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EVALUATION OF THE IMPACT OF CAPACITOR BANK CAPACITY ON ENERGY EFFICIENCY AND POWER FACTOR AT ASTON INN HOTEL TASIKMALAYA

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Abstract— *This study aims to evaluate the impact of capacitor bank capacity on energy efficiency and power factor at Aston Inn Hotel Tasikmalaya. The hotel's electrical system is characterized by a predominance of inductive loads, which generate a considerable amount of reactive power, thereby decreasing the overall power factor. To address this issue, capacitor banks are commonly used as a power factor correction tool, helping to reduce reactive power, minimize energy losses, and lower operational costs. However, the correct sizing of capacitor banks is crucial, as incorrect capacities can lead to system inefficiencies and potential instability. In systems where the power factor is low, there is an increase in electrical current, which contributes to higher energy losses in the form of heat and, consequently, elevated operational expenses. This study adopts a comprehensive approach involving direct measurement of the hotel's electrical system, detailed analysis of load data, and calculation of the ideal capacitor bank capacity required for optimal performance. The aim is not only to improve energy efficiency but also to enhance the overall stability and safety of the hotel's electrical network. The results of this research reveal that the currently installed capacitor bank has a capacity of 300 kVAr, which is significantly larger than the ideal requirement of 55 kVAr as determined through load analysis. This substantial excess in capacity results in a power factor shift from lagging to leading. Such a shift can lead to adverse effects on the electrical system, including potential instability, equipment malfunction, and increased wear and tear on system components. Additionally, it was discovered that the existing Power Factor Controller (PFC) is not operating at its optimal setting, further complicating the situation and preventing the system from achieving the desired power factor improvements. Based on these findings, it is recommended that adjustments be made to the capacitor bank capacity to align with the calculated ideal value. Moreover, a reconfiguration and proper tuning of the Power Factor Controller are necessary to ensure optimal performance. These corrective actions are expected to enhance power factor correction, improve energy efficiency, reduce operational costs, and maintain system stability within the hotel's electrical network.*

Keywords*: Capacitor bank, power factor, energy efficiency, Aston Inn Hotel Tasikmalaya*

I. INTRODUCTION

Energy is one of the critical factors in achieving sustainable development [1]. Electricity is a fundamental need across various sectors, including the industrial and commercial sectors [2]. One of the sectors that heavily relies on a stable and efficient power supply is the hospitality industry. Hotels require a stable and efficient electricity supply to operate various facilities and equipment, ensuring guest comfort and smooth operations [3]. However, inefficient use of electricity can lead to reactive power losses and increased operational costs [4][5][6]. Therefore, efforts to improve energy efficiency are essential to support optimal hotel operations [7][8].

Aston Inn Hotel Tasikmalaya is one of the hotels that requires a continuous power supply to operate various facilities, such as lighting, air conditioning systems, electronic equipment, and other services. In practice, however, the extensive use of electricity often leads to issues such as high reactive power due to the dominance of inductive loads. This condition results in a low power factor, which decreases system efficiency and increases energy losses and operational costs.

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Studies have shown that hotels in tropical regions tend to consume more energy than those in temperate climates, particularly four- and five-star hotels [9]. Additionally, hotels fall into the category of high-energy consumption buildings, especially for lighting, air conditioning, electronic equipment, and other services [10].

Investments in energy-efficient technologies and equipment, such as HVAC (Heating, Ventilation, and Air Conditioning), are often hampered by financial constraints, lack of information, and low awareness of the importance of energy efficiency [11]. One solution that can be implemented to enhance energy efficiency and improve the power factor in electrical distribution systems is the use of capacitor banks. Capacitor banks help reduce voltage fluctuations and improve the power factor, thereby minimizing reactive power losses and operational costs [12]. By providing the required reactive power, capacitor banks can reduce the total current flow, ultimately increasing energy efficiency.

According to the Regulation of the Minister of Energy and Mineral Resources of the Republic of Indonesia No. 28 of 2016, electricity customers with a power factor below 0.85 will incur additional charges for reactive power consumption [13]. Therefore, the use of capacitor banks is crucial in maintaining energy efficiency and avoiding penalties from electricity providers. Power Factor Correction (PFC), which is often carried out using capacitor banks, helps provide the necessary reactive power and improves power quality in the distribution system. The increasing consumption of inductive loads results in a continuous increase in reactive power, leading to a rise in power supply demand [14][15][16]. Moreover, PFC also protects electrical equipment from damage caused by harmonics [17]. Capacitor banks balance the reactive power demand in the electrical system [18][19][20][21], thereby improving the power factor and reducing the required current [22].

Aston Inn Hotel Tasikmalaya currently has a capacitor bank installed with a capacity of 300 kVAr. However, initial observations indicate that this capacitor bank has an excess capacity, leading to a change in the power factor from lagging to leading. This over-compensation of reactive power can increase system voltage and cause instability in the hotel's electrical operations. Therefore, evaluating the capacitor bank's capacity is essential to optimize the hotel's electrical system's efficiency.

Energy efficiency is a primary focus in managing energy resources in the commercial sector, including the hospitality industry [23][24]. Modern hotels are equipped with complex and sophisticated electrical equipment, such as air conditioning systems, water heaters, water pumps, kitchen appliances, and lighting throughout the building. The electrical energy consumption for running all these devices tends to be high, making electricity costs one of the largest components in hotel management [23][25]. Aston Inn Hotel Tasikmalaya, which operates 24 hours a day, faces challenges in managing electricity consumption efficiently without compromising guest comfort and service quality.

The low power factor in the hotel's electrical system is directly related to high energy consumption. The power factor is the ratio of active power (the actual power used) to apparent power (the total power drawn from the electrical grid). In reality, many electrical devices, particularly inductive ones such as motors, air conditioning compressors, and other electronic equipment, tend to generate reactive current, reducing the power factor. This reactive current does not contribute to useful active power but still burdens the electrical grid, increasing the total current flow and causing power losses along the electrical conductors.

The impact of a low power factor can be observed in several aspects. Firstly, it increases power losses in the hotel's electrical network, caused by a higher total current than necessary. Secondly, a low power factor results in higher electricity costs for the hotel, especially due to penalties from electricity providers for power factors below a certain threshold (usually below 0.85). Thirdly, low energy efficiency and high power losses can shorten the lifespan of electrical equipment and its supporting infrastructure, necessitating additional investments for maintenance and replacement.

One method that has been widely applied to address the issue of a low power factor is the use of capacitor banks. Capacitor banks generate capacitive reactive power to counterbalance the inductive reactive power produced by electrical loads. Thus, capacitor banks can reduce the amount of reactive current that the electrical network must supply, thereby increasing the electrical system's power factor. Additionally, installing capacitor banks can reduce the total current flowing through the network, thereby decreasing power losses and improving energy efficiency.

However, installing capacitor banks is not without challenges. A critical factor in their implementation is determining the correct capacity. If the capacity is too small, the power factor correction will not be optimal, and electricity costs and power losses will remain high. Conversely, if the capacity is too large, over-compensation can occur, where the power factor becomes excessively high, causing over-voltage conditions in the system. Furthermore, excessively large capacitor banks can cause harmonic issues in the electrical system, potentially damaging electrical equipment and disrupting operations.

Based on this background, this study aims to evaluate the impact of capacitor bank capacity on energy efficiency and power factor at Aston Inn Hotel Tasikmalaya. Using analysis and simulation methods, this research will determine the appropriate capacitor bank capacitance to improve the hotel's energy efficiency and power factor. In addition, the study will provide recommendations on resetting the capacitor bank and optimizing the Power Factor Controller (PFC) to achieve better energy efficiency and minimize operational costs.This research is expected to benefit the management of Aston Inn Hotel Tasikmalaya in managing electricity consumption more efficiently. Furthermore, the findings of this study can serve as a reference for other hotels and similar commercial buildings facing issues of low power factor and high electricity costs. With the optimization of capacitor bank capacity, it is hoped that energy efficiency can be enhanced, electricity costs can be reduced, and the lifespan of electrical equipment extended.

II. METHODS

This research was conducted to evaluate the impact of capacitor bank capacity on energy efficiency and power factor at Aston Inn Hotel Tasikmalaya. A quantitative approach was used, involving the collection of operational data, calculations, and analysis using the power triangle method to determine the appropriate capacitor bank capacity. The stages of the research are as follows:

A. Data Collection

The data collected in this study include:

- Electrical System Operational Data: Gathering information on the specifications of the installed capacitor bank, the electrical loads used, and the operational conditions of the electrical system at Aston Inn Hotel Tasikmalaya.
- Load Measurement Data: Conducting electrical load measurements to determine the values of active power (kW), reactive power (kVAr), and apparent power (kVA) under various operating conditions. The measurements were carried out using a Power Quality Analyzer to ensure accuracy.
- Power Factor Data (Cos φ): Collecting power factor data when the capacitor bank is turned on and off to observe changes in the electrical system.

B. Calculation of Capacitor Bank Capacity

To calculate the ideal capacitor bank capacity, the active power (P), reactive power (Q), and apparent power (S) are first calculated based on the load data. Next, the initial power factor is determined based on measurements without the capacitor bank. Then, the necessary capacitor bank capacity is calculated to improve the power factor to a more optimal condition. This requirement is determined by the phase angle change before and after power factor correction, ensuring the capacitor compensates for the required reactive power.

C. Data Analysis

After calculating the required capacitor bank, the results are compared with the capacitor bank already installed at Aston Inn Hotel Tasikmalaya. The analysis evaluates:

- Whether the installed capacitor bank meets the requirements of the electrical system.
- The impact of capacitor bank usage on changes in the power factor.
- The potential for over-compensation, which may cause a leading condition and its negative impact on the hotel's electrical system.

D. Power Factor Controller (PFC) Testing

The Power Factor Controller (PFC) on the capacitor bank panel is tested to assess its function in automatically controlling the system's power factor. The test involves observing the PFC's response to changes in electrical load and whether the system can maintain the power factor within the specified target.

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E. Recommendations for Improvement

Based on the analysis results, recommendations are provided regarding the appropriate capacitor bank capacity and adjustments to the Power Factor Controller (PFC). Routine maintenance is also recommended to maintain the optimal performance of the capacitor bank and prevent issues in the hotel's electrical system.

III. RESULTS AND DISCUSSION

This study aimed to evaluate the capacity of the capacitor bank installed at Aston Inn Hotel Tasikmalaya to improve energy efficiency and power factor in the hotel's electrical system. The evaluation involved a comprehensive analysis of operational data, electrical loads, and the currently installed capacitor bank. By comparing the real-time data with the theoretical calculations, the study identifies potential excess or deficit in the installed capacitor bank capacity and its impact on system performance

A. Electrical Load Analysis

The electrical load measurements at Aston Inn Hotel Tasikmalaya revealed that the system is primarily dominated by inductive loads. This is typical in commercial settings like hotels, where equipment such as electric motors, fluorescent lighting, and air conditioning systems are extensively used. These inductive loads generate significant reactive power, negatively affecting the power factor of the electrical system.

Key Measurements:

- Active Power (P): 419.04 kW
- Initial Power Factor: 0.964
- Target Power Factor: 0.99
- Calculated Capacitor Bank Capacity: 55 kVAr
- Installed Capacitor Bank Capacity: 300 kVAr

The results showed that the system's power factor was initially around 0.70 (lagging), indicating inefficiency and potential cost increases. Further calculations using the power triangle method revealed the system's need for only 55 kVAr of capacitor bank capacity to correct the power factor to an optimal level.

Table 1. Classification of Installed Electrical Load

Load Type	Amount (kW)	Percentage
Inductive	356.18	85%
Resistive	62.86	15%
Total	419.04	100%

This breakdown shows that inductive loads comprise 85% of the total load, highlighting the importance of reactive power compensation for efficiency improvements

B. Evaluation of The Installed Capacitor Bank

The installed capacitor bank at Aston Inn Hotel has a capacity of 300 kVAr, which is significantly higher than the calculated requirement of 55 kVAr. This indicates an over-compensation of 245 kVAr, potentially causing operational issues such as a "leading" power factor.

Table 2. Power Factor Data Without Capacitor Bank Panel

Measurement	Power Factor		
	R	S	T
1	0,97	0,971	0,972
2	0,944	0,945	0,942
3	0,985	0,983	0,983
Avarage		0,967	

The power factor data indicates that, even without the capacitor bank, the system already operates at a relatively high power factor of 0.967, which is well within the utility company's standards (above 0.85). Therefore, the additional 300 kVAr capacity may be excessive, leading to over-compensation.

C. Impact of Over-Compensation

The substantial excess in capacitor bank capacity shifts the power factor from a lagging to a leading condition, with observations recorded on the Power Factor Controller (PFC) indicating a leading power factor of 0.96. This over-compensation can have several adverse effects on the system. Firstly, the excess reactive power compensation increases the system's voltage levels, which can push electrical equipment to operate beyond its optimal range, reducing its lifespan and potentially causing breakdowns. This issue is particularly problematic in a hotel environment, where the reliable operation of equipment is critical for guest comfort and service delivery. Secondly, over-compensation causes the system to deviate from the ideal power factor, leading to energy losses. While capacitor banks are designed to improve efficiency by reducing reactive power, excessive use can result in inefficiency due to the generated over-voltage. Lastly, high voltage caused by over-compensation can introduce harmonics into the electrical system, potentially causing equipment malfunction or failure. The study also identified that the PFC on the panel is not optimally managing the on/off state of the capacitors, which exacerbates the over-compensation issue. This malfunctioning of the PFC prevents dynamic adjustment of reactive power compensation, further risking the stability of the hotel’s electrical network.

D. Recommendation for System Optimization

To address the identified issues, several corrective actions are proposed. Firstly, resetting the Power Factor Controller (PFC) is essential. The PFC should be recalibrated to activate the capacitor bank only when necessary and align its capacity with the actual reactive power demand. This dynamic control will prevent over-compensation, maintain an optimal power factor, and avoid unnecessary voltage increases. Secondly, the capacitor bank's capacity must be adjusted to the calculated requirement of 55 kVAr. Alternatively, the bank can be divided into smaller steps, allowing for fine-tuned reactive power compensation that better matches the hotel's varying loads. This adjustment will help maintain a balanced power factor and ensure efficient system operation. Regular maintenance is also crucial; routine checks on the capacitor bank control panel are necessary to ensure the PFC functions properly and to monitor the condition of the capacitors. This practice will help prevent potential damage due to over-voltage and extend the lifespan of electrical equipment. Lastly, continuous monitoring of the hotel's electrical load is vital to adjust the capacitor capacity as needed. Given the dynamic usage patterns in a hotel setting, a responsive and adaptable power factor correction strategy is necessary to accommodate load variations effectively

The over-compensation observed in this study underscores the need for precise calculations and dynamic control in power factor correction practices. While the initial intention of installing a large-capacity capacitor bank was likely to reduce reactive power, the resulting shift to a leading power factor reveals an imbalance that could ultimately hinder system performance. The study highlights that simply installing a capacitor bank is not sufficient; it requires careful sizing, regular monitoring, and optimal control to achieve the desired energy efficiency and equipment protection.

Moreover, this analysis suggests that proactive management of the power factor, through adaptive systems like well-calibrated PFCs and modular capacitor banks, is essential in environments with fluctuating load demands. Aston Inn Hotel's case serves as a reminder that power quality management is a delicate balance between under- and over-compensation, both of which can have far-reaching consequences for system reliability, cost-efficiency, and equipment health.Optimizing the capacitor bank capacity and the PFC settings is crucial to maintaining an efficient and stable electrical system at Aston Inn Hotel Tasikmalaya. By addressing the identified over-compensation, the hotel can prevent potential damage to its electrical equipment, reduce operational costs, and extend the system's overall lifespan. This study provides valuable insights into the importance of precision in power factor correction and the necessity for ongoing monitoring and adjustment in commercial electrical systems.

IV. CONCLUSION

The capacitor bank installed at Aston Inn Hotel Tasikmalaya has a capacity that significantly exceeds the actual requirements of the electrical power system. This leads to excessive reactive power compensation, which not only poses a risk of damage to electrical equipment but also reduces the efficiency of the power system. By recalibrating the PFC and adjusting the capacitor's capacity, the hotel's electrical system can operate more efficiently and safely. Based on the research conducted to evaluate the capacitor bank capacity at Aston Inn Hotel Tasikmalaya, the following conclusions have been drawn:

a. The installed capacitor bank, with a capacity of 300 kVAr, is significantly larger than necessary. According to the calculations, the ideal capacity to correct the power factor and improve the electrical system's efficiency is 55 kVAr. This indicates that the installed capacitor bank experiences an excess of reactive power compensation, which results in a shift in the power factor from a lagging to a leading condition.
b. The power factor of the hotel's electrical system, when the capacitor bank is in use, reaches a value of 0.96 leading, indicating excessive reactive power compensation. This overcompensation can cause overvoltage and instability in the system, potentially affecting the performance of electrical equipment throughout the hotel.
c. The Power Factor Controller (PFC) on the capacitor bank panel was found to be not functioning optimally, leading to the system's inability to automatically regulate reactive power compensation according to the load demand. This malfunction results in uncontrolled changes in the power factor, necessitating a system reset and recalibration.
d. To achieve energy efficiency and optimal performance of the electrical system, it is recommended to adjust the capacitor bank capacity to the calculated requirements and conduct regular maintenance of the PFC and the overall electrical system. With these adjustments, the power factor can be maintained at an ideal level, reducing energy losses and operational costs for the hotel.

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