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Technical analysis of power factor improvement using ETAP 12.6 at Regent Resort & Holiday Inn Canggu

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Abstract: Due to the increase of inductive load will cause a decrease in the power factor which in turn affects the distribution of electrical energy. The power factor improvement method was chosen by the Regent of Resort & Holiday Inn Canggu to meet the PLN Standard, SPLN 70-1, namely: the power factor must be > 0.85 is to install a capacitor bank. In addition to increasing the power factor, the installation of this capacitor bank is also expected to reduce power losses and voltage drops and avoid excess kVARh charges imposed by PLN. Through calculations and simulations using the ETAP 12.6 application, it is obtained that; To increase the power factor close to 0.95, 900kVAR power is required from the capacitor bank installed in LVMDP1 and LMPDP2 to compensate for the reactive power of 875.44 kVAR and 860.92 kVAR, respectively. The capacity of the capacitor bank required for LVMDP1 and LVMDP2 is 19.85 x 10-3 Farad, with a capacity value for each step of 2.20 x 10-3 Farad. By installing a capacitor bank on LVMDP1 and LVMDP2, it can increase the power factor to 0.94 and 0.95 respectively, and reduce the percentage of reactive power usage to active power to 34.3% and 34.7%.

Keywords: capacitor bank, power factor, reactive power

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Introduction

In general, the loads that exist in the distribution network can be divided into two forms i.e., capacitive loads and inductive loads. Capacitive loads absorb active power and emit reactive power so that the voltage rate is delayed and the current wave position shifts ahead of the voltage wave (leading). Inductive loads absorb active power and reactive power so that the current rate is delayed and the current wave position shifts behind the voltage wave (Lagging). If the inductive load is higher, the power factor will decrease. This situation will increase power losses and reduce power distribution capacity [1].

This condition is experienced by Regent Resort & Holiday Inn Canggu, a five-star hotel located in the Canggu area of Bali. The electricity needs at this hotel are met using 2 distribution transformers with a capacity of 2000 kVA and 2 LVMDP (Low Voltage Main Distribution Panels), namely LVMDP1 and LVMDP2 to supply loads in the hotel such as chillers, air conditioners, freezers and motors, electric motor as driving the deep well pump, heat pump, primary pump and return pump, which is all inductive loads. A large number of inductive loads causes a decrease in the power factor which will have an impact on the decrease in power distribution capacity in this hotel.

In addition, a decrease of power factor leads to an increase in reactive power. If the percentage of reactive power to active power is greater than 62% then the hotel is threatened with additional costs of excess reactive power consumption (kVAR) by PLN [2].

To overcome this situation, it is necessary to increase the power factor. There are three different ways to improve the power factor which are widely used in industrial systems i.e.: static capacitor, synchronous condenser, and phase advancer.

In order to improve the power factor, static capacitors are installed parallel to the equipment running on low power factor. The leading current drawn by such capacitors neutralizes or corrects the lagging reactive component of the load current. The static capacitors have many advantages since they are lightweight, easy to install, have low losses, and require lesser maintenance. However, the disadvantages are quite notable where if the voltage is exceeded then the capacitors will be damaged quickly and their repair would be costly. They also have a shorter service life (8-10 years).

Another way to improve the power factor is to use a 3-phase synchronous motor which is overexcited and runs on no load. This setup is known as the synchronous condenser. The interesting part is that the synchronous motor can operate under leading, lagging, or unity power factors. If there is an inductive load present, then the condenser will be connected to the side of the load and will act as a capacitor to correct the power factor. The synchronous condenser has many advantages since it requires low maintenance, can run for up to 25 years, and is not affected by harmonics. However, its disadvantages include the high maintenance, cost, and noise. It also requires additional equipment to start the motor as it has no self-starting torque.

The last method that helps improve power factor is by using an AC exciter also known as a phase advancer. However, this can only be used for induction motors because the stator windings of the motor draw current that lags 90° behind the voltage and results in a low power factor. The only way to get rid of this problem would be to use an external source that would provide exciting ampere-turns. The phase advancer helps in solving the problem when it is connected to the rotor circuit of the motor. The exciting ampere-turns provided by the advancer are at the slip frequency. A leading power factor can also be obtained by providing more ampere turns. The main advantage of using a phase advancer includes a reduced amount of reactive power drawn by the motor. It can also be used in places where a synchronous condenser is unacceptable. However, the phase advancer cannot be used for motors below 200 H.P. which is uneconomical.

Because of its many advantages over the other 2 methods such as lightweight, easy to install, have low losses and require lesser maintenance, producing lesser noise, lower cost and more suitable with most of the loads of the system then the static capacitor chosen as power factor improvement in this study. One type of static capacitor that is famously implemented in power systems is the capacitor bank.

By installing a proper capacitor bank, it is expected that the power factor will increase to fulfill the SPLN 70-1 (PLN Standard), i.e.: the power factor value >0.85 [3]. Improving the power factor through the installation of a capacitor bank will avoid excess kVARh costs [4].

The studies of power factor improvement by adding capacitors have been developed in many scientific research works as described in the following summary. The addition of capacitors to a load of Minimarket electricity is proven to affect the current and power factor of electrical load. The more precise the value Capacitors are added, the higher the value of the electrical load power factor close to 1 [1]. By doing power factor improvement of 565 kVAR can decrease reactive power value and increases the active power, resulting in total active and reactive power consumption almost the same value, and new load additions can be made without adding PLN capacity [5]. Additional Capacitor bank can increase the Power Factor from 0.82 to 0.98 distribution feeder of Sutami 23 Lampung [6]. The power factor is improved from 0.87 lag becomes 0.96 lag by adding a shunt capacitor capacity of 80 kVAr (10 kVAr x 8 Step) Digital Regulator (APFC) 8 step [7]. To increase the power factor to 0.95, 5, a 6172.33 kVAR capacitor of banks must be installed for the main feeder AA, and a 5388.88 kVAR capacitor of banks must be installed for main feeder AA 8 to keep the quality power produced was more optimal [8]. By installing a capacitor bank, the value of power losses on the Barata feeder can be reduced from 4.33 kW to 3.247 kW and 6.627 kVar to 4.947 kVar. Then the power factor which was initially 0.83 became an average of 0.97 in the network system [9]. The installation of capacitors can increase the power factor by 11% to 0,95 (exceeding the minimum average power factor determined by the PLN electricity tariff adjustment) and in addition, the load current decreased 12% from 442.3 A to 389.5 A [10]. Power factor correction will result in the reduction of maximum demand (KVA or KW) and affect the annual saving over the maximum demand charge [11]. After installation of a 1200 KVAR capacitor bank, the power factor increases to 0.99, the amount of power that can be supplied with that power factor is 1600 KW. So that with the application of a capacitor bank, the power factor can be increased and the power supplied will be higher and the power quality will be better [12]. The installation of capacitor banks is useful to improve the power factor from 0.76 to 0.97 by calculating the value of the compensator reactive power corresponding using software ETAP (electrical transient analysis program) [13]. Increasing power factor beyond 0.8 (lagging) using capacitor banks though improves the r.m.s voltage and reduces the power loss but invariably leads to an increase in switching transients which is undesired for optimized [14]. Improvement of power factor makes the utility companies get rid of the power losses while the consumers are free from low power factor penalty charges. By installing suitably sized power capacitors into the circuit the Power Factor is improved and the value becomes nearer to 0.9 to 0.95 system performance [15]. Installation of 35kVAR capacitor bank in the electric installation of rectorate building can improve the quality of system power factor from 0.682 to 0.840 [16]. The applications of capacitor banks on the substation reduce the reactive power flow and reduce the losses in square proportion. As result, improvement in power factor from 0.474 to 0.94 and reactive power reduce 74.7 to 14.7 in stage – 7 [17].

All these above studies confirmed that additional capacitors into the electric system able to improve the power factor and reduce the reactive power (kVAR) effectively. This will certainly have an impact that the installation of capacitor banks as a method of increasing the power factor will be increasingly popular and increasingly chosen in industrial power systems.

However, the method of increasing the power factor with the addition of a capacitor bank is very popular, but for the case at Regent Resort & Holiday Inn Canggu, an in-depth study is still needed. Moreover, in the case at Regent Resort & Holiday Inn Canggu, the study analysis that will be carried out using the help of the ETAP application is first time conducted. It is expected to help management determine the capacity of the capacitor needed to increase the power factor to 0.95 and reduce reactive power to avoid fines imposed by PLN. The results of the study are expected to help convince the management that the selection of the method is appropriate to provide optimal results.

In this paper, the deep study of power factor improvement at Regent Resort & Holiday Inn Canggu through the installation of a capacitor bank will be carried out with help of the ETAP 12.6 application program. Through simulation using ETAP, it will be known the value of the power factor improvement obtained through the installation of a capacitor bank to meet the standards set by PLN.

Methodology

This research was conducted at Regent Resort & Holiday Inn Canggu which is located at Jl. Batu Bolong Beach 93 XX, Canggu, North Kuta, Badung in the period from April to June 2021. While data collecting as input of this study was obtained from (a). Field Observation i.e.: technical specification of the transformer, type, length of the conductor, load, etc; (b). Literature review to collect data from various relevant sources such as books, journals, and regulations related to power factor improvement; and (c). Interview with the related parties at the study object.

The stage of work carried out in this study includes:

First, collecting and reviewing the relevant data related to power factor improvement, including setting up the power factor target. Second, conducting simulation using ETAP 12.6 application and performing technical analysis. The flow process of ETAP 12.6 Simulation of power factor improvement at Regent Resort & Holiday Inn Canggu is shown by flow chart in Figure 1, which is in brief described as follow:

1. Entering data into the ETAP 12.6 program. The data that are required include the length of the conductor, type of conductor, size of the conductor, and load data to be installed on LVMDP1 & LVMDP2.
2. Calculate the initial power factor (Cos φ_1) at LVMDP1 & LVMDP2 using the ETAP 12.6 application.
3. Calculate the size of the capacitor bank for reactive power compensation LVMDP1 & LVMDP2 with the target power factor to be achieved is 0.95.
4. Calculate the capacity of the capacitor bank on LVMDP1 & LVMDP2.
5. Simulating the installation of a capacitor bank using the ETAP 12.6 application to determine the power factor of LVMDP1 & LVMDP2 after installing a capacitor bank. If the power factor value is> 0.85 then the power factor value is following PLN standards, the process is complete. Meanwhile, if the power factor value is < 0.85, then a re-calculation is carried out.

Third, conducting technical analysis and discussion. And finally, compose the conclusion.

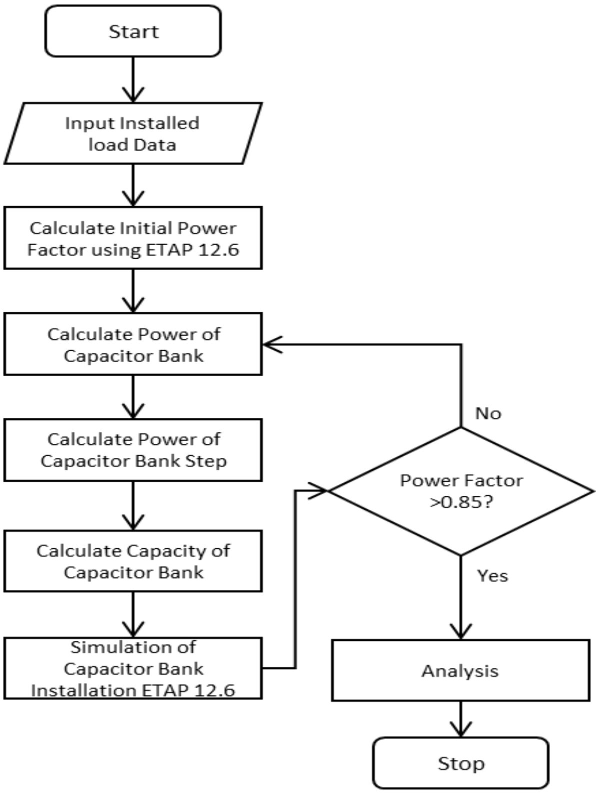

Figure 1. Power factor improvement flowchart

Results and Discussions

Results

Technical Data

1. Single Line Diagram

As one of the important required supporting data, below is the single-line diagram of the Canggu Regent Resort & Holiday Inn electrical system as shown in Figure 2.

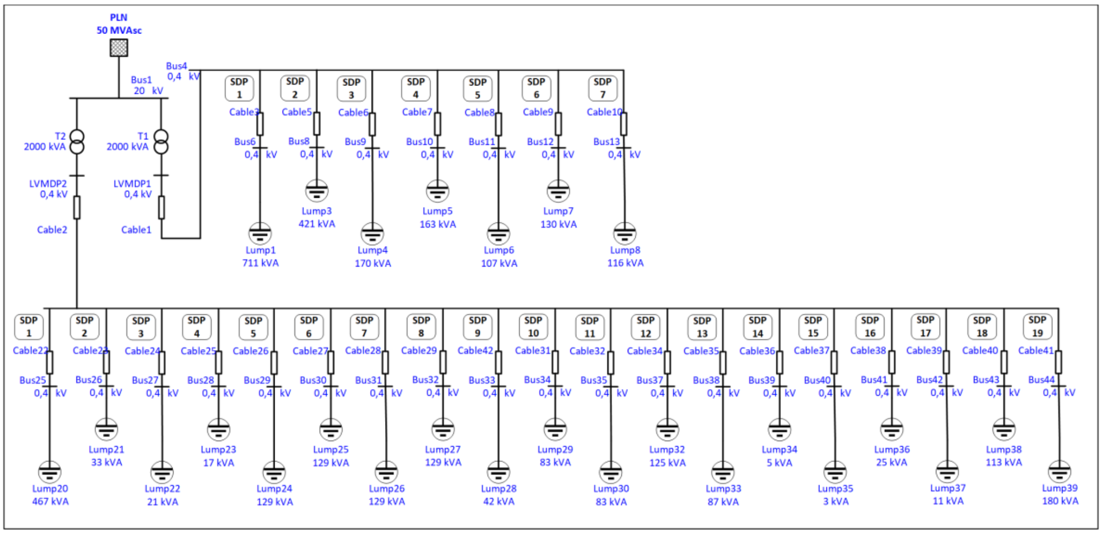

Figure 2. Single-Line diagram

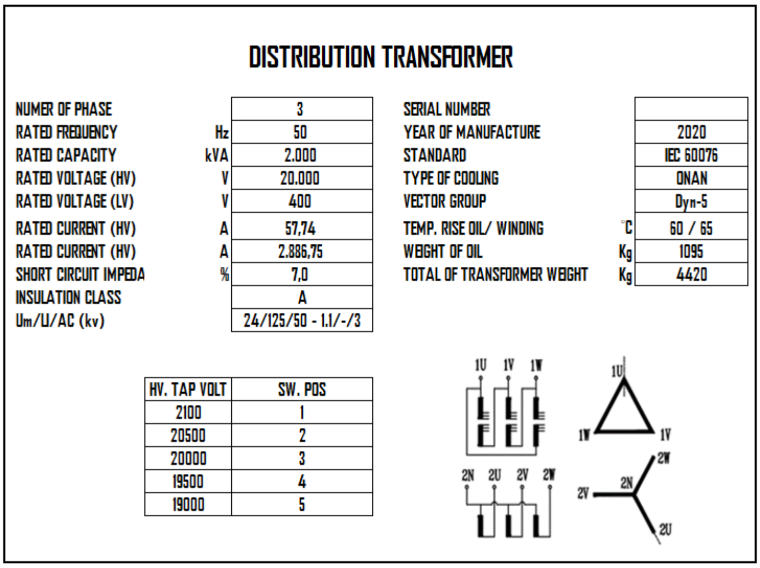

Figure 3. Transformer data

2. Transformer Data

Referring to the planning data obtained from the contractor, the transformer to be used at Regent Resort & Holiday Inn Canggu consists of 2 distribution transformers with a capacity of 2000 kVA each. Details of the transformer data are shown in Figure 3.

3. Conductor Specification

The conductor data that is to be used to distribute electrical power from LVMDP1 and LVMDP2 to each SDP panel (Sub Distribution Panel) are shown in Table 1 and Table 2.

Tabel 1. LVMDP1 conductor specification

No	SDP (Sub Distribution Panel)	Cable Type	Cable Size	Cable Length (m)
1	SDP1	NYY	4(4x1x300) + (1x150) mm2	270
2	SDP2	NYY	2(4x1x500) + (1x150) mm2	25
3	SDP3	NYY	(4x1x240) + (1x120) mm2	40
4	SDP4	NYY	2(4x1x150) + (1x95) mm2	75
5	SDP5	NYY	(4x1x300) + (1x120) mm2	100
6	SDP6	NYY	(4x1x300) + (1x150) mm2	105
7	SDP7	NYY	(4x1x240) + (1x120) mm2	175

Tabel 2. LVMDP2 conductor specification

No	SDP (Sub Distribution Panel)	Cable Type	Cable Size	Cable Length (m)
1	SDP1	NYY	4(4x1x300) + (1x150) mm2	300
2	SDP2	NYY	(4x25) + (1x16) mm2	25
3	SDP3	NYY	(4x10) + (1x10) mm2	30
4	SDP4	NYY	(4x10) + (1x10) mm2	40
5	SDP5	NYY	(4x1x240) + (1x120) mm2	45
6	SDP6	NYY	(4x1x240) + (1x120) mm2	50
7	SDP7	NYY	(4x1x240) + (1x120) mm2	55
8	SDP8	NYY	(4x1x240) + (1x120) mm2	60
9	SDP9	NYY	(4x35) + (1x16) mm2	20
10	SDP10	NYY	(4x1x95) + (1x50) mm2	20
11	SDP11	NYY	(4x1x95) + (1x50) mm2	20
12	SDP12	NYY	(4x1x150) + (1x95) mm2	30
13	SDP13	NYY	(4x1x95) + (1x50) mm2	30
14	SDP14	NYY	(4x6) + (1x6) mm2	20
15	SDP15	NYY	(4x4) + (1x4) mm2	20
16	SDP16	NYY	(4x16) + (1x6) mm2	90
17	SDP17	NYY	(4x6) + (1x16) mm2	100
18	SDP18	NYY	(4x120) + (1x70) mm2	180
19	SDP19	NYY	(4x1x150) + (1x95) mm2	200

4. Load Recapitulation

The 3-phase load of each SDP is shown in Table 3 and Table 4.

Table 3. Load of LVMDP1

No	SDP (Sub Distribution Panel)	Load (KVA)
1	SDP1	711
2	SDP2	421
3	SDP3	178
4	SDP4	163
5	SDP5	107
6	SDP6	138
7	SDP7	116
	Total Load	1834

Table 4. Load of LVMDP2

No	SDP (Sub Distribution Panel)	Load (KVA)
1	SDP1	467
2	SDP2	33
3	SDP3	21
4	SDP4	17
5	SDP5	129
6	SDP6	129
7	SDP7	129
8	SDP8	129
9	SDP9	42
10	SDP10	83
11	SDP11	83
12	SDP12	125
13	SDP13	87
14	SDP14	5
15	SDP15	3
16	SDP16	25
17	SDP17	11
18	SDP18	113
19	SDP19	180
	Total Load	1811

ETAP Simulation Results

1. Initial ETAP simulation before adding capacitor bank

After all the technical data above is inputted into the ETAP Application, the following is the output of the simulation results (before adding the capacitor bank) as shown in Table 5 and Single-Line Diagram in Figure 4.

Table 5. ETAP simulation output (initial status, before adding capacitor bank)

No	LVMDP Name	Power (kW)	Reactive Power (kVAR)	Current Load (A)	PF (Power Factor)	%kVAR/ KW
1	LVMDP1	1266	1289	2785.9	0.7	101.8%
2	LVMDP2	1245	1268	2736.7	0.7	101.8%

Table 5 shows that the reactive power consumption for LVMDP1 and LVMDP2 are 1289kVAR (or 101.8% compared to active power) and 1268kVAR (or 101.8% compared to active power) and the power factor is 0.7% respectively. The use of reactive power far exceeds the 62% requirement and the power factor is lower than 0.85 as stipulated in the Regulation of the Minister of Energy and Mineral Resources (Permen ESDM No.: 07 Tahun 2010) so that will be imposed by PLN [2].

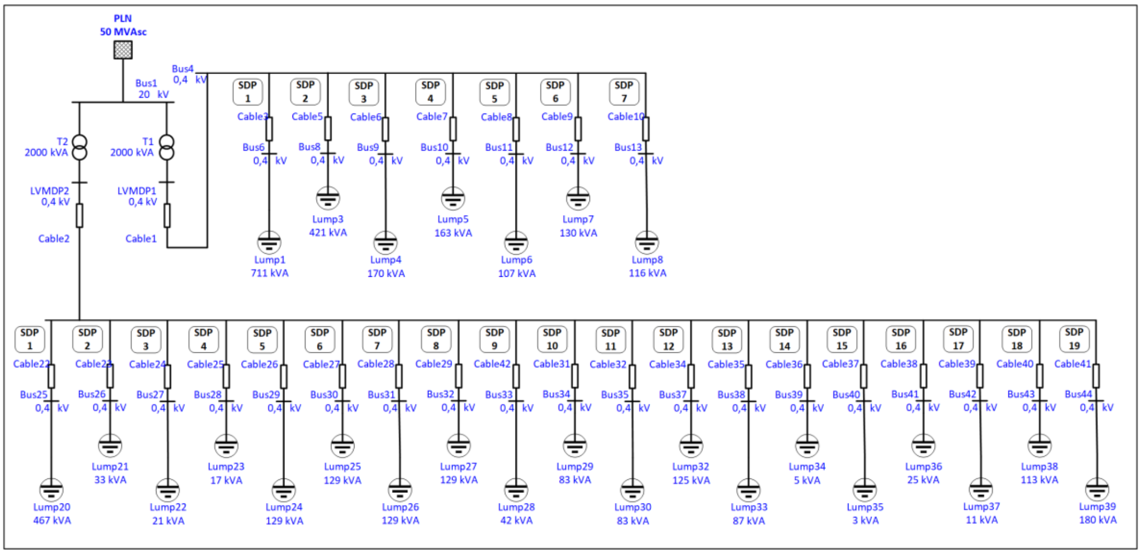

Figure 4. Single-Line diagram DTAP output simulation (before adding capacitor bank)

Calculation of the amount of power in the capacitor bank

By setting the power factor target value to be achieved at 0.95, the calculation of the amount of power in the capacitor bank can be described as follows:

Reactive Power Compensation Calculation in LVMDP1

From the ETAP simulation results in LVMDP1, the active power is 1266 kW with a power factor value of 0.7. To achieve a power factor target of 0.95, the following is calculations that are to be performed:

Reactive Power of Capacitor Bank can be calculated by the following formula [18]:

$$Qc = P(\tan \varphi 1 - \tan \varphi 2) \tag{1}$$

where,

P : Active power of load (Watt)
Cos φ1 : Initial power factor (before compensation)
Cos φ2 : Expected power factor
Qc : Capacitor Reactive power (kVAR)

It was known that P (active power) was 1226 kW, initial Power Factor (Cos φ1) was 0.7 (so that we can calculate $\varphi 1 = 45.57^\circ$), target Power Factor (Cos φ2) was 0.95 (so that we can calculate $\varphi 2 = 18{,}19^\circ$), by using formula (1), we can calculate Reactive Power of Capacitor Bank as follow:

$$Q_c = P(\tan \varphi_1 - \tan \varphi_2) = 875.44 \text{ kVAR}.$$

Reactive Power Compensation Calculation in LVMDP2

From the ETAP simulation results in LVMDP2, the active power is 1245 kW with a power factor value of 0.7. To achieve a power factor target of 0.95, the following is calculations that to be performed:
It was known that P (active power) was 1245 kW, initial Power Factor (Cos φ1) was 0.7 (so that we can calculate $\varphi 1 = 45.57^\circ$), target PF (Cos φ2) was 0.95 (so that we can calculate $\varphi 2 = 18{,}19^\circ$), by using formula (1), we can calculate Reactive Power of Capacitor Bank as follow:

$$Q_c = P(\tan \varphi_1 - \tan \varphi_2) = 860.92 \text{ kVAR}.$$

Calculation of Power at Step Capacitor Bank

If we are going to install a capacitor bank in the electricity network, a PFR (Power Factor Controller) is needed. PFC functions to regulate the work of the contactor from each step of the capacitor bank so that the reactive power that will be supplied to the network or system can work according to the required capacity. If there is a change in load it will automatically correct the power factor according to the specified target. So that it is necessary to determine how many steps are used in the LVMVP1 & LVMDP2 capacitor banks. To find out how much power the capacitor bank at each step, can be performed by the following calculations.

Calculation of Power Steps on Capacitor Banks in LVMDP1

To determine the power of the capacitor bank from each step, it can be calculated by the following formula [18]:

$$Qstep = \frac{Qc\ (total)}{Number\ of\ Step} \tag{2}$$

Referring to the results of the previous calculation, the total power of the capacitor bank that is needed to compensate for the reactive power in LVMDP1 is 875.44 kVAR. If it was selected to use a 9-step capacitor bank, then the Power of each Step, $Qstep$ = 97.27 kVAR.

Since the capacitor capacity available in the market is closest to 100 kVAR per step, using 9 step capacitor banks so that the total power of the capacitor bank that will be required in LVMDP1 is 900 kVAR.

Calculation of Power Steps on Capacitor Banks in LVMDP2

Referring to the results of the previous calculation, the total power of the capacitor bank that needed to compensate the reactive power in LVMDP2 of 860,92 kVAR, using a 9-step capacitor bank. Then by using formula (2), then the power of each Step Capacitor Bank in LVMDP2, $Qstep$ = 95.65 kVAR.

Since the capacitor capacity available in the market is closest to 100 kVAR per step, using 9 step capacitor banks so that the total power of the capacitor bank that will be required in LVMDP1 is 900 kVAR.

Calculation of Bank Capacitor Capacity

The calculation of the required Capacitor Bank Capacity in LVMDP1 & LVMDP2 is described as follows.

a. Calculation of Bank Capacitor Capacity in LVMDP1

The capacity of the capacitor bank can be calculated with the following formula [18]:

$$C = \frac{Qc}{V^2\ x\ \omega} \tag{3}$$

Where,
C : Capacitor capacity (Farad)
Qc : Reactive power of Capacitor (VAR)
V : Three-phase voltage (Volt)
Ω : 2пf

Based on previous calculations, the required reactive power of the capacitor bank in LVMDP1 is 900 kVAR. So by using the formula in equation (3), the capacity of the capacitor bank in LVMDP1 can be calculated as follows:

$$C = \frac{Qc}{V^2\ x\ \omega} = \frac{Qc}{V^2\ x\ 2\pi f} = \frac{900\ x\ 10^3}{380^2\ x\ 2x3.14x50} = 19.85 \text{ x } 10^{-3} \text{ Farad}$$

By using a 9-step capacitor bank with a power capacity for each step of 100 kVAR, then the required capacitor bank capacity for each step on LVMDP1 is 2.21 x 10^{-3} Farad.

b. Calculation of Bank Capacitor Capacity in LVMDP2

Based on previous calculations, the required reactive power of the capacitor bank in LVMDP2 is 900 kVAR. So by using the formula in equation (3), the capacity of the capacitor bank in LVMDP1 can be calculated as follows:

$$C = \frac{Qc}{V^2 \; x \; \omega} = \frac{Qc}{V^2 \; x \; 2\pi f} = \frac{900 \; x \; 10^3}{380^2 \; x \; 2x3.14x50} = 19{,}85 \text{ x } 10^{-3} \text{ Farad}$$

By using a 9 step capacitor bank with a power capacity for each step of 100 kVAR, then the required capacitor bank capacity for each step on LVMDP2 is 2.21 x 10^{-3} Farad.

2. ETAP Simulation after adding capacitor bank

Simulation results of the ETAP 12.6 application on the electrical system at Regent Resort & Holiday Inn Canggu with the addition of a capacitor bank in LVMDP1 & LVMDP2 are shown in Figure 5 and Table 6 below.

Table 6. ETAP simulation output (after adding capacitor bank)

No	LVMDP Name	Power (kW)	Reactive Power (kVAR)	Current Load (A)	PF (Power Factor)	%kVAR/ KW
1	LVMDP1	1301	443	2045.4	0.94	34.1%
2	LVMDP2	1281	420	2003.7	0.95	32.8%

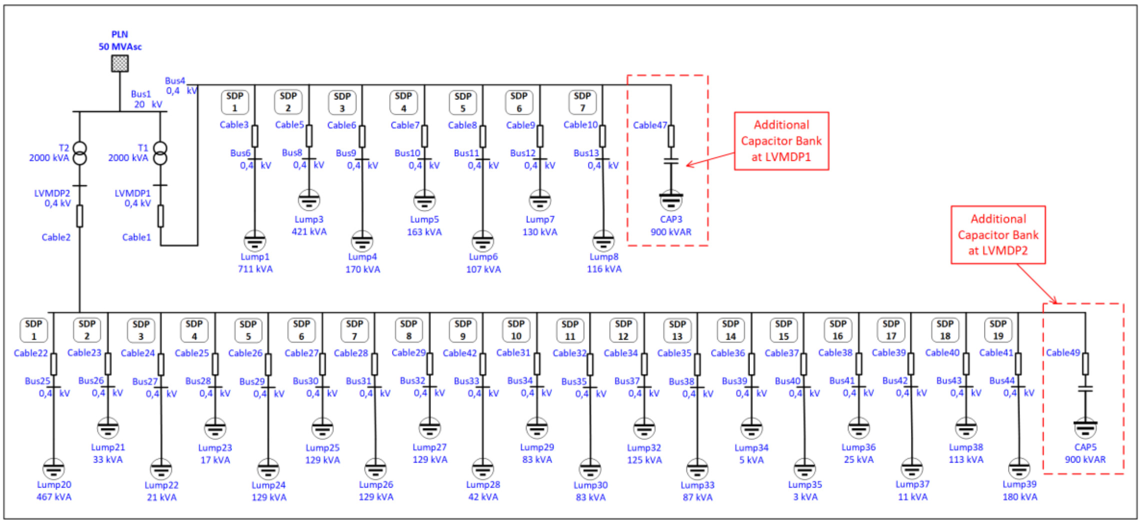

Figure 5. Single-Line diagram DTAP output simulation (after adding capacitor bank)

Table 7. ETAP 12.6 Simulation result before and after additional capacitor bank

LVMDP Name	Power (kW)			Reactive Power (kVAR)			Load Current (A)			Power Factor (PF)		
	Before	After	% Change	Before	After	% Change	Before	After	% Change	Before	After	% Change
LVMDP1	1266	1301	2.8%	1289	443	-65.6%	2785.9	2045.4	-26.6%	0.7	0.94	34.3%
LVMDP2	1245	1281	2.9%	1268	420	-66.9%	2736.7	2003.7	-26.8%	0.7	0.95	35.7%

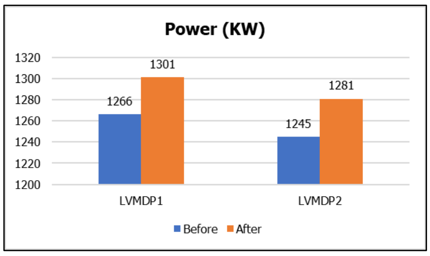

Figure 6a. Power (kW) – before and after

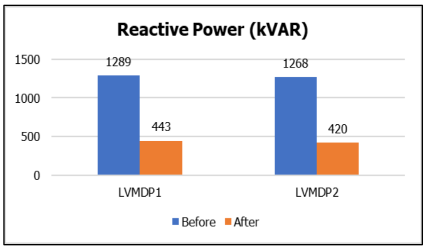

Figure 6b. Reactive power (kVAR) – before and after

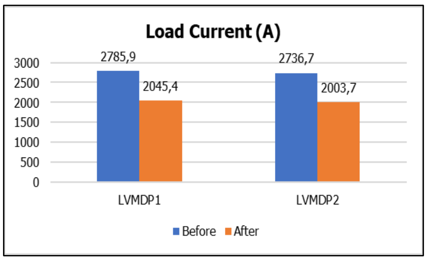

Figure 6c. Load current (A) – before and after

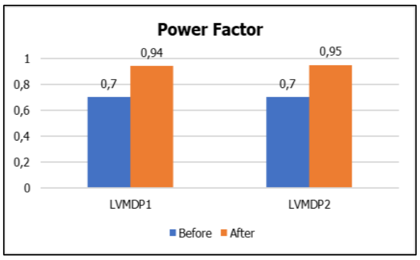

Figure 6d. Power factor – before and after

If we compare the ETAP 12.6 simulation results for the Regent Resort & Holiday Inn electrical system before and after the addition of Bank Capacitors on LVMDP1 and LVMDP2, the results are as shown in the table 7 and graphs on Figure 6a, 6b, 6c, and 6d.

Discussions

Referring to table 7 and figures 6a, b, c, and d, by comparing the situation of the hotel's electrical system, the installation of capacitor banks on LVMDP1 and LVMDP2 has the following effects:

First, increase in active power by 2.8% on LVMDP1 from 1266kW to 1301kW and by 2.9% on LVMDP2 from 1281kW to 1281kW.

Second, decrease in load current by 26.6% on LVMDP1 from 2785.9A to 2045.9A and by 26.8% on LVMDP2 from 2736.7A to 2003,7A. This decrease in load current has a very positive impact on reducing losses from the hotel's electrical system.

Third, a significant reduction in reactive power by 65.6% on LVMDP1 (from 1289kVAR to 443kVAR) and by 66.9% on LVMDP2 (from 1268kVAR to 420kVAR). So that the percentage of reactive power consumption to active power is 34.1% for LVMDP1 (443kVAR against 1301kW) and 32.8% for LVMDP2 (420kVAR for 1281kW).

The power factor increased significantly by 34.3% in LVMDP1 (from 0.7 to 0.94) and by 34.7% in LVMDP2 (from 0.7 to 0.95).

Finally, the decrease in the percentage of usage from reactive to active power to 34.1% and 32.8% respectively, and an increase in power factor to 0.94 and 0.95, respectively, for LVMDP1 and LVMDP2 caused the electrical system at Regent Resort & Holiday Inn to have complied with the provisions stipulated in the Regulation of the Minister of Energy and Mineral Resources. No. 07 of 2010 to avoid the fines imposed by the PLN.

Conclusion

To improve the electrical power factor of Regent Resort & Holiday Inn from 0.7 according to the target close to 0.95 it requires 900kVAR power from capacitor bank that installed on LVMDP1 and LMPDP2 to compensate the reactive power of 875.44 kVAR and 860.92 kVAR respectively.

The capacity of capacitor bank those required on LVMDP1 and LVMDP2 is 19.85 x 10-3 Farad, with capacity value for each step 2.20 x 10-3 Farad.

Based on the simulation result, installation of capacitor bank on LVMDP1 and LVMDP2 able to improve the power factor become 0,94 and 0,95 respectively and reduce the percentage usage of reactive power to active power become 34.3% and 34.7% so that the hotel to avoid the fines imposed by the PLN.

The studies conducted in this research only focus on technical analysis, therefore in the future, it is recommended to conduct an additional study on the economical aspect. So that we will have a more comprehensive study that will be useful for all related stakeholders and give a contribution to industrial power systems.

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