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Research Paper

A Comparison of Active Power Generated Under Normal Circumstances with the Optimization State Electric Power System

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ABSTRACT

To see the power at normal conditions and at optimal conditions, the researchers used the Electrical Transient Analyzer Program (ETAP). Simulation using Load Flow (LF) and Optimal Power Flow (OPF) is a tool to produce power flow during normal conditions and when the power flow is optimal as a comparison for calculating the cost of generation from the power produced by each generator. After carrying out the Load Flow simulation process, when normal conditions were obtained, the simulation results showed that the active power released by the plant was 807.3 MW. Whereas after carrying out the Optimal Power Flow (OPF) simulation process, at optimal conditions. The simulation results show that the active power released by the generator is 806.2 MW.

Keywords: Electrical Transient Analyzer Program (ETAP), Optimal Power Flow (OPF), Losses

1. INTRODUCTION

In the planning, operation and control of electric power systems various problems arise in technical and economic terms, one of which is caused by dynamic system loads. On the other hand, electrical energy cannot be stored in large quantities, so it must be provided when it is needed by consumers, as a result, problems arise in dealing with changing electrical power requirements from time to time.(Hadidian-Moghaddam et al., 2018)If the power sent from the generator buses is greater than the power requirements of the load buses, a waste of power will occur. Meanwhile, if the power generated is lower than required or does not meet the load requirements, local blackouts will occur on the load buses, which will result in losses to consumers.(Farh et al., 2020)

To see the power at normal conditions and at optimal conditions, the researchers used the Electrical Transient Analyzer Program (ETAP). Simulation using Load Flow (LF) and Optimal Power Flow (OPF) is a tool to produce power flow during normal conditions and when the power flow is optimal as a comparison for calculating the cost of generation from the power produced by each generator.(Singh et al., 2020).

2. LITERATURRE REVIEW

2.1. Power Flow Studies or Load Flow

Load flow studies or load flow studies are often also called power flow studies in an electrical system from one point to another and the voltage on the buses that are in the system.(Sun et al., 2020)

Load flow study is the determination or calculation of voltage, current, active power, power factor and reactive power present at various points in an electric power system network under normal operating conditions, both currently underway and expected to occur in the future.(Xie et al., 2021)

Flow analysis studies can be calculated manually or by computer software. So, a power flow study can be defined as a study carried out to obtain information about power flow in the form of voltage, current, active power, reactive power contained in an electrical system in order to evaluate the work of the electric power system as well as analyze generation and loading conditions.(Naderi et al., 2021)

The objectives of the load power flow study are:

a. To know the network components of the electric power system in general.
b. To determine the magnitude of the voltage on each bus (rail) of an electric power system.
c. Calculate the power flows, both real power and reactive power flowing in each channel.
d. Optimum system losses
e. Repair and replacement of conductor sizes and system voltages.

In the study of power flow, various buses are known:(Alvarez et al., 2012)

a. Reference bus (slack bus or swing bus)
- Connected with generators
- The V and phase angle of the generator are known and fixed.
- P and Q are calculated

Slack bus serves to supply the real power shortage P and reactive power Q to the system, or as a bus that bears all the power losses that occur in the network. Usually this bus is the largest generator or an infant bus (infinite bus) such as an interconnection system.(Biswas et al., 2017)

b. Generator Bus (Generator Bus) or (PV Bus)
- Connected to generators.
- The P and V of the generator are known and fixed.
- The phase angle and Q of the generator reactive power are calculated.

c. Loading Bus (PQ Bus)
- Connected with the load.
- The P and Q of the load are known and fixed.
- V and the phase angle of the voltage are calculated.

On each bus there are 4 quantities, namely:

a. Real power or active power (P)
b. Reactive power (Q)
c. Rated voltage (V)
d. Voltage phase angle (θ)

2.2. Newton-Raphson method

MethodNewton-Raphson applies the Taylor series to obtain a mathematical equation as the basis for iterative calculations using the Jacobian matrix. The Newton-Raphson method is a sequential approximation procedure based on an unknown initial estimate and is the use of the Taylor series. The Newton-Rapshon method has better calculations than the Gauss-Seidel method in larger power systems because it is more efficient and practical.(Atwa et al., 2010)

To find active power (P) and reactive power (Q) as follows:

$$P_i = \sum_{j=1}^{n} |V_i||V_j||Y_{ij}|\cos(\theta_{ij} - \delta_i + \delta_j)$$

$$Q_i = -\sum_{j=1}^{n} |V_i||V_j||Y_{ij}|\sin(\theta_{ij} - \delta_i + \delta_j)$$

In this equation the power flow is formulated in polar form. Series method*Taylor*formulated as follows.

$$\begin{bmatrix} \Delta P_2^{(k)} \\ \cdots \\ \Delta P_n^{(k)} \\ \hline \Delta Q_2^{(k)} \\ \cdots \\ \Delta Q_n^{(k)} \end{bmatrix} = \left[\begin{array}{ccc|ccc} \frac{\partial P_2^{(k)}}{\partial \delta_2} & \cdots & \frac{\partial P_2^{(k)}}{\partial \delta_n} & \frac{\partial P_2^{(k)}}{\partial |V_2|} & \cdots & \frac{\partial P_2^{(k)}}{\partial |V_n|} \\ \cdots & \cdots & \cdots & \cdots & \cdots & \\ \frac{\partial P_n^{(k)}}{\partial \delta_2} & \cdots & \frac{\partial P_n}{\partial \delta_n} & \frac{\partial P_n^{(k)}}{\partial |V_2|} & \cdots & \frac{\partial P_n^{(k)}}{\partial |V_n|} \\ \hline \frac{\partial Q_2^{(k)}}{\partial \delta_2} & \cdots & \frac{\partial Q_2^{(k)}}{\partial \delta_n} & \frac{\partial Q_2^{(k)}}{\partial |V_2|} & \cdots & \frac{\partial Q_2^{(k)}}{\partial |V_n|} \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ \frac{\partial Q_n^{(k)}}{\partial \delta_2} & \cdots & \frac{\partial Q_n^{(k)}}{\partial \delta_n} & \frac{\partial Q_n^{(k)}}{\partial |V_2|} & \cdots & \frac{\partial Q_n^{(k)}}{\partial |V_n|} \end{array}\right] \cdot \begin{bmatrix} \Delta \delta_2^{(k)} \\ \cdots \\ \Delta \delta_n^{(k)} \\ \hline \Delta |V_2^{(k)}| \\ \cdots \\ \Delta |V_n^{(k)}| \end{bmatrix}$$

The Jacobian matrix gives a linear comparison between the change in voltage angle and the voltage with little change in active and reactive power. In short form it can be written as follows: $\left(\Delta\delta_i^{(k)}\right)\left(\Delta|V_i^{(k)}\right)\left(\Delta|P_i^{(k)}\right)\left(\Delta|Q_i^{(k)}\right)$

$$\begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} = \left[\begin{array}{c|c} J_1 & J_2 \\ J_3 & J_4 \end{array}\right] \begin{bmatrix} \Delta\delta \\ \Delta|V| \end{bmatrix}$$

2.3. Losses and Efficiency

In a system or work there is a process called transfer (*transfer*). The process of this transfer is a process that cannot be avoided or eliminated, because a system or work requires energy as an initial capital before it is used at its final destination, including in an electric power system called a transmission system. Transmission will always suffer losses due to wasted energy during the transfer process from sources of electrical energy to consumers. These losses occur because there are many factors that affect one of the biggest factors is distance. The distance between an energy source to the load is not close, and even though it is close, there must also be wasted energy which is considered as a cost or shipping fee when a transfer occurs. Calculating simple losses can use this formula:

$$Losses = Input\ Power - Output\ Power$$

Then the difference between the difference between the energy generated and the energy used will be losses in the transmission network that occur during the process of sending the energy. This cannot be avoided or eliminated, only it can be reduced or minimized to a smaller extent by influencing existing factors.

A tool or system always has work efficiency if the tool or system carries out its work and duties efficiently and well. The efficiency in question is that there is a difference in*output*with the same inputs. The two different outputs are due to a factor or condition that influences it, it could be by changing the method of how it works or another way. It can be said efficiency if an input has an output that has been reduced by the previous output and is in the form of a percentage, or it can be seen in the formula below:

Efficiency=(output difference)/(initial output) ×100 %(2.34)

This formula can be used in other forms, not only in terms of work efficiency but also in terms of power efficiency, time efficiency, cost efficiency and others depending on the intended use.

3. RESEARCH METHODS

The power optimization discussed in this study is the optimization of power flow during peak load conditions in the northern Sumatra electricity system with a total of 18 substations. Fuel cost analysis uses the calculation method, while analysis to optimize power flow is carried out using the Optimal Power Flow Analyzer (OPF) method with the help of simulation in a computer software program called the Electrical Transient Analyzer Program (ETAP). Thus the study material consists of:(Mehta et al., 2018)

a. Make a one-line diagram with a total of 18 substations (GI) and 8 generators from the northern Sumatra electricity system.
b. Enter the existing parameters to fill each component.
c. Then simulate by selecting Load Flow (LF) to see the power flow and Optimal Power Flow (OPF) to see the optimal power flow on the Electrical Transient Analyzer Program (ETAP) for simulation results.
d. Calculating the total cost and efficiency of fuel use during normal times and after being optimized with the Electrical Transient Analyzer Program (ETAP).

4. RESULTS

4.1. Power Generation Data Analysis During Normal Conditions

Generator data analysis during normal conditions by running the program*Electrical Transient Analyzer Program*(ETAP), namely by simulating the power flow or Load Flow (LF) in the Electrical Transient Analyzer Program (ETAP). This analysis aims to see the flow of power issued by each generator to send power to the load during normal conditions. The simulation results can be seen in Fig. 1. The following data generated from the Load Flow (LF) simulation on the Electrical Transient Analyzer Program (ETAP) can be seen in Table.1

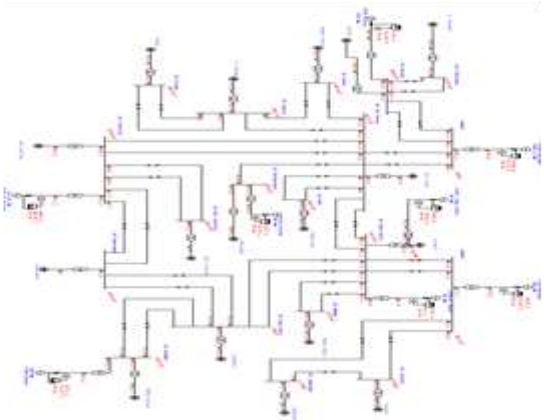

Figure 1. ***One-line Diagrams*****Load Flow System 18 Buses in ETAP**

Table 1. Power Flow Results on ETAP

No	Generator Name	Power (MW)		Current (Amperes)	Freq (Hz)	Tegs (kV)
1	PLTD Paya Pasir	24		1,320	50	19.84
2	PLTU Inalum	90		4,850	50	149
3	PLTU P. Susu	200		10613	50	148.6
4	PLTG Pasir	90		4,966	50	147.8
5	PLG Glugur	95,1		8,275	50	146.4
6	PLTU Belawan	61		3,860	50	148
7	PLTD T. Kuning	124		7.135	50	145.8
8	PLTGU Belawan	68.3		5,956	50	149

Of the total active power capacity by all power plants, it is 2092.14 MW. After carrying out the Load Flow simulation process, during normal conditions. The simulation results show that the active power released by the generator is 807.3 MW. Network losses (Losses) = P generated-Pload = 807.3 MW-802.53 MW = 4.77 MW

Then there is a difference between the overall active power of the load and the overall active power of the plant with losses of 4.77 MW. Generator data analysis after optimizing by running the Electrical Transient Analyzer Program (ETAP), namely by simulating the optimal power flow (OPF) in the Electrical Transient Analyzer Program (ETAP). This analysis aims to see the optimal power flow issued by each generator to send power to the load at optimal conditions. Then run the simulation after filling in the parameters of the voltage limits in the Optimal Power Flow (OPF) case study according to the table above, the simulation results can be seen in Figure 2:

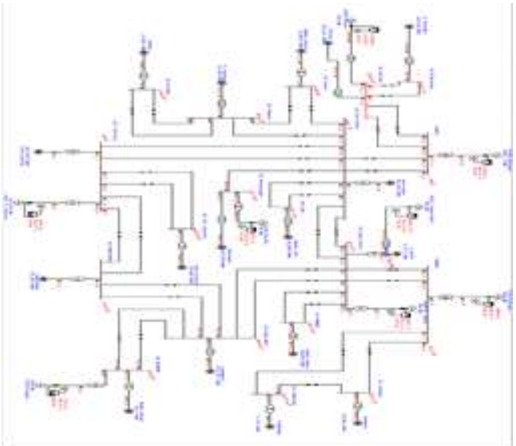

Figure 2 *One-line Diagrams*Optimal Flow 18 bus system in ETAP

Of the total active power capacity by all power plants, it is 2092.14 MW. After carrying out the Optimal Power Flow (OPF) simulation process, at optimal conditions. The simulation results show that the active power released by the generator is 806.2 MW.

Network losses (Losses) = P generated-Pload = 806.2 MW-802.53 MW = 3.67 MW

Then there is a difference between the overall active power of the load and the overall active power of the plant with losses of 3.67 MW. The results of generating power Load Flow (LF) and Optimal Power Flow (OPF) can be seen in Table 2 below.

Table 2. Active Power at Load Flow (LF) and Optimal Power Flow (OPF)

No	Generator Name	Load Flow (MW)	OPF (MW)
1	PLTD Paya Pasir	24	20,1
2	PLTU Inalum	90	75.8
3	PLTG Pasir	90	79,2
4	PLG Glugur	150	95,1
5	PLTU P. Susu	200	97.5
6	PLTD T. Kuning	124	109.5
7	PLTU Belawan	61	115
8	PLTGU Belawan	68.3	214,4
Amount		*807.3*	*806.2*

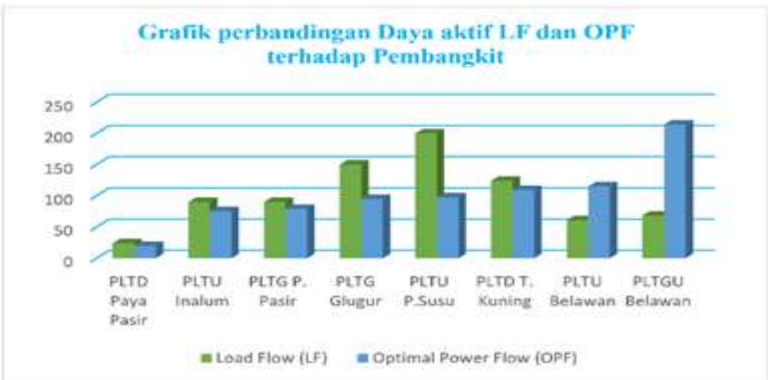

Figure 3. ComparisonActive power at Load Flow and Optimal Flow

On picture. 3 graphs of the comparison of active power generated during normal times and during optimization make generators with a voltage bus lower the power they generate during the optimization process. This effect occurs because generators with swing buses accommodate excess loads that occur when interconnecting with the nearest voltage bus generator. The aim is also to maintain reliability and extend the life of the generator which must continue to work overload during peak load times (WBP), moreover the generator with the swinging bus in this case still has a lot of energy capacity that can be generated so that during the peak load time the generator with the swinging bus is charged bigger and the process reliability of the transmission network system is better and more stable.

CONCLUSION

The conclusion obtained is that the simulation results before optimization show that the active power released by the generator is 807.3 MW and after optimization, it shows the active power released by the generator is 806.2 MW. So that during normal conditions or before optimization there is a difference between the active power of the entire load and the active power of the entire plant with losses of 4.77 MW. After optimizing the difference between the active power of the entire load and the active power of the entire plant, it becomes a loss of 3.67 MW.

Declaration by Authors

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