Dynamic Performance of Synchronous Generator in Steam Power Plant

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***Abstract*—This paper presents dynamic performance of synchronous generator in steam power plant. Steam power plants are the most popular power plants to date. Until the end of 2018, 48.43% of the total installed capacity of power plants in Indonesia is this type of power plant. The largest steam power plant in Indonesia is in Paiton, Probolinggo, East Java, which is the object of this research. In its operation, the generator in this generator experiences dynamics as electricity load changes. This study discusses the analysis of the performance of synchronous generators to changes in electrical load. The analysis includes the voltage, active power, reactive power, power factor, and generator efficiency variables. The results showed that the generator performance remained good despite serving a very dynamic electricity load.**

***Keywords*—Synchronous generator; steam power plant; dynamic performance; efficiency**

I. Introduction

Electrical energy is vital in all activities of human life to meet daily needs. Along with the development of technology that is very rapid, of course, the level of electricity demand every day is increasing in every human and industrial activity [1]-[4]. Power generation to produce electrical energy is also increasing and where the nature of electrical energy is easily channeled and converted into other forms of energy, such as mechanical energy, light energy, heat energy, and others [5]-[7].

Steam turbines play a significant role in the generation and distribution of electricity in an electric power system. Steam turbines are one of the essential components in steam power plants [8]-[10]. The steam turbine is a prime mover that converts steam potential energy into kinetic energy and then is converted into mechanical energy in the form of turbine shaft rotation [11]. Therefore, the steam turbine must be protected from all possible causes of disturbances and abnormal conditions that occur, both interference originating from the steam turbine itself or interference or abnormal conditions originating from other parts of the electric power system [12]-[14].

A generator is a system that functions to change power mechanics into electric power. Mechanical power is the result of generator input power, while electric power is the result of generator output power [15]-[19]. Generator efficiency is the ratio between the output power of the generator and the generator input power [20]. The generator input power is the same as the force generated by the turbine because the turbine and generator work together and can be separated [21]-[24].

The efficiency of the turbine generator will affect the performance of the Steam Power System. The higher the efficiency of the turbine generator, the better the reliability and performance of the generator. Turbines and generators are a unified system that cannot be separated, so turbines and generators have the same problem [30]. The problem is a decline in turbine generator efficiency due to several factors, such as the overload requested from the grid. So that the turbine will be overloaded, which causes the turbine to accelerate at the maximum rate and the generator does not work to the maximum, the factors of maintenance duration and errors in operation and maintenance [25]-[28].

PT Paiton Energy is the first private generating company in Indonesia. PT Paiton Operation and Maintenance Indonesia (POMI) are one of the electrical energy plants which have three units, namely unit 3, unit 7, and unit 8, which supply to Java and Bali and have a total capacity of 2045 MW. The Paiton Steam Power Plant has experienced very vital problems because the imbalance between the loads from the generator exceeds the limit. So that with the excess limit the turbine speed is breakneck and will undoubtedly damage the turbine itself and other effects all units in the Paiton trip due to the problem of imbalance between the turbine and generators. While the Paiton Steam Power Plant units 3, 7, and 8 supply the entire Java and Bali region so the performance of the turbine generator is very influential for channeling electrical energy because it discussed the analysis of the performance of the turbine generator at the Steam Power Plant of PT Paiton Operation and Maintenance, Indonesia. By calculating the turbine generator efficiency, it can be seen that the turbine and generator are working optimally or less optimally and know the problems that often occur with turbines and generators.

The purpose of this study is to identify the problems that cause the performance of generators in the PT POMI Paiton unit 7, know the turbine and generator power output in the PT POMI Paiton unit 7, and determine the generator performance in the PT POMI Paiton unit 7.

II. Fundamental

A. *Steam Power Plant of PT POMI Paiton unit 7*

Steam power plants are plants that use coal combustion sources to heat water to convert water to steam to produce electricity. In Fig. 1, a schematic of steam power plant Paiton unit 7 is shown.

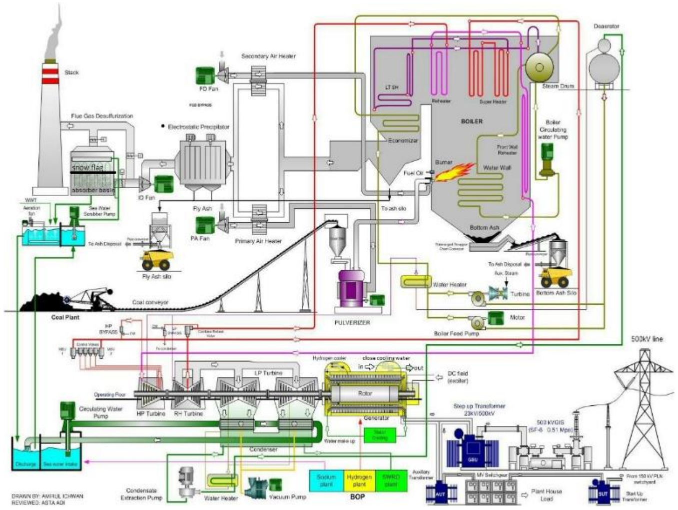

Fig. 1. A Schematic of Steam Power Plant Paiton unit 7.

Coal is moved from coal carriers on the jetty to the conveyor belt using a stacker by a coal removal device called a ship unloader. After the coal is moved from the coal carrier to the conveyor belt, then the coal is transported to the coal reservoir (stockpile) with the conveyor belt [29]. The placement of coal in the stockpile is also arranged according to its quality. There are four central stockpiles and one reserve stockpile. Coal in the stockpile does not need to be covered with a roof because the water content in coal will not exceed 40%.

From this stockpile, coal is transported to a bunker (coal silo) using a conveyor belt. From coal silos, coal is fed into the pulverizer/mill via a coal feeder. A pulverizer is a place for crushing coal so that it becomes fine grain so that it resembles powder. The coal feeder is a regulator of coal capacity that must go into the pulverizer. At the same time, coal is sampled and examined in a laboratory to determine its water content and quality. After the pulverizer, the powdered coal will rise to the furnace because of the hot air push from the PA (Primary Air) Fan. Aside from being a booster, this hot air also functions as a coal dryer, which has been in the form of powder so that it is faster in the combustion process in furnaces. The air from the PA (Primary Air) is also the main component so that combustion can occur inside the furnace [30].

The process of combustion in the furnace begins with fuel, namely diesel fuel, as a fuel used for starting a spray on a spark-plug such as a motor vehicle. There are 8 Spark-plugs found in each corner (corner) of the furnace. After the combustion process starts, slowly, coal is replaced by diesel fuel as fuel until finally only coal is used as fuel. If the quality of the coal used is inferior, the coal will be difficult to burn. As a result, more coal will be needed to produce the same amount of heat. Water to be converted into steam in a boiler comes from the WTP (Water Treatment Plant). The water used is seawater that is purified so that it becomes demineral water and is used to supply boilers.

The water used in the steam turbine cycle is called Demineral Water (Demineralized), which is water that has a conductivity level of 0.015 µs (micro-cements). In comparison, the mineral water we drink daily has a conductivity of around 100 - 200 µs. To get this demineral water, each PLTU unit is usually equipped with a Desalination Plant and Demineralization Plant that functions to produce this demineral water.

The water in the boiler comes from the sea, which goes through various processes in the Water Treatment Plant (WTP) to become demineral water. The initial process of producing demineral water starts from seawater that has been filtered out with its impurities and then pumped by the Sea Water Feed Pump to the Coagulant Storage Tank (seawater is given a coagulant to condense particles such as sand, mud, etc. in order to precipitate). Then the water is pumped to the Primary Sea Water Filter to filter the particles that have been compressed if it is still not filtered; it will be filtered back on the Polishing Filter. Filtered water is then collected in a Filtered Water Storage Tank and then pumped to the Cartridge Filter after being given antiseptic, acid, and sodium bisulfite.

In the cartridge filter, the water is filtered again to get purer water, which is then turned into freshwater through a reverse-osmosis desalination process. However, this water still contains much carbon. Then the carbon is separated in the Decarbonate Tank. Water is transferred to the Permeate Storage Tank using a Decarbonate Pump and Decarbonate Blower. Water from Permeate Storage Tank can be used to supply daily needs, but cannot be used to supply boilers.

Water from the Permeate Storage Tank using the Permeate Supply Pump is then processed again with the second reverse osmosis and then collected in Mixed Beds. This water is called demineral water and is collected in a Demin Water Tank.

The water collected at the WTP is first supplied to the condenser. By using a Condenser Extraction Pump, the water is transferred to the deaerator. In deaerators, oxygen levels are reduced so that there is not too much oxidation. Because if oxidation occurs, the pipe will easily corrode and can cause leakage. The oxygen-depleted water is collected in the Feed Water Storage Tank.

Furthermore, the water in the Feedwater Storage Tank is transferred to the economizer of the Boiler Feedwater Pump. In the economizer, the water gets warmed up from the furnace for the first time even though it has been warmed up several times by the heater. Out of the economizer, water that has been mixed with steam is stored in a Water Separator to be separated between water and steam. Then it will be heated at the superheater. At this superheater, the central heating because these Superheater boiler pipes come into direct contact with the fire. Here the steam will be increased in temperature to around 542 ˚C.

The steam that has been heated in the superheater will go directly to High-Pressure Turbine (HP Turbine). The steam that comes out after turning the HP Turbine is heated again in the boiler through the reheater. Steam heated in a reheater is not as hot as the steam produced by a superheater.

Then the steam from the reheater will go to the Intermediate Pressure Turbine (IP Turbine). After coming from IP Turbine, the steam goes directly to the Low-Pressure turbine (LP Turbine) without being heated up again. Then after the steam rotates LP Turbine, steam will flow into the condenser and condensed. The condensation water is collected and pumped again, and so on. When the steam rotates the turbine, the turbine shaft will also rotate. The turbine shaft itself is integrated between the HP Turbine, IP Turbine, and LP Turbine. The rotation of the shaft is used to rotate the generator and exciter.

The existence of water is essential in the Paiton Unit 7 power plant because it is used for various purposes, namely as the main ingredient in producing steam. Water is put into the boiler to be heated later with very high temperatures and transformed into water vapor. Besides that, water is also used for the cooling process or condenser cooling, which is used to absorb heat from the machines that are being used and as an absorber in the process of flue gas desulfurization (FGD).

There are two types of ash produced from coal combustion in the boiler, namely, fly ash and bottom ash. Fly ash is ash, which is quite small in size so that it is mixed with combustion gases (flue gas). Some of the ash produced from the combustion process will stick to the walls of the boiler pipe, accumulate, compact, and one day it will fall to the bottom of the boiler. This falling ash is known as bottom ash.

Flue gas combustion results in the boiler will be partially exhaled by the primary air fan and used to help the process of drying and heating coal when in the pulverizer. Most of the flue gas produced by combustion flows through the Electrostatic Precipitator (ESP). Electrostatic Precipitator functions to catch dust from coal combustion (fly ash). Smoke will pass through the electrodes, which causes the smoke to become electrically charged. Then by itself, the fly ash will stick to the second electrode wall. Then periodically, the second electrode wall will be shaken to drop the fly ash and be accommodated in the fly ash silo. Combustion smoke that has passed through the Electrostatic Precipitator will pass through the flue gas desulfurization (FGD). In the flue gas desulfurization, there are water curtains that will absorb the sulfur content in the combustion smoke, so that the exhaust gas that comes out through the stack (chimney) will be environmentally friendly.

B. Steam Turbine

A steam turbine is a mechanical device that extracts thermal energy from high-pressure steam into a rotary motion to drive a generator. Steam turbines are the main components in a Steam Power Plant [31] Fig. 2.

The basic working principle of a steam turbine is the combustion of coal to heat water and convert water into hot steam, commonly called thermal energy. Then heat energy is converted into kinetic energy; the process of converting heat energy into kinetic energy occurs in the turbine nozzle. At the nozzle, water vapor increases the speed/acceleration and causes a pressure differential between the sides before the nozzle and after the nozzle. Furthermore, kinetic energy is transformed into mechanical energy in the form of rotary energy from the turbine rotor, where then the rotation on the shaft will also turn the generator to produce electrical energy. Following is a general description of the working principle of a steam turbine.

In general, steam turbines have types of steam turbines that help the turbine work, including:

a) High-Pressure Turbine (HP Turbine): The High-Pressure Turbine (HP) turbine is the first turbine to accept the main steam from a superheater. After that, the steam output will be heated at the reheater. The High-Pressure Turbine (HP turbine) tip is connected to the Governing Valve (GV), and the other end is connected to the Intermediate Pressure (IP) turbine. HP turbine has several parts, namely casing, nozzle chamber, blade ring, dummy ring, LP dummy ring, blading, rotor, bearing, and gland. In this turbine, there is also a valve that is useful for regulating the amount of steam entering the turbine.

b) Intermediate Pressure Turbine (IP Turbine): The steam that has been heated in the reheater enters and plays an IP Turbine. Whereas for the IP turbine, the end is related to the LP turbine. IP Turbine has several parts, namely IP blading and IP rotors.

c) Low-Pressure Turbine (LP Turbine): Dry steam that comes out of the Intermediate Pressure Turbine (IP) is continued to be expanded to LP Turbine without further heating. The steam that comes out of LP Turbine is immediately accommodated and cooled by a condenser to be condensed with cooling media in the form of seawater. After using water, it will be used again as boiler fill water. LP Turbine is of double-flow type because, in this turbine, two output channels go to the condenser.

C. Synchronous Generator

The generator is a tool to generate electricity. The central part of the generator itself is the stator, rotor, and air gap. The working principle of a generator based on electromagnetic induction is that the prime mover rotates the rotor. Thus the poles that are on the rotor will rotate. If a direct voltage supplies the polar coil, then a magnetic field will emerge that rotates at the same speed as the polar rotation [32].

Fig. 2. Steam Turbine.

Fig. 3. Generator in a Steam Power Plant.

Based on Faraday's Law, if the conductor windings are rotated across the lines of magnetic force, then the conductor emits EMF (Electro Motive Force) or GGL (Electric Motion Force) or induced voltage. GGL generated by anchor conductor is an alternating voltage (AC). Fig. 3 shows the generator in a steam power plant.

Types of generators based on the location of the poles are grouped into the following.

a) Inner Pole Generator: Polar generators are generators whose magnetic fields are located in the rotor.

b) Outer Pole Generator: The outer pole generator is a generator whose magnetic field is located on the stator.

The type of generator based on the type of current generated

a) Synchronous Generator: Synchronous generators are electric generating machines that convert mechanical energy into electrical energy as output. The output voltage of a synchronous generator is alternating, therefore a synchronous generator is also called an AC generator. According to Anderson (1982), synchronous generators can produce energy sources, namely alternating voltage (AC). It says synchronous generator if the phase sequence must be the same, the voltage must be the same, the frequency must be the same, and the phase angle must be the same.

b) Asynchronous Generator: Basically, there is no asynchronous generator but that on an asynchronous motor.

Generator type based on the type of current generated

a) Direct Current Generator (DC): The direct current (DC) generator described can be converted into a DC generator, replacing the contact ring with a mechanical switch. A simple switch can be made with a metal ring divided into two separate parts (segments), mounted on an axis. This type of commutator is a denominational collector.

Each loop terminal is connected to the collector segment. When the loop is rotating, an AC voltage is induced in the coil, just like in an AC generator. However, before reaching the load, the induced voltage is converted to DC voltage by the collector, which functions as a mechanical rectifier. The contact segment of the collector moves to a different brush every half loop, keeping the direct current flowing through the electrical load of the circuit.

The rotation speed must be well determined so that the final result is expected. As stated earlier, the rotational speed affects the amplitude and frequency of the induced voltage.

b) Alternating Current Generator (AC): A loop of wire rotates in a magnetic field generated by a magnet, which induces an AC voltage between the loop terminals. The periodic change of voltage polarity is due to changes in the position of the coil relative to the magnetic pole. The voltage amplitude depends on the strength of the magnetic field and is also directly proportional to the rotational speed (1, 2, 3, and 4). If the magnetic field is uniform and the rotational speed is constant, the voltage induced between the loop terminals is sinusoidal with an average value of zero. The frequency is the same as the number of revolutions per second executed by the loop. Each loop terminal is connected to a metal ring. Contact with the ring is made with a fixed brush. If the brush is connected to an electrical load, an alternating current will be formed in the circuit.

III. Methodology

This research uses materials in the form of data related to power in turbines and generators as well as problems that cause turbines and generators that often disrupt the steam power plant of PT POMI Paiton. The location of this research is on Jalan Surabaya - Situbondo km 141, Binor, Paiton, Probolinggo, East Java, Indonesia.

In this study requires tools and materials in the form of hardware and software, namely:

1) Hardware: The hardware used in this study is a unit of Asus core i7 laptop.

2) Software: The software used in this research is Microsoft Word 2016 and Microsoft Excel 2016.

The rare steps of this research are shown in Fig. 4. Based on Fig. 4, it can be explained about the steps in this study. Research preparation is the first stage carried out in writing the final project. In this step, a field study was carried out by observing, interviewing directly the situation of the power plant of PT Paiton POMI and data acquisition licensing related to power in turbines and generators as well as problems that often occur in turbines and generators.

The next step is to identify and formulate the problem. The issue raised as a topic in the discussion of this paper is the analysis of the performance of turbines and generators at the PT POMI Paiton steam power plant. Therefore it is necessary to do a case study and collect data needed to support research in this thesis. The data about the performance of the turbine and generator will make it easier to solve the problems that occur.

The next step is a literature study. This stage has the aim of finding information about theories, methods, concepts, and references in the form of textbooks, journals, internet, manual books relating to the issues raised and can be used as a reference in solving the problems of this research and strengthening the theoretical basis for solve research problems.

This data collection phase is based on primary data. Primary data is data obtained directly from the research subject or source; in this case, the researcher obtains data or information directly using predetermined instruments. In collecting data based on primary data, there are interview and observation methods. The interview is one of the data collection techniques, where its implementation can be done directly dealing with research subjects through oral media by asking questions. Observation is a data collection technique by direct observation of the object under study for observations that researchers do to obtain data by direct observation of the company. After the data is collected, the next step is data processing. This data processor determines the results of the performance analysis of turbines and generators by calculating turbine power, generator, and turbine-generator efficiency, and the data is processed into tables and graphs.

After processing the data, we will get results that can be analyzed based on these data. To find out the performance of the turbine and generator at the PT POMI Paiton steam power plant, it is necessary to analyze the power output of the turbine and generator. Furthermore, these data can determine efficiency, from the efficiency that can determine the performance of turbines and generators and analyze problems that occur in turbines and generators.

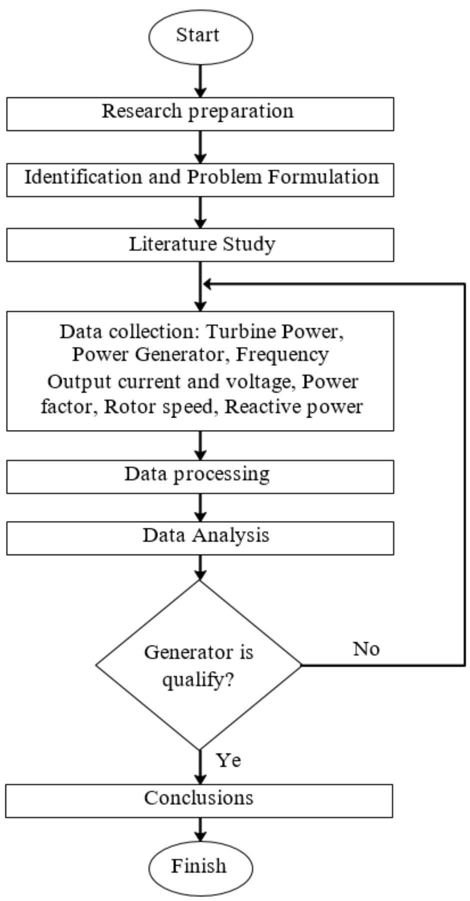

Fig. 4. The Steps of this Research.

IV. Results and Discussion

A. Synchronous Generator of Steam Power Plant

The type of generator used at PT POMI's unit 7 steam power plant is a synchronous generator. This type of generator is very suitable for use in power plants that have high-speed turbines such as steam power plants. In principle, a generator is said to be a synchronous generator if the rotation of the stator field is the same as the rotation of the rotor. If the generator wants to be on grid right, the generator is said to be synchronous if the phase sequence, instantaneous voltage, frequency, and phase angle must all be the same as the grid network. The working principle of synchronous generators is based on electromagnetic induction. When the prime mover is connected to the rotor, the rotor will rotate at a speed corresponding to the number of revolutions produced by the turbine. If the DC voltage as the source of the amplifier field supplies the coil to the field pole, then the magnetic field line appears on the surface of the rotating pole at the same speed as the pole. The lines of the rotating magnetic force will cross the coil anchors contained in the stator so that the EMF (electromotive) coil appears. Next, the EMF generated at the conductor anchors is the AC voltage, which is the generator output voltage.

B. Characteristics of Generators and Turbines in PT POMI Unit 7 Steam Power Plants

At the PT POMI unit 7, the steam power plant has a total capacity of 615 MW, including turbines and generators. In turbines, there are three types of turbines, namely High-Pressure turbines. Intermediate Turbine Pressure and Low-Pressure Turbine. And the power in this turbine is to determine the efficiency of the generator's performance. The generator used is a synchronous generator, which is said to be asynchronous if the phase sequence must be the same, the voltage must be the same, the frequency must be the same, and the phase angle must be the same. Table I shows the characteristics of the turbine while Table II shows the characteristics of the generator. Fig. 2 shows the nameplate of the turbine and generator.

To determine the performance of the 280T330 generator in the Paiton unit 7 steam power plant, there are several parameters such as generator output, power factor, frequency, efficiency, the relationship between active power, reactive power, and power factor and excitation system and power supply voltage. The performance of the generator determines the performance of the generator from 1 December 2018 - 30 December 2018.

TABLE. I. Characteristics of the Turbine

Manufacture	General Electric
Type	280T330
Rated Output	670 KW
Pressure	2400 PSIG
Temperature	1000 °F
Reheat Temperature	1000 °F
Exhaust Pressure	2.18 HGA

TABLE. II. CHARACTERISTICS OF THE GENERATOR

Rated Output	846,231 KVA
Armature Voltage	23 Kv
Armature Current	21,242 A
Power Factor	0.85
Phase	3
Frequency	50 Hz
Rotation speed	3000 RPM
Excitation voltage	683 Volt
Gas Pressure	75 PSIG
Connection	2-Y
Field Ampere	4,670 A

To analyze the performance of 280T330 generator Paiton steam power plant unit 7 with the generator output power output using the unit 7 daily operating power output data. Daily operating data to be analyzed for 30 days, starting from 1 December 2018 to 30 December 2018. The following are power output generator unit 7 for 30 days.

Active power is real power or power that is fed to the load. The size of the active power is influenced by voltage, and current, the higher the current and voltage, the active power will be even more significant and vice versa if the smaller the current and voltage, the active power will also be smaller. The active power of the generator output at the PT POMI Paiton steam power plant is shown in Fig. 5.

In Fig. 5, the generator performance can be observed based on changes in active power with time. The output power of the generator concerning time from December 1, 2018, to December 30, 2018, has fluctuated. The highest active power occurred on December 13, 2018, amounting to 604.85 MW due to the large current and voltage generated, and the load demand by the PLN grid is also significant. The lowest active power occurred on December 16, 2018, amounting to 465.74 MW because the current and voltage generated are small, and the load demand by the PLN grid is also small.

The generator in PT POMI unit 7 steam power plant has an output voltage specification of 23 kV with 3 phases. The generator output voltage is affected by consumer load, frequency, and excitation. Generator output voltage decreases when consumer load increases, conversely generator output voltage rises when the consumer load decreases. In Fig. 6, the graph shows the change in the output voltage of the generator with time for one month.

In Fig. 6, it can be observed the performance of the generator based on changes in the output voltage concerning that of the generator output voltage concerning time from December 1, 2018, to December 30, 2018, experiencing fluctuations. The highest output voltage occurs on December 1, 2018, in the amount of 21.6299 kV because the load generated is large, and the lowest output voltage occurs on December 22, 2018, in the amount of 21.3461 kV because the load generated is small.

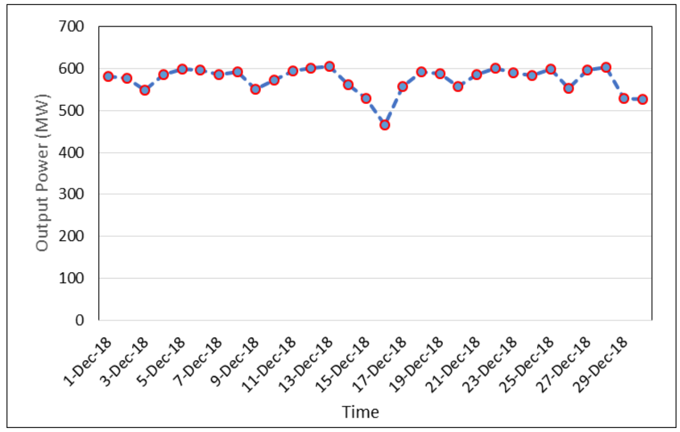

Fig. 5. The Active Power of the Generator Output at the PT POMI Paiton.

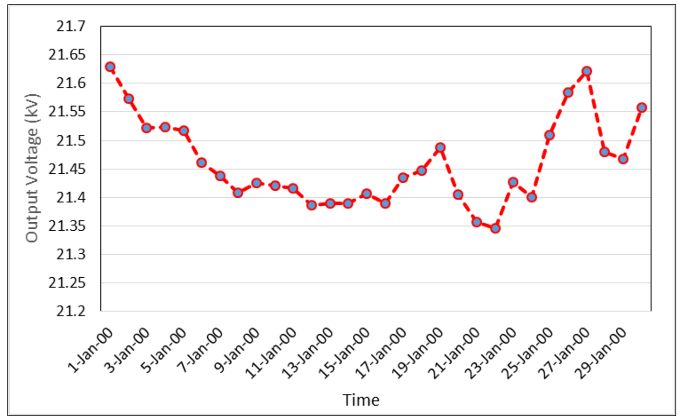

Fig. 6. The Output Voltage of the Generator at the PT POMI Paiton.

In addition to active power, the reactive power of synchronous generators is also analyzed. This reactive power cannot be used directly by the load but instead is converted into another form of energy in the form of magnetic power to generate magnetic electricity in industrial electrical equipment. There are two types of reactive power, namely inductive reactive power used to generate magnetic flux in industrial equipment and capacitive reactive power used to reduce the use of reactive power. Fig. 7 shows the change in reactive power in MVAR concerning time during one month of observation.

In Fig. 7, it can be observed the performance of the generator based on the change in reactive power concerning time from December 1, 2018, to December 30, 2018. The reactive power of the generator during that period fluctuates. The highest reactive power occurred on December 7, 2018, in the amount of 231.7503 MVAR because the excitation current injected to the generator produced was large, and the lowest reactive power occurred on December 25, 2018, in the amount of 11.2169 MVAR because the current injected into the generator produced was small.

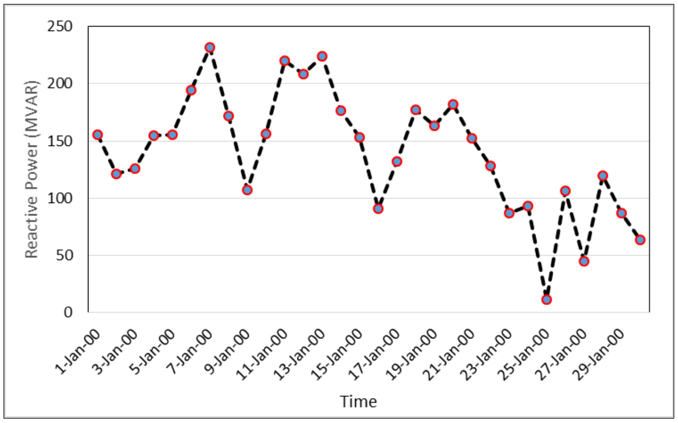

Fig. 7. The Reactive Power of the Generator at the PT POMI Paiton.

The next generator performance analysis is the generator power factor variable. The power factor is influenced by active power and apparent power. The higher the active power and the smaller the apparent power, the higher the power factor so that it approaches the value of 1 and vice versa if the smaller the active power and the higher the apparent power, the smaller the power factor. Fig. 8 shows the graph of changes in power factor from December 1, 2018, to December 30, 2018.

From Fig. 8, it can be observed that the generator performance based on the power factor starting December 1, 2018, until December 30, 2018, has fluctuated. The highest power factor occurred on December 25, 2018, at 0.998 because the reactive power generated was small, and the lowest power factor occurred on December 7, 2018, in the amount of 0.9298 because the reactive power generated was immense. The higher the power factor or a value of 1, the resulting factor can be said to be good.

In Fig. 9, it can be observed the efficiency of synchronous generators at the PT POMI Paiton unit 7 steam power plant. Observations were made from December 1, 2018, to December 30, 2018. The results of observations show that the efficiency of the generator still meets the design with a tolerance of ± 5. The efficiency of generators is affected by losses. The higher the losses, the smaller is the efficiency and vice versa, the smaller the losses, the higher the efficiency.

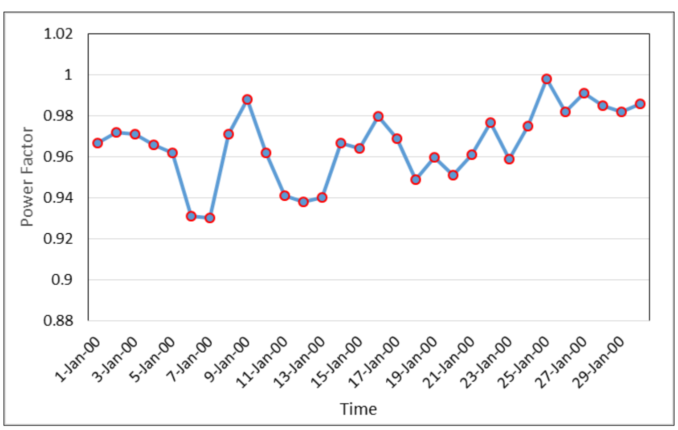

Fig. 8. The Power Factor of the Generator at the PT POMI Paiton.

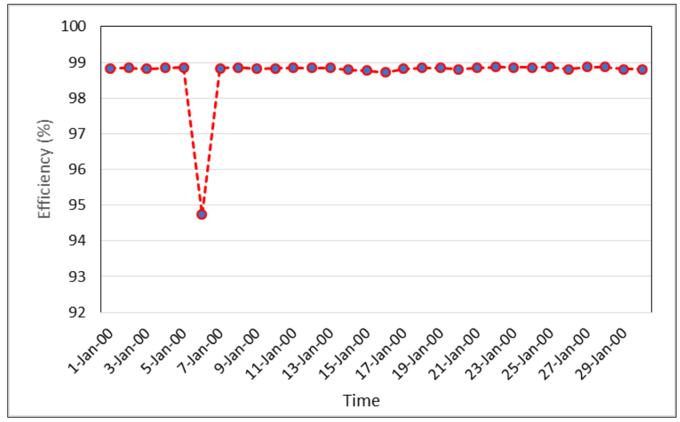

Fig. 9. The Efficiency of the Generator at the PT POMI Paiton.

Based on Fig. 9, it can be observed that the performance of generators based on generator efficiency from December 1, 2018, to December 30, 2018, has fluctuated. On December 6, 2018, it experienced a very drastic decrease because at 06:00 PM, because no output power was detected in the turbine because it was under maintenance and the highest efficiency occurred on December 25, 2018, amounting to 98.87% due to the large load generated.

V. Conclusions

In this research, an analysis of the performance of synchronous generators at the PT POMI Paiton Unit 7 steam power plant includes analysis of changes in active power, changes in output voltage, changes in reactive power, changes in power factors, and changes in generator efficiency. Based on observations during December 2018, it shows that the generator characteristics are in good condition, although experiencing dynamics due to changes in electricity load. In general, the losses on generators are relatively small, so they are not a problem.

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