented on the graph, whereas the time at which the island grid-three phase circuit breaker opens is less than the time the 300kW load is being added, both times in seconds will be denoted on the displayed graph. Therefore, the project gives an insight into how sufficient and reliable the distributed energy resource system can be as it provides a constant power supply to the equipment.

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