Development Energy Management Strategy to Optimize Battery Operation in Islanding Microgrid using Zero One Integer Programming

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Abstract-- **On solar energy microgrid,during the islanding condition and no solar radiation, at night, it only use the battery as a source of energy. This condition raises another problem of how to manage battery operation of each generation to maintain the continuity of the power distribution to each load so that each generation is still able to distribute power without load shedding due to insufficient of energy supply from the battery or if load shedding is done, it must be done at the most minimum.**

To solve the aforementioned problem, energy management strategy to manage power sharing between PV generation in PV-microgrid is developed, which will manage the usage of back-up battery operation on each distributed generation in order to maintain the continuity of power distribution or to minimize the amount of load shedding, by using the zero one integer programming.

The result of the research shown that implementation of the load shedding optimization mechanism using zero-one integer programming on the aforementioned problem, can increase the PDI (Power Distribution Index) from 86,65% to 95,75% at 5 generation simulation, with power sharing method based on Equal Inverter Output Power Operation Mode. Meanwhile, power sharing method based on Equal Battery Level Operation Mode, the implementation of load shedding optimization increases PDI from 95,86% to 99,20%.

Keyword : microgrid, power sharing, load shedding, zero one integer programing

1. INTRODUCTION

One of the problems in microgrid system is how to control the microgrid operation consisting of several solar power generation, especially when the microgrid is not connected to the utility grid, so that the entire load can still supplied power. Meanwhile microgrid operation under limited time of solar radiation, and limited capacity of the energy storage (batteries). Operation control of microgrid when operating on battery power performing management of operation pattern of microgrid based on forecasting data of load and radiation. in addition, the entire power of load to be able to supply, at the end of each the operating cycle, the battery level condition at the optimal level.

Based on the results of a study conducted by Hartono *et al* [1], it is said that the continuity of the operation of a microgrid when islanding condition, can be improved by managing operations of generation in using energy from the battery. By performing the operation control of battery usage on Equal Battery Level operation mode, continuity of microgrid operation can be improved from only 94.43% when operating on standalone mode and 86.65% when operating on Equal Inverter Output Power Mode, to 100% of continuity of microgrid operation without the need to load shedding.

Problems arise when the amount of energy available is not sufficient to supply the load, although it has been applied controlling microgrid operation, so that a load shedding should be done. In the developed simulation [1], optimization mechanism of load shedding has not been applied, this research develop energy management strategy to optimizing load shedding, so that better continuity of microgrid operating will be achieve.

2. POWER SHARING IN MICROGRID

In general, the microgrid power-sharing mechanism can be accomplished using the droop method and Average Current Sharing (ACS). There are several droop methods that can be used include conventional droop, modified droop, combined droop and adaptive droop. Meanwhile there are several methods can be used in ACS methods include master-slave current-programming, average current-programming-chain and circular current-programming. Some research related to the development of power sharing method among other by F. Katiraei and MR Iravani [3], in 2006 to develop power management strategies (active and reactive) of power inverter in microgrid system based on characteristics of voltage droop, voltage regulation and compensation of reactive power as well analysis of dynamic model of small signal some distributed generation (DG) aimed to improving the stability of microgrid. In 2008 Yasser Ibrahim Abdel-Rady and Ehab Mohamed F. El-Saadany [4], perform power-sharing between the inverter at microgrid using decentralized of adaptive droop control to improve the stability of the inverter, because the dynamics of power sharing resulting in instability of the system, so that easy to oscillate.

Development of power-sharing method using ACS approach conducted by Xiao Sun *et al* [5] in 2003, with this approach each inverter will supply the load with the same amount of current value. In this study reviewed, effects distribution of disruption from each inverter to the overall microgrid performance. In 2004 Josep M Guerrero et al [6] compared the effect of output impedance parameters of each generation plant in the development of power-sharing method using droop method and method of ACS. From the results of studies conducted, it appears that the ACS method gives better results than the droop method. Furthermore, Josep M. Guerrero et al [7] in 2007, develop power sharing method using decentralized control system is based on resistance measurement of output impedance of the inverters are connected in parallel in a distributed generation system. In 2011, Azrik M. Roslan et al [8], developed a power sharing method using ACS by including the effect of line impedance parameters.

In 2012, research on the development of power-sharing method based on the SOC of the battery in each generation, using decentralized droop control, performed by Xiaonan Lu *et al* [9]. Based on this approach, amount of power that will be distributed, proportionally to SOC value of battery, so that generation plant with high SOC value will deliver greater power than the power generation which has a lower battery SOC. Hartono *et al* [1] proposed power sharing method during islanding condition and running on battery, based on equal battery level in order to achieve better continuity of microgrid operation.

3. LOAD SHEDDING IN MICROGRID

Hak-Man Kim *et al* [10] propose the load-shedding problem is approached as a bankruptcy problem. A load-shedding scheme mathematically formulated based on the Talmud rule is suggested. A multiagent system for islanded microgrid operation is constructed. The proposed load-shedding scheme is tested on sample islanded microgrids based on the multiagent system to show the feasibility. Huan Xu *et al* [11] study simple storage dynamics into a load-shedding model to understand the effects of intermittency in generation and/or demand on the characteristics of the electricity network. By considering a scenario where the electricity is supplied by a combination of solar photovoltaic (PV) cells, wind turbines, and base diesel generation. Seon-Ju Ahn *et al* [12] focuses on the problem of determining the power references of DGs for the optimal operation of a microgrid. The optimization of a microgrid has important differences from the case of a large power system and its conventional economic dispatch (ED) problem.

4. PROPOSED METHOD

Microgrid operation method during islanding condition developed by Hartono *et al* [1], when the amount of power that is smaller than the required power by load, each power generation will operate in standalone mode, supplying each load owned, not applying mechanism of load shedding optimization. Load shedding is done when the total amount of power plants, either from a battery or solar energy, is smaller than the power that must be supplied to the load.

$$\sum_{i=1}^{n} P_{S,i} < \sum_{i=1}^{n} s_i P_{L,i} \qquad (1)$$

$$P_{S,i} = (P_{pv,i} + P_{bat,i}) \qquad (2)$$

Where $P_{S,i}$ power capacity of PV and battery, s_i is *zero-one integer* variable, value of $s_i = 1$ when load connect to grid, and 0 when disconnect from grid. In standalone operation apply the following equation :

$$\left(P_{pv,i} + P_{bat,i}\right) > P_{L,i} \text{ then } P_{inv,i} = P_{L,i} \qquad (3)$$

$$\left(P_{pv,i} + P_{bat,i}\right) < P_{L,i} \text{ then } P_{inv,i} = 0 \qquad (4)$$

Looked, during standalone operation, when the number of sources is smaller than the required load power, the power generation is not operating. While it operates on the microgrid, and total of sources power smaller compared owned load power, generation plant still capable to supplying power, at least as big as owned power source,

$$\left(P_{pv,i} + P_{bat,i}\right) < P_{L,i} \text{ then } P_{inv,i} = \left(P_{pv,i} + P_{bat,i}\right) \qquad (5)$$

This is due to when operates on microgrid, power generated is not always to supply the owned load but also supplies a load of other plants. So that when the total number of energy sources is smaller than the amount required load power, equation (1) load shedding must be done, by zero one integer programming (ZOIP) method to determain which generation load must be disconnected in order to obtain a total load, that close to total existing power sources,

$$min\ Ls_i = \sum_{i=1}^{n} P_{S,i} - \sum_{i=1}^{n} s_i P_{L,i} \qquad (6)$$

5. MODEL AND DATA SIMULATION

A. Output Power of Solar Cell

The calculation of the solar cell output power refers to the equations used HOMER, [13] :

$$P_{PV} = Y_{PV} f_{PV} \left(\frac{\bar{G}_T}{\bar{G}_{T,STC}}\right) \left[1 + \alpha\left(T_c - T_{c,STC}\right)\right]$$

where :

- f_{PV}, derating factor (%) from PV
- Y_{PV} , PV output power on standard test condition
- $\bar{G}_{T,STC}$, radiation power on standard test condition (1kW/m^2)
- $T_{c,STC}$, temperature of solar panels on a standard test conditions (25^{o}C)
- α, temperature coefficient to output power (%/^{o}C)
- $\bar{G}_T$, Solar Radiation (W/ m^2)
- T_c , temperature of solar panels (^{o}C)

When temperature is ignored in the calculation, then the above equation becomes :

$$P_{PV} = Y_{PV} f_{PV} \left(\frac{\bar{G}_T}{\bar{G}_{T,STC}}\right) \qquad (7)$$

Total output power of solar cell, $P_{pv,tot}$, for N_s number of seris panels dan N_p number of parallel panels is expressed in the following equation :

$$P_{pv,tot} = P_{PV} N_s N_p \qquad (8)$$

B. Energy Capacity of Battery

The amount of energy capacity of battery, stating amount of energy stored in the battery, determined by battery capacity, nominal voltage of the battery and the amount of maximum allowable discharge,

$$E_{eff} = C_{bat} . Dod_{bat} . V_{nom}$$

where :

- E_{eff} , energy capacity at a concentration value (Wh)
- C_{bat} , battery capacity (Ah)
- Dod_{bat} , *Deep of Discharge* , maximum allowable discharge (%)
- V_{nom} , nominal voltage of battery (V)

The battery charge and discharge characteristics can be expressed using Peukert's equation,

$$t = H\left(\frac{C_{bat}}{IH}\right)^k$$

where :

H: average discharge time
I : actual discharge current (amperes)
k : Peukert's constant
t : real time discharge the battery (in hours)

In applications developed, Peukert's constant k = 1, so the above equation becomes,

$$t = \frac{C}{I}$$

Where, discharge time is determined by the size of the battery capacity, C and the amount of discharge current I. While the determination of the state of charge (SOC) of the battery can be expressed by the following equation [14],

$$SoC_{t+1} = \begin{cases} SoC_t + \eta_c p_b \Delta t & ,charging \\ SoC_t - \dfrac{1}{\eta_d} p_b \Delta t & ,discharging \end{cases}$$

$$SoC_{min} \leq SoC_t \leq SoC_{max}$$

where :

- η_c, η_d , Effeciency battery charging dan battery discharging
- p_b , battery power
- Δt , time of battery charging and discharging

The amount of battery charging efficiency, η_c according to [15] approximately 90%, as part of the energy will remain stored in the battery, while during discharge η_d reaches 100%.

C. Performance Parameters

In accordance with [1] The performance parameters of the test stated in *Power Distribution Index* (PDI) and *Battery Charging Index* (BCI). Power distribution index states the ratio between the load power must be supplied in comparison with the load-supplied power,

$$PDI = \frac{supplied\ load\ power}{load\ power\ must\ be\ supplied}$$

Battery charging Index states ratio between capacity of charged battery compare to maximum capacity of the battery,

$$BCI = \frac{capacity\ of\ charged\ battery}{maximum\ capacity\ of\ battery}$$

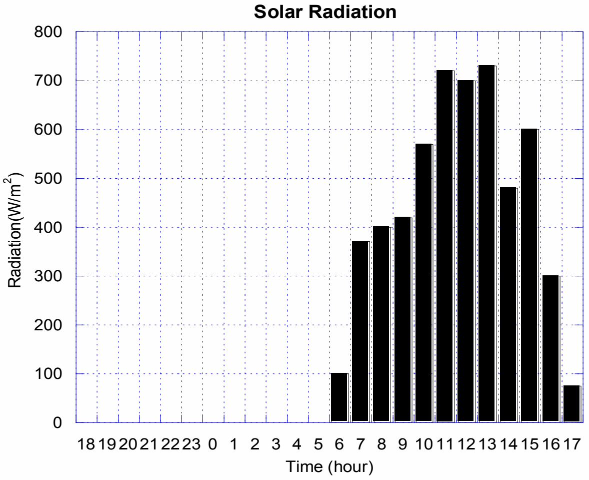


Fig.2. Simulation data of radiation forecasts

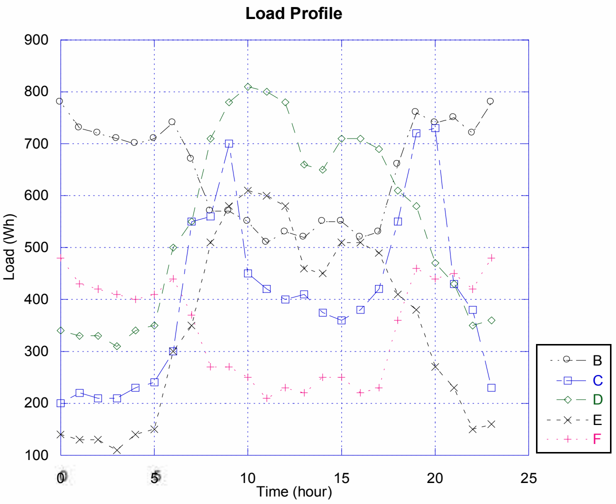


Fig.3. Simulation data of load forecasting of PV generation

To test the developed method, used simulation data, among others, forecasting of solar radiation, which will be used to estimate the amount of power to be generated from the solar cell, load forecasting and specifications of PV generation. Base on these data, operation of microgrid will be managed, to obtained better continuity of operation.

Based on forecasting of solar radiation are like shown in Fig.2. the solar cell output power of each PV generation based on the following calculation :

$$E_{pv} = A.W.\eta$$

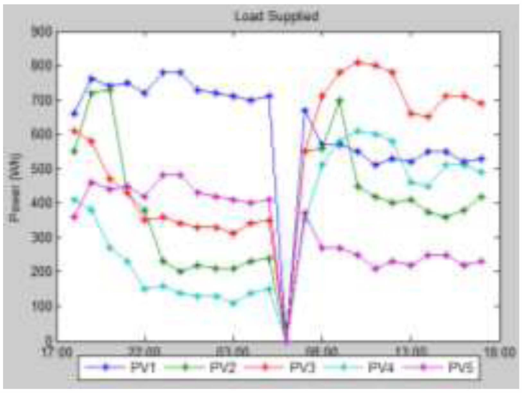
Where : E_{pv} , output power of solar panel (*W*); A , area of solar panels (m^2); W , solar radiation (W/m^2) dan η , efficiency of solar panel. Load profile as shown in Fig.3. and parameters of each generation refers to the data as shown in table 1.

TABLE 1. Specifications Of Simulation 5 Solar Power Generation

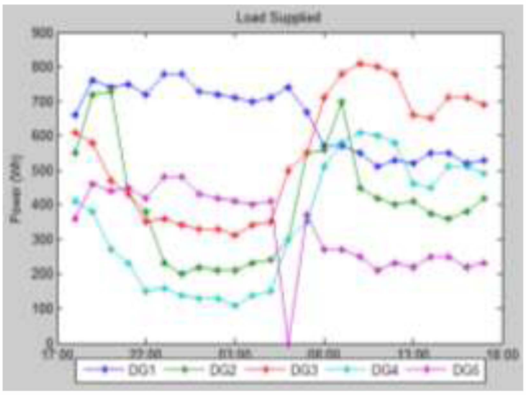
Parameters	Gen.1	Gen.2	Gen.3	Gen.4	Gen.5
Battery (Ah)	500	250	300	150	200
Vnom (V)	24	24	24	24	24
Dod(%)	15	15	15	15	15
Inv (Watt)	1250	1250	1250	1000	700
Efinv(%)	80	80	80	70	80
Wppv(Wp)	180	180	180	180	180
nPV	12	8	10	8	10
Efpv(%)	15,187	15,187	15,187	15,187	15,187
Length-pv(m)	1,658	1,658	1,658	1,658	1,658
Width-pv(m)	0,834	0,834	0,834	0,834	0,834

6. Result And Discussion

The simulation results of 5 PV generation shows, in equal battery level operation mode, without applying mechanism of load shedding with ZOIP method, at 6 am all PV generation can not supply power due to all the battery capacity at a minimum level, even to supply the owned load, Fig. 4 (a). The performance parameters of the power distribution index (PDI) without ZOIP method is 95.86%, it's means during the simulation only 95.86% of the total load must be supplied, were able to be supplied power, while 4.14% have to do a load shedding. Meanwhile, when mechanism of load shedding optimization applied, the obtained PDI is 99.20%, this is because at when operates on microgrid configuration, each PV generation with battery capacity under load itself, each generation, operating in parallel so is able to supplying power to other load generator, as shown in Fig. 4 (b) there is only one PV generation that really is not able to supply power or by only 0.8% of the total load power should be supplied.



(a)



(b)

Fig.4. Comparison load supplied of the simulation load shedding mechanism without ZOIP (a) and with ZOIP (b)

Battery level condition of both mode almost have the same pattern, the differences were most significant, occurred when disconnection load conditions, where the battery level without ZOIP is still higher due to the condition of each plant to operate standalone and are not capable of supplying power because it is not sufficient to supply the load. Meanwhile, with ZOIP, battery level when disconnection load everything almost zero because the overall available power is used to supply the load.

The results of testing the application of load shedding optimization on equal inverter output power operating mode, almost the same, as seen, PDI parameter increased from 86.64% when using the simulated without load shedding optimization, became 96.66% when applied load shedding optimization mechanism.

7. CONCLUSION

The result of the research shown that implementation of the load shedding optimization mechanism using zero-one integer programming on the aforementioned problem, can increase the PDI (Power Distribution Index) from 86,65% to 95,75% at 5 generation simulation, with power sharing method based on Equal Inverter Output Power Operation Mode. Meanwhile, power sharing method based on Equal Battery Level Operation Mode, the implementation of load shedding optimization increases PDI from 95,86% to 99,20%.

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