Analysis of smart grid power flow system with Gauss-Seidel method

Syarifah Muthia Putri*1, Dina Maizana2, Zulkifli Bahri3
1Faculty of Engineering, Electrical Engineering, University of Medan Area

*E-mail: syarifahmuthiaputri@gmail.com

Abstract. The use of smart grid systems is a good opportunity for the future of electric energy resilience in the future. The design of smart grid systems that use electrical energy sources through the PLN (National Power Plant), PV Solar System and Battery as a backup can improve efficiency in the electricity grid. To ensure that the system is feasible, it is necessary to analyze the power flow in the system. The analysis is performed on each case contained in the network with Gauss-Seidel Method. The analysis shows that case 1 is the most optimal power supply from PLN and RE (Renewable Energy).

1. Introduction
The provision of electrical energy through solar cells to increase the capacity of electric power is one way so that the availability of electrical energy sources is guaranteed. Combining electrical energy sources PLN (National Power Plant) with a solar cell is a lot to do now. This requires electrical energy conversion management to produce optimal energy usage. The problem of instability is important to be eliminated because instability in the supply of electrical energy sources in a combination of PLN and solar cells will affect the stability of power usage.

If a system experiences a situation of instability such as voltage stability, that is a decrease in voltage within a few minutes, there will be interference. And if this reduction is too noticeable, it will cause the integrity of the system to close to extinction, especially in protecting devices such as the generation, transmission, or loading of equipment. This degradation process will cause a power outage in the form of a decrease in voltage [1].

Power flow analysis is needed to determine the operating conditions of the power system in a steady, through solving the power flow equation on the network. The main objective of the power flow study is to determine the voltage magnitude, voltage angle, active power flow and reactive power in the line, and transmission losses that arise in the power system [2,3].

Research on power flow has been done by several researchers using the Gauss-Seidel method [4, 5], Neuton Raphson method [6], and Fast Decouple [7]. In completing some applications used through the Matlab Program such as the use of genetic algorithms [8], artificial neural networks [5], or using other applications such as ETAP stands for Electrical Transient Analyser Program [9]. The objective of this paper is to analyze the power flow in a smart grid system using the Gauss-Seidel method.

2. Methodology
Power flow calculation is performed on a smart grid system consisting of 3 buses as shown in Figure 1. with two types of data quantities. Channel admission data is shown in Table 1, Table 2, Table 3, Table
and Table 5. The Table shows the load and load data for each case. Admittance of channels in units per unit on a 100 kVA basis.

### Table 1. Network Wire Data

| Channel | Channel Admittance (PU) | Shunt Admittance |
|---------|-------------------------|------------------|
| 1 - 2   | -j10                    | 0                |
| 1 – 3   | -j10                    | 0                |
| 2 – 3   | -j10                    | 0                |

### Table 2. Bus Generation and Load and Voltage Data in case 1

| Bus | Voltage (pu) | Generating power | Load power |
|-----|--------------|------------------|------------|
|     |              | kW               | kW         |
|     |              | kVar             | kVar       |
| 1   | 1.01         | ---              | 0          |
| 2   | 1            | ---              | 443        |
| 3   | 1            | 5                | 0          |

### Table 3. Bus Generation and Load and Voltage Data in case 2

| Bus | Voltage (pu) | Generating power | Load power |
|-----|--------------|------------------|------------|
|     |              | kW               | kW         |
|     |              | kVar             | kVar       |
| 1   | 1.01         | ---              | 0          |
| 2   | 1            | ---              | 443        |
| 3   | 1            | 0                | 0          |

### Table 4. Bus Generation and Load and Voltage Data in case 3

| Bus | Voltage (pu) | Generating power | Load power |
|-----|--------------|------------------|------------|
|     |              | kW               | kW         |
|     |              | kVar             | kVar       |
| 1   | 1.01         | ---              | 0          |
| 2   | 1            | ---              | 400        |
| 3   | 1            | 0                | 0          |
### Table 5. Bus Generation and Load and Voltage Data in case 4

| Bus | Voltage (pu) | Generating power (kW) | Load power (kVar) |
|-----|--------------|-----------------------|------------------|
| 1   | 1.01         | ---                   | 0                |
| 2   | 1            | ---                   | 400              |
| 3   | 1            | 5                     | 0                |

If there are problems in the system, surely undesirable things can happen as follows:

Case 1; The PV solar system does not respond to communication calls.

Case 2; Battery is not functioning.

Case 3; If there is a lack of energy, but the PV solar system is not functioning, and the battery is also not functioning.

In the power flow analysis, some buses manage an electric power system, and there are three types of buses, namely P-Q buses or load buses, P-V buses are called generator buses, swing buses or slack buses. Applications of Kirchhoff’s current laws on buses can be given:

$$I_i = \sum_{j=0}^{n} Y_{ij} - \sum_{j=1}^{n} Y_{ij} v_j , j \neq i \quad (1)$$

Active and reactive power:

$$\frac{P_{i+1} + Q_{i+1}}{v_i} = v_i \sum_{j=0}^{n} Y_{ij} - \sum_{j=1}^{n} Y_{ij} v_j , j \neq i \quad (2)$$

From the above equation, the calculation of power flow can be done by iteration.

The simulation process uses MatLab software using the Gauss-Seidel method. [10]

To solve Vi iteratively, then:

$$V_i^{(k+1)} = \frac{P_i^{\text{sch}} + Q_i^{\text{sch}}}{V_i^{(k)}} \sum_{j=0}^{n} y_{ij} v_j^{(k)} , j \neq i \quad (3)$$

With $y_{ij}$ the channel admittance in the per unit, $P_i^{\text{sch}}$ and $Q_i^{\text{sch}}$ are the active and reactive power expressed in the per unit, the current entering the bus is assumed to be positive. For loaded buses, active and reactive power away from the bus. Active and reactive power, $P_i^{\text{sch}}$, and $Q_i^{\text{sch}}$ are negative. For equation $P_i$ and $Q_i$ are as follows:

$$P_i^{(k+1)} = R\{V_i^{(k)} \sum_{j=0}^{n} Y_{ij} v_j^{(k)} - \sum_{j=1}^{n} Y_{ij} v_j^{(k)}\}, j \neq i \quad (4)$$

$$Q_i^{(k+1)} = -im\{V_i^{(k)} \sum_{j=0}^{n} Y_{ij} v_j^{(k)} - \sum_{j=1}^{n} Y_{ij} v_j^{(k)}\}, j \neq i \quad (5)$$

Iteration starts from k = 0. The criteria for PQ buses are:

$$|v_i^{(k+1)} - v_i^{(k)}| \leq \varepsilon \quad (6)$$

3. Results and discussion

### Table 6. Simulation result

| Case 1 (pu) | Case 2 (pu) | Case 3 (pu) | Case 4 (pu) |
|-------------|-------------|-------------|-------------|
| V1          | 1.01        | 1.01        | 1.01        | 1.01        |
| V21         | 1.005-0.2215i | 1.005-0.2215i | 1.005-0.2i  | 1.005-0.2i  |
| V22         | 0.95574-0.2643i | 0.9556-0.2656i | 0.9644-0.24142i | 0.96452-0.24017i |
| V23         | 0.9413-0.27966i | 0.9408-0.28109i | 0.95252-0.25523i | 0.95294-0.25377i |
| V24         | 0.9366-0.2806i | 0.9360-0.28205i | 0.94889-0.25598i | 0.94937-0.2545i |
| V25         | 0.93537-0.28476i | 0.93481-0.28625i | 0.94799-0.25965i | 0.94851-0.25813i |
| V31         | 0.99412-0.10825i | 0.99385-0.11075i | 0.99499-0.1i | 0.99524-0.0975i |
| V32         | 0.99168-0.12874i | 0.99127-0.13184i | 0.99276-0.12014i | 0.99313-0.11704i |
From Table 6, iteration can be seen as many as 5 iterations and the voltage values on bus 2 and bus 3 can be determined. The reactive power value on bus 3 can be searched including the value of power supplied through PLN. The value of the power flow through each bus can be calculated and subsequently, the value of the losses of each channel is also determined.

![Power Flow Diagram]

**Figure 2.** Power flow for case 1
Figure 3. Power flow for case 2

Figure 4. Power flow for case 3
From Figure 1 it can be seen that to fulfill the supply of loads, electrical energy from PLN and RE is needed. Losses that arise are reactive power losses. With the Gauss-Seidel method, the value of reactive power from RE sources can be calculated. Figures 2, 3, 4, and 5 show the different voltage and power quantities for each different case. Power flow is indicated by the direction of the arrow. In all cases the same power flow is indicated. The data in Table 1 shows a comparison between several cases, namely:

**Cases 1 and 2**
Where in case 1 Power RE = 0.05 pu and in case 2 the value of Power RE = 0. From the simulation results, it can be seen that the load power supply flows entirely from PLN for case 2. The power flowing from bus 1 to 2 and bus 1 to 3 increases in active power while in the power flow from bus 3 to 2 the opposite occurs. The reactive power losses from bus 1 to 2 and bus 1 to 3 are greater in case 2 than case 1. But from bus 2 to 3 the reactive power losses in case 1 are greater than case 2. Active power losses appear in case 2 for power flow from bus 1 to 2, although the value is very small compared to the value of reactive power losses.

**Case 1 and 4**
There was a reduction in load and power supply from PLN and RE for both cases. From the simulation results obtained in case 4 a decrease in power flowing from one bus channel to another bus. This is due to the reduced load on case 4. Reactive power losses are also reduced for all channels. Only a few reactive power losses are seen in the channel from bus 1 to bus 2, from bus 1 to bus 3, and from bus 2 to bus 3 and this also appears in case 2 where the power to the load remains but the supply of power from RE = 0

**Case 2 and 3**
There is a decrease in load in case 3. In cases 2 and 3 the power supply to the load is taken only from PLN. From the simulation results, it can be seen that in case 3 there is a decrease in power flow from each bus to another bus. The active power losses that arise in the power line from bus 1 to 2 in case 3 are the same as the active power losses in case 2 even though the value is very small compared to the reactive power losses.
4. Conclusion
Power flow simulation using the Gauss-Seidel method can be carried out. To supply power to the maximum load obtained from PLN and RE in case 1 where the simulation results show no active power losses that arise, only reactive power losses arise as in case 4 with load reduction. Active power losses occur in the power line from bus 1 to bus 2 for cases 2 and 3 which occur due to load changes and changes in power supply from RE. With the reduction in load and power supply only obtained by PLN, there will be active power losses from buses 1 to 2 and buses 2 to 3.

Acknowledgment
The author would like to thank the University of Medan Area for helping us to carry out this investigation.

References
[1] R Pandey, and Payal Suhane, Voltage Stability Analysis of Smart Grid and Application of FACTS Controller: A Review, International Journal of Science and Research (IJSR) ISSN (Online): 2319-7064.
[2] E H Harun, Analisis Tegangan Setiap Bus Pada Sistem Tenaga Listrik Gorontalo Melalui Simulasi Aliran Daya,
[4] A M Eltamaly1 and A N A. Elghaffar, 2006, Load Flow Analysis by Gauss-Seidel Method; A Survey, International journal of mechatronics, electrical and computer technology (IJMEC).
[5] S Bera, M Cebebi, 2013, Power flow analysis by Artificial Neural Network, International Journal of Energy and Power Engineering, 2(6), 204-208.
[6] D K Mander, G S Virdi, 2017, Result Analysis on Load Flow by Using Newton Raphson Method, International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, 6 (7).
[7] Y Yao, M W Li, 2012, Designs of Fast Decoupled Load Flow for Study Purpose, International Conference on Future Electrical Power and Energy Systems, Energy Procedia 17, 127 – 133.
[8] H. Kubba, and Samir Sami Mahmood, 2009, Genetic algorithm based load flow solution problem in electrical power systems, journal of engineering, volume 15, number 4.
[9] M N Malik, A I Toor, M ASiddiqui, N Husain and A Nadeem, 2016, Load Flow Analysis Of An Eht Network Using Etap, Journal of Multidisciplinary Engineering Science and Technology (JMEST), ISSN: 2458-9403, 3(6).
[10] I Kawengian, I Patras, Ml Tuegeh, 2013, analisa perbandingan perhitungan aliran daya sistem minahasa dengan metode gauss-seidel, newton-raphson dan fast decoupled, Jurnal teknik elektro dan komputer, 2 (3).