ANALYSIS OF THE EFFECT OF GENERATOR LOAD CHANGES ON GENERATOR PERFORMANCE EFFICIENCY AT PT.PLN(PERSERO) ANGGREK PLTU

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ABSTRAK

Hasil penelitian menunjukkan bahwa efisiensi generator masih relatif stabil pada kisaran beban 70–80% dari kapasitas maksimumnya. Perhitungan efisiensi generator rata-rata selama pengukuran 7 hari pada bulan September 2024 mencapai 90,89%, menunjukkan kinerja optimal dalam menghasilkan daya listrik dengan susut energi yang minimal. Untuk menjaga efisiensi tersebut, diperlukan perawatan rutin agar generator tetap dalam kondisi optimal untuk produksi listrik dan menjaga kestabilan pasokan listrik bagi masyarakat dan industri.

Kata Kunci: Efisiensi Generator, Variasi Beban, PLTU, Susut Daya Kinerja Generator.

ABSTRACT

The research indingcate that generator efficiency remains relatively stable within the 70–80% load range of its maximum capacity. The average generatore fficiency calculation for 7- day measurement in September 2024 reached 90.89%, demonstrating optimal performance in generating electrical power with minimal energylosses. To maintain this efficiency, regular maintenance is required to ensure the generator remains in optimal condition for electricity production and sustain a stable power supply for communities and industries.

Keywords: *Generator Efficiency, Load Variation, Steam Powerp Lant-(PLTU), Power Losses Generator Performance.*

A. INTRODUCTION

Steam Power Plant or abbreviated as (PLTU) is the largest generating unit because technically its capacity is also the largest. This causes many obstacles to occur during operation of the electric power system, which requires special attention. Technically, the PLTU has the most problems in its operations, this is because the energy conversion process that occurs in the PLTU is quite long in each part of the energy conversion process path, and their ability to deal with changes in load is not the same. Considering the long energy conversion process in a PLTU, the ability of a PLTU to deal with changes in load in the system is very dependent on the size of the energy storage area, for example in the combustion chamber and boiler drum. The impact of the slow ability of a PLTU to deal with changes in load will cause fuel waste which will affect the efficiency of the Steam Power Plant (PLTU).

B. RESEARCH METHOD

I. A generator is a machine used to produce electrical energy from a mechanical energy source. Generators also move electrical charges to move through an external circuit, but generators do not produce electricity that is already in the coil windings.

Figure 1 : Image of a generator located at PT.PLN (Persero) Anggrek

In general, a generator is a machine that can convert kinetic energy (mechanical) into electrical energy (electric). Usually the generator is also called a "genset" which means generator set. Generator set with the understanding is a set of combined equipment from two different devices, namely the engine and generator or alternator engine as a rotating device, while the generator as a power generating device. A generator is a device that can convert mechanical energy into electrical energy. Mechanical energy can come from heat, water, steam, etc. The electrical energy produced by a generator can be in the form of AC (alternating current) or DC (direct current).

II. Types of Loads on Generators

a. Types of Loads on Generators

Resistive load is a load produced by electrical devices that have natural resistance properties, for example heating elements and incandescent lamps. This type of load has a passive nature, meaning it is unable to produce electrical energy and will consume electrical energy. Resistive loads can also cause electrical energy to turn into heat, because resistors act to inhibit the flow of electrons through them by lowering the voltage of the flowing electricity.

b. Inductive Load

Inductive loads are generated by electrical equipment that has windings such as transformers, induction motors, and other equipment. The nature of the winding is to prevent changes in the value of the electric current. The windings found in electrical equipment are what block the value of the electric current, causing the current to lag 90o from the electric voltage (AC).

c. Capacitive Load

Capacitive load is a load that has capacitance capability. Capacitance capability is the ability to store energy generated from electrical discharge or electrical charging in a circuit. The current will also be leading to the voltage due to this component. The leading current itself is a condition where the phase angle of the current is relative to the voltage where the current precedes the voltage.

III. Generator Power Losses

a. Copper loss

Copper losses are losses in the stator winding which is a stationary part. These losses indicate the amount of power that is converted into heat by the resistance of the conductor. The following is the formula for copper losses:

$$p_s = 3.I_s^2 .R_s \quad (1)$$

$$P_{m= I_m^2 .\ R_m} \quad (2)$$

b. Iron Loss

Iron core losses are losses that occur due to the heat in the iron in the stator and rotor sections due to the emergence of eddy currents and hysteresis effects.

Pb (Iron Loss) = 30%. Full Load Loss (3)

c. mechanical losses

Mechanical losses consist of friction losses that occur due to friction between the rotating parts of the generator and the stationary parts of the generator, such as friction in generator bearings, and windage losses can occur due to friction between the rotating parts of the generator and the air inside the generator housing (casing).

$$Pmech = 0{,}1.P_{out} \quad (4)$$

IV. Generator Efficiency

Efficiency in generators is generally defined as the ratio between the generator output power and the generator input power (Sinkron et al., 2024). The generator will work with optimal efficiency at a load percentage of 70-80% of maximum capacity.

The calculation of efficiency in synchronous generators directly can use the equation:

$$\eta = \frac{Pout}{pin} x100\% \qquad (5).$$

C. RESULTS AND DISCUSSION

I. Results

During the research, the author obtained several data during 7 days of measurements in September 2024.

Table 1 : Generator monitoring data that occurred at PLTU Anggrek unit 2

Date	Time	Pout Generator (MW)	excitation current (A)	generator current (A)	Voltage (KV)	Cos ϕ
17/9/2024	00.00.00	22,39	2,10	893,50	18,08	0,8
	01.00.00	22,71	2,12	907,42	18,07	0,8
	02.00.00	22,40	2,06	893,22	18,10	0,8
	03.00.00	22,72	2,04	906,82	18,08	0,8
	04.00.00	22,89	2,06	912,72	18,10	0,8
	05.00.00	22,40	2,04	895,04	18,07	0,8
	06.00.00	20,13	1,99	804,79	18,05	0,8
	07.00.00	21,96	1,95	877,67	18,05	0,8
	08.00.00	22,29	2,03	892,16	18,03	0,8
	09.00.00	22,16	2,11	887,00	18,03	0,8
	10.00.00	21,62	2,17	866,50	18,01	0,8
	11.00.00	21,82	2,19	875,48	17,98	0,8
	12.00.00	21,88	2,23	877,89	17,98	0,8
	13.00.00	21,98	2,22	880,89	18,01	0,8
	14.00.00	21,52	2,20	862,12	18,01	0,8
	15.00.00	22,01	2,21	882,60	18,00	0,8
	16.00.00	21,69	2,21	868,80	18,02	0,8
	17.00.00	21,99	2,22	879,15	18,05	0,8
	18.00.00	21,92	2,24	875,99	18,06	0,8
	19.00.00	22,06	2,22	883,80	18,01	0,8
	20.00.00	21,64	2,22	865,44	18,05	0,8
	21.00.00	22,44	2,21	897,72	18,04	0,8
	22.00.00	22,07	2,16	883,01	18,04	0,8
	23.00.00	22,39	2,16	894,97	18,05	0,8
18/9/2024	00.00.00	20,82	2,07	831,62	18,07	0,8
	01.00.00	22,12	2,10	885,05	18,04	0,8
	02.00.00	22,11	2,11	883,01	18,07	0,8
	03.00.00	21,60	2,04	861,63	18,09	0,8
	04.00.00	22,32	2,06	892,13	18,05	0,8

	05.00.00	22,48	2,06	898,81	18,05	0,8
	06.00.00	22,47	2,14	898,24	18,05	0,8
	07.00.00	22,02	2,13	882,13	18,01	0,8
	08.00.00	21,46	2,20	860,21	18,01	0,8
	09.00.00	22,36	2,33	896,22	18,00	0,8
	10.00.00	22,08	2,35	886,74	17,97	0,8
	11.00.00	22,11	2,33	887,98	17,97	0,8
	12.00.00	21,64	2,39	867,73	18,00	0,8
	13.00.00	22,11	2,35	888,29	17,97	0,8
	14.00.00	21,54	2,32	864,88	17,97	0,8
	15.00.00	22,91	2,45	919,82	17,97	0,8
	16.00.00	22,26	2,34	894,31	17,97	0,8
	17.00.00	22,67	2,37	908,02	18,02	0,8
	18.00.00	21,21	2,33	848,88	18,03	0,8
	19.00.00	21,94	2,29	879,19	18,01	0,8
	20.00.00	22,43	2,30	898,40	18,02	0,8
	21.00.00	22,75	2,29	910,97	18,02	0,8
	22.00.00	22,48	2,26	900,35	18,02	0,8
	23.00.00	22,36	2,25	893,70	18,05	0,8
19/9/2024	00.00.00	21,48	2,18	857,99	18,07	0,8
	01.00.00	22,15	2,17	885,45	18,05	0,8
	02.00.00	21,81	2,14	871,10	18,07	0,8
	03.00.00	21,56	2,08	861,31	18,07	0,8
	04.00.00	21,65	2,10	864,73	18,07	0,8
	05.00.00	22,60	2,12	903,93	18,04	0,8
	06.00.00	21,71	2,16	869,10	18,02	0,8
	07.00.00	21,99	2,24	881,06	18,01	0,8
	08.00.00	22,37	2,34	896,85	18,00	0,8
	09.00.00	22,33	2,35	895,95	17,98	0,8
	10.00.00	22,36	2,39	896,58	18,00	0,8
	11.00.00	22,38	2,39	897,30	18,00	0,8
	12.00.00	21,88	2,34	877,17	18,00	0,8
	13.00.00	22,60	2,35	907,74	17,97	0,8
	14.00.00	22,38	2,40	897,97	17,98	0,8
	15.00.00	23,31	2,42	935,41	17,98	0,8
	16.00.00	23,30	2,40	933,08	18,02	0,8
	17.00.00	22,49	2,33	899,78	18,04	0,8
	18.00.00	22,70	2,37	908,10	18,04	0,8
	19.00.00	22,28	2,30	890,68	18,05	0,8
	20.00.00	22,98	2,26	920,15	18,02	0,8
	21.00.00	23,29	2,27	930,77	18,06	0,8
	22.00.00	23,27	2,20	929,40	18,07	0,8
	23.00.00	22,65	2,15	905,45	18,05	0,8
20/9/2024	00.00.00	22,62	2,13	902,54	18,09	0,8
	01.00.00	22,71	2,11	906,22	18,08	0,8
	02.00.00	22,02	2,06	878,15	18,09	0,8
	03.00.00	21,73	2,01	867,23	18,08	0,8
	04.00.00	22,94	2,14	913,52	18,12	0,8
	05.00.00	22,60	2,07	902,38	18,07	0,8
	06.00.00	22,94	2,15	917,03	18,05	0,8
	07.00.00	21,68	2,16	867,28	18,04	0,8
	08.00.00	21,83	2,21	874,29	18,02	0,8
	09.00.00	21,66	2,23	868,33	18,00	0,8
	10.00.00	22,00	2,33	882,41	17,99	0,8
	11.00.00	21,57	2,32	865,05	18,00	0,8
	12.00.00	22,08	2,33	886,92	17,97	0,8
	13.00.00	22,28	2,39	894,20	17,98	0,8
	14.00.00	21,66	2,40	869,19	17,98	0,8
	15.00.00	22,09	2,40	887,39	17,97	0,8
	16.00.00	22,47	2,40	901,49	17,99	0,8
	17.00.00	22,98	2,42	919,94	18,03	0,8
	18.00.00	22,66	2,37	907,39	18,02	0,8
	19.00.00	22,69	2,32	908,28	18,03	0,8
	20.00.00	23,02	2,30	920,68	18,05	0,8

	21.00.00	22,65	2,25	904,80	18,07	0,8
	22.00.00	22,07	2,21	881,58	18,07	0,8
	23.00.00	21,72	2,14	867,29	18,07	0,8
21/9/2024	00.00.00	22,86	2,14	913,51	18,06	0,8
	01.00.00	22,96	2,16	917,25	18,07	0,8
	02.00.00	21,63	2,09	863,45	18,08	0,8
	03.00.00	22,31	2,06	891,65	18,05	0,8
	04.00.00	22,46	2,08	897,67	18,05	0,8
	05.00.00	22,55	2,11	900,87	18,07	0,8
	06.00.00	21,92	2,17	877,12	18,04	0,8
	07.00.00	21,99	2,27	880,67	18,02	0,8
	08.00.00	22,23	2,30	892,05	17,98	0,8
	09.00.00	22,77	2,37	913,92	17,98	0,8
	10.00.00	21,69	2,33	871,42	17,97	0,8
	11.00.00	21,44	2,38	861,19	17,97	0,8
	12.00.00	22,27	2,42	894,12	17,98	0,8
	13.00.00	22,92	2,50	920,51	17,97	0,8
	14.00.00	21,73	2,47	872,65	17,97	0,8
	15.00.00	22,41	2,45	901,09	17,95	0,8
	16.00.00	22,20	2,45	890,03	18,00	0,8
	17.00.00	22,51	2,43	901,39	18,02	0,8
	18.00.00	22,87	2,42	914,68	18,04	0,8
	19.00.00	22,94	2,37	918,64	18,02	0,8
	20.00.00	22,67	2,36	906,03	18,06	0,8
	21.00.00	22,90	2,34	914,37	18,07	0,8
	22.00.00	23,37	2,32	933,02	18,08	0,8
	23.00.00	22,43	2,22	895,59	18,07	0,8
22/9/2024	00.00.00	21,46	2,12	856,93	18,08	0,8
	01.00.00	21,87	2,11	873,51	18,07	0,8
	02.00.00	22,10	2,07	883,24	18,05	0,8
	03.00.00	21,57	2,05	861,00	18,08	0,8
	04.00.00	22,49	2,09	898,88	18,05	0,8
	05.00.00	23,14	2,16	923,96	18,07	0,8
	06.00.00	22,94	2,18	918,02	18,04	0,8
	07.00.00	22,31	2,21	893,37	18,02	0,8
	08.00.00	22,24	2,26	890,88	18,02	0,8
	09.00.00	22,60	2,31	907,10	17,98	0,8
	10.00.00	11,86	1,91	474,89	18,02	0,8
	11.00.00	11,95	1,89	478,59	18,01	0,8
	12.00.00	12,67	1,91	508,58	17,98	0,8
	13.00.00	22,97	2,37	921,92	17,98	0,8
	14.00.00	21,38	2,30	857,34	18,00	0,8
	15.00.00	22,04	2,34	884,25	17,98	0,8
	16.00.00	23,26	2,35	933,22	17,98	0,8
	17.00.00	22,84	2,33	915,67	18,00	0,8
	18.00.00	22,83	2,36	912,96	18,05	0,8
	19.00.00	22,55	2,20	903,03	18,02	0,8
	20.00.00	22,02	2,20	879,53	18,07	0,8
	21.00.00	21,58	2,14	862,25	18,06	0,8
	22.00.00	22,81	2,18	912,17	18,05	0,8
	23.00.00	22,90	2,14	916,37	18,04	0,8
23/9/2024	00.00.00	22,18	2,13	886,73	18,05	0,8
	01.00.00	22,57	2,11	901,50	18,07	0,8
	02.00.00	22,25	2,04	889,40	18,05	0,8
	03.00.00	21,41	2,00	854,80	18,08	0,8
	04.00.00	22,55	2,03	901,48	18,05	0,8
	05.00.00	22,94	2,08	916,27	18,07	0,8
	06.00.00	23,21	2,14	927,88	18,05	0,8
	07.00.00	22,84	2,17	914,03	18,04	0,8
	08.00.00	21,92	2,16	879,06	18,00	0,8
	09.00.00	22,33	2,25	895,35	18,00	0,8
	10.00.00	22,71	2,30	911,96	17,97	0,8
	11.00.00	22,30	2,34	894,69	17,98	0,8
	12.00.00	22,97	2,32	921,36	17,99	0,8

	13.00.00	23,46	2,32	940,64	18,00	0,8
	14.00.00	23,70	2,32	951,22	17,98	0,8
	15.00.00	23,18	2,31	928,90	18,01	0,8
	16.00.00	22,63	2,28	906,16	18,02	0,8
	17.00.00	22,73	2,23	910,77	18,01	0,8
	18.00.00	22,62	2,29	904,95	18,04	0,8
	19.00.00	22,48	2,23	899,18	18,04	0,8
	20.00.00	22,65	2,19	906,77	18,02	0,8
	21.00.00	22,77	2,21	910,13	18,05	0,8
	22.00.00	22,98	2,16	917,67	18,07	0,8
	23.00.00	22,41	2,08	894,89	18,07	0,8

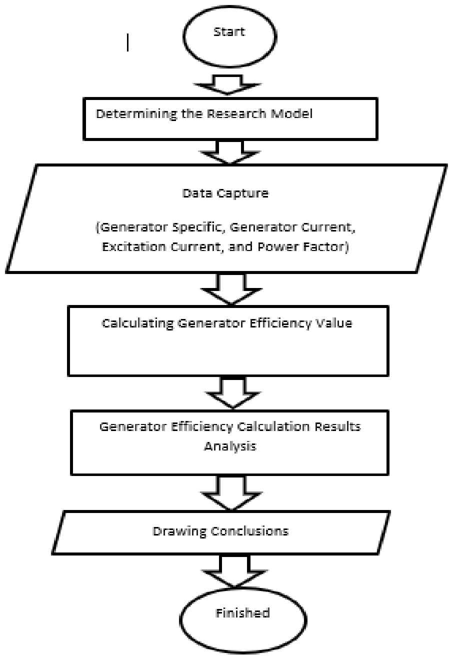

Figure 2 : Flowchart illustrating the methodology used in

Table 2 : Generator output calculation results for 7 days of measurement

Time	Day to-							Average
	1	2	3	4	5	6	7	
0	22,39	20,82	21,48	22,62	22,86	21,46	22,18	21,97
1	22,71	22,12	22,15	22,71	22,96	21,87	22,57	22,44
2	22,40	22,11	21,81	22,02	21,63	22,10	22,25	22,05
3	22,72	21,60	21,56	21,73	22,31	21,57	21,41	21,84
4	22,89	22,32	21,65	22,94	22,46	22,49	22,55	22,47
5	22,40	22,48	22,60	22,60	22,55	23,14	22,94	22,67
6	20,13	22,47	21,71	22,94	21,92	22,94	23,21	22,19
7	21,96	22,02	21,99	21,68	21,99	22,31	22,84	22,11
8	22,29	21,46	22,37	21,83	22,23	22,24	21,92	22,05
9	22,16	22,36	22,33	21,66	22,77	22,60	22,33	22,31
10	21,62	22,08	22,36	22,00	21,69	11,86	22,71	20,62
11	21,82	22,11	22,38	21,57	21,44	11,95	22,30	20,51
12	21,88	21,64	21,88	22,08	22,27	12,67	22,97	20,77
13	21,98	22,11	22,60	22,28	22,92	22,97	23,46	22,62
14	21,52	21,54	22,38	21,66	21,73	21,38	23,70	21,99
15	22,01	22,91	23,31	22,09	22,41	22,04	23,18	22,56
16	21,69	22,26	23,30	22,47	22,20	23,26	22,63	22,55
17	21,99	22,67	22,49	22,98	22,51	22,84	22,73	22,60
18	21,92	21,21	22,70	22,66	22,87	22,83	22,62	22,40
19	22,06	21,94	22,28	22,69	22,94	22,55	22,48	22,42
20	21,64	22,43	22,98	23,02	22,67	22,02	22,65	22,49
21	22,44	22,75	23,29	22,65	22,90	21,58	22,77	22,62
22	22,07	22,48	23,27	22,07	23,37	22,81	22,98	22,72
23	22,39	22,36	22,65	21,72	22,43	22,90	22,41	22,41

Table 3 : Percentage loading calculation results for 7 days of measurement

	Day to-							
Time	1	2	3	4	5	6	7	Average
0	82,10	69,39	71,59	75,40	76,20	71,55	73,94	74,31
1	83,30	73,73	73,83	75,69	76,54	72,91	75,22	75,89
2	82,15	73,70	72,71	73,39	72,12	73,65	74,16	74,55
3	83,33	71,99	71,87	72,43	74,35	71,89	71,37	73,89
4	83,95	74,39	72,18	76,47	74,85	74,95	75,17	75,99
5	82,16	74,95	75,33	75,32	75,17	77,12	76,48	76,65
6	73,83	74,90	72,36	76,47	73,07	76,48	77,37	74,93
7	80,52	73,39	73,30	72,25	73,30	74,38	76,14	74,75
8	81,74	71,55	74,57	72,76	74,10	74,14	73,07	74,56
9	81,27	74,52	74,42	72,20	75,89	75,33	74,45	75,44
10	79,29	73,59	74,52	73,32	72,32	39,52	75,70	69,75
11	80,01	73,69	74,61	71,90	71,47	39,82	74,32	69,40
12	80,23	72,15	72,93	73,60	74,25	42,25	76,56	70,28
13	80,61	73,72	75,33	74,25	76,39	76,56	78,21	76,44
14	78,91	71,80	74,59	72,20	72,44	71,26	79,01	74,32
15	80,71	76,36	77,70	73,64	74,71	73,45	77,26	76,26
16	79,55	74,22	77,68	74,91	74,00	77,52	75,42	76,19
17	80,63	75,57	74,98	76,61	75,02	76,13	75,75	76,39
18	80,39	70,69	75,68	75,54	76,22	76,10	75,39	75,72
19	80,90	73,15	74,27	75,64	76,48	75,16	74,93	75,79
20	79,37	74,77	76,61	76,75	75,57	73,39	75,49	75,99
21	82,28	75,82	77,64	75,50	76,32	71,92	75,89	76,48
22	80,93	74,93	77,57	73,56	77,90	76,04	76,59	76,79
23	82,10	74,52	71,59	72,39	74,75	76,34	74,69	75,76

Table 4 : Generator Efficiency calculation results for 7 days of measurement

	Day to-							
Time	1	2	3	4	5	6	7	Average
0	82,10	69,39	71,59	75,40	76,20	71,55	73,94	74,31
1	83,30	73,73	73,83	75,69	76,54	72,91	75,22	75,89
2	82,15	73,70	72,71	73,39	72,12	73,65	74,16	74,55
3	83,33	71,99	71,87	72,43	74,35	71,89	71,37	73,89
4	83,95	74,39	72,18	76,47	74,85	74,95	75,17	75,99
5	82,16	74,95	75,33	75,32	75,17	77,12	76,48	76,65
6	73,83	74,90	72,36	76,47	73,07	76,48	77,37	74,93
7	80,52	73,39	73,30	72,25	73,30	74,38	76,14	74,75
8	81,74	71,55	74,57	72,76	74,10	74,14	73,07	74,56
9	81,27	74,52	74,42	72,20	75,89	75,33	74,45	75,44
10	79,29	73,59	74,52	73,32	72,32	39,52	75,70	69,75
11	80,01	73,69	74,61	71,90	71,47	39,82	74,32	69,40
12	80,23	72,15	72,93	73,60	74,25	42,25	76,56	70,28
13	80,61	73,72	75,33	74,25	76,39	76,56	78,21	76,44
14	78,91	71,80	74,59	72,20	72,44	71,26	79,01	74,32
15	80,71	76,36	77,70	73,64	74,71	73,45	77,26	76,26
16	79,55	74,22	77,68	74,91	74,00	77,52	75,42	76,19
17	80,63	75,57	74,98	76,61	75,02	76,13	75,75	76,39
18	80,39	70,69	75,68	75,54	76,22	76,10	75,39	75,72
19	80,90	73,15	74,27	75,64	76,48	75,16	74,93	75,79
20	79,37	74,77	76,61	76,75	75,57	73,39	75,49	75,99
21	82,28	75,82	77,64	75,50	76,32	71,92	75,89	76,48
22	80,93	74,93	77,57	73,56	77,90	76,04	76,59	76,79
23	82,10	74,52	75,50	72,39	74,75	76,34	74,69	75,76

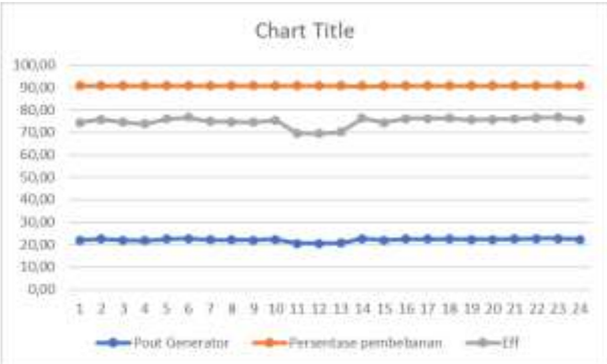

Figure 2: Relationship between Generator Pout, Load Percentage, and Generator Efficiency

Based on the image above, the generator efficiency is constant for every change in generator output. This can happen because the generator efficiency tends to be stable at the ideal value during the loading percentage which is in the range of 70-80% of the generator's maximum capacity.

D. CONCLUSION

Based on the results of the analysis and discussion in this thesis, it can be concluded that the generator efficiency at the Anggrek PLTU is relatively stable in the loading range of 70-80% of the generator's maximum capacity. This shows that the generator works optimally under these loading conditions. The calculation of generator efficiency is carried out by measuring the output power, input power, and power losses in the stator, rotor, iron, and mechanics. From the calculation data for 7 days of measurement in September 2024, the average generator efficiency reached around 90.89%. These results indicate that the generator has good performance in generating electrical power by minimizing energy losses.

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