International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-9 Issue-2, December 2019

Generator Performance in Steam Power Plant

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Abstract*: This paper presents generator performance in a steam power plant. Location of this research is steam power plant, PT Paiton Unit 7, on Jalan Surabaya - Situbondo km 141, Binor, Paiton, Probolinggo, East Java, Indonesia. In the steam power plant, PT Paiton Unit 7 is used synchronous generators. The generator is said to be synchronous if it meets the requirements, among others, 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.The performance of the generator can be known by looking at changes in active power, changes in output voltage, changes in output current, changes in reactive power in MVAR, changes in apparent power in MVA, changes in power factor, changes in frequency, changes in efficiency and percentage of the supply voltage.

***Keywords* : Generator, performance, steam power plant.**

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]-[5]. 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 [6]-[9].

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 [10]-[13]. 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 [14]. 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 [15]-[18].

A generator is a system that functions to change power mechanics into electric power.

Revised Manuscript Received on December 30, 2019.
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Mechanical power is the result of generator input power, while electric power is the result of generator output power [19]-[23]. Generator efficiency is the ratio between the output power of the generator and the generator input power [24]. 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 [25]-[29]. 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 can not 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 [31]-[33]. 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 3.7 and 8 units, 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 load 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 is 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 PLTU unit 7.

II. LITERATURE REVIEW

Several studies related to the performance of large-capacity generators have been carried out. Jepersen [34] conducted a study entitled Analysis of Load Effects on the Efficiency of Synchronous Generator Unit 1 at the steam power plant of PT Bukit Asam Tbk Tanjung Enim, South Sumatra, Indonesia. The study uses a calculation method based on the ratio of output power to input power.

From this study, it can be concluded that from the results of calculations on March 24, 2016, to March 30, 2016, produced an average generator efficiency of 84.745% per day. This efficiency is greatly influenced by the load used. If the load used is more significant, the efficiency of the generator is higher and vice versa.

Yusuf and Lutfi [35] conducted a study entitled Analysis of Steam Turbine Item 61-101-JT Performance on Ammonia-II Section at PT Pupuk Iskandar Muda, Aceh, Indonesia, using data design or commissioning and actual data. From the research, it can be concluded that the performance of the steam turbine in the design conditions is 86%, while the actual condition is 74%. The decline in the performance of the steam turbine is caused by the lack of steam pressure entering the turbine, the temperature of the incoming stream is shallow due to pressure and temperature are the main factors in the performance of the steam turbine to work optimally. The leakage of oil caused by damage to the Clynder servo and the lack of money maintenance done to the turbine.

Sertiandi [36] conducted a study entitled Analysis of Calculation of Turbine and Generator Efficiency in Wadaslintang hydroelectric power station, Java, Indonesia, using quantitative data collection methods. From the research, it can be concluded that in researching for five days, the efficiency produced on the first day was 89.77%, the second day was 89.77%, the third day was 91.02%, the fourth day was 91.25%, the fifth day was 91.59%. For five days, efficiency is greatly influenced by the load. The intake value will affect the turbine power down. Turbines and generators can be said to work well and optimally if the turbine and generator efficiency values are above 50%.

Supardi et al. [37] conducted a study with the title Effect of Rotational Speed and Loaded on the Output of Low-Speed Phase 1 Phase Induction Generator using quantitative methods. From the research, it can be concluded that the higher the voltage, the higher the rotational speed and vice versa, and the higher the spin speed so the higher the frequency. The lower the voltage and frequency, the higher the load. When the generator is at no-load condition, the generator can generate a voltage of 220 volts and 83.9 Hz, when connected to a capacitor of 16 microfarads and rotated at a speed of 850 rpm. When the rotation speed is around 525 - 850 rpm, the voltage will be around 65-220 volts, and the frequency will be around 52.1 - 83.9 Hz. Variation with a rotating speed of 605 - 850 rpm with a load ranging from 5-15 watts will cause the frequency range at 51.8 - 85 Hz and the voltage ranges at 101 - 204 volts.

Basofi and Amien [38] conducted research with the title Study of the Effect of Excitation Flow on Synchronous Generators that Work Parallel to Changes in Power Factors by using measurement methods in the laboratory of the Center for Development of Educators and Education Personnel Empowerment Fields in Medan. From the research, it can be concluded that at the inductive load, the generator power factor decreases away from the value two because the excitation current in the generator is enlarged. If the excitation current in the generator is enlarged, the generator will supply higher reactive power. If the generator is consuming reactive power when the excitation current is reduced to the measurement limit. At the capacitive load, the generator power factor increases to near value one due to the excitation current in the generator being enlarged. If the excitation current in the generator is enlarged, the generator will absorb less reactive power.

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.

Figure 1. Steam power plant of PT POMI Paiton

This research method uses quantitative methods. The quantitative method is one method that answers research problems related to data in the form of numbers and statistics. In the quantitative method, there are stages of activities as follows:

1. Literature Study

The author conducted a research study of literature by directly looking for literature related to the performance of generators in the PT POMI unit 7 steam power plant.

2. Data Collection

The author conducts actual data collection activities in the form of primary data regarding the problem of generator performance in the PT POMI unit 7 steam power plant.

3. Consultation

The author conducted interviews with officers in the field regarding the problem of generator performance at the PT POMI unit 7 steam power plant.

IV. RESULTS AND DISCUSSION

A. Synchronous Generator

In the PT POMI unit 7 steam generator as a generator, it uses a synchronous generator. The generator is said to be synchronous 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. The working principle of a synchronous generator is based on electromagnetic induction. When the prime mover is coupled to the rotor, the prime mover operates then the rotor will rotate at a speed corresponding to the number of turns expected. If direct voltage (DC) supplies the polar coils, a magnetic field (magnetic force lines) arises on the polar surface that rotates at the same speed as the poles. The lines of the rotating magnetic force will cut the anchor coil contained in the stator so that the EMF (electromotive force) coil arises. The EMF generated at the anchor conductor is AC voltage.

B. Characteristics of Turbines and Generators 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 1 shows the characteristics of the turbine while teble 2 shows the characteristics of the generator. Figure 2 shows the nameplate of the turbine and generator.

Tabel 1. 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

Tabel 2. 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 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, as shown in Table 3, Table 4, and Table 5.

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.

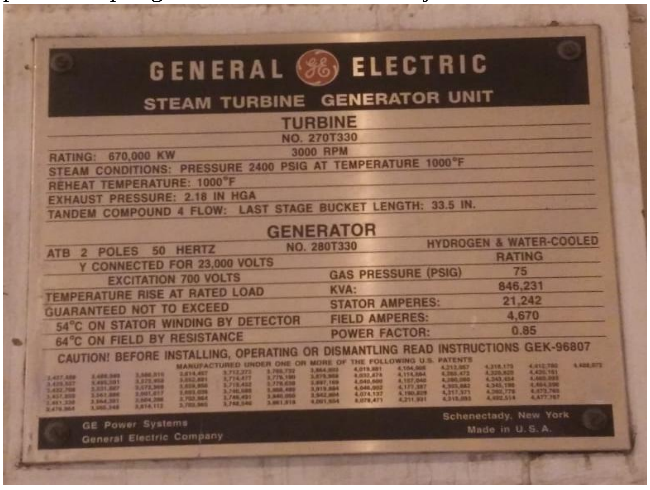

Figure 2. The nameplate of the turbine and generator at the PT POMI unit 7

Tabel 3. Performance of the generator at the PT POMI unit 7

Tanggal	Output Power (MW)	Output Voltage (KV)	Output Current (KA)	Reactive Power (MVAR)	Apparent Power (MVA)
1 Dec 2018	580.74	21.6299	15.3587	155.7428	601.2599
2 Dec 2018	577.53	21.5730	15.1092	121.3029	590.1308
3 Dec 2018	549.10	21.5214	14.5498	125.6617	563.2950
4 Dec 2018	584.90	21.5241	15.6543	154.5494	604.9752
5 Dec 2018	598.00	21.5165	15.7964	155.8092	617.9683
6 Dec 2018	596.61	21.4613	16.0361	194.1103	627.3896
7 Dec 2018	585.68	21.4376	16.2549	231.7503	629.8606
8 Dec 2018	592.81	21.4085	15.6468	172.2469	617.3280
9 Dec 2018	549.46	21.4253	14.3936	107.5573	559.8898
10 Dec 2018	572.05	21.4203	15.6424	156.6696	593.1155
11 Dec 2018	594.02	21.4156	16.3008	220.4833	633.6192
12 Dec 2018	599.62	21.3866	16.2340	208.0814	634.6987
13 Dec 2018	604.85	21.3895	16.5912	224.4063	645.1330
14 Dec 2018	562.23	21.3902	15.1555	176.4972	589.2778
15 Dec 2018	529.38	21.4061	13.9709	153.3730	551.1465
16 Dec 2018	465.74	21.3898	12.1307	90.8816	474.5290
17 Dec 2018	557.17	21.4347	14.7851	132.0773	572.6133
18 Dec 2018	590.96	21.4478	15.7723	177.0717	616.9150
19 Dec 2018	587.73	21.4875	15.6933	163.1330	609.9532

20 Dec 2018	557.19	21.4050	15.0660	181.6839	586.0646
21 Dec 2018	585.03	21.3574	15.6295	152.2356	604.5085
22 Dec 2018	600.93	21.3461	15.7608	127.9377	614.3989
23 Dec 2018	589.21	21.4275	15.3810	87.1956	595.6262
24 Dec 2018	581.98	21.4009	15.4006	93.1206	589.3824
25 Dec 2018	598.29	21.5089	15.2255	11.2169	598.3939
26 Dec 2018	552.26	21.5847	14.4466	106.6516	562.4678
27 Dec 2018	596.17	21.6217	15.0751	45.2428	597.8860
28 Dec 2018	602.90	21.4798	15.6065	119.9151	614.7101
29 Dec 2018	528.29	21.4670	13.6663	87.1173	535.4296
30 Dec 2018	525.97	21.5581	13.6934	63.3725	529.7744

Tabel 4. Power factor of the generator at the PT POMI unit 7

Tanggal	Output Power (MW)	Reactive Power (MVAR)	Power Factor	Apparent Power (MVA)	Calculated Power Factor
1 Dec 2018	580.7389	155.743	0.967	601.2599	0.96587
2 Dec 2018	577.5292	121.303	0.972	590.1308	0.97865
3 Dec 2018	549.0996	125.662	0.971	563.295	0.9748
4 Dec 2018	584.9013	154.549	0.966	604.9752	0.96682
5 Dec 2018	598.0036	155.809	0.962	617.9683	0.96769
6 Dec 2018	596.6061	194.110	0.931	627.3896	0.95093
7 Dec 2018	585.6758	231.750	0.930	629.8606	0.92985
8 Dec 2018	592.811	172.247	0.971	617.328	0.96029
9 Dec 2018	549.4615	107.557	0.988	559.8898	0.98137
10 Dec 2018	572.0495	156.670	0.962	593.1155	0.96448
11 Dec 2018	594.0206	220.483	0.941	633.6192	0.9375
12 Dec 2018	599.6204	208.081	0.938	634.6987	0.94473
13 Dec 2018	604.8458	224.406	0.940	645.133	0.93755
14 Dec 2018	562.2251	176.497	0.967	589.2778	0.95409
15 Dec 2018	529.3762	153.373	0.964	551.1465	0.9605
16 Dec 2018	465.7449	90.882	0.980	474.529	0.98149
17 Dec 2018	557.1729	132.077	0.969	572.6133	0.97304
18 Dec 2018	590.9567	177.072	0.949	616.915	0.95792
19 Dec 2018	587.7334	163.133	0.960	609.9532	0.96357
20 Dec 2018	557.1918	181.684	0.951	586.0646	0.95073
21 Dec 2018	585.0255	152.236	0.961	604.5085	0.96777
22 Dec 2018	600.9309	127.938	0.977	614.3989	0.97808
23 Dec 2018	589.2092	165.894	0.959	595.6262	0.98923
24 Dec 2018	581.9796	93.121	0.975	589.3824	0.98744
25 Dec 2018	598.2888	11.217	0.998	598.3939	0.99982
26 Dec 2018	552.264	106.652	0.982	562.4678	0.98186
27 Dec 2018	596.1718	45.243	0.991	597.886	0.99713
28 Dec 2018	602.9004	119.915	0.985	614.7101	0.98079
29 Dec 2018	528.2949	87.117	0.982	535.4296	0.98667
30 Dec 2018	525.9704	63.372	0.986	529.7744	0.99282

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.

From the data in Table 3 and Table 4, it can be observed that the power factor is influenced by active power and apparent power. The higher the active power and the smaller the apparent power, the more significant 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.

Tabel 5. Efficiency of the plant at the PT POMI unit 7

Tanggal	Output Power of Turbine (MW)	Output Power of Generator (MW)	Efficiency	Calculated Efficiency
1 Dec 2018	587.5307	580.7389	0.9884	98.8320
2 Dec 2018	584.2541	577.5292	0.9885	98.8472
3 Dec 2018	555.6177	549.0996	0.9883	98.8186
4 Dec 2018	591.7336	584.9013	0.9885	98.8474
5 Dec 2018	604.9114	598.0036	0.9886	98.8589
6 Dec 2018	577.8399	596.6061	1.0325	94.7302
7 Dec 2018	592.5973	585.6758	0.9883	98.8314
8 Dec 2018	599.7007	592.8110	0.9885	98.8521
9 Dec 2018	555.9867	549.4615	0.9883	98.8253
10 Dec 2018	578.7730	572.0495	0.9884	98.8367
11 Dec 2018	600.9650	594.0206	0.9884	98.8447
12 Dec 2018	606.6203	599.6204	0.9885	98.8483
13 Dec 2018	611.9060	604.8458	0.9885	98.8499
14 Dec 2018	569.0054	562.2251	0.9881	98.7932
15 Dec 2018	535.8788	529.3762	0.9879	98.7660
16 Dec 2018	471.7113	465.7449	0.9874	98.7203
17 Dec 2018	563.8012	557.1729	0.9882	98.8241
18 Dec 2018	597.8526	590.9567	0.9885	98.8496
19 Dec 2018	594.5946	587.7334	0.9885	98.8484
20 Dec 2018	563.8725	557.1918	0.9882	98.8083
21 Dec 2018	591.8348	585.0255	0.9885	98.8482
22 Dec 2018	607.8410	600.9309	0.9886	98.8655
23 Dec 2018	596.0281	589.2092	0.9886	98.8577
24 Dec 2018	588.7214	581.9796	0.9885	98.8558
25 Dec 2018	605.1307	598.2888	0.9887	98.8700
26 Dec 2018	558.9192	552.2640	0.9881	98.8072
27 Dec 2018	602.9961	596.1718	0.9887	98.8685
28 Dec 2018	609.7981	602.9004	0.9887	98.8689
29 Dec 2018	534.6879	528.2949	0.9880	98.8067
30 Dec 2018	532.3057	525.9704	0.9881	98.8083

Tabel 5 shows the efficiency of the steam power plant at the PT POMI unit 7.

Retrieval Number: B7505129219/2019©BEIESP
DOI: 10.35940/ijitee.B7505.129219
Journal Website: www.ijitee.org

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

Based on the data in Table 5, it can be observed that the efficiency data conducted on December 1, 2018, to December 30, 2018, still meet the design with a tolerance of ± 5. The efficiency of generators is affected by losses. The higher the losses, the smaller the efficiency and vice versa, the smaller the losses, the higher the efficiency.

V. CONCLUSIONS

In the steam power plant, PT Paiton Unit 7 is used synchronous generators. The generator is said to be synchronous if it meets the requirements, among others, 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.

The performance of the generator can be known by looking at changes in active power, changes in output voltage, changes in output current, changes in reactive power in MVAR, changes in apparent power in MVA, changes in power factor, changes in frequency, changes in efficiency and percentage of the supply voltage.

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