Comparison of load flow analysis using PSAT and ETAP

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Abstract. The level of electrical quality has become a necessity in supporting human activities, especially in voltage stability. To support the calculation of voltage stability, various load flow methods have been developed. Load Flow Analysis is very important in planning and implementation in designing future power system expansion and in determining the best operation of the existing system. The tools for calculating simulation based power flow are the Power Tool Analysis Toolbox (PSAT) and the Transient and Electrical Analysis Program (ETAP). This paper discusses the comparison of the performance of the two load flow simulation tools, PSAT and ETAP. The Gandul Substation network data in Indonesia in April 2019 with a load of 15.37 MW is used for simulations. Load flow analysis is performed using Newton Raphson method with a network of 11 buses (150 kV, 20kV). The simulation results show that PSAT has a deviation of about 0.663% to the Bus Voltage from GIG and ETAP simulation has a deviation of about 0.562% to the Bus Voltage from GIG.

1. Introduction
The increase in electricity demand is generally in line with the growth of development in a country. As infrastructure development in Indonesia in the last five years 2014-2019, electricity consumption per capita increased rapidly and reached 21.18%. In meeting this need, PT PLN has increased installed power capacity to 62,600 MW and network to 1,028,679 kmc [1]. In addition, the level of quality of electricity produced by PLN also continues to be improved in terms of voltage stability.

Voltage stability is the ability of the power system to maintain the voltage so that all buses in the electrical network system have normal voltage. Power system voltage stability analysis is performed by calculating complex voltages on all buses and then calculating the power flow on the network bus. Computational analysis is called Load Flow Analysis. Load flow analysis can be used in continuous planning of the performance of the current power system and analysing the effectiveness of system expansion needs in meeting increasing load demand. Load flow analysis provides an overview of the operating conditions of the entire power system, from generator networks, transmission lines, distribution lines, to loads in an area [2].

By using load flow analysis, we can know the voltage at locations throughout the transmission system, for alternating current (AC) consisting of active and reactive power, phase angle or element magnitude and time and follows in each channel [3]. Load flow analysis is very important in planning and implementing in designing future power system expansion and in determining the best operation of the existing system [4].

Many researchers have proposed numerical analysis methods in solving non-linear algebraic equations of load flow problems such as the Gauss-Seidel method, Newton Raphson method and the Fast-Decoupled method [5-7]. By utilizing a computer, the method of solving load flow analysis
becomes simpler and the results can be relied upon. Currently there are many free simulation software that can be accessed online for load flow analysis, including PSAT [8], ETAP [9], MATPOWER, UWPFLOW, etc.

In this paper, a simulation model of the electrical network system for Gandul Substation (GIG) was developed and analysed. Simulation models have been developed using PSAT software which is a free Power System Analysis tool box for MATLAB Simulink and ETAP software which is commercial software used throughout the world for design, simulation, operation, and automation of generation, distribution and power systems industry. Testing is done to determine the performance of the simulation program used. The results of the simulation program based on the model built were compared with PLN data on April 1, 2019 at a load of 15.37 MW.

2. Method

2.1. Overview of Gandul 20kV transmission network system

Gardu Gandul of PT. PLN (GIG) is a power station with extensive electricity distribution lines. GIG acts as a gateway for the distribution of electricity from the Muara Karang subsystem to the South Jakarta, Depok and Central Jakarta regions. In addition, GIG also channels a portion of electricity to Central Jakarta and South Tangerang. The Gandul substation has four transformers and 41 feeders with a working voltage of 20 kVA. Single Line Gandul 20 kVA diagram shown in Figure 1 dan Figure 2. The line used has a resistance of 0.079 ohms / km, a reactance of 0.376H / km, a Suscept of 0.276F / km, and the line length for each bus is presented in Table 1.

![Figure 1. Single line diagram of the Gandul subsystem at the old building.](image-url)
2.2. Simulation

PSAT is a MATLAB toolbox that was developed since 2004 and is designed for power systems analysis and control. This toolbox has supported Simulink to facilitate user flexibility simply by using block diagram or schematic drawings to represent various components of the power system [10]. Another advantage of PSAT is that it can be run in free software in the GNU / Octave environment so
that it can be categorized as active FOSS (Free and Open Source Software) for power systems [11].

PSAT can analyse fundamental static and dynamic load-flow such as CPF (Continuation Power Flow), OPF (Optimal Power Flow), small signal stability analysis, time-domain simulations etc. In this research, Newton-Raphson (NR) algorithm is used in power flow analysis.

ETAP is a comprehensive analysis tool for power system design and testing developed by Operation Technology Inc. (OTI). ETAP is an enterprise software with specializes in the analysis, simulation, monitoring, control, optimization, and automation of electrical power systems. The ETAP software is designed with an excellent human friendly interface which is very easy to understand. Different types of analysis can be performed by using the respective study modes such as Load Flow, Unbalanced Load Flow, ANSI Short Circuit Analysis, Motor Starting Analysis, Harmonic Analysis, Transient Analysis, Star Protection Coordination, Optimal Load Flow, Reliability Analysis, Optimal Capacitor Placement, DC Load Flow, DC Short Circuit Analysis and Battery Sizing Analysis [12].

In the PSAT and ETAP software, the model used in the transmission line is π-model for the cable as shown in the PSAT library and the cable for the ETAP library. The line length conductor parameters used (with resistance, reactance and perception as stated before) as in table 1. Figure 4 shows the results of GIG network modelling using ETAP. Meanwhile, GIG network modelling using PSAT is shown in Figure 5.

3. Results and discussion

The simulation has been run using PSAT 2.1.7 in MATLAB R2014a and ETAP 12.6.0. All simulations have been carried out on a computer with 1.80GHz Core i7-8550U processor specifications, 8GB RAM, and Windows 10 operating system.
Figure 4. Schematic diagram of selected buses of GIG (using PSAT).

Table 2. The result of power flow of selected buses analyses by PSAT.

| Voltage (kV) | P Load MW | Q Load MVar |
|-------------|-----------|-------------|
| Pelangi     | 19.98     | 0.409       | 0.297       |
| Canggah     | 19.98     | 4.115       | 3.430       |
| Besan       | 19.98     | 3.236       | 2.208       |
| Sepupu      | 19.98     | 3.316       | 2.332       |

Table 3. The Result of Power Flow of Selected Buses Analyses by ETAP.

| Voltage (kV) | P Load MW | Q Load MVar |
|-------------|-----------|-------------|
| Pelangi     | 20        | 0.421       | 0.261       |
| Canggah     | 20        | 4.180       | 2.590       |
| Besan       | 20        | 3.348       | 2.075       |
| Sepupu      | 20        | 3.335       | 2.079       |

Simulation results of the voltage and phase quantities for the selected buses are tabulated. Table 2 is the results using ETAP and Table 3 results using PSAT. Table 4 presents the results of comparison of simulation results with PSAT, ETAP, and measurement result data from GIG. Based on the four data presented, it appears that the average PSAT simulation error when compared with measurement data is 0.633% with a range between 0.25% to 1.35%. Meanwhile, simulations using ETAP have an error rate of 0.562% with a range between 0.15% to 1.25%. There is a highest error in Transformer-3 for both simulations but still within a reasonable range and the lowest error in Transformer-2. ETAP has a smaller error than PSAT with a difference of 0.1% and this can occur because of differences in the level of numerical processes where ETAP is more precise than PSAT.
**Table 4.** Comparison of voltage magnitudes between PSAT, ETAP and GIG data.

|        | PSAT | ETAP | GIG | %PSAT | %ETAP |
|--------|------|------|-----|-------|-------|
| TRAFO 1 - 20 kV | 19.98 | 20   | 20.04 | 0.300% | 0.200% |
| TRAFO 2 - 20 kV | 19.98 | 20   | 20.03 | 0.250% | 0.150% |
| TRAFO 3 - 20 kV | 19.98 | 20   | 20.25 | 1.351% | 1.250% |
| TRAFO 4 - 20 kV | 19.98 | 20   | 20.13 | 0.751% | 0.650% |
| AVERAGE        | 0.663% |      | 0.562% |       |       |

4. Conclusion

Comparison of load flow simulation for Gandul Substation (GIG) using PSAT, freeware toolbox for MATLAB, and ETAP, a well-known commercial software specifically designed for electric power system simulation, has been presented in this paper. PSAT simulation results have a difference of about 0.663% to the Bus Voltage from GIG and ETAP simulation results have a difference of about 0.562% to Bus Voltage from GIG data for the four selected data buses. In addition, there is a 0.1% difference between the results of the PSAT and ETAP simulations.

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