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Optimal Configuration of Power and Connection Point of PVP for Localized Diesel Power Plant Optimization

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ABSTRACT

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Keywords: Distributed Generation; Photovoltaic plant; Diesel power plant optimization; ETAP; Diesel Plant Optimization

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OPTIMAL CONFIGURATION OF POWER AND CONNECTION POINT OF PVP FOR LOCALIZED DIESEL POWER PLANT OPTIMIZATION

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Abstract

In this work, we analyze the effective model of PV plant (PVP) as a distributed generator to serve the load in a system where Diesel power plant (DPP) is used. The aim is to find the optimum configuration of PVP power and location, and load in a system to achieve the minimum DPP fuel consumption, as well as optimizing the working parameters of the feeder on which the PVP's are connected. An algorithm is proposed to provide the best practice solution for the problem. Based on power flow simulation in ETAP, we then compare the result from several logic configurations to find the best option of PVP power and location in a system with respect to the intended parameters mentioned. The result shows that DPP fuel consumption and grid parameters are improved. The results are presented as a recommendation to the studied DPP system as well as the similar system.

Keywords: Distributed Generation, Photovoltaic plant, Diesel power plant optimization, ETAP, Diesel Plant Optimization.

1. Introduction

Lengthy dependency of oil in most of developing countries has contributed to the irreplaceable use of diesel power plant (DPP). DPP has been used as main power producer to feed the load from cities to localized areas. For localized areas with hazardous terrain or even isolated small islands, this could turn to be the obstacle in keeping the continuity of load serving and fuel availability. From different stand point, the use of Photovoltaic power plant (PVP) has been so popular in past decade with variety of application and scale. The one that so popular is the integration of PVP using Distributed Generation (DG) approach to be working in a system with DPP as primary source.

The typical problem of DPP is that most of its generators has already close to their maximum service life, which related to the problem with its parts because of many workhours. Moreover, DPP also facing the problem with providing the continuity of fuel availability especially for isolated region/island. On the other hand, total replacement of DPP with different energy source also facing the problem of both

finance and efficiency, which is not consider as an option. The possible way is (1). to look for another power source as primary power plant and try to installed it gradually, and (2). to ease the workload of DPP generators and to lengthen its service life. In this work, the algorithm is proposed to the latter option.

Several works has been done to investigate the implementation of Distributed Generation technology in order to optimized network parameter where it is connected. In [1], the use of DG with different types of energy source by using objectives function of optimization was explained. Therefore, this paper will discuss the effect of PVP output power and load in order to make a rearrangement of generator working shifts, making sure its effective workload as possible.

2. Object of Study

The research object is 20 kV, 50Hz power grid of Ambon Island, located in Eastern Indonesia. The power grid contains 13 feeders, served by six Diesel Power Plant (DPP), with each three DPP working in parallel, (Figure 1). DPP 1 and 2 are the

main DPP, whereas DPP 3-6 are rented to support the main DPP because of engine failure of its several generator set. The grid is simulated in ETAP program with scheme provided in Appendix 1 & 2.

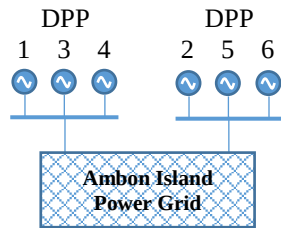


Figure 1. Ambon Island Power Grid

3. Research Methods

When additional power source injected its power through a particular point of interconnection (POI) in the network, it will reduce power flow along the power line because of power distribution from two different sources. Therefore, the level of additional power injected to the network determines how much power flow can be reduce along the power line. Hence, based on I^2R equation, power dissipated can be reduce. Moreover, the introduction of new power source able to reduce the workload of the generators. Thus, the relation between the PVP output power, the load and the generator optimum workload must be taken into consideration.

An algorithm that consist of set of criteria is to be create with the accordance with regulation and standard as a rule of thumb to solve the problem. But prior to that, several points needs to be taken into consideration such as:

- The generator load factor needs to be at a certain level where SFC level is at its maximum or 70-80% of nominal power when generator data is unavailable.
- The generators are consists of different type of nominal power and SFC level, therefore an operating shift for generators based on this factors need to be established.
- When using PVP to ease the workload of generators, an optimal PVP output power must be taken into consideration when determining PVP installed

capacity with respective to the local solar insolation potential.

- The economic factor of the results have to be improve after the implementation of the proposed algorithm.
- Since generator with higher capacity often have higher SFC thus it is best to use generator with low SFC to regulate with the uncertainty of solar insolation.
- Generator with lower SFC are to be

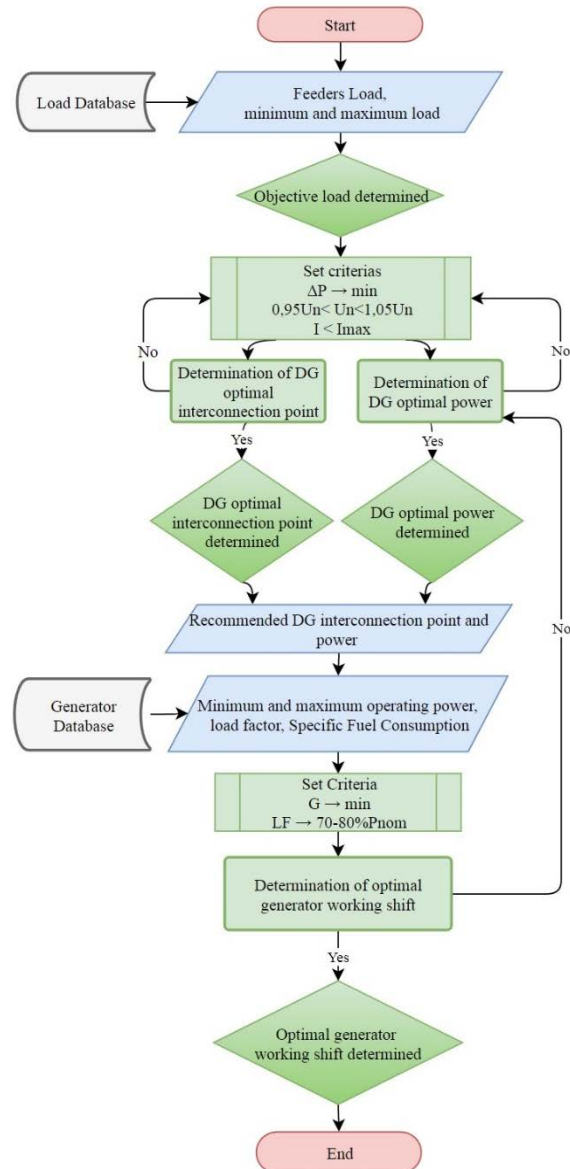


Figure 2. Optimization algorithm of DPP with PVP as DG

serving base load, while generator with higher SFC will be serving intermediate to peak load.

Based on these points, an optimization algorithm is made as shown in Figure 2.

3.1. Optimal DG POI and Power

Optimal POI and power of DG in a network system can be determine by a method in [2].

3.2. Generator Scheduling

The determination of generator working shift at time of, t are depends on several parameters such as load $P_L(t)$, the PVP power output $P_{PVPout}(t)$ and the generator power output $P_{Gout}(t)$. By formulating these parameters, it is possible to define the optimum working shift of generators on a real time fashion. Here the optimum working shift means that the workload of generators, LF can be put to optimum while fuel consumption, G can be put to minimum. Hence, these two parameters are taken as selection criteria. Prior to selection all generator set should be divided into Base Load Generator, G_{BL} and Load Following Generator, G_{LF} . G_{BL} are generators with low SFC that serve base load with constant $LF=0,75$. G_{LF} are higher SFC that serve both intermediate and peak load with more flexible $LF=0,7-0,8$. Moreover, low capacity generators G_{BL} will be turn off to compensate higher capacity generator in the case when last generator G_{LF} produces too much energy. This will ensure the flexibility of G_{LF} in serving the load while continuously minimizing fuel consumption as low as possible. The G_{LF} generators switching order are based on their SFC values (low to high).

In practice, G_{BL} and G_{LF} generators have to satisfy the following condition.

$$\frac{\sum_{i=1}^n (P_{G_{BL},i} \cdot LF) + \sum_{i=1}^n (P_{G_{LF},i} \cdot LF)}{P_{L1}} = 1 \quad (1)$$

Where, LF for $G_{BL} = 0,75$ and for $G_{LF} = 0,7-0,8$.

2.2. PVP Generator Optimization

The generator output power P_{Gout2} or the net load that has to be fed by generator after PVP integration, P_{L2} practically can be determine by the following expression.

$$P_{Gout2} = P_{L1} - P_{PVPout} = P_{L2} \quad (2)$$

Thus, generators condition in Eq. (1) after integration of PVP can be rewritten as.

$$\frac{\sum_{i=1}^n (P_{G_{BL},i} \cdot LF) + \sum_{i=1}^n (P_{G_{LF},i} \cdot LF)}{P_{L1} - P_{PVPout}} = 1 \quad (3)$$

The calculation of fuel consumption are taken from [3].

4. Analysis & Results

Through method in [2], the simulation is held in ETAP program and the results shows that the amount of PVP power needed by the power system in total is 10MW with configuration shown in Appendix 1. The result of PVP integration to the reduction of DPP power generation is shown in Figure 3. The scheme of simulated power system in ETAP can be seen in Appendix 1&2.

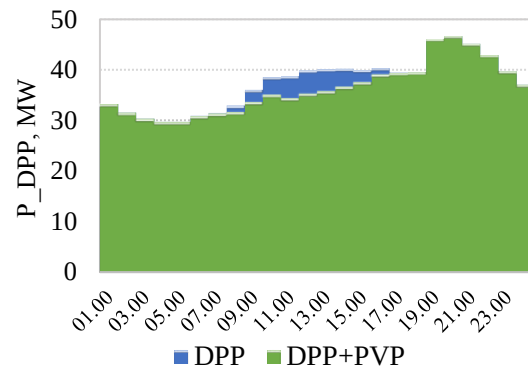


Figure 3. Yearly average total DPP generation. Using the method in [3], several results are taken as shown in a table below. The result shows are the state of yearly energy production, fuel consumption and cost on fuel before and after generator rescheduling, and integration of PVP after rescheduling.

Table 1. DPP characteristics at based scenario.

DPP	W, MWh/yr	G, ton/yr	3, mln. \$/yr
1. DPP Poka	43094	259590	\$194
3. DPP Rent 1	36719	197345	\$147
4. DPP Rent 2	55900	299491	\$224
2. DPP Hative	19648	105953	\$79
5. DPP Wika1	112557	669499	\$500
6. DPP Wika2	60842	317324	\$237
Σ	328760	1849203	\$1 381

Table 2. DPP characteristics after rescheduling.

DPP	W, MWh/ yr	G, ton/yr	3, mln. \$/yr
1. DPP Poka	9227	53509	\$40
3. DPP Rent 1	40537	214967	\$161
4. DPP Rent 2	71758	379532	\$283
2. DPP Hative	47961	253979	\$190
5. DPP Wika1	106717	613770	\$458
6. DPP Wika2	52560	259093	\$193
Σ	328760	1774852	\$1 325

Table 3. DPP characteristics after rescheduling with PVP.

DPP	W, MWh/ yr	G, ton/yr	3, mln. \$/yr
1. DPP Poka	9227	53509	\$40
3. DPP Rent 1	40537	214967	\$161
4. DPP Rent 2	66774	352945	\$264
2. DPP Hative	47961	253979	\$190
5. DPP Wika1	101483	583660	\$436
6. DPP Wika2	52560	259093	\$193
Σ	318542	1718155	\$1 283

After the implementation of working shift rescheduling, the number of working hours of total generator in a year are increased as a result of equal load distribution with lower load factor by 37,5% and reduced to 3,4% after the introduction of PVP. It also supposed to lengthen the service life of generators by imposing the right load at all time. Economically, all DPP are able to save \$56 million per year after rescheduling process, and further \$98 million per year after the addition of PVP to the grid.

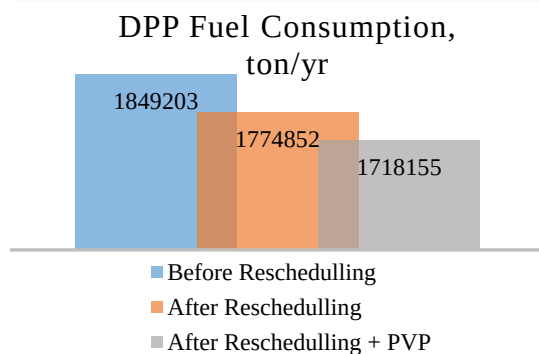


Figure 4. DPP Fuel consumption

5. Discussion & Conclusion

DPP optimization algorithm through DG connection to the grid and generator working shift rescheduling shows good result that can be implemented in many DPP station. Moreover, the algorithm can be used as recommendation for the studied power system as well as related electrical project with distributed generation based on renewable energy source.

6. References

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Appendix 3. Configuration of DG Power and Interconnection Point

Feeder	P_DG, MW	POI	Feeder	P_DG, MW	POI
F1	2	107	F7	No Vacant Land	-
F2	2	III*205	F8	No Vacant Land	-
F3	No Vacant Land	-	F9	No Vacant Land	-
F4	No Vacant Land	-	F10	No Vacant Land	-
F5	3	III506	F11	No Vacant Land	-
F6	1	III603	F12	2	III1214
*III = Step-Down Substation (at MV side)			F13	No Vacant Land	-