Power Factor Improvement for Tile Factory

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Abstract- In industries, the overall power factor is very poor because of inductive loads. A lower power factor causes a higher current flow for a given load. As the line current increases, the voltage drop in the conductor increases, which may result in a lower voltage at the equipment. With an improved power factor, the voltage drop in the conductor is reduced, improving the voltage at the equipment. Loads drawing reactive power also demand reactive current. Installing power factor correction capacitors at the end of existing circuits near the inductive loads reduces the current carried by each circuit. The reduction in current flow resulting from improved power factor may allow the circuit to carry new loads, saving the cost of upgrading the distribution network when extra capacity is required for additional machinery or equipment, saving the factory thousands of kyats in unnecessary upgrade costs. In addition, the reduced current flow reduces resistive losses in the circuit. This paper describes the power factor improvement for Wai Yan Lwin Tile Factory. The suitable size capacitor bank is calculated for each of the improved power factors from 0.77 to 0.98.

Indexed Terms- Power Factor,Power Factor Correction, Industrial Load, Capacitor Bank

I. INTRODUCTION

Nowadays, the quality of electricity is becoming more and more important due to the increasing usage of electricity in our ever life. The modern tendency in industry is to produce as cheaply and quickly as economically possible and its advantages can be derived from the use of electricity that have led to a steady increase in the amount of electrical apparatus used for industrial purpose. Power quality has become a serious problem in power system. Problems of power quality in industrial plants are growing due to the increasing number of inductive load and poor power factor. Industrial plants consume large amounts of electricity and poor quality can lead to expensive interruptions. The objectives of an industrial power system are to provide reducing operating costs, improving efficiency and increasing availability. It is necessary to maximize power quality and improve system performance.

Therefore, the capacitor banks were used in distribution system to improve the power factor and voltage regulation and so on. The overall power factor of industrial plants may be very poor because of inductive loads absorbing reactive power. In power distribution system of the plant, shunt capacitors are used for power factor correction. Generally, capacitor installations are economical because of low operating cost and ease of installation to improve industrial power factor. [1]

II. FUNDAMANTAL OF POWER FACTOR IMPROVEMENT

Most industrial loads such as induction motors operate at moderately low power factor. Around 60% of the unity load consists of motor and hence the overall power factor of the power system is law. Depending on the level of the load, these motor are inherently low power factor devices. The power of these motor varies from 0.30 to 0.95, depending on the size of the motors and other operating conditions. Therefore, the power factor level is always concern for industrial power system, utilities,and the user. The system performance can be improved by correcting the power factor. [5]

A. ANALYSIS OF POWER FACTOR

Power factor is a measure of how effectively electrical power is being used by a system. And power factor is the percentage of electricity that is being used to do useful work. Power has three components: working, reactive and apparent power. Working power is the current and voltage actually consumed. It performs the actual work, such as creating heat, light and motion. Working power is expressed in kilowatts (kW), which registers as kilowatt-hour on electric meter. Reactive does not useful work, but it is needed to sustain the electromagnetic field associated with many commercial/ industrial loads. It is measured in kilovolt-amperes-reactive, or kVAR. The total required capacity, including working and reactive power, is known as apparent power. It is expressed in kilovolt-amperes or kVA. The fundamentals ofpower factor are shown in Figure 1.

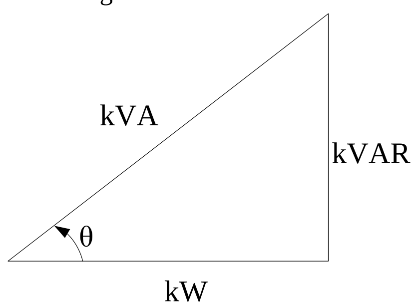

Figure 1. Power Triangle [2]

Power factor is the ratio of working power to apparent power or kW/kVAR. Power factor values can carry from 0 to 1.00. Typically, values range from 0.80 to 0.98. A power factor below 0.80 is considered low.

There is also a difference between a lagging and leading power factor. The terms refer to whether the phase of the current is leading or lagging the phase of the voltage. A lagging power factor signifies that the load is inductive, as the load will consume reactive power, and therefore the reactive component Q is positive as reactive power travels through the circuit and is consumed by the inductive load that shown in Figure2. A leading power factor signifies that the load is capacitive, as the load supplies reactive power, and therefore the reactive component Q is negative as reactive power is being supplied to the circuit.

If the current leads the voltage (greater angle than voltage) then the power factor is leading (capacitance load). If the current lags the voltage (less than voltage) then the power factor is lagging (inductive load).

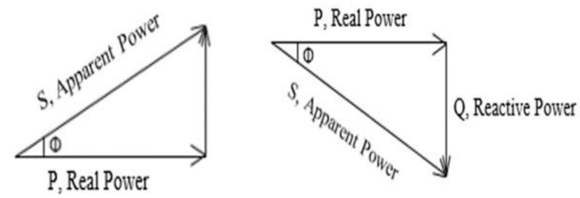

Figure 2. Lagging and Leading Power factor

B. Main Causes of Low Power Factor

1) Single phase and three phase inductive motors.
2) Varying load in power system.
3) Industrial heating furnaces
4) Transformers
5) Transmission lines and cables
6) Electrical discharge lamps
7) Harmonic currents [3].

C. Need for Power Factor Correction

A power factor of 0.7 for example, indicates that only 70% of power supplied to your business is being used effectively and 30% is being wasted. The wasted power is the reactive power. Most loads are inductive in nature, which means the power factor will typically be less than unity. The further power factor is from the unity, the greater the apparent power drawn and therefore, the greater the current draws for the system. The increased current may require an increase in the size of the transformers and installation wiring. Increased current also results in increased heat which affects the longevity and lifespan of an electrical system. This can add a great deal of cost to the installation and may also limit the expansion of a plant.

A poor power factor will result to high RMS and peak currents drawn from the power source. This means a higher transmission loss in the part of electric stations. A higher current may require a larger transmission lines that are expensive they may repair equipment too often. The electric stations charge the losses to their consumers.A poor power factor will result to high current harmonics and this potentially cause flicker issues. If the product is to be used in lighting, the flicker effect will be very obvious. A lower power factor product will lose the power quantity of the system [5].

D. Power Factor Correction

The process of supplying reactive power (lagging or leading) to bring the power factor closer to unity is known as power factor correction. This can be done by using inductor, capacitor and synchronous condenser. If the power factor of the plant is low, it uses more power than it needs to do the work. Poor power factor should be corrected as it substantially increases costs.
Power factor correction tries to push the power factor of the electrical system such as the power supply towards 1, and even though it doesn't reach this it gets to as close as 0.95 which is acceptable for most applications [4].

The basic principle for power factor improvement is to connect a device which take leading current in parallel with inductive loads to neutralize the effect of lagging current.. Loads such as a heater require the supply of only the real component of current. Some loads, such as an induction motor, require both real and reactive currents.

$$\text{Power Factor} = \frac{\text{kW}}{\text{kVA}}$$

kW and kVA are the real and apparent power, respectively.

E. Advantages of Power Factor Improvement

The advantages that can be achieved by applying the correct power factor correction are:

1) Increase in efficiency of system and devices
2) Low Voltage Drop
3) Reduction in size of a conductor and cable which reduces cost of the Cooper.
4) .An increase in available power
5) Line Losses (Cooper losses) is reduced
6) Appropriate size of electrical machines (transformers, generators, etc.)
7) Eliminate the penalty of low power factor from the electric supply station
8) Low kWh (kilo watt per hour)
9) Saving in the power bill
10) Better usage of power system, lines and generators etc.

Saving in energy as well as rating and the cost of the electrical devices and equipment is reduced

III. PRINCIPLESOFCAPACITORBANK

Economical operation of the modern power systems requires more distributed voltage support than ever before. Load and distributed generation characteristics have both changed to require increased VAR support throughout the power system. Capacitor banks are the most economical form of adding VARs to the system. Further, the capacitor banks can be applied on individual loads, branch locations, or at the group load. Furthermore, the banks can be fixed or switched. There are various methods available for switching in these capacitor banks. The shunt capacitor installations are used in distribution and high voltage systems, where significant reactive power is supplies to the power system. Also, if a capacitor unit fails, then the voltage of the good capacitor unit increases. These voltages have to be kept within acceptable limits. The capacitor units are manufactured, tested, and used in power factor correction applications. Proper specification of the applicable parameters is important for safe and efficient operation. Some of the specifications applicable to these units are voltage, frequency, insulation class, momentary ratings, nominal kVAR rating, and allowable operating service conditions. In order to compensate for the reactive power, the shunt capacitors are used at the motor terminals. [2]

IV. INSTALLATION OF SHUNT CAPACITOR BANK

Shunt capacitors provide reactive power locally, resulting in reduced maximum kVA demand, improved voltage profile, reduced line/feeder losses, and decreased payments for the energy. Maximum benefit can be obtained by installing the shunt capacitors at the load. Power factor correction capacitors can be installed at high voltage bus, distribution, or at the load of the system. The following power factor correction approaches are commonly used in the industrial plants. [2]

A. Group Capacitor Bank

A group capacitor bank installation is shown in Figure 3. In this approach, the power factor correction is applied to a group of loads at one location. This technique is suitable for utility or industrial customers with distributed load.

If the entire load comes on or off together, then it is reasonable to switch the capacitor bank in this manner. If part of the load is switched on and off on a regular basis, then this type of reactive compensation is not appropriate. It is economical to have a large capacitor bank for reactive compensation rather than several smaller banks.

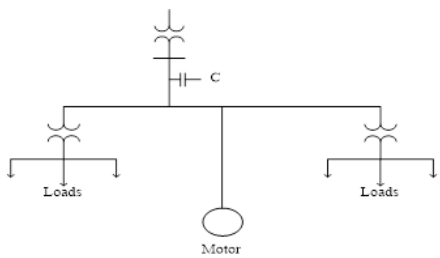

Figure 3. Group Capacitor Bank [2]

B. Branch Capacitor Bank

In certain industrial applications, the load is switched on and off based on shifts. Such a load group can be related to individual feeders or branch circuits. Therefore, it is advantageous to switch the capacitor banks along with the specific branches. An example of branch capacitor bank scheme is shown in Figure 4. This type of capacitor bank will not help reduce the losses in the primary circuit.

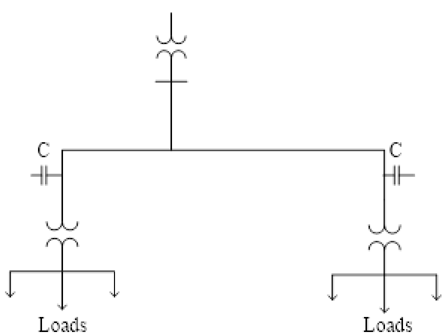

Figure 4. Branch Capacitor Bank [2]

C. Local Capacitor Bank

An example of local capacitor bank application for the power factor correction is shown in Figure 5. In this scheme, the individual loads are provided with separate capacitor banks. This type of reactive compensation is mainly suitable for industrial loads. The localized power factor correction can be expensive [2].

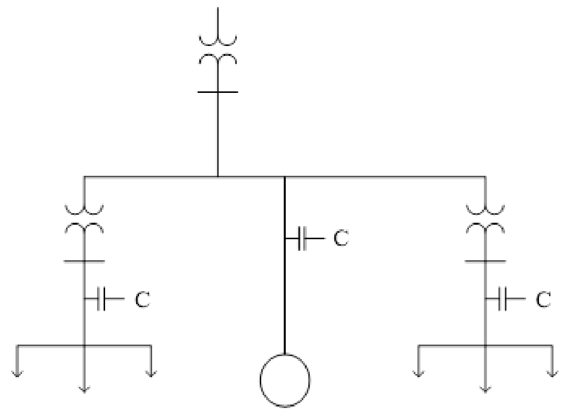

Figure 5. Local Capacitor Bank [2]

V. POWER DISTRIBUTION SYSTEM OF WAI YAN LWIN TILE FACTORY (SAGAING)

Wai Yan Lwin Tile Factory (Sagaing) is supplied power from two main transformers (500kVA, 11/0.4kV). The incoming line is 11kV transmission line from Padamyar power sub-station. There are two transformers to step down the voltage of the main transformer. In Wai Yan Lwin Tile Factory (Sagaing), there are also three generators for emergency situations. These generators have 400kVA, 700kVA (old) and 700kVA (new) respectively.

There are eight sections. They are Gasifier, R.M.P Ball Mill, Spray Dryer, Hydraulic Press Machine, Kiln, Glazing Ball Mill, Digital Printing and Packing. One line diagram of distribution System for Wai Yan Lwin Tile Factory (Sagaing) is shown in Figure. 6.

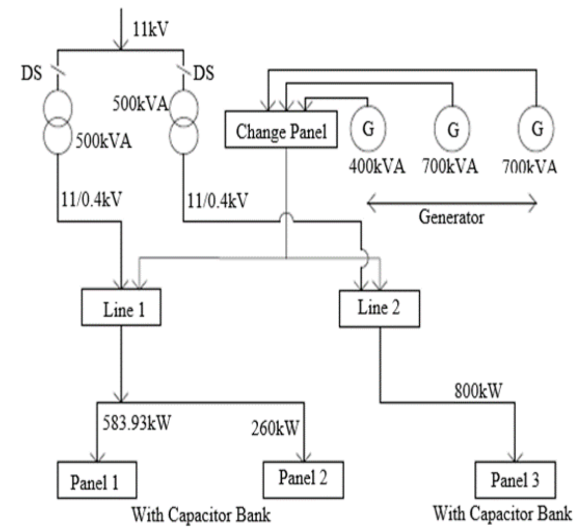

Figure 6. One Line Diagram of Distribution System for Wai Yan Lwin Tile Factory

VI. DESIGN CALCULATION OF CAPACITOR BANK

In this design calculation,sutible size of shunt capacitor bank for all induction motors used in tile factory.The following data are obtained from Wai Yan Lwin Tile Factory.

Existing load=1340.03kW
Existing kVA=1733.29kVA
Existing kVAR=1099.376kVAR
Existing Power Factor=0.77
Desired Power Factor=0.98
Transformer Rating=500kVA (2Nos)
Voltage=0.4kV
If the power factor is raised to 0.85;

Apparent power,
S = Present Active Power / Desired Power Factor
= 1340.03/0.85
= 1576.5 kVA

The sized of capacitor required is determined from the kVAR at the two values of power as follows:

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

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

= 799.376 kVAR

At power factor pf = 0.85;
The capacitor bank rating=Q (uncorrected)-Q (corrected)
= 1099.376 - 799.376
= 300 kVAR

Therefore, the capacitor bank rating required to improve power factor from 0.77 to 0.85 is 300 kVAR.

If power factor is improved from 0.77 to 0.85;
% Loss reduction = 100 [1 - (Original pf / Improved pf) 2]
= 100 [1 - (0.77 / 0.85) 2]
= 17.93 %

% Line-current reduction=100[1 - (Present pf/Improved pf)]
= 100 [1 - (0.77/0.85)]
= 9.41 %

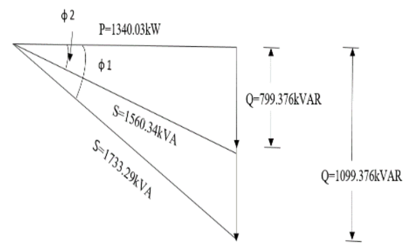

Figure 7. Power Triangle Diagram for before and after Correction

VII. CALCULATION RESULT BY USING CAPACITOR-BANK

By correcting the power factor of an installation supplying locally the necessary reactive power, at the same level of required output power, it is possible to reduce the current value and consequently the total power absorbed on the load side; this implies numerous advantages, among which a better utilization of electrical machines and electrical lines. After power factor improvement by capacitor banks at transformer of Wai Yan Lwin Tile Factory, the calculated results are shown in Table 1. Then, the required power factor improvement value results are plotted in Figure 8. And the values of loss reduction for desired power factor are plotted in Figure 9. And line current reductions at various power factor are plotted in Figure10.

Table 1. Calculation Result by using Capacitor Bank at Various Power Factor

Active Power (kW)	Rective Power (kVAR)	Power Factor (Cos Φ)	Required Reactive Power Value of Capacitor Bank (kVAR)	Loss Reduction (%)	Line Current Reduction (%)
1340.03	799.376	0.85	300	17.93	9.41
1340.03	649	0.9	450.376	26.8	14.4
1340.03	440.42	0.95	658.95	34.3	18.64
1340.03	272.06	0.98	827.32	38.26	21.43

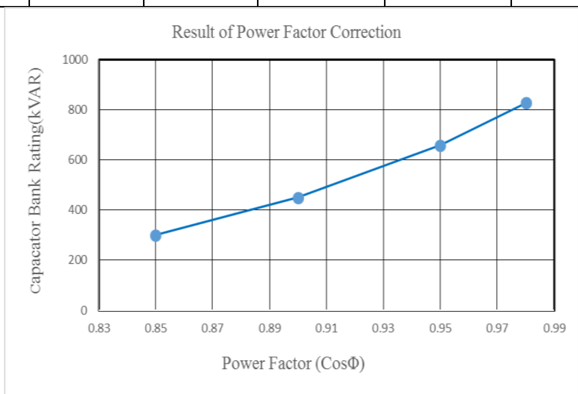

Figure 8. Result of Power Factor Improvement Curve by using Capacitor Bank at Various Power Factor

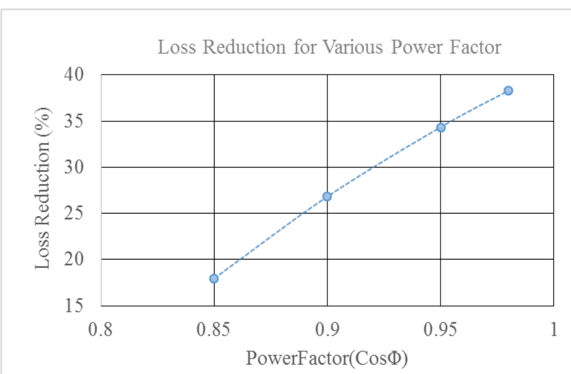

Figure 9. Loss Reduction Curve for Various Power Factor

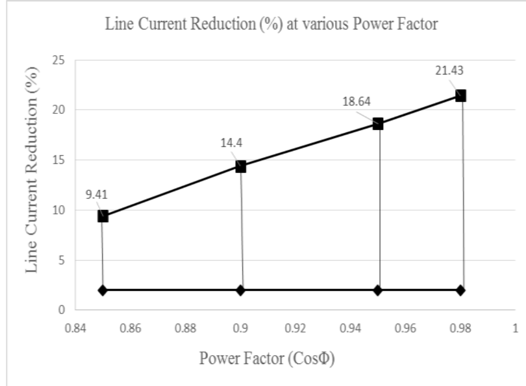

Figure 10.Line Current Reduction for Various Power Factor

VIII. CONCLUSIONS

In this paper, power factor improvement by using capacitor bank is analyzed and power consumption of the factory, percent of loss reduction, percent of line current reduction and capacitor bank size are calculated.

Capacitor bank is a correction device for voltage regulation and for improving power factor for industrial loads. Capacitor banks are used to improve voltage regulations, improve power factor, reduction of voltage and current unbalances, etc. This can result saving in electricity costs, reduced line losses and line currents, rise the tile products, etc. A capacitor bank has the ability to improve the power factor to near unity, reduced reactive power costs, and improved power quality.

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