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Analysis Of The Effect Of Excitation Current On The Synchronology Generator On Loading At Plta Renun PT PLN (Persero) UPDK Pandan

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ABSTRACT
This study will discuss the effect of the excitation current of the PLTA RENUN synchronous generator on each load change to maintain the nominal output voltage of the generator with a variable transmission voltage of 150 kV. The analysis data is obtained from the Daily Operation Report of the RENUN HEPP in accordance with changes in the generator load or changes in the value of the transmission voltage to determine its effect on changes in the AVR excitation current. The daily data obtained is then compared with the initial setting or AVR characteristics during the Commissioning Test, the resulting deviation will be used as input for the Pandan UPDK Engineering in carrying out the next corrective action. Thus the reliability of the PLTA RENUN in serving P2B to maintain the stability of the 150 kV Sumbagut transmission system is maintained.

Keywords : ***AVR, Electrical Energy, Generator***

INTRODUCTION

Fluctuations in voltage changes in the 150 kV transmission system very often occur along with changes in loading on the Sumbagut inter connection system, so that a generator generator is required to always be able to stabilize the generator output voltage which is generated in accordance with the allowable nominal voltage through an Automatic Voltage Regulator (AVR). With the importance of the function of the excitation system in a power plant, on this occasion, the author will discuss the Effect of Excitation Current on Synchronous Generators on the Loading of the PLTA RENUN PT PLN (Persero) UPDK Pandan.

The synchronous alternator used in the RENUN hydrophone plant is a vertical type equipped with thrust bearings or thrust bearing located at the bottom of the rotor (VIC-AC). In addition, the generator at the RENUN HEPP plant has a cylindrical and protruding pole shape with the part that creates a magnetic field located in the rotor winding while the one that causes electromotive force in the stater winding.

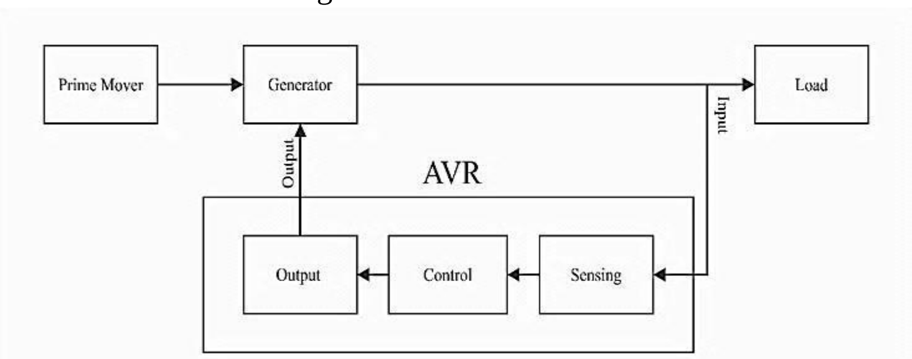

Figure 1. Block Diagram of Automatic Voltage Regulator(Al-tom: 2015)

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METHODS

This study uses a descriptive exploratory research type, because the discussion is in the form of a description and explanation of the problem to be analyzed with the following background:

- To determine the magnitude of something or the frequency of an event, researchers already have a clear problem definition, specific hypothesis, and detailed information.
- To get information, insight, knowledge, ideas, ideas, and understanding as an effort to formulate and define problems, formulate hypotheses, and can be continued with more advanced further research.
-

RESULTS AND DISCUSSION

Generator Capability Curve Analysis

Capability Curve or capability curve is a curve limiting the operation of the generator in producing reactive power generator that is connected in parallel with the system in an effort to maintain the generator output voltage in accordance with its nominal voltage from fluctuations in system voltage. The capability curve of each generator will differ from each other depending on the characteristics and capacity of each generator, including the Renun HEPP generator, which has a capability curve which can be shown in Figure 2 below.

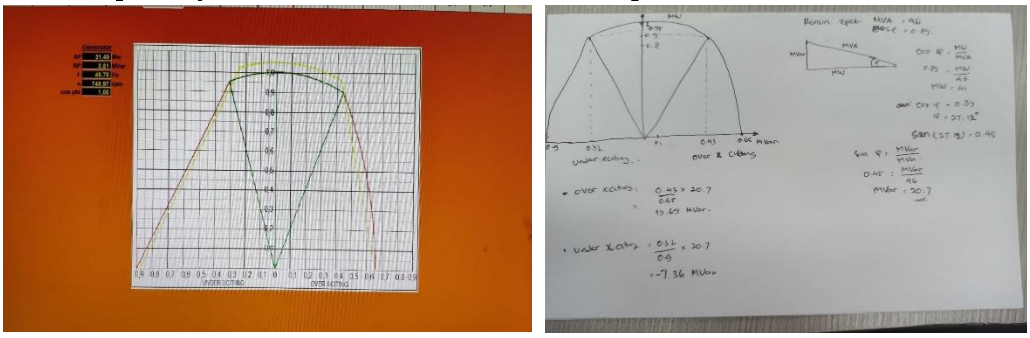

Figure 1. Capability Curve

From Figure 2, the RENUN HEPP capacity curve can be seen that the maximum allowable reactive power is 13 MVAr lag and 20 MVAr lead, this means that the RENUN HEPPgenerator is only allowed to supply reactive power to the system a maximum of 20 MVAr to keep the generator output voltage within the same amount. nominally, it can be said in this condition the generator is in a capacitive state to compensate for the inductive load of the higher system. To be able to achieve these conditions, the field current / generator excitation current must be increased through *control voltage regulator*. The addition of excitation current to the generator must always pay attention to the maximum allowable reactive power value. If the generator produces reactive lagging power greater than the allowable limit, the generator will experience over-excitation or Over Excitation, this can result in excessive heat in the rotor winding or rotor winding.

On the other hand, the generator is only able to absorb reactive power of 20 Mvar from the system to keep the generator output voltage at its nominal value. It can be said in this condition the generator is in an inductive state to compensate for the capacitive load of the higher system. This is very rare for generators that are connected in parallel to the system, in

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addition to meeting the P2B demand so that the generator generator must be able to supply reactive power to the system, the load condition which is always inductive from the generator also makes generator generators rarely lead. To be able to reduce the reactive power of the generator, the field current / generator excitation current must be lowered through *control voltage regulator*. The decrease in excitation current in the generator must always pay attention to the maximum allowable reactive leading power value. If the generator produces reactive leading power greater than the allowable limit, then the generator will experience less excitation or *Under Excitation* this may result in overheating of the stator winding or *stator winding.*

Analysis of the Effect of Load on Power Factor

The relationship between generator power and the cos angle due to the influence of the load. There are three kinds of power generated by the generator, namely active power (MW) and reactive power (MVAR) and the result of these two powers is total power/apparent power (MVA). This data is taken from data *Commissioning* RENUN HEPP generator. The data shows that changes in active and reactive power greatly affect the magnitude of cos generated by the generator.

Tabel 1. *Logsheet* Generator

No	Daya Aktif MW)	Daya Reaktif (MVAr)	Cos	Arus Generator Ia (A)	Tegangan Terminal (kV)	Arus Medan If (A)	Tegangan Medan (V)
1	12	2.17	0.86	666	11	652.55	58.21
2	25	1.99	0.88	1360	11	687.87	61.34
3	31	1.22	0.92	1992	11	715.87	74.54
4	41	0.67	0.96	2419	11	757.85	80.46

Table 1 is the data *commissioning* from the generator used in the RENUN HEPP plant. The data is the relationship between the active and reactive power generated by the generator and its effect on changes in cos . Seen in Table 1 shows the greater the value of reactive power, the smaller the value of the power factor or cos. The calculation of active power and reactive power above can be show that changes in active and reactive power greatly affect the amount of cos produced by the generator. This can be shown by calculating the MW and MVAR by taking the data *Commissioning* RENUN HEPP generator.

No-Load Generator Test Analysis

The no-load test on a generator is carried out to determine the condition of the generator excitation system. This test is carried out by increasing the field current gradually so that the terminal voltage of the generator is obtained. The magnitude of the field current will be proportional to the generator terminal voltage until a saturation value or saturation area is obtained. In the saturation region or the terminal voltage reaches its nominal value, the voltage will slow to increase while the field current continues to increase.

Table 2 shows the relationship between the field current and the output voltage generated by the generator. This data is taken from data *commissioning* which is on the generator when *open circuit* or zero load used in the RENUN HEPP plant.

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Table 2. Ideal Data for Generator Terminal Excitation and Voltage

No	Voltage (KV)	Field Current (A)	Field Voltage (V)
1	1.24	45	10.6
2	2.15	80	17.6
3	3.31	120	25.6
4	3.94	147	30
5	4.82	180	36.3
6	6	226	45
7	7.08	267	52.6
8	7.97	302	59.6
9	9	352	68.4
10	9.92	398	76.5
12	11.42	483	93
13	12.07	532	102

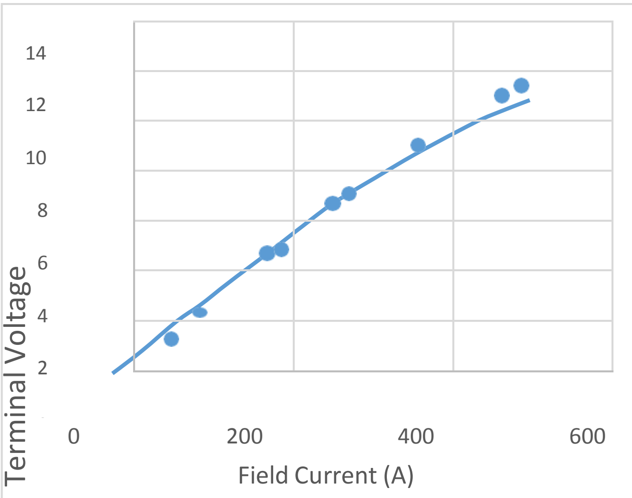

Figure 3. Graph of Ideal Field Current Data and Generator Output Voltage

Seen in Figure 3 shows that the increase in the field current supplied by the excitation system affects the output voltage or generator terminal also increases. The field current is used to supply or generate flux in the rotor coils. This proves that the greater the magnetic field on the rotor, the greater the induced emf produced by the stator coil until its saturation peaks. Then in 2020 a zero load test was carried out on the generator. This test was carried out to ensure that the excitation system was still in good condition because at that time the AVR was only repaired after *fuse* from *thyristor* damaged during MO.

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Table 3. Testing Data for Generator Terminal Current and Voltage 2020

No	Voltage (KV)	Field Current (A)	Field Voltage (V)
1	1.54	52	15.8
2	2.25	88	18.5
3	3.45	133	27
4	3.97	153	33
5	4.88	188	37.3
6	6.21	233	48.2
7	7.10	273	53
8	7.82	288	62.7
9	9.02	364	68
10	9.96	402	88.2
11	11.08	446	89.2
12	11.48	492	95.2
13	12.02	528	100

Based on Table 3, a graph of the relationship between the field current and the generator output voltage can be drawn as shown in Figure 3.

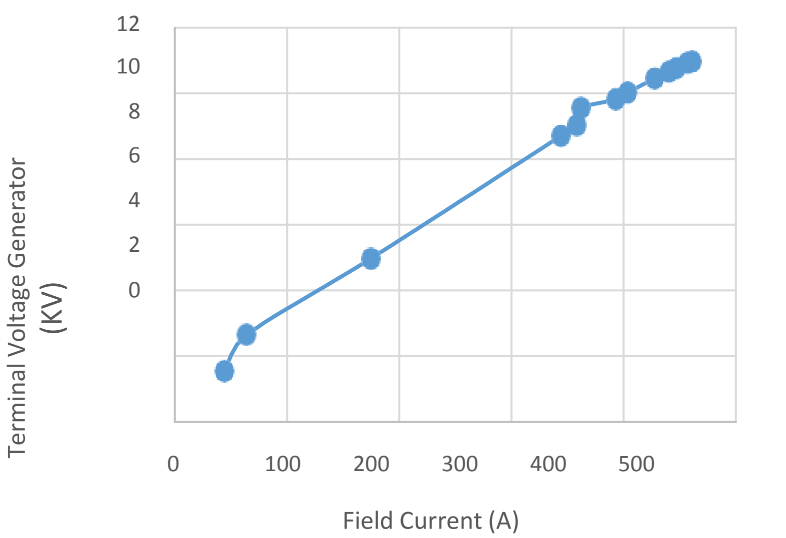

Figure 4. Graph of No-Load Test

In the no-load test graph as shown in Figure 4, it can be seen that there is a slight deviation or deviation from the value of the ideal data based on *commissioning test* ever done. However, it appears that the resulting deviation value is relatively small, this is very likely to occur considering the age of using the AVR PLTA HEPP which is more than 10 years, as well as errors in data reading factors and measurement set points are also one of the causes of deviations in the measurement data. To be able to see the value of the deviation from the two

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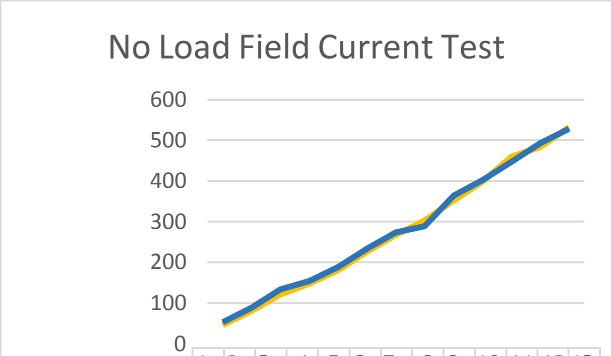
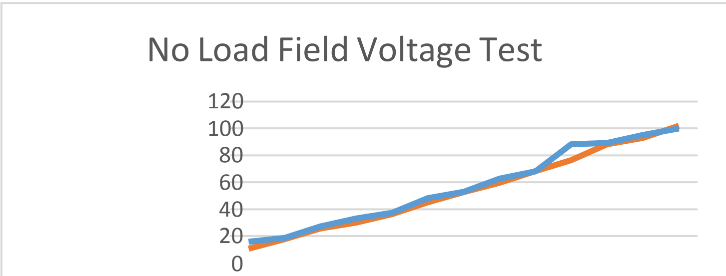
tests, it can be seen in the graphs of Figure 4 and Figure 5 below.



	1	2	3	4	5	6	7	8	9	10	11	12	13
Comm	45	80	12	14	18	22	26	30	35	39	45	48	53
Pengujian 2017	52	88	13	15	18	23	27	28	36	40	44	49	52

Figure 5. Deviation Graph of No-Load Test Excitation Current



	1	2	3	4	5	6	7	8	9	10	11	12	13
Comm	11	18	26	30	36	45	53	60	68	77	88	93	102
Pengujian 2020	16	19	27	33	37	48	53	63	68	88	89	95	100

Figure 6. Deviation Graph of No-Load Test Excitation Voltage

Analysis of Excitation Current Testing Against Reactive Power

This test is carried out during peak loads where at that time there is often an increase in resistive and inductive loads. Of course, the effect of the load is closely related to changes in the power generated by the generator. The inductive load will affect the reactive power generated by the generator. The reactive power of the generator increases when the inductive load is borne by the generator. This will affect the terminal voltage of the generator which is getting lower so it is necessary to increase the field current supplied by the excitation system

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to keep the voltage constant.*output*generator remains at its nominal value.

Table 4. *Logsheet* 7th Nov 2021

Time	Excitation		SUTT (kV)	KV	A	MW	MVAR	Cosφ
	A	V						
17:00	745	79	159	11,1	2180	40	0,3	0,93
18:00	749	79	159	11,1	2180	40	0,5	0,9
19:00	749	79	159	11,1	2180	40	0,6	0,9
20:00	753	79	159	11,1	2180	40	0,6	0,9
21:00	753	79	159	11,1	2180	40	0,7	0,84
22:00	753	79	159	11,1	2180	40	0,8	0,82

Table 4 shows that when a peak load occurs, namely when the demand for inductive loads increases, the generator will supply reactive power to an increasing load. On the other hand, an increase in reactive power will affect the output voltage or the generator terminal will decrease. The voltage drop will cause disruption to the performance of the generator. To prevent interference, the excitation system will work to increase the value of the field current so that the voltage *output* generator is still at the recommended value. As the reactive power increases, the excitation supplied by the excitation system will also increase to maintain the terminal voltage value. In this test it is also seen that the inductive load greatly affects the value of cos. Increasing the inductive load causes the value of cos to decrease.

The decreasing Cosφ should affect the real power value. However, the real / active power is still in a constant state because the active power can also be influenced by turbine mechanics and frequency settings *prime mover*. Unlike the case with the value of reactive power which is getting bigger due to the decrease in cos. When cosφ = 0.82 with reactive power value = 0.8 MVAR, the field current must work above the recommended value to control the terminal voltage. The results of this test can be obtained by graphing the relationship between field current and reactive power off peak load as shown in Figure below.

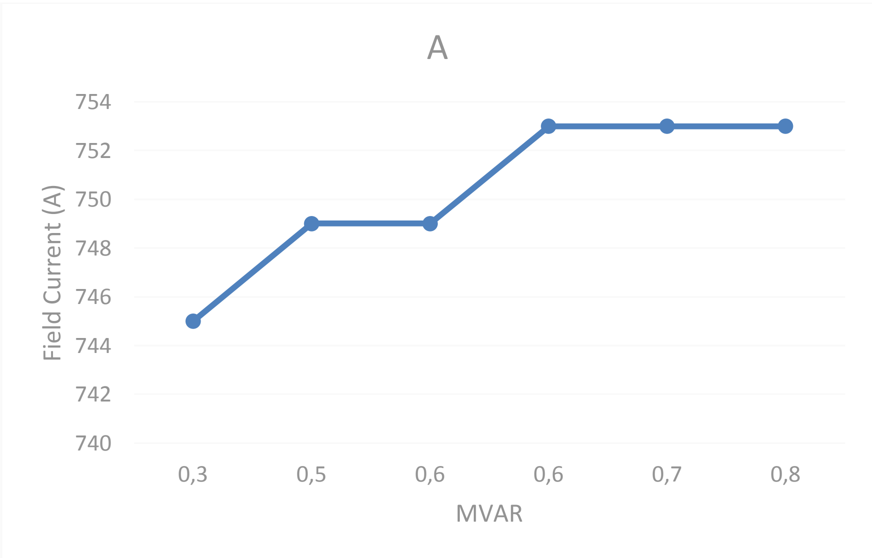

Figure 7. Graph of Excitation Current Relationship with Peak Load Reactive Power

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Then the following is the test data when the inductive load is at its minimum and the resistive load increases.

Table 5. Excitation Data at 23.00-03.00 WIB On 23 Oct 2021

Jam	Excitation		SUTT (kV)	KV	A	MW	MVAR	Cosφ
	A	V						
23:00	753	79	152	10,9	2160	40	0.3	0,99
00:00	755	79	152	10,9	2180	40	0.3	0,98
01:00	755	79	152	10,9	2180	40	0.4	0,99
02:00	757	80	152	10,9	2180	40	0.5	0,99
03:00	757	80	152	10,9	2180	40	0.5	0,99

Table 5 shows the excitation data when the resistive load increases so that when compared to the previous data, the reactive power in this test tends to be small due to a decrease in the inductive load or inductive load at its minimum. This will affect the amount of cos, which is between 0.98 - 0.99. Due to the small reactive power, the excitation supplied to the generator is close to its minimum value in controlling the generator terminal voltage. From table 5 above, a graph like the following is obtained:

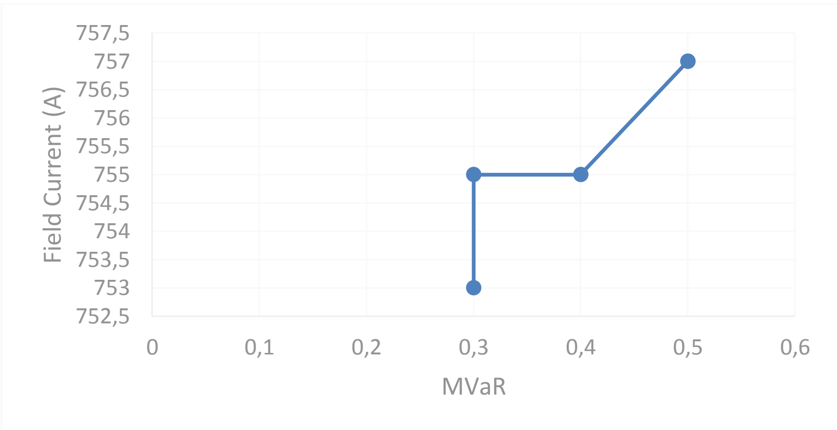

Figure 7. Graph of the Relationship of Excitation Current and Reactive Power Off Peak Load

From table 4 data taken when the peak load and table 5 data taken outside the peak load, it can be shown that the reactive power (MVAR) on the synchronous generator is very influential in maintaining the generator output voltage at its nominal value, which is approximately 11.1 kV. At peak load, the 150 kV system voltage is relatively higher due to the large number of inductive loads that must be maintained by the system, resulting in the generator output voltage being lower below the nominal voltage. For this reason, the reactive power (MVAR) of the generator needs to be increased*lagging*so that the generator is able to send reactive power to the system. Thus the generator output voltage will again increase according to its nominal value. To increase the reactive power of the synchronous generator, the AVR needs to increase the value of its excitation current according to the amount of reactive power required by the generator.

On the other hand, in conditions outside the peak load, the inductive load requirements of the system begin to decrease, so the value of the reactive generator power is relatively smaller to maintain the generator output voltage does not exceed the nominal voltage, in other words the AVR must also reduce the excitation current to the generator rotor to reduce reactive power (MVAR) generator.

Loaded Generator Excitation Current Testing Analysis

The tests in this sub-chapter are carried out by comparing the operating data at each load change to the resulting excitation current value. This is done to see and analyze the effect of changes in the value of the excitation current on the RENUN HEPP generator at every load change in order to obtain the nominal output voltage of the generator. The analysis data is obtained from the daily report of the RENUN HEPP operation at the desired load.

Table 6. Loading Data for RENUN HEPP

No	Daya Aktif MW)	Daya Reaktif (MVAr)	Factor Daya	Arus Generator Ia (A)	Tegangan Terminal (kV)	Arus Medan If (A)	Tegangan Medan (V)
1	12	2.17	0.86	666	11	652.55	58.21
2	25	1.99	0.88	1360	11	687.87	61.34
3	31	1.22	0.92	1992	11	715.87	74.54
4	41	0.67	0.96	2419	11	757.85	80.46

This test is taken when the generator is parallel to the system and has been loaded. From the data in table 6 above, it can be seen that on a generator that is already in parallel with the system, it appears that the increase in excitation current is directly proportional to the increase in load. This means that the AVR will provide a greater field current to the generator rotor coil when the generator load is increased, the magnitude of the increase in the field current given from the AVR to the rotor is not linear, according to the voltage conditions of the transmission system where the generator is parallel. It aims to maintain a fixed generator output voltage of 11 kV (according to the nominal voltage of the generator), the speed of the AVR to produce field currents to maintain the generator output voltage is dependent on the circuit settings. *Regulating device* which was explained in the previous chapter.

From the description of the data in table 6 above, it is known that the explanation is in accordance with equation 2.2b in the previous chapter, namely that the terminal voltage generated by the generator will be directly proportional to the magnitude of the induced emf in the field coil. Because the generator rotation is kept constant at 750 Rpm to keep the frequency at 50 Hz, the setting of the induced emf generated is only influenced by the amount of flux generated by the excitation current. So that the greater the loading carried out, the greater the excitation current injected from the AVR to the generator rotor.

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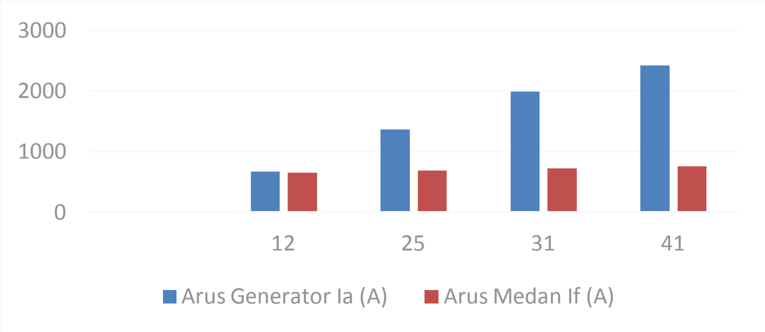

Figure8 . Comparison of Generator Current and Field Current

CONCLUSION

Based on the analysis and discussion results, it can be concluded that:

1. From the tests that have been carried out by comparing the commissioning test data for the AVR PLTA RENUN, it can be concluded that the AVR PLTA RENUN remains in good condition, this is also evidenced by the ability of the AVR PLTA RENUN in its speed to maintain the generator output voltage according to its nominal value, and to maintain the reactive power of the generator within range according to a predetermined capability curve.
2. The lower the system voltage, the lower the generator voltage, so the AVR must supply a higher excitation current. This has an impact on increasing the reactive power of the generator. The large reactive power affects the change or decrease in the generator terminal voltage. By adjusting the supply of excitation current or field current to the generator, the output voltage can also be stabilized so that reactive power can also be controlled.
3. The AVR will provide a larger field current on the generator rotor coil when the generator load is increased, the magnitude of the increase in the field current given from the AVR to the rotor is not linear, according to the voltage conditions of the transmission system, the terminal voltage generated by the generator will be directly proportional to the magnitude of the induced emf at the generator. field coil.

REFERENCES

Allan, C Morse and C. Richard Mummert. 2000. *Digital Excitation System Provides Enhanced Performance And Improved Diagnostics.*Eaton : IEEE.

Anonymous. 2006.*Single Line and Schematic Diagram of Renun Power Station.*

Anonymous. 2006.*ELIN – Automatic Voltage Regulator (AVR)*. RENUN PLTA.*Generator Control And Protection.*Shoutern Illinois University: Edward Ville.

Azis, M., 1984, Alternating Current Generator Operation, Gresik PLTU Maintenance Division, Gresik, p. 46.

J. Mozina Charles and Michael Reichard. 2007.*Coordination Of Generator Protection With Generator ExcitationControl And Generator Capability*. IEEE Power Engineering Society General Meeting. Jerkovic, V., Miklosevic, K., Zeljko, S., 2010,*Excitation System Models of Synchronous Generator*, Faculty of Electrical Engineering Osijek,

International Journal of Economic, Technology and Social Sciences
e-ISSN 2775-2976
International Journal of Economic, Technology and Social Sciences
url: https://jurnal.ceredindonesia.or.id/index.php/injects
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Croatia, 142.
Pane, Ennopati. 2009. Study of Excitation System Using Permanent Magnet Generator (Application on Synchronous Generator at PLTD PT. Manunggal Wiratama). Medan. North Sumatra University.
Ridzki, Imron. 2013. Analysis of the Effect of Excitation. Malang: Malang State Polytechnic.
Weedy, BM, Cory, BJ, 1998,*Electric Power System*, John Wiley & Sons Ltd., Chichester, England, 77.