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Stability analysis of smart grid management system on campus building

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ABSTRACT

Medan Area University is one of the private universities in North Sumatra that is also involved in the development of renewable energy technology. This technological development has initiated the University's efforts to develop an electrical system by developing a smart grid system in order to reduce the University's operational costs. However, in its realization, it has its own challenges, such as power flow stability and transient stability. Both problems can be analyzed using ETAP 12.6 software. In one of the cases analyzed, the smart grid system can reduce the use of the active power of the transformer by 11 kW and a current of 19.7 Amp. Meanwhile, in the Indonesian State Electricity Company (PLN) off condition, the smart grid system has not been able to supply the load because the availability of renewable energy sources is not sufficient for the load requirement. As well as the results of the voltage and frequency analysis, the highest voltage is 376.4 Volts, the lowest is 375.9 Volts, which is still in the stable category of 380 Volt voltage deviation because it is not +5% and -10%, and the overall frequency of the cases discussed is consistent stable at nominal 50 Hz.

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1. INTRODUCTION

Solar radiation is a source of unlimited energy, including renewable energy. Humans can process it into a source of electrical energy [1]. The processing of solar radiation into electrical energy is carried out through solar cells. With the existence of electrical energy from solar cells can ensure the availability of electrical energy [2], [3]. Electricity is an important component in a building [4]. Like other universities, the educational process at the Medan Area University during lectures and carrying out daily activities cannot be separated from the use of electrical energy. On campus, electricity is used for academic activities, laboratories, administration, events and student dormitories. Due to the large number of loads, the power requirements and costs for electrical energy on campus are relatively high. On certain day the main source of electrical energy provided by Indonesian State Electricity Company (PLN) is insufficient, resulting in power outages [5], [6]. So it is realized that an electricity network that is regulated with renewable energy sources is needed to meet the needs of electrical energy.

One way to avoid the cessation of electricity supply from PLN is to rely on electrical energy sources from solar panels [7]. Through the feasibility analysis of using electrical energy sources from solar panels, a smart energy management is needed [8], [9]. Several studies have examined the smart grid management system between sources and loads [10]–[12], in strategies [13], [14], maintaining a balance between loads and sources [15], and uncontrollable demand and energy [16].

To determine the stable operating state of the system can be sought through power flow analysis [17], [18]. The results of the power flow analysis are the magnitude and phase angle of the voltage on each channel (bus) of real power and reactive power on each channel used to determine the magnitude of losses (loss of power and voltage), and the allocation of reactive power [19]. To perform power flow analysis there are several methods that can be used, namely the Newton Raphson method, Gauss Seidel, fast decoupled, and Newton–Raphson adaptive [20]–[23].

Electric transient and analysis program (ETAP) is a platform that can help simplify and is very comprehensive for the design, simulation, control, operation, optimization, generation, transmission, distribution and industrial power systems [24]–[27]. ETAP can used to create project one line diagrams or one line diagrams for various analyzes including arc flash, load flow, short circuit, relay coordination, cable capacity, transient stability [28]. In the 12.6 stage power flow simulation the user can choose one of the Newton Raphson, Gauss Seidel, fast decoupled and adaptive Newton-Raphson analysis methods. To determine the stability of the transient network, we can use the transient analysis feature in ETAP 12.6.

The purpose of this study is to analyze the stability of the smart grid management system in campus buildings using ETAP simulation. Which will be analyzed the factors that affect the stability of the system such as voltage, frequency, and power of the source and load. The six varied cases will provide such as the PLN, solar panels, and batteries in different condition and give assumption of the load constant.

2. METHOD

The method used in this study is a simulation method using ETAP 12.6 software using the Newton-Raphson method of power flow analysis. Data collection was carried out for 14 days based on daily load data from PLN. Data and specifications of electrical equipment used include data on transformers, solar cells, batteries, inverters and loads (see Figure 1) [6]. After the required data are met can see in Table 1, the next step is to design a single line diagram of the Medan Area University smart grid using ETAP 12.6 and simulate it. The data used in the ETAP application it can be shown in Table 1.

The Cases that will be discussed in this study will be divided as follows: i) the case 1, where the solar cell and the battery are off; ii) the case 2, where the battery is off; ii) the case 3, where the battery assume as a source; iv) the case 4, where the battery assume as a load; v) the case 5, where the solar cell is off and the battery assume as a load; and vi) the case 6, where the PLN is off, and the solar cell and the battery assume as sources.

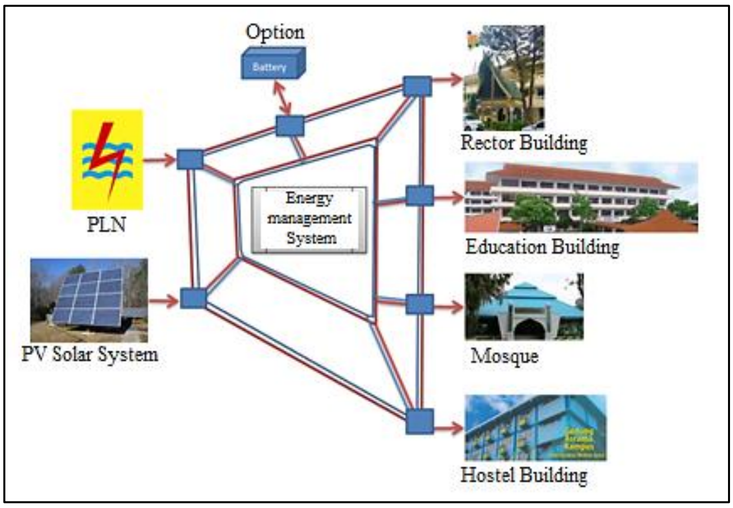

Figure 1. Smart grid system management of Medan Area University [5]

3. RESULTS AND DISCUSSION

After the circuit is made in the ETAP 12.6 software, it is then filled in with the data listed in Table 1. The power flow simulation is carried out in each different case. The results of the simulation can be seen in the following sub-sections.

Table 1. The simulation data for power grid, photovoltaic (PV) solar, battery, inverter and load application

Power grid				
Parameter	Rating			
Rating kV	20 kV			
SC level 3-ph	100 MVAsc			
Nominal distribution transformer	500 kVA			
Frequency	50 Hz			
Primary voltage	20 kV			
Secondary voltage	0.38 kV			
PV array				
Generate data	Operation mode	Volt (DC)	kW (DC)	Amp (DC)
PV 1	PF control	177.66	5.301	29.84
PV 2	PF control	177.66	5.301	29.84
Battery				
Rating	Value			
Of cell	98 cell			
Rated Voc	202.2 Voc			
Inverter				
DC rating				
Power	6,111 kW			
Volt	200 V			
AC rating				
Power	5,5 kVA			
Voltage	0,380 kV			
Operation system	PF *control*			
Output connection	3 phase			
Load				
ID	Type	Rating (kVA)	kW	%PF
Rectorate building	Static load	176	162	95
Dormitory building	Static load	143	132	95
Mosque	Static load	5	5	95
Education building	Static load	148	136	95

3.1. The case 1, where the solar cell and the battery are off

The simulation results on the single line network diagram the case 1 in Figure 2 show that on bus 2 (rectorate building) and bus 5 (dormitory building) shows the color changes to pink. This indicates that the buses are in a marginal or critical condition. This is because the total of the two loads that must be supplied is quite large, namely 264 kW with the ability of the transformer to send power of 389 kW or more than 50% of the transformer's ability.

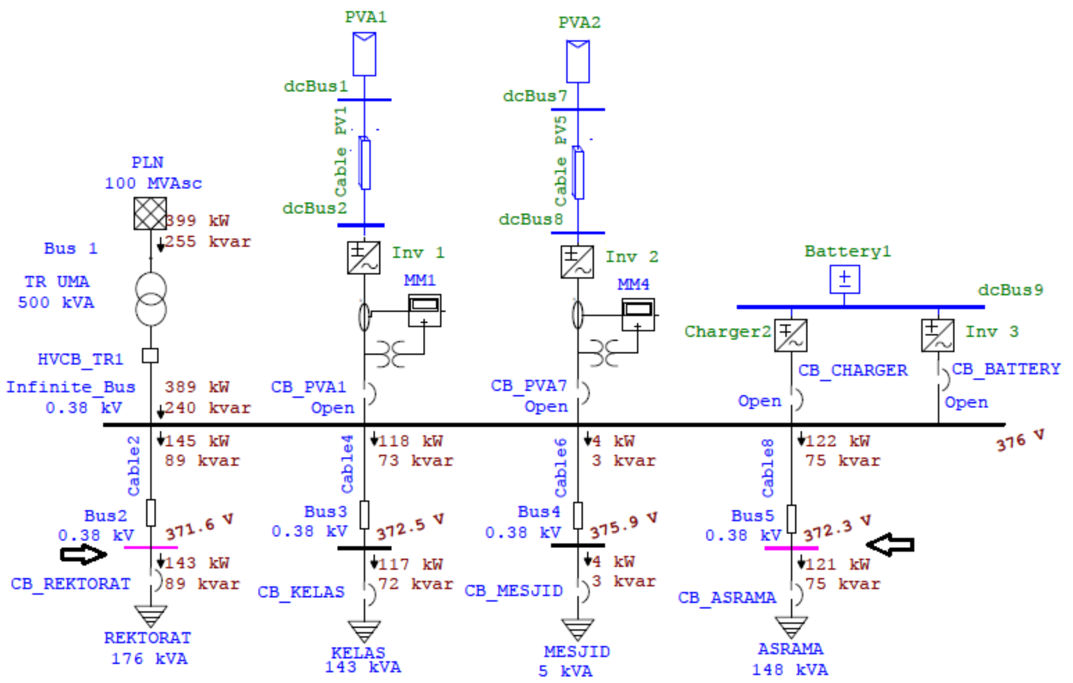

Figure 2. Single line diagram of power flow simulation uses ETAP 12.6 for the case 1

3.2. The case 2, where the battery is off

The results of running the power flow on the single line diagram for the case 2 show that bus 2 (rectorate building) is still in marginal condition because the total load on bus 2 is quite large, namely 176 kVA. While on bus 5 back to normal conditions. This shows the influence of solar cells as an additional source (see Figure 3).

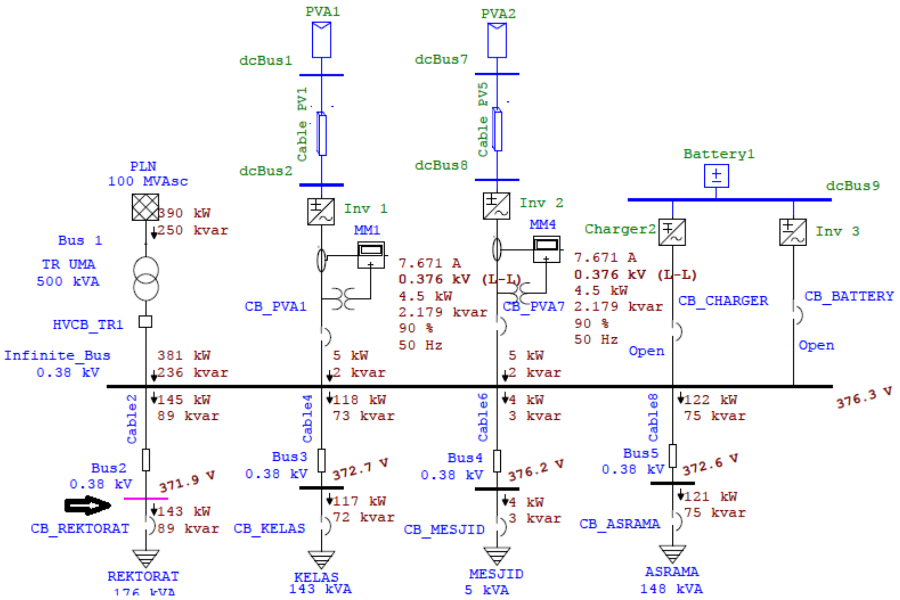

Figure 3. Single line diagram of power flow simulation uses ETAP 12.6 for the case 2

3.3. The case 3, where the battery assume as a source

The results of the running load flow in Figure 4 use ETAP 12.6 using 3 (three) energy sources consisting of PLN, solar cells and batteries. From the simulation results, there is bus 2 (rectorate building) in marginal condition. For the status of the smart grid in general, it works under normal circumstances. The simulation results in case 3 can be seen that there is a decrease in the active power of the transformer, namely in case 1 by 389 kW to 378 kW in case 3, and there is an active power loss in the network of 6 kW.

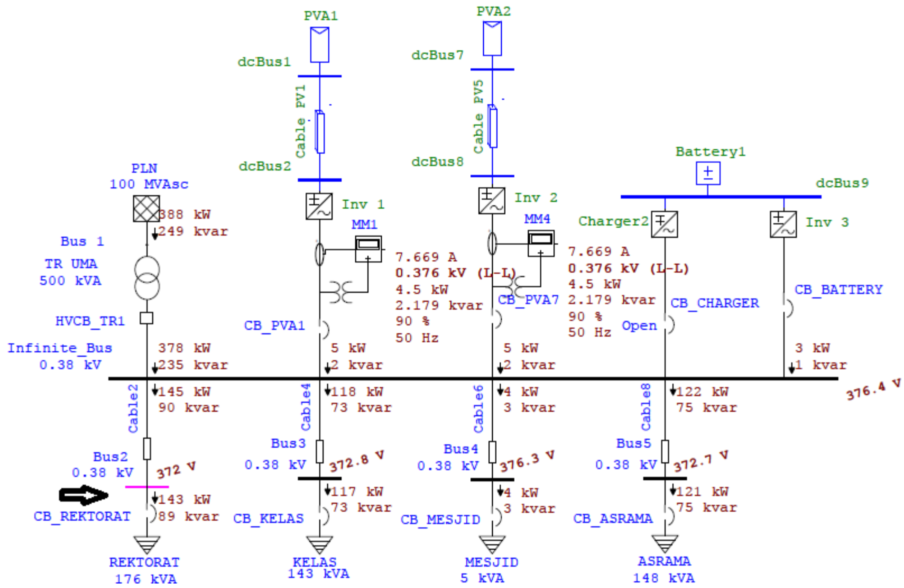

Figure 4. Single line diagram of power flow simulation uses ETAP 12.6 for the case 3

3.4. The case 4, where the battery assume as a load

From Figure 5 marginal or critical conditions only occur on bus 2 and battery being an additional load that requires active power is 3 kW. Even though there is an additional battery as a load, the highest total load is only 143 kW on bus 2. Meanwhile, the total power sent from PLN is 384 kW. But with the help of power from solar panels, only bus 2 is still in critical condition.

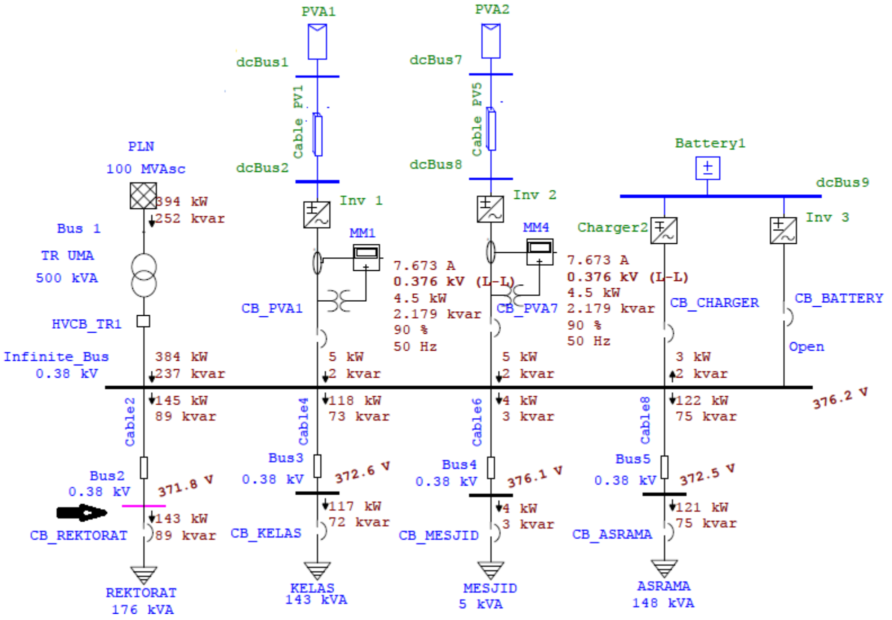

Figure 5. Single line diagram of power flow simulation uses ETAP 12.6 for the case 4

3.5. The case 5, where the solar cell is off and the battery assume as a load

Figure 6 shows the simulation results for the transformer, bus 2 (rectorate building), bus 3 (education building), and bus 5 (dormitory building) marked in red on the symbols and buses. This indicates that there is an overload but still within tolerance (marginal). This condition is where the supply is obtained through PLN only. Meanwhile the battery changes function to become a load. This can be said to be an additional load but no additional energy source.

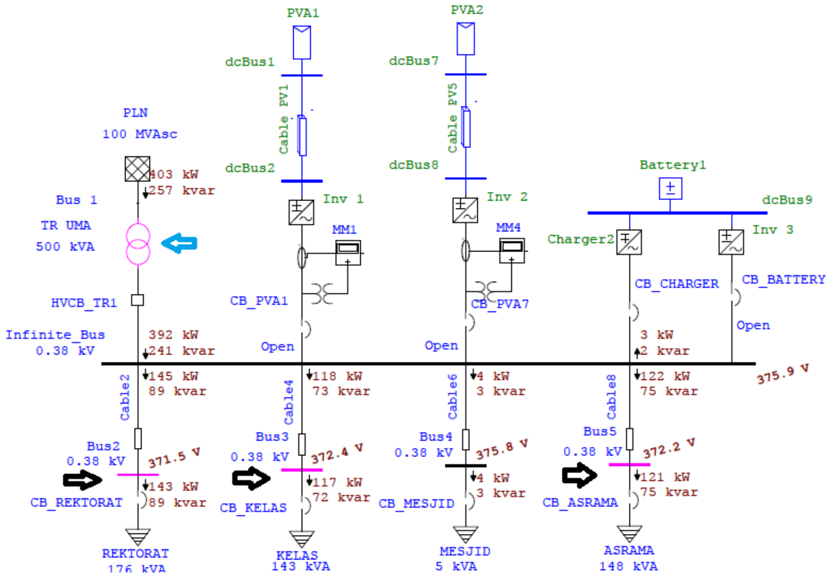

Figure 6. Single line diagram of power flow simulation uses ETAP 12.6 for the case 5

The increasing use of the power required by the load causes the transformer to get overloaded (marginal). Meanwhile the solar cell does not respond. In this situation there is an increase in active power from 389 to 392 kW. This is due to the absorption of active power of 3 kW by the battery. And on the smart grid network there is a total active power loss of 4 kW.

3.6. The case 6, where the PLN is off, and the solar cell and the battery assume as sources

Based on the simulation results shown in Figure 7, shows the simulation results of load flow on the inverter connected via solar cells, and the battery works in critical conditions (not permitted) with a red mark on DC bus 2, dcbus 8 and dcbus 9. It is because the solar panel and the battery are unable to meet the load demand. Which is because the total active power at load is 402 kW, while the total active power supplied through the solar cells and battery is only 13 kW?

In the case 1 when the solar cell and battery are not responding, the active power of the transformer is 389 kW. Compared to the case 2 when the solar cell responds, this has an impact on decreasing the active power supply transformer work from 389 to 381 kW, a reduction of 8 kW. This is due to the addition of an active power supply of 10 kW from the solar cell. This will also add up to 16 kW of reactive power losses [2]. However, in the case 3, the active power of the transformer decreased again to 378 kW. That's because of the addition of a 3 kW battery as a source. With the addition of PV sources and batteries, the system will work optimally [5]. Where as in the case 4, the active power of the transformer returned to 384 kW due to a change in the function of the battery as an additional load. It is not the same as that which applies to the case 2. System optimization will change due to battery charging [6]. In the case 5, solar cells do not respond while the battery remains as a load of 3 kW, the active power of the transformer is 392 kW. And transformers are in critical condition. There is an increase from the case 1. For the case 6 if PLN does not respond, the source is expected only from the solar cells. In this situation, a large power capacity is needed from the solar cell to be able to supply the entire load. So that it can be seen from the simulation results in Figure 7, that the percentage imbalance of solar cells.

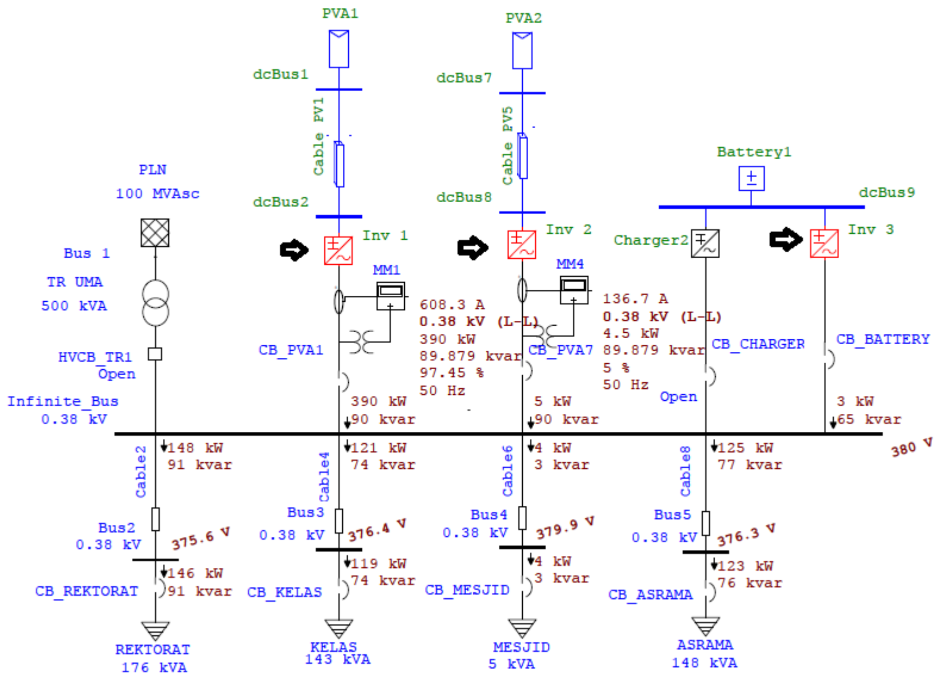

Figure 7. The simulation result of power flow analysis uses ETAP 12.6 in the case 6

3.7. The comparison of current simulation results for each case

From the results of the power flow simulation using the ETAP 12.6 application shown in Table 2. In case 1 the source only came from PLN. From the simulation results, it is found that the current flowing on bus 2 (rectorate building) is the most current of around 261.5 Amp. While the ability of the transformer to flow a current of 702.3 Amp. This shows that the load requirement on bus 2 is around more than 40% of the total load requirement.

Table 2. The load current simulation result of power flow analysis for each Case using ETAP 12.6

Bus ID	Case 1 [A]	Case 2 [A]	Case 3 [A]	Case 4 [A]	Case 5 [A]	Case 6 [A]
Bus 2	261.5	261.7	261.8	261.8	261.5	264.3
Bus 3	213	213.1	213.2	213.1	212.9	21.2
Bus 4	7.5	7.5	7.5	7.5	7.5	7.6
Bus 5	220.3	220.5	220.5	225.2	225.1	222.6
Infinite_bus	702.3	702.9	703.1	707.6	707	844.4
PV solar	0	15.342	15.338	15.346	0	745
Battery	0	0	0	0	0	0

Based on the simulation results case 2 there was an additional source using solar panels. Here the use of current from the transformer is reduced from 702.3 to 687.5 Amps. This is because the solar cell is capable of supplying a current of 15.4 Amps. In other words, when the solar cells are active, the system can save a current of 15.4 Amps.

Based on the simulation results case 3 there was a reduction in the use of current from the transformer of 19.7 Amps. This shows that the solar cell and battery supply a current of 19.7 Amps. So that the condition of the solar cells and active batteries can save the use of current from PLN by 19.7 Amps. And it shows a smart system. Based on the simulation results case 4, the source is still from PLN and solar panels while the battery changes function to become a load. Here there is an increase in current reaching 707.6 Amps on the infinite bus, compared to what happened in cases 1 and 2, namely 702.2 Amps and 703.1 Amps respectively in case 3. This is because the battery is an additional load that requires current . that is equal to 4.8 Amp. But compared to case 1, there is still a 10 Amp reduction in working current when the battery is charging.

Based on the simulation results case 5, the source was obtained only through PLN and there was an increase in current usage from 702.3 to 707 Amps. This is due to the use of a current that charges the battery at 4.8 Amps. And this will cause the transformer to experience more load. Based on the simulation results the case 6, the source is only from solar panels to supply the building load and the battery. With the ETAP simulation for a solar panel value of 5 kW, the simulation operation cannot be run nor has an error. That happens because the solar panels are not able to supply the entire load. So that the simulation can be processed, the capacity of one of the solar panels is increased by 390 kW from 5 kW. Next the ETAP simulation operation can be run. And consequently a solar panel with a capacity of 5 kW must supply a current of 136.7 A beyond its capacity. For this state the system is not stable.To find out the comparison of the voltage and frequency of the transition simulation in all the cases discussed the graph in Figures 8 and 9.

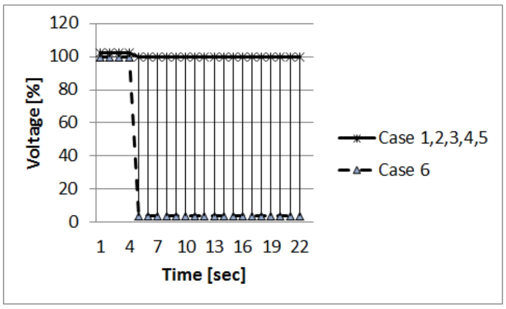

Figure 8. Graph of comparison result of voltage response in 6 cases

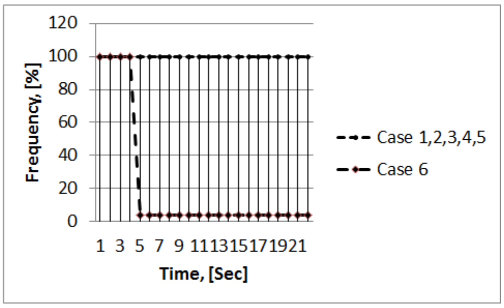

Figure 9. Graph of comparison result frequensi response in 6 cases

From Figure 8 from the results of the transient analysis using ETAP 12.6, it can be observed that when the system has no load, the working voltage is 102.5% or 389.5 Volts and when a load is given in the 3rd second there is a voltage drop and it works at 99.5% or 378 Volts. Based on the voltage stability standard set by PLN, which is +5% and -10% of the nominal voltage of 380 Volts, this applies in cases 1 to 5, so this voltage is still in the stable category [29]. While the lowest voltage is in the case 6, which is 15 Volts. This is because the energy source is only supplied from solar cells and batteries. The voltage in the case 6 is in the unstable category.

Figure 9 shows the results of the run transient at ETAP 12.6 in the predetermined scheme. In cases 1 to 5 there is no change when simultaneously loading at the 3rd second loaded, the simulation of the transition tends to be constant, because there is no interference with the energy source. Fixed frequency works well at nominal 100% or 50 Hz. Based on the stability standard, the frequency limit refers to the IEEE/C37.106-1987 [28] standard, which is 99-101% or 49-52 Hz, meaning that the frequency in the electricity network system is stable. Then it does not exceed the limit of 101% or 51 Hz and is not less than 99% to 49 Hz. However, in the case 6, there is a change in the decrease in frequency, namely to 4% or 2 Hz when simultaneously loading at the 3rd second. Based on the stability standard, the frequency limit refers to the IEEE/C37.106-1987 [28] standard, which is 99%-101% or 49-52 Hz, meaning that the frequency of the electricity network system in the case 6 is unstable (prohibited operation), which is prohibited. It is because less than 99% or 49 Hz.

4. CONCLUSION

Based on the simulation results and the stability of the flow of electricity on the smart grid management system, several conclusions can be drawn including: in a situation where the source comes from PLN and solar cell even though the battery functions as a source or vice versa only 1 bus at the load is experiencing critical or marginal conditions. But if the solar cell turns off, a condition occurs where the transformer becomes overloaded (marginal) due to charging the battery. While the available source is just the solar cells, the solar cell value required must be able to support the load. The voltage and frequency values have reached stability because they meet the standard voltage stability set by PLN, namely +5% and -10% of the 380 Volts nominal voltage, the overall voltage is still in the stable category, the frequency is also in the stable category. It should be avoided that the supply only comes from the Solar cells because it will affect the stability of the system voltage and frequency unless the available the solar cells capacity are equal to or greater than the available load capacity.

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