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Determination of the Suitable Power Delivery Method towards Compatible Line Loadability in Microgrid Using PowerWorld Software

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Abstract

Microgrid system which is integration of RE resources as DG into electrical grid is increasing substantially due to encouraging government policy. With the development of Microgrid, it is necessary for utility companies to deliver efficient power from power generation to consumer. Power crisis is one of the major issues and the production of power should be efficient and reliable in power dispatch. So, the objective of this project is to select a suitable power dispatch method towards compatible line loadability in Microgrid. The operating mode of Microgrid used in this project is the islanding mode. The method of power dispatch, which is power flow, economic dispatch and optimal power flow was identified in Microgrid. Each of the three methods was then analyzed by using the different conditions of power management such as using a single generator, loads distance as well as types of distributed generators used. The conditions of power management that involve in this project are power during one DG is used, distance between DG and load and different types of DG. Simulation was conducted to choose a suitable method of power dispatch towards compatible line loadability in Microgrid by using PowerWorld software.

Keywords

Distributed Generator, Microgrid, Power Flow, Economic Dispatch, Optimal Power Flow, Demand Side Management, Power Management

1. Introduction

A Microgrid is defined as a group of Distributed Generation (DG), energy storage devices and loads, serviced by a distribution system [1]. The capacities or sizes of Microgrid vary from few kilowatts up to Megawatts [2]. For the conventional DG usually used fuel and diesel as micro source. Nowadays, most DG used Renewable Energy which is photovoltaic (PV), high concentration photovoltaic (HCPV), wind turbine (WT), and hydro plants. For energy storage, batteries, super capacitors, and flywheels were used [3]. These types of sources and energy storage devices produce voltage in ac or dc with various amplitudes and frequencies. To convert source, power converter is needed, for example VSC (Voltage Source Converter) [4]. However, applications of DG in large-scale have faced complex challenges that need to be solved before the benefits of DG can be realized [5]. The Microgrid has three operating modes. First is the grid-connected mode (non-autonomous) that operates in parallel to the grid. Second is the island mode (autonomous) that operates without utility grid and provides uninterruptible power supply service. Third is ride-through between two modes [6]. The development of Microgrid is based on the encouraging government policy, and it was an attractive plan [7]. Malaysia is one of the countries that develop a Microgrid system to deliver power at local demand especially for rural areas. Rural areas at Peninsular Malaysia, (Perak) Sabah and Sarawak have their own Microgrid to supply power to local demand with the maximum capacity usually not more than 50 MW [8]. In recent years, the development of Microgrid power stability has become a major issue and must be solved properly [9]. To deliver suitable power to consumers, the method of power dispatch must be identified.

In this project, three methods have been approached which are power flow (PF), economic dispatch (ED) and optimal power flow (OPF). Power flow describes a steady state analysis whose target is to determine the voltages, currents, and real and reactive power flows in a system under load conditions [10]. Power Flow is about minimizing the total real power losses and maximizing the power transfer to consumers. Power Flow methods will also draw a higher cost to the operating generator. In other words, power is delivered by considering losses in line and maximizing the power generation output. The cost of operation and generation was neglected [11]. Economic Dispatch is about minimizing the operating cost during power losses in the line and minimizing the generating cost in generation. Economic Dispatch is also said to determine the cost of power generating DG and it will minimize the overall cost of fuel, PV and WT needed to serve the system load [12]. This method also applies to economic scheduling of plants output without considering transmission losses in line. Then the output of each of the plants has to achieve the total cost of generating at a minimum [13]. For optimal power flow, it is a method of combining power flow and economic dispatch method [14]. Optimal power flow also combined both methods which are minimizing the total real power losses, maximizing the power transfer to consumer, minimizing the operating cost during power losses in line and minimizing the generating cost in generation. The OPF problem aims to achieve an optimal solution of a specific power system objective, such as fuel, PV and WT generation cost while maximizing the power transfer to consumer [15]. OPF will also minimize the total of active power losses and minimize the operating cost when it has losses in line [16].

There are many such things that must be considered to evaluate the suitable method of power dispatch in Microgrid. The condition of Power Management (PM) is required for sound operation of a Microgrid [17]. The PM used in this project is condition of power when one DG is used in a certain value of load [18]. For the second PM is the distance between the DG with load because long, medium or short distance of transmission line will affect the power quality to consumer [19]. For the last PM is type of different DG used in Microgrid system. The different types of DG draw a different power output level, for example, is fuel type that draws a high power output as compared to PV and WT [20]. By considering the PM in Microgrid, the suitable method for power dispatch can easily be selected towards compatible line loadability.

Power Management is applied into this study, such as using a single unit of generator, distance between loads and generators as well as types of distributed generation (DG) used.

1.1. Problem Statement

The existing government policy today is moving to development of Microgrid with some RE as DG source. The use of DG in Microgrid gives the impact on power quality and stability during the process of power dispatch. The performance of power during islanding mode causes a change on power dispatch quality to consumers. This is because, during islanding modes, the DG will continue to supply power to local demand and lead to issues of power quality.

1.2. Project Objectives

The objectives of this study are to identify the method of power dispatch used in Microgrid, to analyze the method of power dispatch by using the different Power Management on Microgrid through PowerWorld software and to evaluate the suitable method of power dispatch towards compatible line loadability on Microgrid.

1.3. Scope of Projects

This project focuses on finding a suitable power delivery method toward compatible line loadability. The scope of this project is to find the suitable power delivery method on Microgrid starting from power generation to consumers. The mode of Microgrid used in this project is islanding mode.

2. Literature Review

2.1. Microgrid

With the development of DG nowadays based on renewable energy sources (RES) was increase the development of Microgrid in certain areas [1]. Microgrid can be defined as combination, group or cluster of electricity generation, system electrical energy storage (EES) and load. The meaning of DG is a generation of electricity that supplies a power close to power consumer via some distribution network. With the development of Microgrid, it gives a lot of benefit especially for rural areas. In a modern power sector, to supply the reliable power to consumers, demand side management (DSM) and supply side management (SSM) play an important role in supplying an efficient power in low level of losses. To supply reliable power to consumers, the implementation of DG must be developed in distribution area.

Microgrid can be concluded as implementation of micro source and ESS complete with power electronic equipment to be installed in the system [2]. It will provide electricity with reliable power for consumers. The implementation of DG as Microgrid system will help to reduce losses and increase the system efficiency to deliver power as compared to main grid.

Microgrid has three types of area which is remote microgrid, facility grid and utility grid [3]. A remote microgrid uses decentralized control method as operation system and it never has connection between utilities. For the power that use is maximum and limited for the customers. Its power quality demand is high quality as compared to a facility Microgrid. The next type of Microgrid is Facility Microgrid. Its connection is normally connected to host utility and usually a single business-entity Microgrid. For the last type of Microgrid is utility Microgrid. The utility Microgrid has the connection to the utility at one point (it could be also multiple connection points for grid connected reliability) of point common coupling (PCC). The PCC acts as circuit breaker to connect and disconnect from the main grid. The area of utility grid is large (compared with facility Microgrid) and contains a lot of different types of DG and load.

2.2. Power Quality in Microgrid

Microgrid is a regionally limited energy system of distributed energy resources, consumer and optimal storage [9]. It optimizes one or many of the following power quality and reliability and sustainability and it may continuously run in islanding mode either on-grid or off-grid status. The interconnection of DG to the utility grid through power electronic converters has raised concern about power quality and proper load sharing between different DG and the grid. During islanding mode, the power quality will change and vary at certain times.

Since the equivalent physical inertia of Microgrid is almost same with the main grid, some medium or even small problems, such as the output power fluctuation of PV panel, wind turbines and the cut in or cut off loads may result in power quality and stability issues [10]. So, to solve this problem author states that small-signal models of a Microgrid contain asynchronous generator due to wind turbines, a synchronous diesel generator, power electronic due to energy storage and power network are used. The simulation results show the fact that ESS can release or absorb power more quickly which track and compensate the change of wind power to eliminate the power unbalance.

2.3. Method of Power Dispatch in Microgrid

There are some methods to deliver power to local demand load. The method that usually used in system dispatching is power flow, economic dispatch and optimal power flow. The increase in DG technologies in distribution level is due to an increase in demand for load [21]. The growing of high needed in reliability and quality power causes the suitable method of power dispatch from generation level to distribution level. This method can determine the viability of one DG technology in economic way. So, to deliver reliable power to consumers, a suitable method must be considered first. When the method was identified, the location of installation DG can be identified.

2.3.1. Power Flow

Power flow is the most important requirement in PM and planning tools. Besides that, Power flow analysis is the backbone of power system analysis [12]. This is very important for planning, operation, scheduling and exchange of power between utilities because the main information of power flow analysis is to evaluate the value of magnitude and phase angle of voltage at each bus and the real and reactive power flowing in each transmission line between the interconnected buses. By using this power flow method, the losses in line will be minimized. So, it will maximize the real power transfer to consumers. For the cost of generating power and operating power due to line losses had neglected because power flow does not considered cost.

2.3.2. Economic Dispatch

In identifying the output of the regulated source and the minimum operating cost of Microgrid, economic dispatch is performed [7]. Also, to get the lower cost, economic dispatch method is the efficient and suitable method in supplying power to load [14].

It can be concluded that by optimizing all the micro source will give the lowest cost along with the change of load profile. Including wind and battery storage as micro source will draw the low cost compared with others. The micro source of CHP microgrid provides real and reactive power [15]. Another microgrid consisting of wind turbine, photovoltaic, storage battery, micro turbine, fuel cell, thermal and electric loads is selected as the research object.

Through this paper, it can be concluded that different types of micro source have different costs, especially for CHP microgrid that shows the highest cost. The economic dispatch is playing an important role because delivering power to consumers must be less in delivery cost [23]. There are many costs involved which are installation cost, O&M cost, economic factor in DG part.

2.3.3. Optimal Power Flow

The method to identify line losses during power dispatch can be determined by looking for VSC that operates in the voltage regulator mode and optimal reference power settings for the remaining VSCs working in power dispatcher mode [16].

In solving the optimization problem, Genetic Algorithm has been utilized so the total losses can be reduced. Reducing the converter and distribution system losses will increase the survivability and reliability of the Microgrid.

In making the economy more environmental, Microgrid can implement micro-sources load and energy storage by using new energy power generation because it will satisfy the demand of customers to get the higher power quality reliability of power source and that optimizing the operation of Microgrid was a very complex optimization problem that contains multiple goals and constraints [17]. So, in this paper, it takes the minimum economic cost and power losses as a constructive function by considering lot of constraints by constructing a multi-objective function model. This paper improves the chaos optimization algorithm and uses this algorithm to the optimization of microgrid, resulting a better result than the traditional mutative scale chaos optimization algorithm. The optimization goal is to minimize the overall microgrid operating cost and pollutant by programmable generator (PG) and non-programmable generator (NPG) (PV and WT) [18].

From this paper, it can be concluded that the optimization in power dispatching can be achieved if data was inserted correctly by considering many aspects. The optimal dispatch is very important to deliver optimum power to consumers at less cost [21]. The method of optimal dispatch can be calculated by using the levelized cost of energy (LCOE). It will be calculated by dividing the sum of investment and capital cost, O&M cost and fuel cost with the total power produced over the lifetime. The Microgrid uses optimal power flow not only to minimize the operating, fuel, purchasing cost and demand charge, but also considers the voltage deviation, line losses and power factor [22]. It will also adjust the real and reactive power from DG and storage by looking at capacity and power factors.

2.4. Power Management

To deliver reliable power to consumer the criteria should be met by PM is load sharing between DG, specific limit of DG which is type of DG used and cost generation, power quality including voltage harmonics and stability of system during transient [19].

3. Methodology

3.1. Analyzing the Method with Different Conditions of Power Management

After the power dispatch method was identified, the circuit of Microgrid was designed using PowerWorld Software that consists of three areas which is Community area, Campus area and Small Industrial area. The switch of PCC was designed to make the Microgrid being operate in islanded mode or grid operating mode. In this project, only focusing on island mode which PCC switch has been open and disconnect from the utility grid. The 11 kV of nominal voltage was set at each area, and 33 kV of nominal voltage was set at bus of utility grid. After that, the different condition of Power Management that had been considered is condition only one

DG is used in certain value of load in every area. The first Power Management is condition is when one DG is used in certain value of load in every area. Only one DG used to generate and transmit power to consumers in every area. The system slack bus was set at Small Industrial area which is it can absorb and release power when needed. For the second Power Management is line distance between DG and load and between every area. The different line distance can draw a different line loss in each area. For the last Power Management is type of DG used. At Community area, the natural gas generator, steam turbine type was used while at the Campus area, the generator that has been used is biomass which is wood waste. Lastly, for the industrial area, it used natural gas generator, gas turbine type.

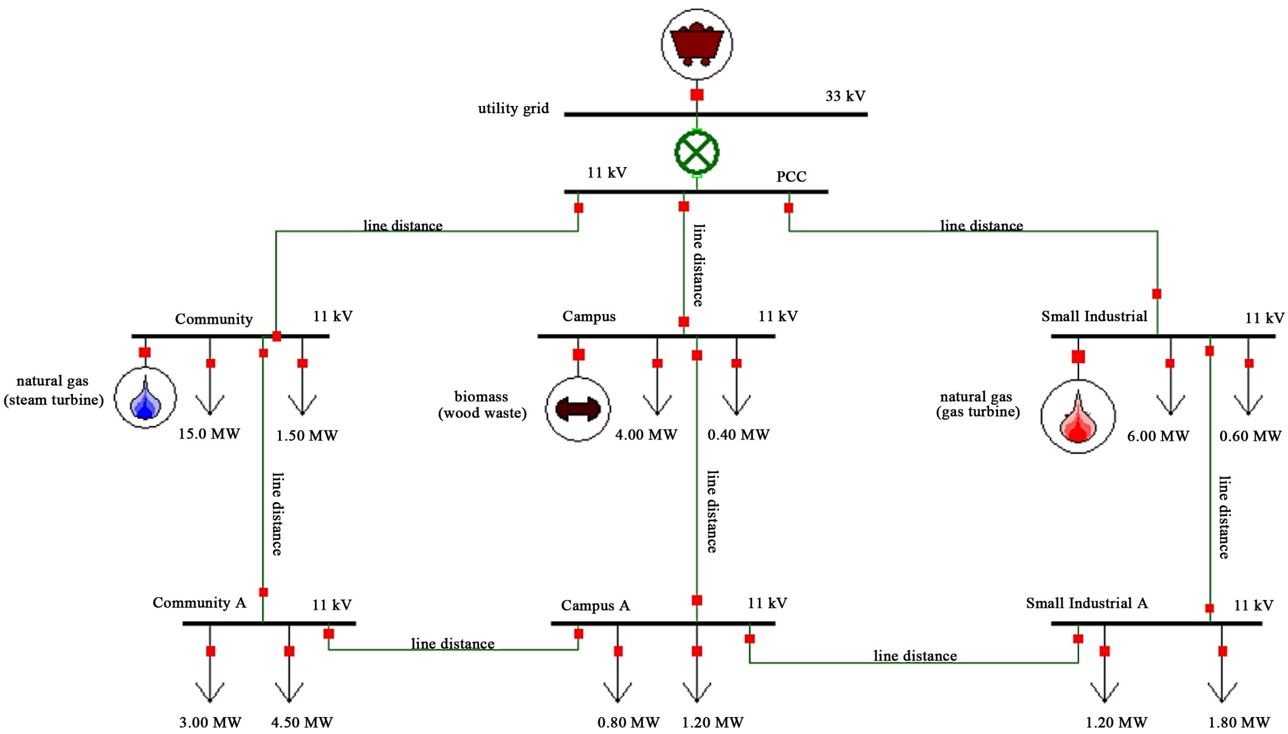

Figure 1. Microgrid system with different condition of Power Management.

Figure 1 shows the design of Microgrid systems with different conditions of Power Management. After the different condition of Power Magement was identified, the three methods which are PF, ED and OPF, have been applied and simulated. The data from three methods was being analyzed and recorded. After the simulation was being analyzed, the suitable method of power dispatch towards **Figure 1**.

3.2. Evaluation of Suitable Method towards Compatible Line Loadability

After the simulation was being analyzed, the suitable method of power dispatch towards compatible line loadability was being evaluated by using bar graph. The suitable method was chosen to deliver reliable and efficient power to power consumers.

4. Results and Discussion

Comparing the total real power, P of output data between Power Flow, Economic Dispatch and Optimal Power Flow can be summarized using bar graph method as shown in Figure 2 and Figure 3.

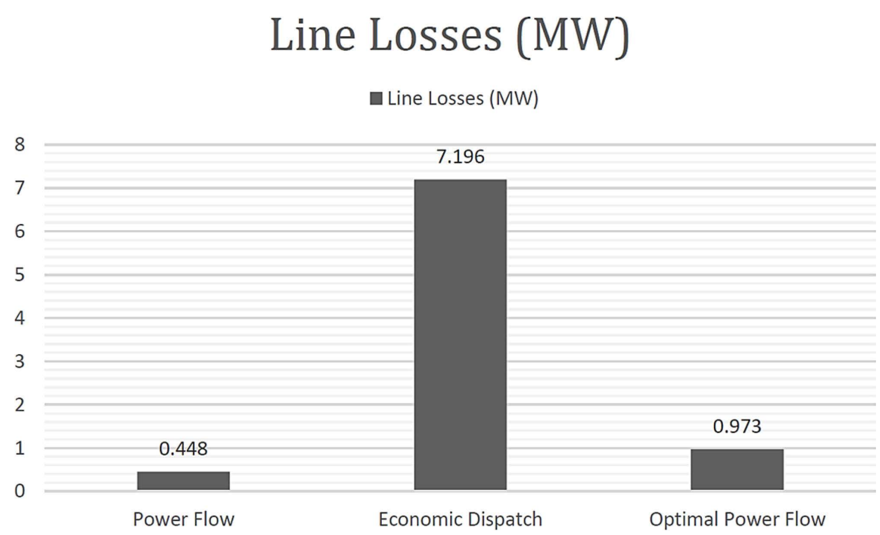

Figure 2. Bar graph of total line losses.

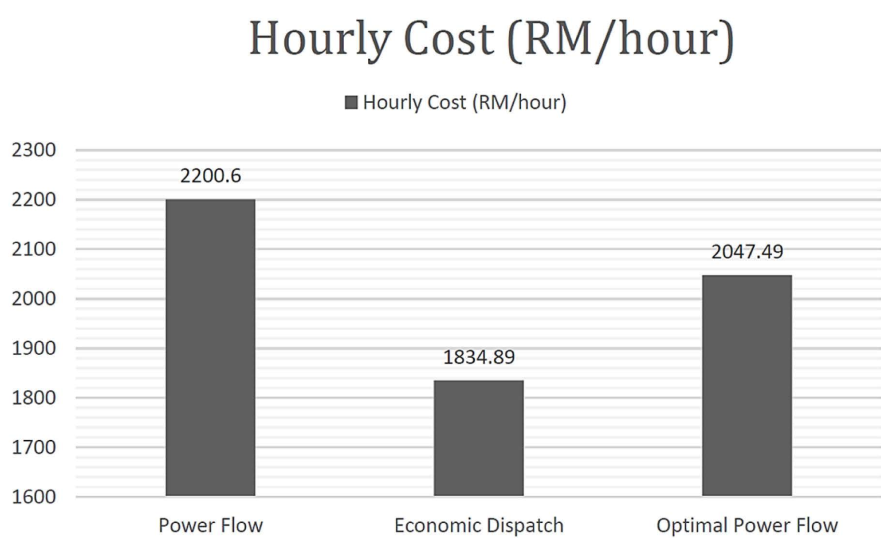

Figure 3. Bar graph of total hourly cost.

From the above comparison, the total line losses of economic dispatch method are much higher than power flow and optimal power method. High line losses provide us with the interpretations that there will be possibilities for the power factor to decrease even lower than the allowable limit on transmission level (which is the lowest should be only at 0.9 in Malaysia, no lower than this). High line losses would also directly impact the generating capacitor of the distributed generators because DGs will have to generate more than they should generate just because of to compensate the losses to provide enough power up the loads. High line losses would also "hurt" the transformer due to their intended power transfer capacity has been exceeded unintentionally. In terms of effective operation to deliver efficient power to consumers, the line losses should be low in value, therefore, Economic Dispatch will be out of consideration.

Next, the Power Flow theoretically tells us that this method of power transfer will focus on transferring power as high as possible without exceeding the line limit, but as a result, as expected, this method will incur higher hourly cost (RM/hour) compared with the rival Optimal Power Flow. The results show a lower line loss which is 0.4448 MW as compared to Optimal Power Flow which is 0.973 MW. The difference between this method was only 0.5282 MW. But the total hourly cost for Optimal Power Flow is much lower which is 2047.49 RM/h as compared to Power Flow which is 2200.60 RM/h. As a result, by sending power to the load at higher cost, this could possibly end with higher utility tariff to the consumer or lower generating profits to the generators, which both are unwanted and preferably should be avoided.

In brief, Optimal Power Flow works by "harmonizing" the earlier approach, Economic Dispatch and Power Flow. By using Optimal Power Flow method, it can save the hourly cost by almost 153.11 RM/h. For the generation, it generates an optimum value which 40.97 MW. Optimal Power Flow will be targeting minimal line losses and at the same time to incur a minimal hourly cost. The simulation agrees with the theory in this condition.

In conclusion, the method of Optimal Power Flow is the most suitable method to deliver the efficient and reliable power to consumer. It is because it only draws 0.973 MW line losses and saves the hourly cost amount which is 153.11 RM/h. Lastly, it also generates an optimum generation value to consumers which is 40.97 MW.

5. Conclusions

This paper focuses on finding the suitable power delivery method towards compatible line loadability on Microgrid system. There are three methods in power dispatch which are Power Flow, Economic Dispatch and Optimal Power Flow which is combination between two methods. All three methods were simulated by using PowerWorld software with different conditions of Power Management. The output data was then recorded and tabulated. After that, it was analyzed by making a comparison between three methods by considering the total line losses and total hourly cost of generator. It shows that the Optimal Power Flow is the most suitable method to deliver power to power consumers because the total line losses in system are not too high compared to Economic Dispatch. For the total hourly cost, it draws a lower cost as compared to Power Flow method. So, to deliver an efficient and reliable power to power consumer, Optimal Power Flow method was chosen.

The future of electrical grids all over the world relies on the application of smart grid. Also, to bring the generators closer to the grid, the distribution level is the suitable stage, therefore distributed generators will come into play. By not exceeding the line limits, this condition will directly be impacting to a higher level of power factor to be closer to unity (which is 1). Thus, by having a high level of power factor, then definitely the losses will be at their minimum. Lower losses mean we are not "hurting" the transformer due to their apparent power capacity that has been set during their production stage. These significant factors will clearly help microgrid operators or designers get the best outcome towards cost-effective operations.

For the future work of this paper, the other Power Management can be considered harmonic distortion and transient stability in Microgrid system. With Power Management, harmonic distortion and transient stability affect the operating cost of generator and line losses.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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