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Power Factor Improvement in the New Civil Engineering Building at State Polytechnic of Samarinda

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ABSTRACT: The State Polytechnic of Samarinda is grappling with reactive power issues, primarily stemming from the considerable number of electrical loads, including computers, fluorescent lamps, printers, air conditioners, and electric motors, present in its buildings and laboratories. As a solution, the installation of a static var compensator (SVC) is proposed to enhance the electrical power factor at the Samarinda State Polytechnic, with a specific focus on the new Civil Engineering Department building. To assess the impact on the power factor, simulations were conducted using MATLAB R2021a Simulink software. The findings reveal that the utilization of a static var compensator resulted in an average power factor increase of 25% across all experiments. However, the targeted power factor of 0.99 was not attained. Furthermore, employing the SVC led to a reduction in current in the R phase by an average of 1.8%, in the S phase by an average of 35%, and in the T phase by an average of 37%. Concurrently, there was an average increase in active power by 3.5%, while apparent power decreased by an average of 14%, and reactive power decreased by an average of 74%. Despite encountering some limitations, the implementation of SVC proved successful in enhancing the power factor in the simulation, presenting a viable solution for improving power quality in the buildings of Samarinda State Polytechnic.

KEYWORDS: Matlab/Simulink, Power factor, Stasic Var Compensator.

INTRODUCTION

Electricity plays a crucial role as an energy source in various industrial, commercial, and daily life activities. Recognizing the significant importance of electrical energy, especially in light of the increasing limitations of non-renewable energy sources, strategic measures to support the optimal provision of electrical energy are essential for preserving its sustainability.

According to the Ministry of Energy and Mineral Resources, electricity consumption has steadily increased, as indicated in the electricity statistics data for the year 2020. In that year, Indonesia's per capita electricity consumption reached 1.08 GWh (Ministry of Energy and Mineral Resources, Directorate General of Electricity, 2021). The escalating demand for electrical energy presents challenges to the power system. One aspect of this challenge is the degradation of power quality, which can result in reduced energy efficiency. Therefore, a crucial parameter to consider in managing electrical energy in a building is its power quality.

Power quality is paramount in maintaining the stability and continuity of the electrical power system in an industry (Sari et al., 2020). The quality of power distribution in the electrical system is determined by the specifications of the electrical channels and load characteristics. The demand for power supply is increasing due to the annual rise in load. Inductive loads, such as electric motors and transformers, require reactive power in their operation (Esye & Lesmana, 2021). Due to the flow of reactive current in the network, the power factor deteriorates, the voltage at the end of the network decreases, and the current value in the channel increases, leading to significant power losses in that channel (Risjayanto & Wrahatnolo, 2019).

Efforts to improve the quality of electricity usage are crucial in various industries, institutions, and households today. One measure for enhancing power quality is to improve the power factor. The power factor is the ratio of active power (P) to apparent power (S) (Rofii & Ferdinand, 2018). A good power factor approaches unity. The minimum standard value for power factor set by the national electricity company (PLN) based on SPLN 70-1 regulation is >0.85. If the power factor is less than 0.85, PLN will calculate the excess usage of Kilovolt Ampere Reactive Hours (kVARh), in addition to the consumed kilowatt-hours (kWh) (Esye & Lesmana, 2021). Therefore, improving the power factor is essential to reach the desired level. Increasing the power factor value can be achieved by adjusting the reactive power value, as the active power remains constant, using the reactive power compensation method. This method is applied to a device called the static var compensator (Nugraha & Winarno, 2021).

SVC, which stands for Static Var Compensator, is the first Flexible AC Transmission System (FACTS) device developed (Abidin & Mauladi, 2017). This device is connected in parallel to the system and combines capacitors connected in parallel (with fixed or variable capacitance) and coils, allowing it to operate in both inductive and capacitive modes (Persero, n.d.). Its primary function is to regulate voltage and reactive power in the power system. Additionally, this device can generate or absorb reactive power in various ranges. Because it is a more affordable FACTS device, SVC often becomes the focus of power studies (Ćalasan et al., 2020).

Technical colleges like the State Polytechnic of Samarinda (POLNES) currently have various loads such as computers, fluorescent lights, printers, air conditioners (AC), electronic and power electronics laboratory modules, and in laboratories and workshops, there are electric motors controlled by static converters (Rusda et al., 2017). This can generate reactive power, which ultimately lowers the power factor value. Based on these issues, it is proposed to improve the power factor in the installation at the State Polytechnic of Samarinda by planning the installation of static var compensators (Karim et al., n.d.).

The Department of Civil Engineering at the State Polytechnic of Samarinda in the new building has facilities such as classrooms, faculty rooms, departmental administrative rooms, prayer rooms, auditoriums, and computer laboratories. This Civil Engineering building is equipped with electrical equipment such as LED lights, air conditioners, printers, computers, speakers, digital clocks, and water pumps. These devices have the potential to lower power quality by contributing faulty voltage and current.

MATERIALS AND METHODS

Research Object

The objective of this research is to compensate for reactive power using a static var compensator in the new Civil Engineering building at the State Polytechnic of Samarinda to enhance the power factor in the building. The simulation will be conducted using MATLAB R2021a.

Research Operational Framework

Fig. 1 illustrates the operational framework of the research. It depicts that the research process commences with a literature review, encompassing an examination of existing literature and case studies. Subsequently, reference data and field data are acquired from the New Civil Engineering building at the State Polytechnic of Samarinda. The analysis will be conducted using MATLAB R2021a (Simulink), with the literature review furnishing specifications and functions of the static var compensator.

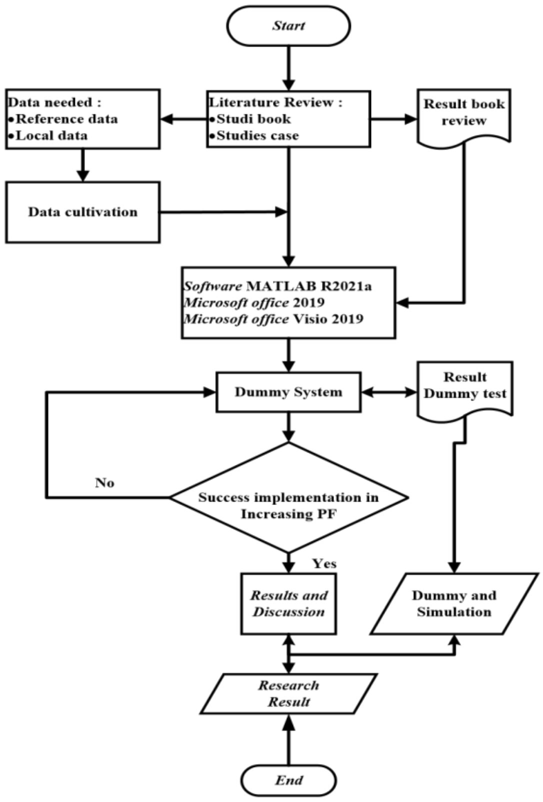

Fig.1. Operational framework

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The research then advances to the data processing stage, where both reference and field data will be analyzed using Simulink, yielding processed data in the form of power flow. Subsequently, this processed data will undergo further analysis to determine the compensation for reactive power.

Finally, the last stage involves results and discussion, which will present the research findings in the form of a model and simulation demonstrating the improvement in power factor before and after using the SVC in the New Civil Engineering building at the State Polytechnic of Samarinda.

RESULTS AND DISCUSSION

Electrical Simulation Design Results Without Static Var Compensator The first result come in Monday february 20, 2023

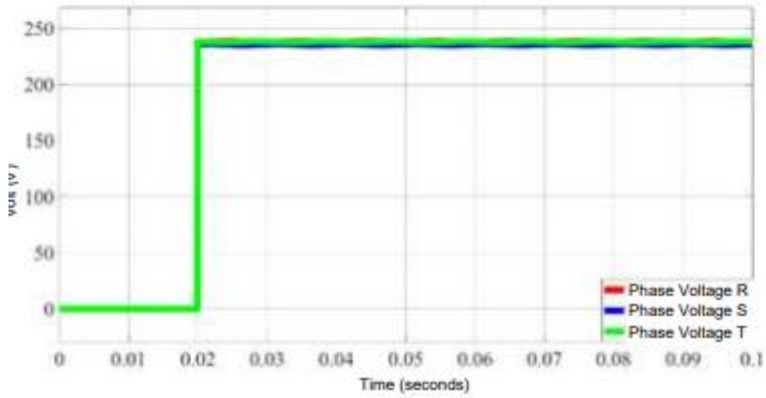

Fig.2. Voltage Response on Monday, February 20, 2023

Based on Fig.2., it shows the voltage response on Monday, February 20, 2023, at 17:00 in the new Civil Engineering building with phase R voltage of 237 V, phase S voltage of 235 V, and phase T voltage of 237 V.

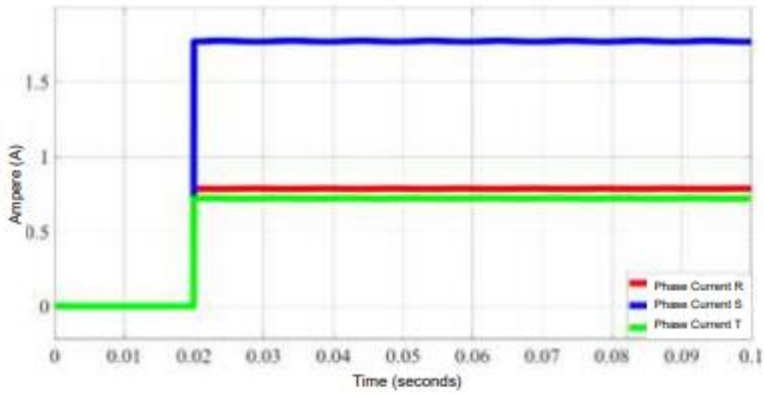

Fig.3. Current Response on Monday, February 20, 2023

Fig.3. demonstrates the current response with phase R current of 0.78 A, phase S current of 1.7 A, and phase T current of 0.72 A on Monday, February 20, 2023, at 17:00 in the new Civil Engineering building.

Based on Fig.4., it shows an active power response of 445 Watts on Monday, February 20, 2023, at 17:00 in the new Civil Engineering building.

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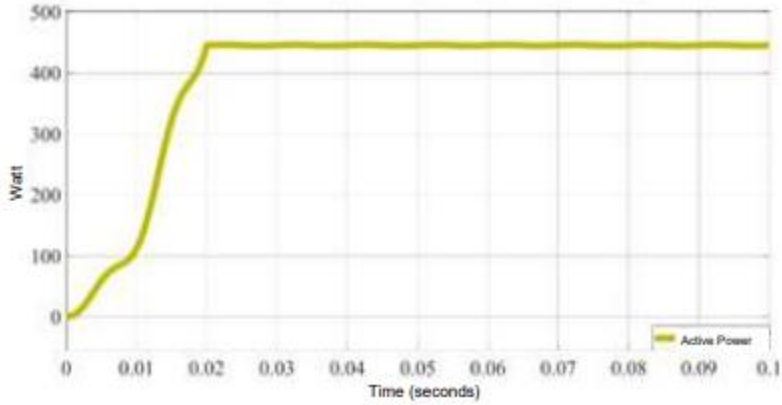

Fig.4. Active Power Response on Monday, February 20, 2023

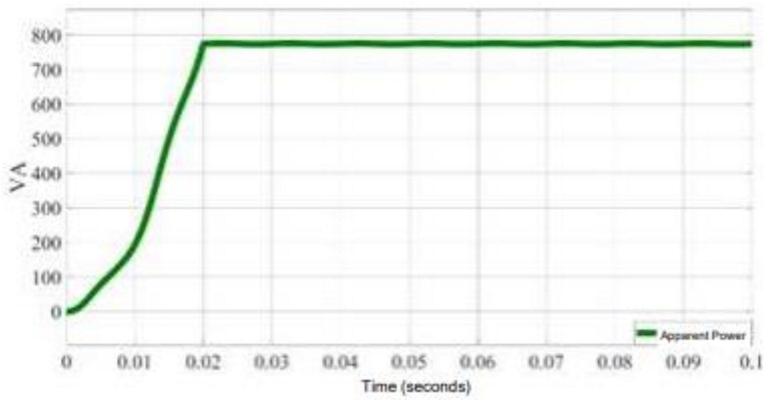

Fig.5. Apparent Power Response on Monday, February 20, 2023

Based on Fig.5., it shows an apparent power response of 774 VA on Monday, February 20, 2023, at 17:00 in the new Civil Engineering building.

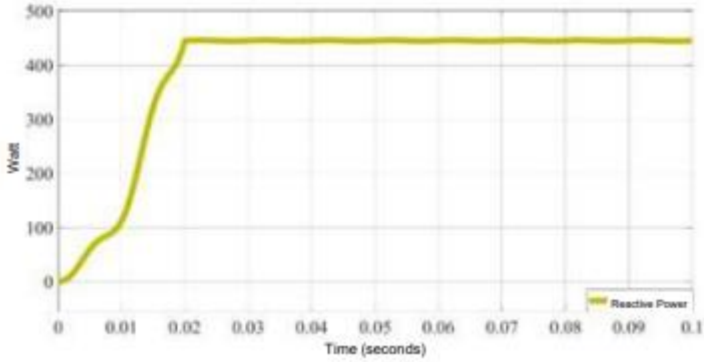

Fig.6. Reactive Power Response on Monday, February 20, 2023

Based on Fig.6., it shows a reactive power response of 617 Var on Monday, February 20, 2023, at 17:00 in the new Civil Engineering building.

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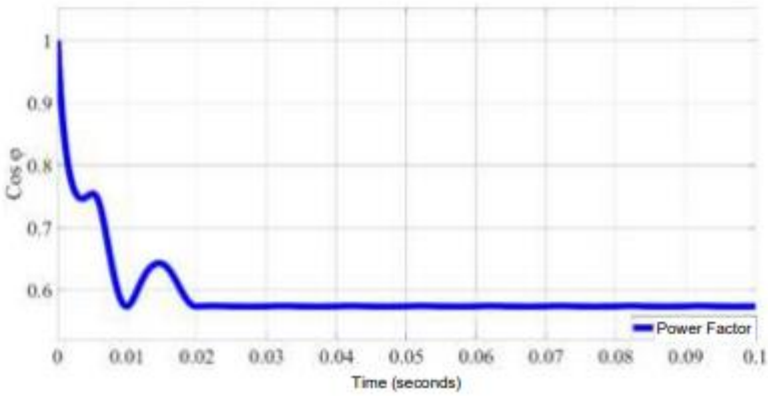

Fig.7. Power Factor Response on Monday, February 20, 2023

Based on Fig.7. shown in graphical form, the power factor value in the new Civil Engineering building on Monday, February 20, 2023, is 0.57.
Based on the simulation results without the use of a static var compensator, electrical parameters for the new Civil Engineering building at State Polytechnic of Samarinda were obtained during one week at 17:00, as shown in Table 1.

Table 1. Simulation Results of the Electrical System in the New Civil Engineering Building without SVC

Day	Voltage (V)			Current (A)			Active Power (Watt)	Apparent Power (VA)	Reactive Power (Var)	Power Factor
	R	S	T	R	S	T				
Monday	237	235	237	0.78	1.7	0.72	445	774	617	0.57
Tuesday	238	235	238	2.1	1.8	0.53	710	1070	760	0.66
Wednesday	239	237	239	2.5	1.5	0.6	750	1070	675	0.7
Thursday	236	236	238	9.7	1.1	0.8	2390	2780	1130	0.85
Friday	236	236	238	8.5	1.5	1.9	2360	2850	1420	0.82
Saturday	238	238	240	7.4	1.2	0.55	1800	2190	1100	0.82
Sunday	241	240	242	8	1.2	0.74	2030	2430	1160	0.83

The experiment conducted on the electrical system in the new Civil Engineering building without using a static var compensator for one week at 17:00, simulated using Matlab Simulink, yielded outputs of voltage, current, active power, apparent power, reactive power, and power factor that closely approximate the measured results used as a reference. This experiment serves as evidence that the electrical system simulation in the new Civil Engineering building without using a static var compensator can function effectively.

Power Factor Improvement

Based on the measurement data, the average values for active power are 1504 Watts, apparent power is 1882 VA, reactive power is 981 Var, and the power factor is 0.79. From the results of the average values, further processing will be conducted to obtain the reactive power compensation value as follows:

$Qc = P(\tan \varphi_1 - \tan \varphi_2)$
Where :
P = 1504 Watt
$\cos \varphi_1 = 0{,}79$ than $\tan \varphi_1 = 0{,}77$
$\cos \varphi_2 = 0{,}99$ than $\tan \varphi_2 = 0{,}142$

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thus :

Qc = 1504(0,77 − 0,142)

= 944 Var

For 3 steps, 944/3 = 314 Var per step. With this value of reactive power compensation, the capacitance value can be determined using the following equation:

Where:

Reactive power = 314 Var

Voltage = 220 V

Frequency = 50 Hz

The capacitor current (Ic):

$$Ic = \frac{Var}{V}$$

$$Ic = \frac{348}{220}$$

$$= 1,42 \text{ Ampare}$$

The capacitive reactance (Xc) is:

$$Xc = \frac{V}{Ic}$$

$$Xc = \frac{220}{1,581}$$

$$= 154,92 \text{ Ohm}$$

The required capacitor is:

$$C = \frac{1}{2\pi FXc}$$

$$C = \frac{1}{2 \times 3,14 \times 50 \times 139,152}$$

$$= 20,557\ \mu F$$

Based on the calculation results for power factor improvement, it is found that the required reactive power compensation is 944 Var. To achieve this value, compensation is done in 3 stages, and each stage requires a capacitor of 341 Var. The capacitance used for each stage is 20.557 μF.

Results of Electrical Simulation Design with Static Var Compensator

The result when SVC added

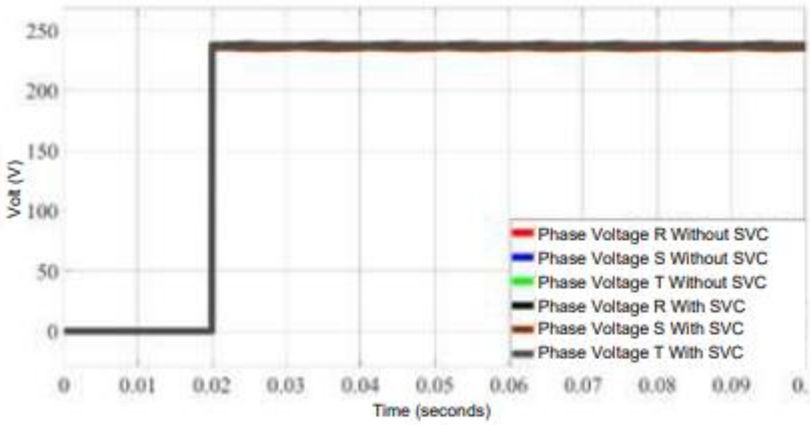

Fig.8. Voltage Response on Monday, February 20, 2023, with Static Var Compensator

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It can be observed that the voltage response on Monday, February 20, 2023, at 17:00 in the new Civil Engineering building did not change. Previously, phase R voltage was 237 V, phase S was 235 V, and phase T was 237 V in the simulation without static var compensator. In the simulation with static var compensator, the phase R voltage remained at 237 V, phase S at 235 V, and phase T at 237 V, as seen in Fig.8.

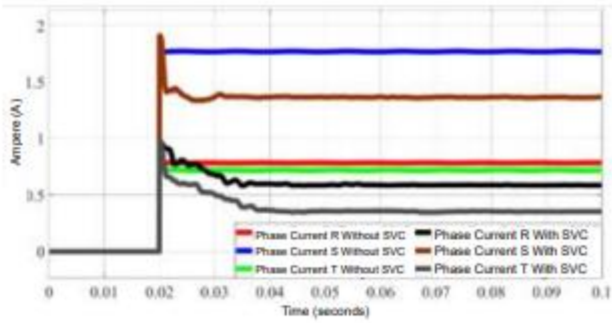

Fig.9. Current Response on Monday, February 20, 2023, with Static Var Compensator

Next, the current response on Monday, February 20, 2023, at 17:00 in the new Civil Engineering building experienced a decrease. Phase R current was 0.2 A, phase S was 0.3 A, and phase T was 0.37 A, whereas in the simulation without static var compensator, phase R current was 0.78 A, phase S was 1.7 A, and phase T was 0.72 A. In the simulation with static var compensator, phase R current became 0.58 A, phase S became 1.36 A, and phase T became 0.35 A, as shown in Figure 9.

Furthermore, on Monday, February 20, 2023, at 17:00 in the new Civil Engineering building, the active power increased by 51 Watts. Initially, in the simulation without static var compensator, the active power was 445 Watts, which then became 496 Watts in the simulation with static var compensator, as seen in Figure 10.

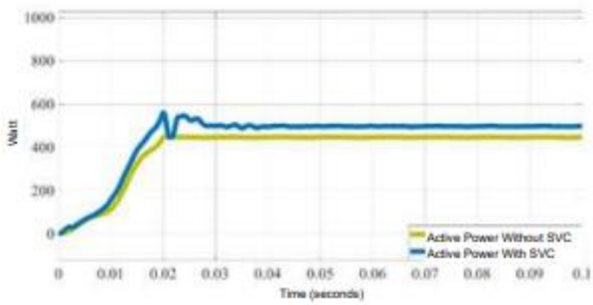

Fig.10. Active Power Response on Monday, February 20, 2023, with Static Var Compensator

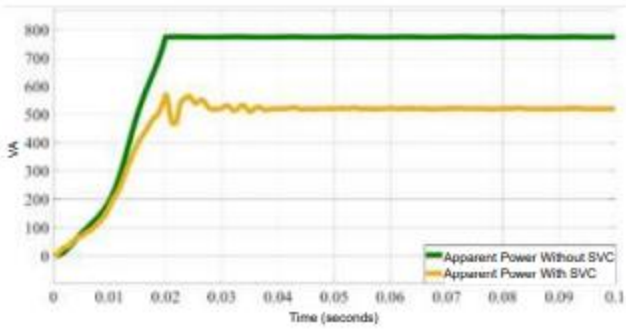

Fig.11. Apparent Power Response on Monday, February 20, 2023, with Static Var Compensator

Then, on Monday, February 20, 2023, at 17:00 in the new Civil Engineering building, the apparent power decreased by 254 VA. Initially, in the simulation without static var compensator, the apparent power was 774 VA, which then became 520 VA in the simulation with static var compensator, as shown in Figure 11.

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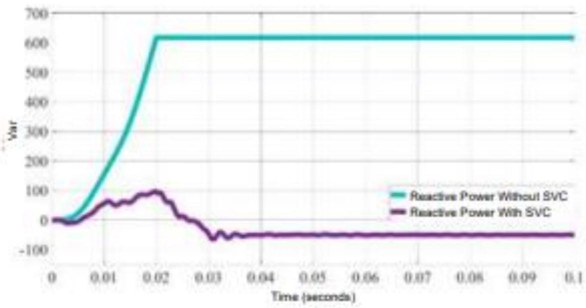

Fig.12. Reactive Power Response on Monday, February 20, 2023, with Static Var Compensator

Furthermore, on Monday, February 20, 2023, at 17:00 in the new Civil Engineering building, the reactive power decreased by 667 Var. Initially, in the simulation without static var compensator, the reactive power was 617 Var, which then became -50 Var in the simulation with static var compensator, as seen in Figure 12.

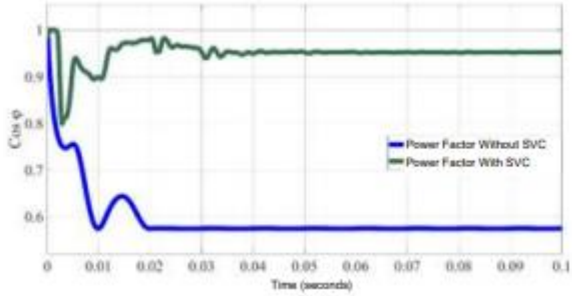

Fig.13. Power Factor Response on Monday, February 20, 2023, with Static Var Compensator

Table 2. Simulation Results of the Electrical System in the New Civil Engineering Building with SVC

Day	Voltage (V)			Current (A)			Active Power (Watt)	Apparent Power (VA)	Reactive Power (Var)	Power Factor
Not Implement SVC										
	R	S	T	R	S	T				
Monday	237	235	237	0.78	1.7	0.72	445	774	617	0.57
Tuesday	238	235	238	2.1	1.8	0.53	710	1070	760	0.66
Wednesday	239	237	239	2.5	1.49	0.6	750	1070	675	0.7
Thursday	236	236	238	9.7	1.1	0.8	2390	2780	1130	0.85
Friday	236	236	238	8.5	1.5	1.9	2360	2850	1420	0.82
Saturday	238	238	240	7.4	1.2	0.55	1800	2190	1100	0.82
Sunday	241	240	242	8	1.2	0.74	2030	2430	1160	0.83
Implement SVC										
Day	V oltage (V)			C urrent (A)			Active Power (Watt)	Apparent Power (VA)	Reactive Power (Var)	Power Factor
	R	S	T	R	S	T				
Monday	237	235	237	0.58	1.36	0.35	496	520	-50	0.95
Tuesday	238	235	238	1.96	1.35	0.38	763	865	85	0.88
Wednesday	239	237	239	2.42	0.84	0.38	800	855	-3	0.93
Thursday	236	236	238	9.62	0.71	0.24	2440	2500	455	0.97
Friday	236	236	238	8.35	0.95	1.3	2430	2480	430	0.97
Saturday	238	238	240	7.27	0.65	0.37	1850	1960	420	0.94
Sunday	241	240	242	7.95	0.66	0.41	2086	2161	460	0.96

The power factor response increased on Monday, February 20, 2023, at 17:00 WITA, from 0.57 without static var compensator to 0.95 in the simulation with static var compensator, as shown in Figure 13.
Based on the simulation results using a static var compensator, electrical system parameters for the new Civil Engineering building at State Polytechnic of Samarinda were obtained during one week at 17:00, as shown in Table 2.

The experiment of the electrical system simulation in the new Civil Engineering building at the State Polytechnic of Samarinda was conducted for one week at 17:00 WITA. The experiment was carried out in two phases: without a static var compensator and with a static var compensator. Changes in voltage, current, active power, apparent power, reactive power, and power factor were observed in each simulation, including:

1. In the experiment, it was observed that there was no significant change in voltage over the course of one week when using the static var compensator (SVC). This is because the SVC is designed to compensate for reactive power in the simulation design created in Matlab Simulink, rather than to significantly alter voltage.
2. The power factor value showed a significant improvement when using the SVC, with an average increase of 25% in all simulation results. This indicates that the SVC successfully functions in increasing low power factors. However, the experiment results did not yet meet the desired power factor value of 0.99, although simulations on Thursday and Friday came close to the target.
3. The simulation results with SVC showed an increase in power factor, resulting in a decrease in current in phase R by an average of 1.8%, in phase S by an average of 35%, and in phase T by an average of 37%. Additionally, as the current decreased, active power increased by an average of 3.5%, while apparent power decreased by an average of 14%, and reactive power decreased by an average of 74%.

Various conditions in improving the power factor in the simulation of electrical power flow, with and without using a static var compensator, show that the static var compensator is able to help enhance the power factor in the simulation of electrical power flow in the new building of the Civil Engineering Polytechnic State of Samarinda. This proves that a static var compensator can be applied to the electrical power system in the new Civil Engineering building to improve the power factor

CONCLUSION

Based on the results and discussions of the power factor improvement in the new Civil Engineering building at State Polytechnic of Samarinda as outlined in the previous chapter, the following conclusions can be drawn:

1. This study produced electrical system simulations in the new Civil Engineering building at State Polytechnic of Samarinda before the use of a static var compensator. The simulation results closely resembled the actual measurement results.
2. This study produced electrical system simulations in the new Civil Engineering building at the State Polytechnic of Samarinda using a static var compensator, which effectively increased the power factor by an average of 25% in each week's simulation.
3. The installation of a static var compensator to improve the power factor in the new Civil Engineering building at State Polytechnic of Samarinda required 944 Var of reactive power compensation. To achieve this value, compensation was carried out in three stages, with each stage requiring a capacitor of 341 Var. The capacitance used for each stage was 20.557 μF.
4. From the simulation of static var compensator installation in the electrical system of the new Civil Engineering building at State Polytechnic of Samarinda over one week, it was observed that voltage remained unchanged, but current decreased by an average of 1.8% in phase R, 35% in phase S, and 37% in phase T. Active power experienced an increase of an average of 3.5%, while apparent power decreased by an average of 14%, and reactive power decreased by an average of 74%. Lastly, the power factor experienced a significant increase, averaging 25%.

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