Improvements to Capacitor Bank Requirements in 20kv Voltage Distribution Network Panels for Power Plant 2 at PT. Toyota Motor Manufacturing Indonesia

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ABSTRAK

Penelitian ini bertujuan untuk mendeskripsikan dan menganalisis efektivitas penggunaan kapasitas capasitor bank pada sistem distribusi pembangkit listrik 2 PT. TMMIN. Fokusnya adalah menganalisis desain awal kebutuhan bank kapasitor pada setiap panel di lini produksi gardu induk, meliputi Pengecatan, Perakitan dan Pengelasan, untuk meningkatkan kebutuhan bank kapasitor sesuai standar teori kelistrikan. Metode perhitungan Faktor Daya digunakan untuk mengukur kapasitas bank kapasitor yang dibutuhkan. Faktor daya dipengaruhi oleh jenis beban listrik yang bersifat resistif, induktif, atau kapasitif, yang nilainya berkisar antara 0 hingga 1. Faktor daya yang mendekati 1 menunjukkan daya aktif yang tinggi dan kualitas daya listrik yang lebih baik, sedangkan faktor daya yang mendekati 1 menunjukkan daya aktif yang tinggi dan kualitas daya listrik yang lebih baik, sedangkan faktor daya yang mendekati 0 menunjukkan daya reaktif yang tinggi. mengurangi kualitas daya dan meningkatkan penggunaan energi listrik. Nilai faktor daya arus diperoleh dari kondisi tegangan aktual dan daya aktif, dan nilai bank kapasitor yang dibutuhkan dihitung dengan target faktor daya sebesar 0,9 atau 0,95. Berdasarkan perhitungan, panel yang dapat diperbaiki adalah panel 3, 4, 5, 6 Pengecatan, panel 1 Rakitan, dan panel 1 Pengelasan. Hasil penelitian menunjukkan bahwa 2 panel MDB mencapai kondisi ideal dengan 6 langkah bank kapasitor 2x50kVAR, sedangkan 6 panel MDB lainnya memerlukan tambahan 2 langkah bank kapasitor 2x50kVAR untuk mencapai kondisi ideal.

Kata Kunci: *Faktor daya, Daya reaktif, Daya Aktif, Improve, kapasitor bank*

ABSTRACT

This research aims to describe and analyze the effectiveness of using capacitor bank capacity in PT's power plant 2 distribution system. TMMIN. The focus is to analyze the initial design of capacitor bank requirements for each panel in the substation production line, including Painting, Assembly and Welding, to increase capacitor bank requirements according to electrical theory standards. The Power Factor calculation method is used to measure the required capacitor bank capacity. The power factor is influenced by the type of electrical load which is resistive, inductive or capacitive, with a value range between 0 and 1. A power factor close to 1 indicates high active power and better electrical power quality, while a power factor close to 0 indicates high reactive power. reducing power quality and increasing electrical energy use. The current power factor value is obtained from the actual voltage and active power conditions, and the required capacitor bank value is calculated with a target power factor of 0.9 or 0.95. According to calculations, the panels that can be repaired are panels 3, 4, 5, 6 Painting, panel 1 Assembly, and panel 1 Welding. The results show that 2 MDB panels reach ideal conditions with 6 steps of 2x50kVAR capacitor bank, while the other 6 MDB panels require an additional 2 steps of 2x50kVAR capacitor bank to achieve ideal conditions.

Key words: *Power Factor, Reactive power, Active power, Reactive power, Improve, capacitor bank*

INTRODUCTION

In an era of uncertainty regarding the availability of energy sources, efficient use of electricity is very important for industry. One way to increase electrical energy efficiency is to improve the power factor using capacitor banks, which compensate for reactive power and prevent wastage of energy and costs. By increasing the power factor, industry can reduce operational costs, optimize the use of electrical power, and support environmental sustainability (Hasibuan et al., 2023).

The use of capacitor banks is very effective for increasing the electrical power factor by compensating for reactive power. However, implementation requires careful planning. According to SPLN regulation 70-1, PLN sets a minimum standard for power factor of more than 0.85. If it is less than that, PLN will consider additional use of Kilo Volt Ampere Reactive Hours (kVARh) (Wicaksono et al.,2021).

At PT. TMMIN Karawang, the electricity distribution system has 3 substation production lines with several main transformers connected to the distribution panel. Each panel is equipped with a capacitor bank, but it has not yet reached ideal conditions. Currently, the average power factor of 12 transformers is 0.87. Even though there is no fine yet, a slight decrease could cause the power factor to fall below 0.85. Therefore, improvements to capacitor banks are necessary to achieve ideal conditions, improve the electricity distribution system, and increase the efficiency of using capacitor banks in accordance with the electrical system.

LITERATURE REVIEW

Active Power (P)

Active power is the power actually required by the load. The unit of active power is W (Watt) and can be measured using a Wattmeter electricity measuring instrument [3].

The equation for active power at the load in a single phase system is as follows :

$$P = V \times I \times Cos\,\varphi \qquad (1)$$

The equation for active power at the load in a three-phase system is as follows :

$$P = \sqrt{3} \times V \times I \times Cos\,\varphi \qquad (2)$$

Reactive Power (Q)

Reactive power is the power required to form a magnetic field or the power generated by an inductive load. The unit of reactive power is VAR (Volt Ampere Reactive) (Febriani, et al., 2024).

The reactive power equation for the load in a single phase system is as follows:

$$Q = V \times I \times Sin\,\varphi \qquad (3)$$

The reactive power equation for the load in a three-phase system is as follows:

$$Q = \sqrt{3} \times V \times I \times Sin\,\varphi \qquad (4)$$

Power Factor

Power factor, or power factor (Cos φ), is a value that shows the ratio between active power and apparent power, arising due to power losses. In single-phase installations, Cos φ is usually set at 0.8 because the value rarely varies much. To keep the kWh output the same and reduce the total power requirement (VA), the reactive power (VAR) must be reduced (Ferdiansah et al., 2023).

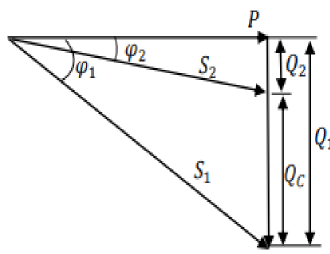

Figure 1. Power Triangle

power factor equation in a single phase system is as follows:

$$\text{Power Factor} = \cos\varphi = \frac{P\ (kW)}{S\ (kVA)} \qquad (5)$$

The power factor equation in a three-phase system is as follows:

$$P = \sqrt{3} \times V \times I \times Cos\,\varphi \qquad (6)$$

$$P = S \times Cos\,\varphi \qquad (7)$$

$$S = \sqrt{3} \times V \times I \qquad (8)$$

Capacitor Bank

Capacitor Banks are devices used to improve the quality of electrical energy supply by improving the voltage on the load side, increasing the power factor (Cos φ), and reducing transmission losses. This capacitor has capacitive (leading) characteristics, which can reduce or eliminate inductive (lagging) characteristics. Its main function is to balance the inductive characteristics. Although often measured in kVAR (Kilovolt Ampere Reactive) (Adhimanata, 2024), capacitor banks also include capacitance quantities such as Farads or microfarads.

$$Q = \sqrt{S^2 - P^2} \quad (9)$$

$$Q = S \times \sin\varphi \quad (10)$$

$$Q = P \times \tan\varphi \quad (11)$$

METHOD

1. Linear Studies
   Collection of related data
2. Analysis Method
   Analyze the condition of the installed capacitor bank and the magnitude of the power factor by collecting data on the electrical system at power plant 2 PT. TMMIN.
3. Calculation and Simulation Methods
   Calculate the power value on the Transformer panel and calculate the capacitor value used to determine the running capacitor value using calculations.

RESULTS

Calculation of Increased Bank Capacitor Requirement

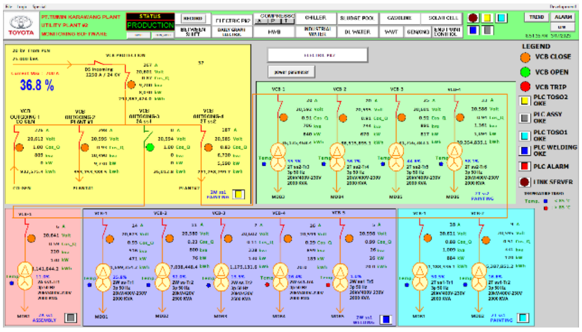

Figure 2. Single – Line Diagram of Power Plant 2 Distribution System on PT SCADA

Electrical system at PT. TMMIN in Karawang receives a voltage supply of 20 kV from PLN. This voltage is then channeled through twelve main transformer panels with a capacity of 1000 kVA each to reduce the voltage to 220 V and 380 V. Next, the voltage will be distributed to various production lines as shown in Figure 2.

Power Data on Main Transformer

The power factor calculation used in this research uses the electrical power contained in the main transformer panel. In total there are 12 main transformer panels which are then distributed to the loads in the factory. The amount of power in each transformer panel can be seen in table 1.

Table 1. Data on High Voltage and Low Voltage Transformers

	HIGH VOLTAGE 20KV				***LOW VOLTAGE***				
SHOP	**Trafo (kVA)**	**I (A)**	**Active Power Efficiency (80%)**	**Ideal Cos φ**	**Panel MDB**	***Voltage* (V)**	**I (A)**	**Power Used (kW)**	**Cos φ >0,95**
2T SS1 *Painting*	TR #1 2000	58	1443,84	0,95	MDB 1	380	2890	920	0,94
	TR #2 2000	58			MDB 2	380	2890	207	
2T SS2 *Painting*	TR #3 2000	58	1443,84	0,95	MDB 3	380	2890	632	0,93

	TR #4 2000	58	1443,84	0,95	MDB 4	380	2890	702	0,93
	TR #5 2000	58	1443,84	0,95	MDB 5	380	2890	840	0,94
	TR #6 2000	58	1443,84	0,95	MDB 6	380	2890	1012	0,94
2A SS1 *Assembly*	TR #1 2000	58	1443,84	0,95	MDB 1	380	2890	298	0,93
	TR #1 2000	58	1443,84	0,95	MDB 1	380	2890	423	0,93
	TR #2 2500	72			MDB 2	420	3400	92	
2W SS1 *Welding*	TR #3 2500	72			MDB 3	420	3400	22	
	TR #4 2000	58	1443,84		MDB 4	420	3400	236	
	TR #5 2000	58	1443,84	0,95	MDB 5	380	2890	29	0,95

Analysis and Calculation Results

From the data obtained in table 1, the active power efficiency (kW) installed in all 2000 kVA transformers will be calculated, apart from transformers that do not have capacitor banks installed. The calculation of the efficiency of active power installed in a 2000 kVA transformer is 80% of the active power, which can be calculated using equation (1), namely:

$$P = \sqrt{3} \times V \times I \times Cos\,\varphi$$

Where,

V = 380 V Cos φ = 0,95

I = 2890 A √3 = 1,73

the calculation,

$$P = 1{,}73 \times 380 \times 2890 \times 0{,}95$$
$$= 1804891{,}7 \text{ W}$$
$$= 1804{,}8 \text{ kW}$$

Power Efficiency 80%

$$= \frac{80}{100} \times 1804{,}8\, kW = \mathbf{1443{,}84\ kW}$$

From the calculation above, the efficiency of active power installed in a 2000 kVA transformer is **1443.84 KW**.

Analysis of Results and Calculations on Installed Active Power

From the power factor data (Cos φ) obtained, then determine the design of the capacitor bank requirements by carrying out calculations in order to improve the capacitor bank requirements that have been installed in each substation panel of MDB plant 2. The power factor in each MDB panel has met the minimum standard applied in the factory electrical system, namely 0.95. To determine the number of capacitor banks required, calculations are carried out on each MDB panel (Main Distribution Panel).

The following is a calculation of the need for capacitor banks for active power installed in all 2000 kVA transformers, apart from transformers that do not have capacitor banks installed. Based on power efficiency 1443,84 kW

and ideal cos φ 0.95, can be calculated using equation (11) by knowing the amount of reactive power (kVAR) for each load on all MDB panels.

Calculation of capacitor bank requirements based on equation (11):

$$Q = \mathrm{P} \times \mathrm{Tan}\,\varphi$$

Where :

P = 1443,84 kW

Cos φ = 0,95 = Tan φ = 0,33

The calculation,

$$Q = 1443{,}84\ \text{kW} \times 0{,}33 = \mathbf{476{,}46\ kVAR}$$

The above calculation can be proven correct based on equation (9), which is as follows:

$$Q = \sqrt{S^2 - P^2}$$

Where :

P = 1443,84 kW

Cos φ = 0,95

The calculation,

$$S = \frac{P}{Cos\ \varphi} = \frac{1443{,}84}{0{,}95} = \mathbf{1519{,}83\ kVA}$$

$$Q = \sqrt{1519{,}83^2 - 1443{,}84^2}$$

$$= \sqrt{2309883{,}22 - 2084673{,}94}$$

$$Q = \sqrt{225209{,}28} = \mathbf{474{,}56\ kVAR}$$

It can be concluded that the two calculations above have almost the same value. So, the ideal capacitor installed on all 2000 kVA transformer MDB panels, with an installed power of 1443.84 kW = 476.46 kVAR or 6 step (2x50 kVAR) capacitor bank and includes the addition of 1 step spear capacitor.

Table 2. Calculation Results of Ideal Capacitor Needs with Actual Capacitors Installed Based on 80% Power Efficiency of 1443.84 kW on a 2000 kVA Transformer.

SHOP	Panel MDB	Ideal Cos φ	Ideal Installed Capacitor (kVAR) / (2x50kVAR)	Actual Capacitor Installed (2x50kvar)	Corrective Action
2T SS1 Painting	MDB 1	0,95	476,46 / 6 step	6 Step	Ideal condition
2T SS2 Painting	MDB 3	0,95	476,46 / 6 step	4 Step	Add 2 steps of capacitor bank to ideal condition
	MDB 4	0,95	476,46 / 6 step	4 Step	Add 2 steps of capacitor bank to ideal condition
	MDB 5	0,95	476,46 / 6 step	4 Step	Add 2 steps of capacitor bank to ideal condition
	MDB 6	0,95	476,46 / 6 step	4 Step	Add 2 steps of capacitor bank to ideal condition
2A SS1 Assembly	MDB 1	0,95	476,46 / 6 step	4 Step	Add 2 steps of capacitor bank to ideal condition
2W SS1 Welding	MDB 1	0,95	476,46 / 6 step	4 Step	Add 2 steps of capacitor bank to ideal condition
	MDB 5	0,95	476,46 / 6 Step	6 Step	Ideal condition

From the data from the calculation results above, based on the calculations it was found that 2 MDB panels had reached the ideal condition, with 6 step capacitor banks of 2x50 kVAR installed, and the other 6 MDB panels required the addition of 2 step capacitor banks of 2x50 kVAR each to achieve ideal conditions. capacitors are installed on each MDB panel

CONCLUSION

Based on the results of the discussion of the Practical Work report, several conclusions can be drawn as follows: Calculation of the design of capacitor bank requirements based on installed power aims to determine the initial design of capacitor bank requirements that are needed according to applicable calculation rules in order to improve the capacity of capacitors already installed at PT. TMMIN. Based on calculations, it is known that 2 MDB panels are in accordance with the calculation requirements (Ideal condition), the other 6 panels still require improvement by adding 2 step capacitor banks to achieve ideal conditions. This is necessary so that the electrical energy distribution system and production processes can run better. And as proof of the learning that has been obtained, it can be implemented directly in the field.

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