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SIMULATION STUDY OF RESIDENTIAL DISTRIBUTION MICROGRID

T. M. Priya[1], Shashi Ranjan[1] and L. Ramesh[2]
MGR Vision 10 MW, M.G.R Educational and Research Institute (University), Chennai, India
E-Mail: priyatm1619@gmail.com

ABSTRACT

The term 'micro' means small; grid means 'a network or a matrix'. Many such small networks, centrally supervised and interconnected to form a self-generated power called the Micro-grid. For a pervasive Green energy to exist, three probable solutions are taken into account; generation, economy and sustainable power generation. Sustainable power generation utilizes the renewable resources and hence are more environment friendly with lower carbon footprints. The key objective of this work is to model a self-sustained Micro-grid from the existing Indian distribution feeder, which means a small scale interconnected, centralized single controllable system where the particular region is supplied with distributed energy resources like solar and wind instead of the main grid.In this work,the existing system, implemented in PSCAD, is taken from the Indian Distribution Feeder, which comprises of 2 regions each supplied with 100 KVA transformers. One region is 33 bus systems and the other region is 38 bus systems. They are taken as two separate MGs and these further are split into two sub MGs producing a total of four MGs altogether. Distributed energy sources like wind, solar and diesel are designed individually and interconnected finally to make up a Standalone MG. The results are obtained in PSCAD software package.

Keywords: sustainable power generation, standalone micro-grid, solar, wind, diesel, conventional sources.

INTRODUCTION

In the present scenario, power generation capacity doubles for every ten years. For instance, India's power generation capacity for the year, 2004 is 1,12, 700 MW and for the year 2014, it has doubled to 2,34,600 MW. If this situation persists, then for the next ten years it would not be a surprise even if the generation raises up to 4.75 lakh MW. Conventional sources like thermal, wind, hydro, nuclear and other sources brings up the installed capacity to around 1,95,000 MW. The answer to the energy crisis could be found if the difference between the demand (kW) and consumption (kWh) is understood. The review of standalone Microgrid [MG] deals with several novel advancements and applications in this field which will be discussed in this section. According to main objective of this work, residential MG and its implementation is discussed in [2]. It focuses on implementing MG for residential purpose and also involves modeling of distribution energy sources model like wind and solar [3] with necessary equations and strategies for obtaining energy from photovoltaic cells. Hybrid energy makes the system stable by incorporating diesel into the system. It is modeled and simulated in PSCAD [4]. Following the modeling, there is a necessity to evaluate the feasibility of the control strategies which are to be adopted for MG operating in islanded mode [5]. Energy management in grid connected and standalone MG is also discussed and evaluated in [6]. Another new approach, desalination, for optimal operation of MG is introduced in [7]. It deals with sea water characteristics and water demand of the island residents, a strategy for allocation of power for load, batteries and diesel generators are introduced along with economic and environmental benefits of the system. It makes use of Nondominated sorting genetic algorithm II. Frequency control is another major issue which needs to be considered for an effective operation of the system and the solutions to overcome this problem is feasibly obtained in [8]. It makes use of battery energy storage systems, diesel generator and strategies for coordinated frequency control. A system is considered standalone only when the system is able to provide sustainable results even after certain irresistible disturbances in the system such as the inability to connect to main grid or defunct of certain distributed energy sources used in the system. In this case, autonomous distribution of energy provided by diesel is explained in [9]. Several case studies and its results involving the management of voltage and power using the battery storage system and diesel are discussed in [10]. [11] Deals with financial analysis of the system to implement MG in rural side as it provides various decision strategies to obtain appropriate solution for a sustainable energy management.

Review on standalone MG provides a thoughtful solution to the current situation prevailing in many developing countries like India. This work is a continuation of the previous work 'Design and Analysis of Sustainable LV Residential Microgrid' which is represented in the paper [1]. The proposed model is simulated in PSCAD incorporating the modeling of wind, solar and diesel into the system along with few case studies.

EXISTING DISTRIBUTION SYSTEM

The layout of existing systems for region 1 and region 2 are shown in the Figure 1 and 3, respectively (shown on page 6). These two regions, from the Indian distribution feeder, are taken for the study. The grid

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capacity is 11KV for both the regions. Region 1 has two feeders namely Feeder-1 and Feeder-2. Similarly, Region 2 also has two feeders namely Feeder-1 and Feeder-2. The regions comprise of domestic and agricultural loads. The PSCAD implementation of these two regions and the results obtained from the existing system will be discussed in the next section.

Existing system of Region 1

The existing system of region 1 consists of three feeders where all the loads are connected to 100KVA transformer. The power supply to the loads are provided by the Indian Distribution System, and it is radial type of distribution. This region is a low voltage distribution system where most of the loads are domestic and agricultural loads. The generation capacity is 11KV and a step down transformer is used to step down the voltage from 11KV to 440V. This region consumes of about 36KW load for domestic purpose, 7.355KW load for agricultural purposes and 13KW for other purposes. Figure-1 shows the existing system for region 1 implemented in PSCAD.

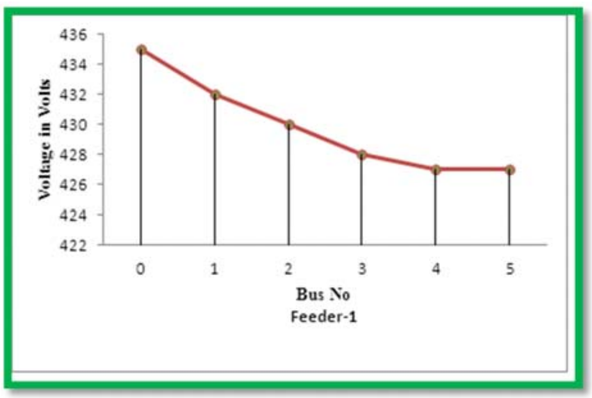

Figure-2(a). Output voltage of existing system1 (Feeder1).

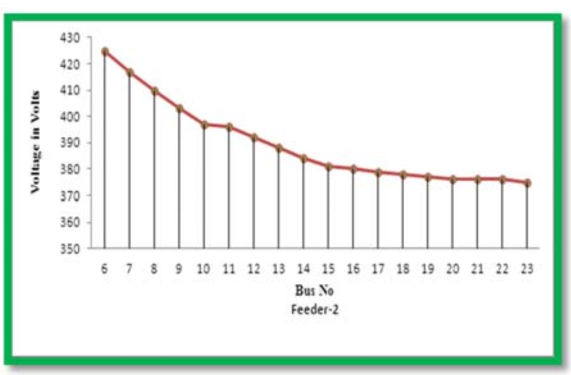

Figure-2(b). Output voltage of existing system1 (Feeder2).

Existing system of Region 2

The existing system of region 2 consists of two feeders where all the loads are connected to the 100KVA transformer. Similar to region 1, the supply is provided to the feeders through Indian distribution system and a step down transformer is used to step down the voltage from 11 KV to 440V for a generation capacity of 11KV. This region consumes an overall domestic load of about 67KW and agricultural load of about 37.5HP. Figure 3 shows the existing system for region 2.

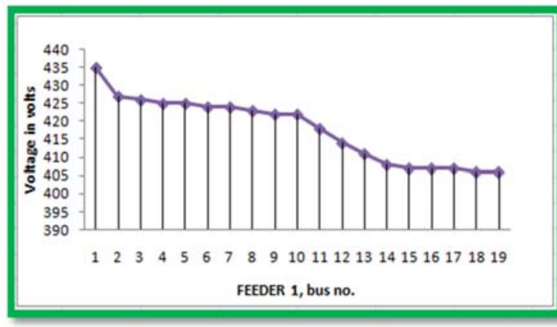

Figure-4 (a). Output voltage of existing system2 (Feeder1).

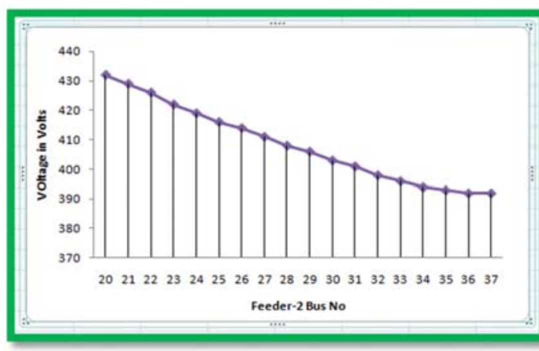

Figure-4 (b). Output voltage of existing system2 (Feeder2).

It is clear from the graphs obtained, in Figure-2 and Figure-4 that the output voltages drop drastically from the first bus to last bus in both the regions supplied with existing distribution system.

Table-1(a). Load specifications for region1.

Basic details of the existing layout-1	
Domestic Load (KW)	36 KW
Agricultural Load in (KW)	7.355 KW
Other Load (KW)	13 KW

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Table-1(b). Load specifications for region 2.

Basic details of the existing layout-2	
Domestic Load (KW)	62 KW
Agricultural Load in (HP)	37.5 HP

Table-1 shows the load specifications for the regions 1 and 2.

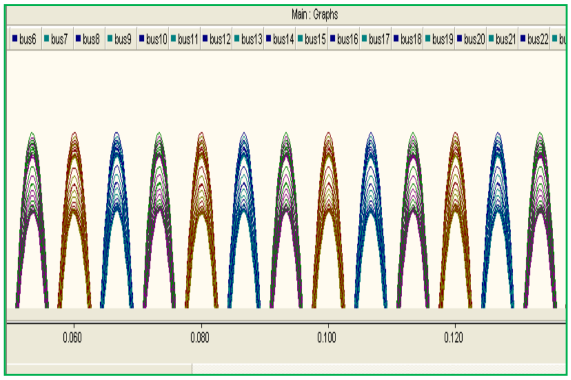

Figure-5(a). Output obtained in PSCAD for existing system1.

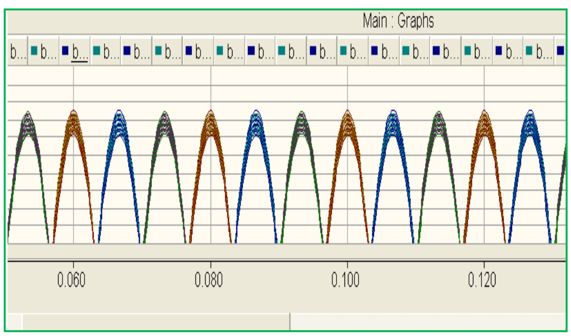

Figure-5(b). Output obtained in PSCAD for existing system2.

The output voltages obtained at each buses is shown in the Figure-5. It is clear from the graphs that there is drastic drop in the voltage levels from the first bus to the last bus.

MODELING OVERVIEW

Modeling of wind and solar are already discussed in our previous work. Hence, modeling of diesel is available in PSCAD library, which is discussed in this section. Figure 6 shows the modeling of diesel available in PSCAD library.

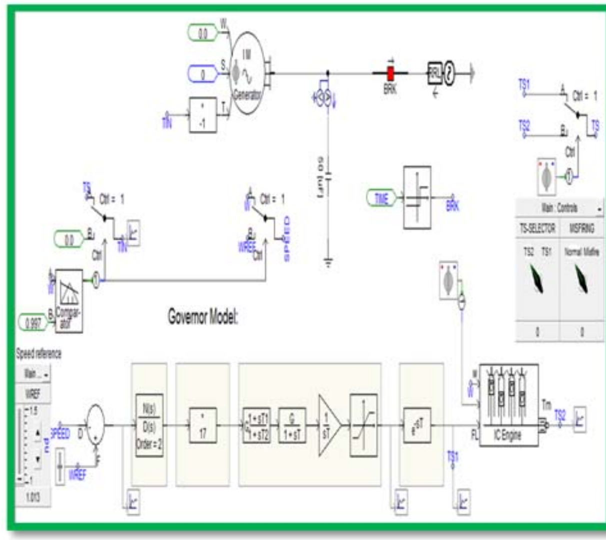

Figure-6. Modeling of diesel in PSCAD.

The generator used here is an induction generator and the prime mover to the generator is the diesel engine. The diesel engine used here is to represent cylinder ripple and misfire. The machine is started as a motor (Direct on line start).Until the speed builds up, the input torque is not applied. In this condition, the governor also is not activated. Once the simulation has reached a steady state, the speed reference is changed to observe the governor response. Governor model used here is Woodward Governor model and initial input is given as 0.793. Machine is started in 'Torque 'mode from rest. The induction generator operates at a speed of 1.013 PU. The steady state torque under this condition is given as 0.793 PU. And, the BRK is closed at 0.5 seconds.

RECONSTRUCTED MG

The existing system of the two regions is divided into four MGs. It is depicted in the Figure-7(shown on last page). Feeder-1 of the region 1 is taken as MG1. Feeder-2 of the region 1 is taken as MG2. Feeder-1 of region 2 is taken as MG3 and Feeder-2 of region 2 is taken as MG4. MG1and MG3are supplied with wind energy. MG2 and MG4 are supplied with solar energy. Like power grid, diesel energy is also connected to one of the buses of the system. Depending upon the capacity of the loads, the required power for wind, solar and diesel are calculated. The MG is reconstructed into two types namely the interconnected mode and the grid connected mode.

Interconnected mode

Figure-7 shows the structure of interconnected MGs. Interconnected MGs disconnect the utility grid from their system and shares power among them. If there is a failure in any one of them, then the other 3 will compensate the overall loads. In case of failure of any wind or solar energy, then diesel comes in handy, which

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will be explained in the next section. Figure 8 shows the graph of interconnected system.

Standalone mode

Figure-7 shows the structure of Standalone MG. Similar to interconnected MG, it is also isolated from the utility grid. In this mode, all the MGs are interconnected and they are supplied with diesel energy. Figure-8 shows the graph of standalone MG and it clearly depicts that the standalone MG produce better results than the interconnected MG. In case, whole system is a failure, then grid connected system comes into practice, which will be explained in the next section.

Grid connected mode

Figure-7 shows the structure of grid connected mode. As the name indicates, 'grid connected mode', it consists of the system connected with the grid supplying the entire load. In this mode, the supply is provided from renewable sources, diesel and main grid as well. The opening and closing of the breakers help in switching to different operations. Breaker, BRK is connected between the main bus and the utility system. BRK1 is the corresponding breaker of MG1. BRK2, BRK4, BRK5, BRK6 and BRK7 correspond to MG2, diesel energy, main grid, MG3 and MG4 respectively. Reliable and sustainable power supply is given to all the loads in this way. Figure-8 shows the graph of grid connected system. This comparative graph shows that the results obtained from the grid connected MG is better than interconnected MG.

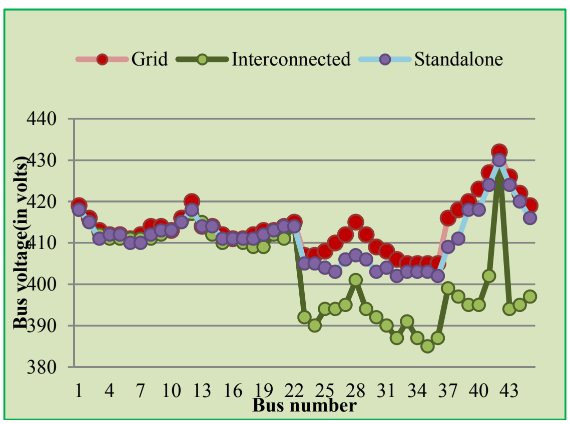

Figure-8. Grid connected Vs Interconnected Vs standalone MG.

CASE STUDY ANALYSIS

Analysis of Standalone MG, in case of failure of wind supply in MG1 and MG3

MG1 and MG3 are supplied with wind energy. In this case study, standalone alone MG is studied and analyzed considering the failure of MG1 and MG2 supply. Figure-9 shows the graph of comparison between the interconnected MG and the standalone MG. The results show that the Standalone MG provides better results than interconnected MG. This is because the interconnected MG does not include diesel in its system whereas Standalone MG includes diesel in its system and hence proven that diesel energy makes the system 'Stand Alone' sustainable source of energy.

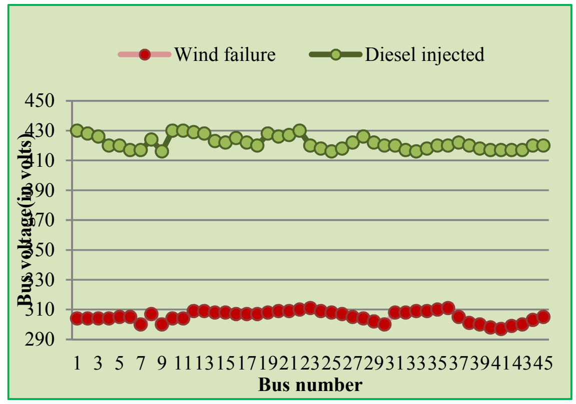

Figure-9.

MG2 and MG4 are supplied with solar energy. In this case study, standalone MG is studied and analyzed considering the failure of MG2 and MG4 supply. Figure-10 shows the graph of comparison between the interconnected MG and the standalone MG. The results show that the Standalone MG provides better results than interconnected MG.

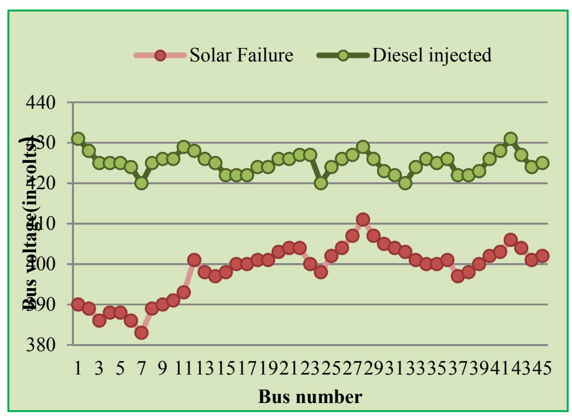

Figure-10. Wind failure and diesel injected.

From Figure 9 and 10, the failure of wind energy in fig 9 results is very low compared to failure of solar energy results in Figure-10. This is because the solar energy is available only during the day time whereas the wind energy is available all day long. Therefore, the average availability of power from solar is taken and analyzed in Figure-9.

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COST ESTIMATION

Figure-11 shows the cost estimation graph for each MG. It is the graph plotted between investment and payback period. The payback period for MG1 and MG3 is 5.5 years and similarly the payback period for MG2 and MG4 is 7 years. Payback period for diesel is 3 years.

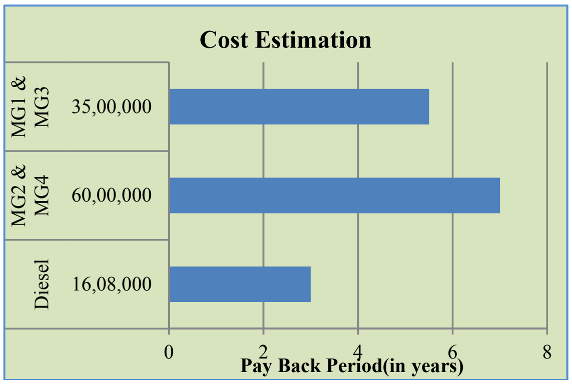

Figure-11. Investment Vs Pay back period.

CONCLUSION AND FUTURE WORK

MG for residential purpose is simulated in PSCAD/EMTDC software. It includes the renewable energy sources and diesel energy. Wind, solar and diesel energy models are designed in PSCAD. Standalone MG is the prime focus of this work. The results obtained show that the Standalone MG provides better results than Interconnected MG. However, the results obtained can be future improved by using energy storage batteries and hence can be made stable by using controllers, which will be carried out in future.

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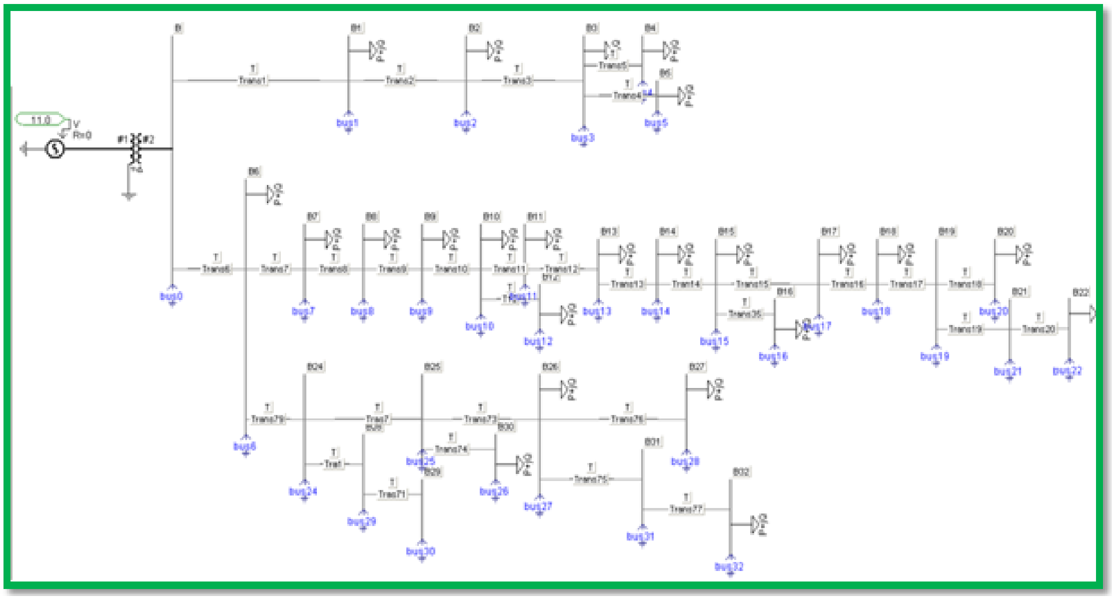

Figure-1. PSCAD implementation of existing system of region 1.

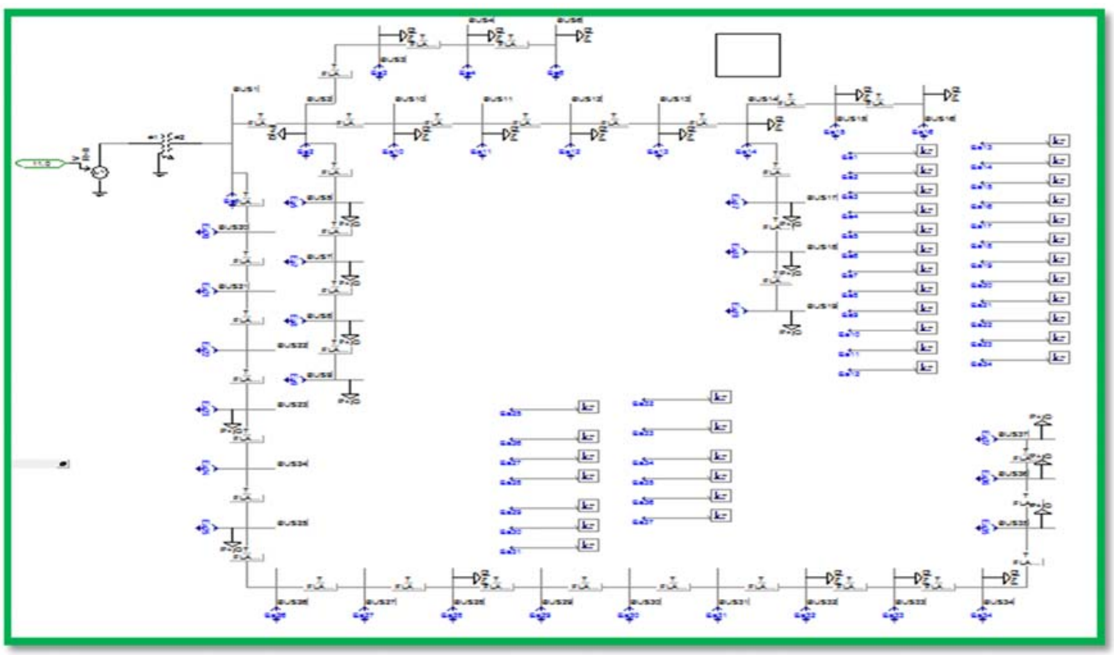

Figure-3. PSCAD implementation of existing system of region 2.

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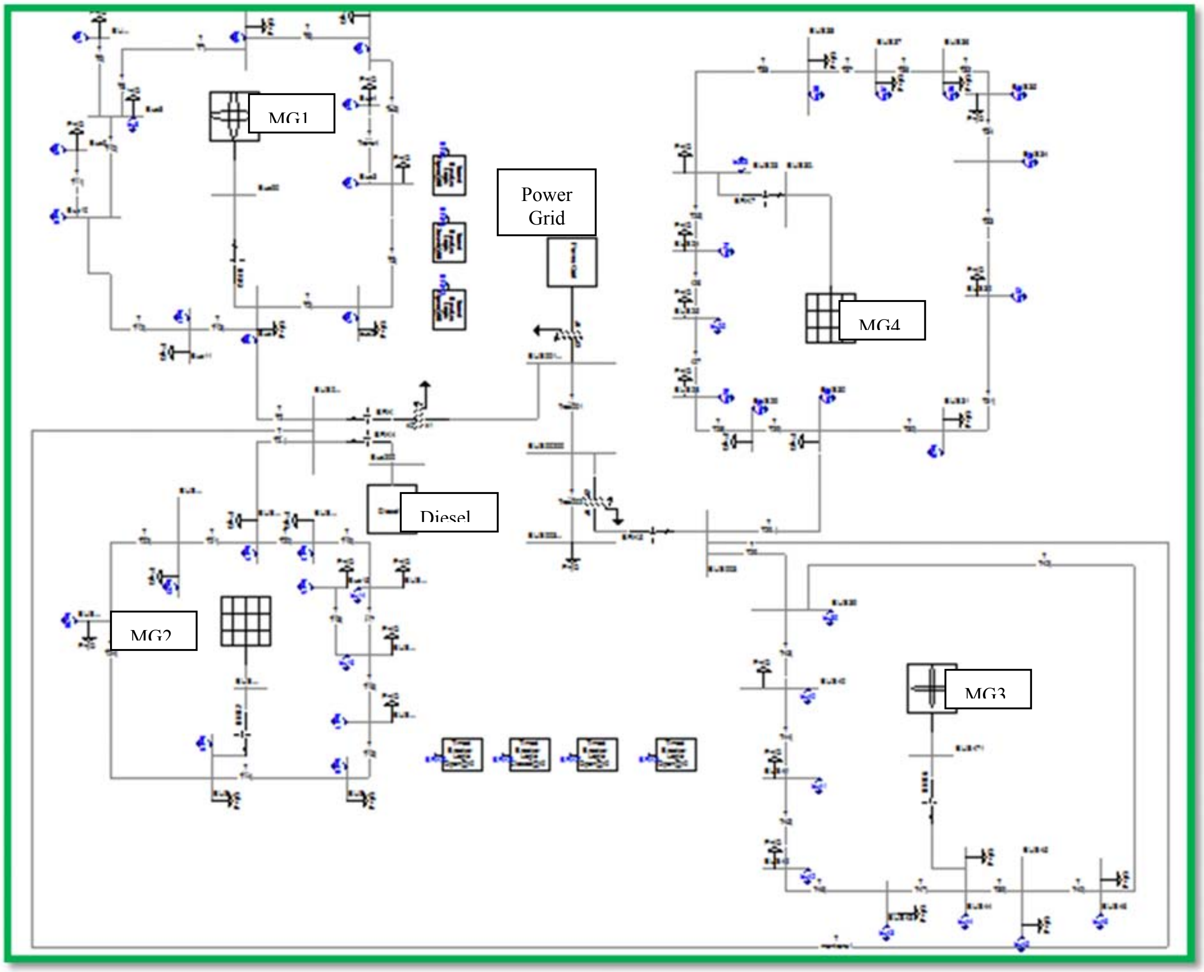

Figure-7. Proposed model.