The Implementation of the Automatic Dispatching System (ADS) to Support the Smart Grid Pilot Project for Distribution Grid Improvement in Sumba Island

Dimas Bangun Fiddiansyah
Digital Management Division
PT PLN Head Office
Jakarta, Indonesia
email : dimas.bangun@pln.co.id

Dr. Hanny Benchmark
USAID SINAR
Jakarta, Indonesia
email :
hanny.berchmans@tetratech.com

***Abstract* — In order to minimize the oil fuel consumption, in its power generation, PLN (Perusahaan Listrik Negara) as an electric state company has promoting a de-dieselization program which either integrated PV and existing diesel into Hybrid or install PV in the isolated system, to get optimum performance and reliability. However, the intermittent characteristic of PV should be considered since this would impact the frequency instability of the network system itself. To maintain the stability of the system, new system operations should be adopted. Thus, ADS (Automatic Dispatching System) is introduced to compensate the fluctuation sources from PV. Before ADS was implemented, dispatch combination between Diesel Generator (DG), and Photovoltaic (PV) has triggered unreliable supply since there is no load control center as well as the insufficient communication channel available. Implementing ADS, this allows PLN to minimize fuel consumption, and develop the first operational Smart Grid system. Subsequently, ADS has proven capable of maintaining frequency stability in the system that contains intermittent power generation. Based on the simulation study, and actual measurement testing, it can maintain the stability frequency within in its normal range (49,5 < Hz < 50,5).**

Keywords* — *Automatic Dispatching System, Diesel Generations, Photovoltaic, Smart Grid system

I. Introduction

In recent years, PV based generating systems have been widely implemented into distribution systems due to environmental concerns. VRE (Variable Renewable Energy), such as PV and wind energy may bring additional reliability benefits to the system, as they can be operated along with the DG units, thereby minimizing customer interruptions, in case of system emergencies [9]. However, PV power output is not constant and tends to fluctuate depending on weather conditions. This fluctuating power causes frequency deviations and reduction in reliability of the isolated power utility or microgrid when large output power from several PV systems is penetrated in the utility [8]. On the other hand, the rising energy needs could not be fulfilled by the current weak grid supplied by the majority generation based on DG [7]. However, the intermittent characteristic of PV has major concern to be solved especially in isolated grid. Meanwhile, there are hundreds of units of DG that need either to get them hybridized with VRE or interconnect existing DG and VRE altogether in the system.

To prepare for the reliable system operation in the mentioned program above, pilot project in Sumba Island can be discussed since it has VRE penetration among most of the diesel generation. Thus, on grid PV system is currently being considered as an attractive, and clean option for isolated grid operations. This application is a means to reduce diesel fuel consumption. VRE that integrated with DG systems are currently being considered as an economic, and clean option for isolated microgrids, to offset oil fuel consumption by shifting generation from existing units; However, the security and stability of the system are a challenge from the increasing penetration VRE [6]. Meanwhile, Indonesia adopted European countries use electric frequency 50 Hz. If this electric frequency in the power network is not constant, the electrical equipment connected to it would have potential to get damage. So, the frequency needs to be maintained in a tolerable range. To keep this frequency stable and constant, it needs an automatic control scheme that can identify changes in frequency, then mitigate those changes by choosing which dispatch from DG has the lowest economical losses, which is known as the Automatic Dispatching System (ADS) [10].

The ADS was installed at the several DG units in eastern grid of Sumba Island since it is interconnected to the 1 MWp installed capacity of solar PV. Consequently, an isolated grid such as Sumba system has a potential risk of frequency instability. It is because the electricity sources are supplied by PV with intermittent characteristics. Under such conditions, implementing an efficient secondary controller through load frequency control (LFC) plays an important role in restoring power system stability [3].

Figure 1. Sumba distribution grid and its planning expansion

Sumba island is in the southern part of Indonesia, which has population more than 250 thousand with the electricity demand less than 7 MW. Meanwhile, installed capacity of the total generation close to 16 MW, which majority 70 % supplied by diesel generation, and the others sourced from renewable energy, such as hydro, biomass and PV as indicated in Figure 1.

The load profile in Sumba has typical load profile characteristic which has low load in the daytime and increasing load demand in the evening. The Majority of typical load on the PLN East Sumba network is of a residential type with the characteristics of time in Figure 2. The peak-load 6.8 MW, and during, the daytime load, has parallel operation with the maximum PV generation week's cycle, which fluctuates between 3,7 MW – 4,8 MW.

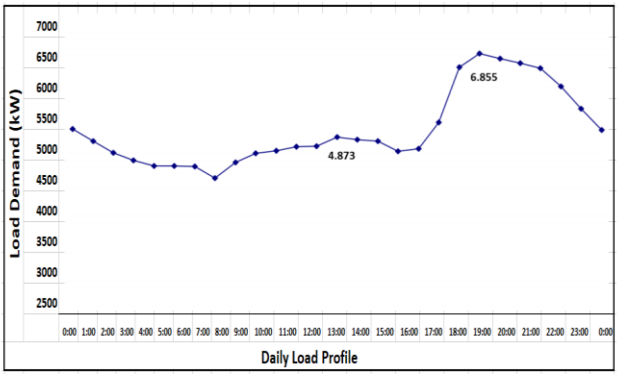

Figure 2. Typical daily load profile in Sumba Island

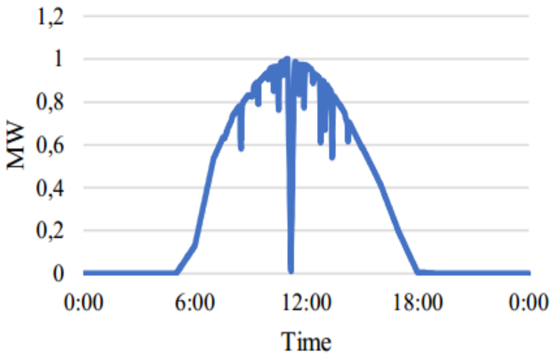

Figure 3. PV Output Power

Currently, Sumba Island has two main grids, eastern and western grid which the majority supply based on diesel fuel generation. East grid has PV generation with the installed capacity 1 MWp, which now represent 10 % of the capacity. Meanwhile, most of the diesel generations are operating in load following mode with manual dispatching. In addition to diesel, the Sumba electricity network is supplied with a Hambapraing PV with a capacity of 1 MWp which the output is varies with time movement as shown in Figure 3.

TABLE 1. POWER GENERATION COMPOSITION IN SUMBA

No	Owner	DG Unit Name	Installed Capacity (MW)
1	PLN	Cummins	1.2
2		Cummins QSK 1	0.7
3		Caterpillar	0.7
4		MTU	0.5
5		MAN 1	0.5
6		MAN 2	0.3
7		SWD DRO 1	0.3
8		SWD DRO 2	0.27
9		Yanmar	0.25
10		Deutz BA 1	0.25
11		Deutz BA 2	0.25
12		Deutz BA 3	0.25
	Total		5.47
13	Rent	Dossan 1	0.5
14		Dossan 2	0.5
15		Dossan 3	0.5
16		Dossan 4	0.5
17		Dossan 5	0.5
18		Dossan 6	0.5
19		MTU 10 V	0.4
20		MTU 12 V 1	0.5
21		MTU 12 V 2	0.5
22		MTU 12 V 3	0.5
23		MTU 12 V 4	0.5
24		MTU 12 V 5	0.5
	Total Rent		5.9
	Renewable Energy		
25	IPP	PV Farm	1
26	Local Gov	Biomass	1
27	IPP	Hydro	1
	Total Renewable		3

In TABLE 1 above, it can be seen that the PLN's DGs available on the isolated grid will be given the ability to respond to changes in load. In most cases, PLN's DG will be used to provide peak loads. PLN's generators can work with droop governor or with the isochronous governor. Thus, the isochronous governor regulates the valve/gate of the turbine to carry the frequency return to its nominal value [12]. So, the system with isochronous governor has the capability to restore the system frequency to 50 Hz after instability occurs. Then, the DG that works isochronous will be connected to ADS [3].

The objective of this paper is to evaluate the system performance of distribution grid using ADS and its impact in managing power quality and maintaining the penetration level of PV operation.

This paper is organized as follows, Section II presents ADS algorithm and control basic design of ADS which include simulation study of frequency path with combination of Droop and Isochronous governor. Section III describes ADS configuration that applied in the distribution grid. It also presents the development phase for smart grid and advantages using ADS in an isolated grid. Then, the output results of ADS installation are reported in Section IV, including the differences before and after ADS implementation based on the stability system performances.

II. METHOD

In this paper, ADS Algorithm is proposed as modeling to represent conceptual design of ADS used in the system. Hence, the model is implementing in the actual condition to justify whether the design is applicable and contribute benefit to the power quality in the system. In this study, ADS can be modeled by making an isochronous governor model that is connected to the PLN's generator in the system as showed in Figure 4. Then, the dynamic model of the governor is simulated using a simulation tool [3].

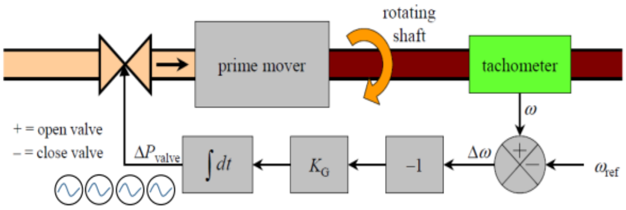

Figure 4. Control Basic Architecture Design of the ADS System

ADS is provided with an algorithm to turn the isochronous generator off and on when the load is either too low or too high. Hence, the generator needs to be switched off when the load is low because low loading will impact in inefficient energy conversion processes in its. So, the generator needs to be switched on when the load is getting high since the load will not get sufficient sources. This would lead to the collapse of the system frequency [3].

The proposed algorithm can be seen in the flow chart in Figure 5. Referring to table 1, the PLN has largest generator, DTG Cummins 1.2 MW, will be the generator with the most priority to continue running. Its priority to be switched on is ordered by the magnitude of its rating. Subsequently, the generator that has the lowest capacity, DTG Deutz BA 3 250 kW, will be the generator option with the most priority to be switched off. Hence, the lower the DG rating, the more frequently it will be either switched on or off. The DG with the largest installed capacity is prioritized to be switched off because if it is changed prioritized to turn it on and off, there would be a greater frequency swing than if the PLN DTG with the smallest rating is often turned on and off [3].

In general, ADS has automatically decided which generations have to be switched on, synchronized, loaded or stopped. Consequently, this solution can handle any type of power generation technology, as well as can be applied to any grid in any size. Meanwhile, solar PV and the diesel plant are developed at Kambajawa Distribution Station.

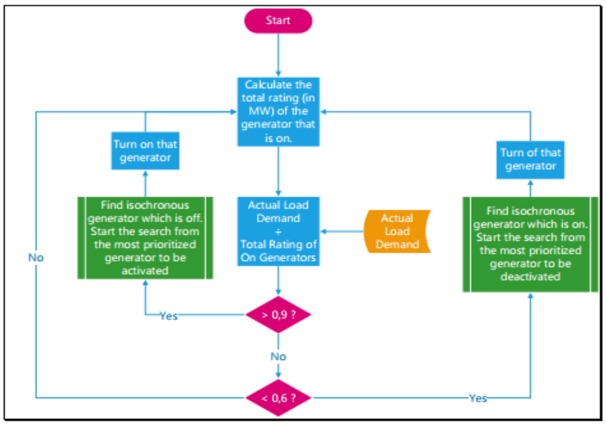

Figure 5. Algorithm of ADS

Current ADS reflects Multiple Generator status (on/off, synchronized or disconnect) and Multiple generator dispatch. Hence, ADS send power instruction, not just control signal. Thus, it reads the status of the grid and the generations in real-time instantaneously, and automatically instructs the diesel generations to dispatch certain actual power to stabilize the frequency, while at the same time, it maintain generations in operation within its optimal power settings.

Based on the simulation carried out by [3], the use case of 9 unit PLN's DG with primary controller, or Droop Governor, and 3 units with Isochronous governor is simulated to verify the output frequency within its in normal range (49,5 s.d 50,5 Hz). As shown in Figure 6 below, the simulation study indicated that frequency trajectory from the interconnection of Unit PLN's DG with Droop Governor and Unit PLN's DG with Isochronous Governor. The blue chart indicated Droop 5% with delay governor 20 s, while orange one showed Droop1,6% with delay 60 seconds.

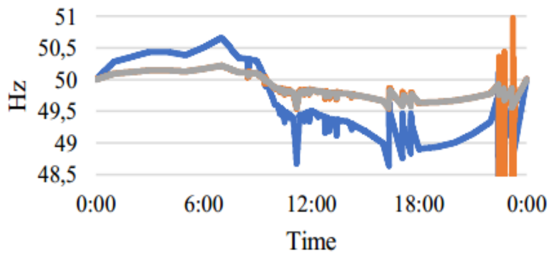

Figure 6. Frequency path with combination of Droop and Isochronous governor

Using ADS is expected that the isolated grid frequency can be adjusted in the tolerable range, without the need to implement an energy storage system [3].

III. ADS Configuration and its Proposed Design in the Distribution Grid

Automated dispatching control system (ADS) is a control system tool which has function to monitor the system of the load flow in power network from various power generation types whether conventional and variable renewable energy, thus it capable to enter the electricity and energy market, as well as to accommodate the energy mixed. ADS is used to manage the various power supply characteristics capable of meeting the fluctuation of their load demands. On the other hand, ADS will be the flexible solution as the demand response in this distribution grid.

ADS have been widely implemented in any system voltage level system whether in medium voltages or high voltages. Meanwhile, the important role in the configuration of ADS, as the main direction of control system development, was the formation and implementation of SCADA, which collaborates information about the processes and centralize control. Thus, ADS is a type of automated process control which can control any type of power generation roles in the grid [2].

There are several methods that can be applied to improve Grid quality in Sumba system : implement ADS over East grid gensets, interconnect both grids (east and west grid) through high voltages lines, implement ADS over west grid power generation once upgraded, and develop the first operational smart grid power management [1].

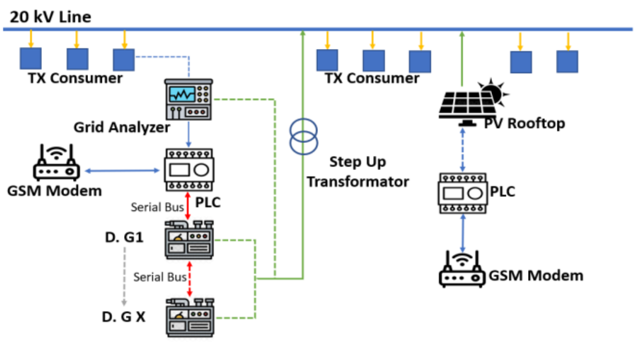

Figure 7. Conceptual Layout of Proposed System Components

Figure 7 describes the conceptual layout of the system. Depending on model, grid analyzer can read the grid from the LV bus (option 1) or from a consumer type step down transformer on the main HV outcome (option 2). Thus, the PLC can be replaced by a full size computer or a laptop computer, while GSM modems or more complex telecoms can be implemented for remote management and/or integrate with an active solar SCADA. Meanwhile, there are basic requirements to be implemented for preliminary phase in smart grid, which consists of [1] :

1. All flexible generators to be operated exclusively in full range load following mode, with minimum operation setting defined at 30% or lower and maximum operation setting defined at 80%
2. All flexible generators to have ECU's, electronic governors and Modbus and, optionally, TCP/IP protocols. Removal or redefinition of the now obsolete grid KPI of SFC; to be substituted by the actual international standard of liters per kWh delivered
3. Integrate them in the ADS/AGC system for automatic and sequential dispatching of the generators according to grid load behavior.

Implementation Phase for Diesel Reduction strategy and smart grid Introduction in Sumba Island as illustrated in Figure 8 was the upcoming flexibility solution for distribution grid improvement in Sumba Island since high grid losses and fuel consumption dominated the operational system, which disrupt the power quality and reliability of electricity sources to the customers [1].

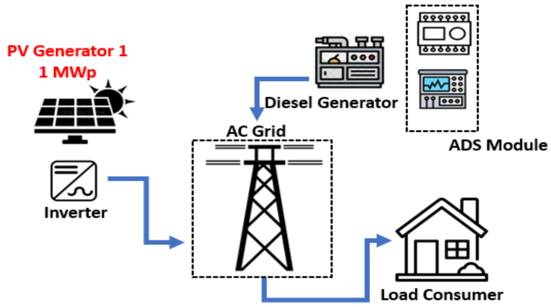

Figure 8. Pilot project outline for Diesel Reduction and PV integration

The development for smart grid can be executed by implementing the following systematic method as mentioned [1] :

1. Grid impact study, by doing the simulation study and modeling of the power system in existing Sumba grid that combined with the proposed generations, would be obtained the load flow analysis and the other electric output parameters.
2. Sizing and design of diesel buffering engine/engines, would be required to estimate the appropriate diesel capacity that are feasible to integrate with VRE. Hence, diesel sizing also compulsory to determine the ramping rate in the system
3. All diesel should be equipped with ECU/Modbus controls, and operated in stepped dispatching procedure
4. Sizing Solar PV up to 60% of diesel, one way to implement the high level penetration by integrating the PV share which is higher than diesel generation. This can be combined by applying ADS, as the hybrid controller unit that has function to control the flexible operation mode between PV and diesel. Subsequently, the ADS would match the synchronization between generation sources and the load demand.
5. Data acquisition units in all grid key nodes, data acquisition as the controlling and monitoring unit can be applied to assist the communication and remote

surveillance to ensure the smooth operation in the system.

Consequently, there are some advantages of using ADS in the isolated grids. During the test, the ADS has capable to control the grid frequency at stable rate by managing the operation of Kambajawa diesel power plant to meet the variability of power load/demand as well as the variability of 1 MWp solar PV power plant output. Thus, PLN will continue to observe the situation, especially during critical hours (peak hours or high ramping rate hours) to ensure whether the controllers and the generation power system balance power supply and power load if a nearby 1 MWp solar PV power plant supplies electricity intermittently due to weather condition [2].

In addition, ADS operation mode and its dispatch would not only guarantee the power quality and grid stability, but also it will support the induced load reduction from the Solar PV and other VRE that would be installed in the future. By allowing PLN to capitalize on the fuel usage savings and the cost spin-down effect of the incorporation of continuously lower cost VRE generation, which subsequently would lower PLN's operational cost as well as increase corporate profits.

IV. Output Results

The main issue in the distribution grid before ADS installation was the difficulty to maintain frequency stability in East Grid when the intermittency condition occurred as the result of fluctuation of output operation from the PV due to the PV soothing and solar irradiance changing.

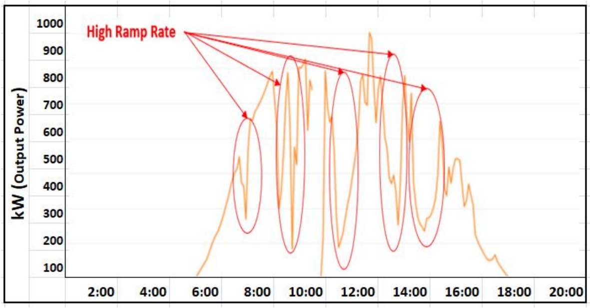

Figure 9. Typical electricity production of the Solar PV 1 MWp in East Sumba during cloud events.

The High Ramping Rate triggered the sudden changing of power frequency, which can impact the power quality and stability in distribution grids which is implied in Figure 9 where the PV output varied during cloud events.

There are preexisting condition before ADS integrated in the system, such as manual dispatching and wider range of grid frequency operation, constant power spillage by overpowering the grid, high thermal losses, and high-power leaking to neutral, high instability of the grid during operation hours of PV, and Black out/feeder disconnection due to under frequency.

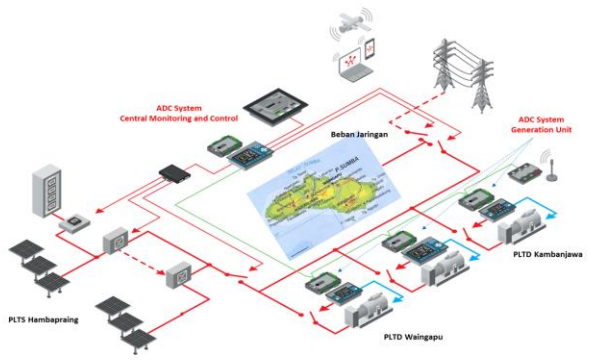

Figure 10 The proposed of ADS configuration in distribution grid

ADS system can control the complex mini grid operation that consist of PV and diesel generation as implied in Figure10, which is possible to integrate between many renewable energy sources with diesel generation by maintaining stable power quality with high efficiency and security level [1].

Figure 11. Typical electricity production as the impact of the Solar PV's operation

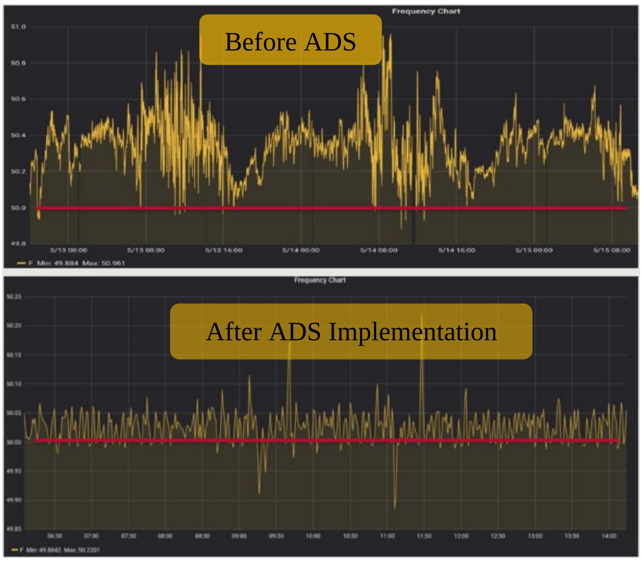

Figure 12. Typical electricity production in the system, before and after ADS installation

The graph displayed in figure 11 and 12 above described that ADS has primary roles to maintain the frequency stability in its nominal ranges by adjusting mechanical power in the power generations. The fig implied that before ADS installation, the frequency fluctuated above the tolerable limit. After ADS installation is applied, the frequency can be maintained within normal range (49,5<Hz<50,5). Yet, ADS utilization offers flexible operation since main devices can be modified as needed, as well as modifying its control algorithms in a good manner. Subsequently, the outcome emerges after ADS Installation which referring to the data diagram obtained that frequency system fluctuation is better adjusted within the nominal required range compared with the previous condition. In this use case, ADS can support distribution grid improvement by maintaining the stability of frequency in the system.

V. Conclusion and Future Works

1. The ADS implementation is possible to raise smart grid's operational performance, and provide reliability as well as quality power to their consumers, while minimizing the operation cost, which can be achieved by embracing the ADS installation as the first step to improve the power quality, thus minimizing losses in the distribution grid.
2. The development urgency of ADS in Sumba considers high generation cost, flexibility of system operation, and the potency of power factor correction. On other hand, ADS has proven capable of maintaining frequency stability in the system that contains intermittent power generation. Both the simulation, and actual measurement testing, it can maintain the stability frequency within normal range (49,5<Hz<50,5)
3. ADS implementation and grid monitoring system can be considered as the main part in integrating variable renewable energy into small power network, not only to compensate the fluctuations characteristics of VRE, but also to maintain grid stability and prevent the grid operations from abnormalities, such as over frequency, phase imbalance and frequency hunting.
4. The success of ADS installation, testing and operation boosted PLN's understanding and confidence to replicate the innovation to increase VRE integration in the upcoming de-dieselization program.

ACKNOWLEDGMENT

The author would like to express the gratitude to the joint working team between PLN and USAID ICED team who have great effort to develop and configure ADS implementation project in Sumba Island. Within the period 2018-2019. Subsequently, the ADS project obtained full support from the US Government. Thus, this smart grid project would be typical of pilot project in the future in deploying sustainability of renewable energy since this project can be potential solution to be expanded in de-dieselization program into more affordable electricity access as well as promoting clean energy environment.

References

[1] USAID - ICED II Team: 'The Summary of Grid Improvement in Kupang and Sumba ', May 2018, pp. 1–21

[2] USAID - ICED II Team: "Development of Automatic Dispatch Controller System and Grid Monitoring for East Sumba Grid ', Sharing Presentation, May 2019, pp. 1–46

[3] Bangun Primanta Holand, Haryanto Nanang "Design of Automatic Dispacth for Control System For Frequency Control of Isolated Electrical Grid" School of Electrical Engineering and Informatics, Institut Teknologi Bandung, Master Thesis, 2021

[4] T. Reber, K. Burman and B. Hirsch, "Sustainable Energy for Remote Indonesian Grids: Strategies to Accelerate Nationwide Deployment," Department of Energy by the National Renewable Energy Laboratory (NREL), Denver West Parkway, CO, 2016.

[5] H. Kanchev, F. Colas, V. Lazarov and B. Francois, "Emission Reduction and Economical Optimization of an Urban Microgrid Operation Including Dispatched PV-Based Active Generators," IEEE Transactions On Sustainable Energy, vol. 5, no.4, pp. 1397-1405, October 2014.

[6] W. Mendieta and C. A. Canizares, "Primary Frequency Control inIsolated Microgrids using Thermostatically Controllable Loads, "IEEE Transactions On Smart Grid, vol. 12, no. 1, pp. 1-13, 2020.

[7] A. Veldhuis and A. Reinders, "Potential and Cost-Effectiveness of OffGrid PV Systems in Indonesia," in 2014 IEEE 40th Photovoltaic Specialist Conference (PVSC), 2014

[8] M. Datta, T. Senjyu, A. Yona, T. Funabashi and C.-H. Kim, "A Coordinated Control Method for Leveling PV Output Power Fluctuations of PV–Diesel Hybrid Systems Connected to Isolated Power Utility," IEEE Transactions On Energy Conversion, vol. 21, no. 1, pp. 153-162, March 2009

[9] K. Zou, A. P. Agalgaonkar, K. M. Muttaqi and S. Perera, "An Analytical Approach for Reliability Evaluation," IEEE Transactions On Smart Grid, vol. V, no. 6, pp. 2657-2665, 2014.

[10] Johansson, Thomas & Phatwardhan, Anand and Nakicenovic, "Global Energy Assessment: Toward A Sustainable Future, Cambridge University Press, 2012

[11] Bangun Primanta Holand, "Automatic Dispacth for Control System Design" School of Electrical Engineering and Informatics, Institut Teknologi Bandung, Poster, 2020

[12] P. Kundur, Power System Stability and Control, McGraw-Hill, 1994