Economic and Industrial Application of Power Factor Improvement

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Abstract

Power factor correction is a vital tool for maintaining the terminal voltage of an electrical system that operates at low power factor since any sudden change in power factor and current affect the terminal voltage of the system. If the power factor of any electrical system is improved to unity with the application of capacitors, the current of the same value of the power to be supplied is reduced to a minimum. This results in total reduction of power losses, terminal voltage drop and sizes of transformers, alternators, cables and switchgears. In order to encourage the large electricity end users to keep their loads at a unity or near unity power, electricity tariff is structured in such a way to depend on the consumers' power factor. Power factor correction will result in reduction of maximum demand (KVA or KW) and affect the annual saving over the maximum demand charge. Also some expenditure will be incurred annually in the form of the interest and depreciation made over the power factor correcting equipment. Hence EEP computer application software was used to analyse the total cost that associated with power factor correction and annual saving with the application of power factor improvement. With this method, some percentage of money spent annually on electricity tariff will be reduced.

Keywords: Power factor, Active Power, Reactive Power, Apparent Power, Capacitor bank, Load

1. Introduction

During recent years, increasing attention has been paid to minimize the energy cost and inefficiency in electricity generation, transmission and distribution system [9]. When designing a compensation scheme; one should attempt to achieve the most economical solution in which the saving achieved in the equipment cost is significantly greater than the procurement cost of the reactive power [10].

Power factor is the cosine of the phase angle between voltage and current in an AC circuit. A very high capital cost of electrical power system materials such as switchers, alternators, transformers, and distribution and transmission lines is required to deliver the same amount of power at a low power factor. More energy losses occur at low power factor which result in poor efficiency and reliability of the system since energy losses are proportional to the square of the current [4]. Furthermore low voltage drop at low power factor leads to poor regulation; to keep the supply voltage within the permissible limit, a voltage regulating equipment must be installed [4]. This proofed to be an additional burden on the power end users that operate at low power factor. Having analyzed the drawback that associated with low power factor in electrical power system, the power utilities must impose a power factor of 0.8 and above on both industrial and domestic consumer/applications. With recent deregulation of power system all over the world, electricity tariffs are designed in such a way to penalize the consumers with low lagging power factor and encourage them to install power factor correction devices [4]. Hence the power factor of a system can be improved by connecting capacitors in star or delta in parallel with any equipment that is operating at a low power factor. This paper analyses power factor improvement in the industrial sector with application of capacitors. With application of power factor improvement, there will be a considerable reduction in heating of the power system's switchgears, alternators and transformers which will improve the efficiency and reliability of the power system [6]. Maintaining a high power factor in a power plant can yield direct saving such as reduced power bills, releases of system capacity, improves power system voltage, decreases power losses and make the system to be more efficient. The cost of improving the power factor in existing power plants depends on the value of the power factor selected and equipment chosen to supply the compensating reactive power [I5].

2. Objectives of the research

The objectives of the research are as follows:

1. To formulate a mathematical model for optimization of electricity tariff in an industrial sector with the application of power factor improvement.
2. To estimate the annual power output in a power plant.
3. To estimate the annual power consumption of the consumers.
4. To develop the best approaches that will help power utility companies to improve power factor.
5. To see the effect of using penalty tariff to discourage application of reactive loads in the power system.
6. To introduce a computational approach for improvement of power factor in the industrial sector.
7. To reduce power losses in electrical power system with the application of power factor improvement.
8. To investigate current reduction and sizing of cables in power distribution systems.
9. To improve terminal voltage drop in a power system with the application of power factor improvement.

3. Power in AC Circuits

The product of voltage *v* and current i at any instant of time is called instantaneous power p, and is given by [2]:

P= vi 1

Let consider the average power *P* in a circuit that contains resistance and inductance.

$P=(V_m \sin wt)(I_m \sin wt-\phi)$ 2

P= VmIm sinwt sin (wt - ϕ)

$p = V_mI_m \{-\frac{1}{2}[\cos(wt+wt-\phi) - \cos wt-(wt-wt+\phi)]\}$ 3

$p=\frac{1}{2}V_mI_m[\cos(\phi)-\cos(2wt-\phi)$ 4

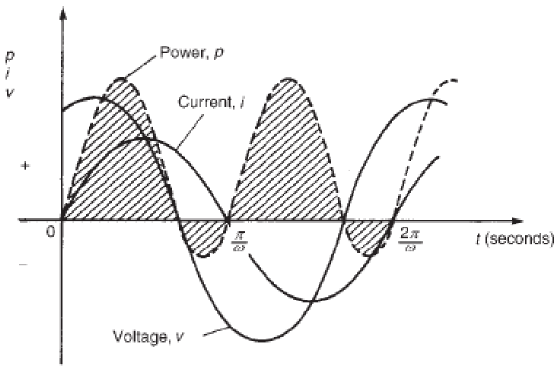
Therefore

$p=\frac{1}{2}V_mI_m[\cos(\phi)-\cos(2wt-\phi)]$ 5

Thus the average power $\frac{1}{2}V_mI_m\cos(\phi)$ 6

$P=\frac{1}{2}\sqrt{2}\,xV_m\sqrt{2}I_m\cos(\phi)$ 7

$P = VI\cos\phi$ watts 8



Source: John Bird

Figure1: Waveform of power

Figure.1 is a power in an AC Circuit with resistance and inductive reactance. The waveforms of *v*, i and p, are shown in Figure 1 for an R–L circuit. The waveform of power is seen to pulsate at twice the supply frequency [3].

3.1. Active Power

Active Power is the product of the applied voltage and active component of the current. From the power triangle as shown in fig 2, it is the real component of the apparent power. It is measured in watt or kW [3].

P=IVcosϕ 9

3.2. Reactive Power

Reactive Power is the product of the applied voltage and reactive component of the current. From the power triangle as shown in fig 2, it is imaginary component of the apparent power. It is measured in Var or kVar [3].

P=IVsinϕ 10

Effect of Reactive Power

The wattles or reactive power does no real work in a power system but on the other hand it increases the current taken by the load and reduces the power factor the circuit [3].

3.3. Apparent Power

Apparent Power is the product of r.m.s values of current and voltage. It is denoted by S and measure in VA or KVA [12].

Apparent Power = S 11

S=P±jQ 12

Where P is the active power and Q is the reactive power.

$S=\sqrt{(Reactive\ Power)^2+(Active\ Power)^2}$ 13

$S=\sqrt{(IVsin\phi)^2+(IVcos\phi)^2}$ 14

$S= VI(\cos\phi+j\sin\varphi)$ 15

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4. Power Factor

Power Factor is the cosine of the phase angle between the applied voltage and the current drawn from the circuit. It varies from zero to unity. The power factor can be explained by the vectorial and sinusoidal relations of power triangle as shown in figure 2. The term cosϕ is known as power factor of the circuit. If the circuit is inductive, the current is lags behind the voltage and the power factor is called lagging power factor and if the circuit is capacitive then current leads the voltage and power factor is said to be leading power factor [7].

The low power factor's problem can be solved by connecting power factor improvement capacitors in delta or star to the plant distribution system. Power factor correction capacitors reduce the total current drawn from the distribution system and subsequently increase the system's capacity by raising the power factor level [13].

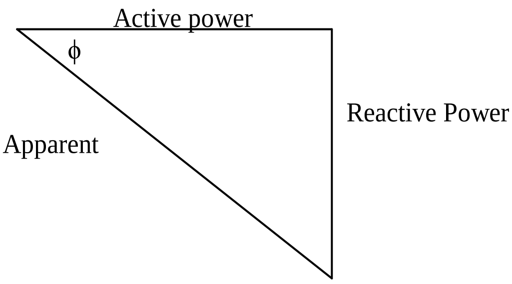

Figure2.0: Power Triangle

Power factor is expressed as shown in equation 16

$$\cos\phi = \frac{Active\ Power}{Apparent\ Power} \qquad 16$$

4.1 Advantages of power factor Improvement

i. It lowers transmission and distribution lines, transformers and alternators coppers losses.

ii. Voltage improvement by lowering the terminal voltage drop at the transmission and distribution lines, transformers, alternators, bus bar etc.

iii. Reduction of KVA demand charge for the large electricity consumers if a power factor penalty is introduced or the utility charges for maximum KVA demand is enforced.

iv. Power factor improvement reduces load current.

v. Power factor correction reduces KVA loading of electrical equipment such as transformers and alternators which may relieve an overloaded system or release capacity for additional growth of load.

vi. Power factor correction improves plant efficiency.

Vii. Reduced overloading of cables, transformers, switchgears, alternators etc.

5.0 Tariff

The tariff is the rate of supplying electricity to various types of consumer's i.e. Domestic consumers, Commercial consumers, Agricultural consumers and Industrial consumers [4]. Electricity charges for both industrial and commercial facilities consist of energy charge or the Kilowatt-hour charge which is directly proportional to the fuel used in producing and delivering that energy and demand rate i.e. kilowatt or KVA charge. This is usually related to the capital investment that must be made to build the generation, transmission and distribution facilities for delivering electrical energy to the consumers [15]. Electrical energy companies in the world incurred losses due to low power factor at the receiving ends especially for the bulk power consumers. To reduce the losses that associated with low power factor in a certain level, many countries in the world are undergoing power sector reform in order to make electricity to be more reliable. The tariff for various classes of electricity consumers who use a certain amount of electric energy is directly proportional to Kilowatt-hour (kWh) and maximum (KW) or (KVA) demand [2].

Monthly bill = N (κ x KVA + y x KWh) 17

Where k is the charge per KVA maximum demand assessed and y is the charge per Kwh of energy consumed.

K= ₦38.50k

∂ =₦756. 00k

5.1 Power Factor Correction

Power factor improvement can be achieved by connecting static capacitors in parallel with the equipment that is operating at a lagging power factor. This results in a reduction of customer demand and energy charges [8]. Static capacitors have several benefits such as small losses or loss free, high efficiency, reliable, low capital cost, low maintenance cost and easy to install [4]. In three phase power system, capacitors can be connected in star or delta for power factor correction as shown in figure 3 and figure 4. The value of the static capacitors required for power factor improvement can be determined as follows:

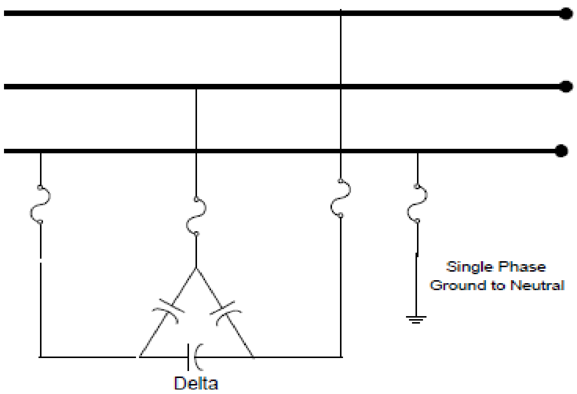

Figure 3: Delta Connection of capacitors

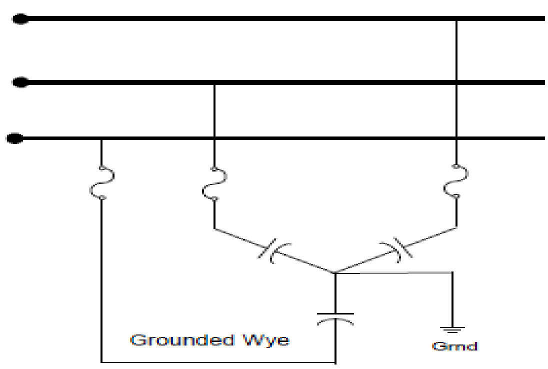

Figure 4: Star Connection of capacitors

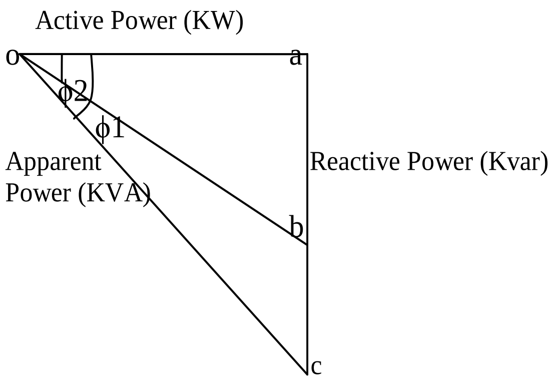

Figure5: Power Triangle

The leading KVar supplied by power factor correction equipment is given by bc as shown in figure.5.

bc = ac-ab

=Kvar1-Kvar2 18

= oaTanϕ1-oaTanϕ2 19

= oa (Tanϕ1-Tanϕ2) 20

= KW (Tanϕ1-Tanϕ2) 21

The value of capacitance needed for power factor correction is stated below

bc = IcV 22

$$I_c = \frac{b_c}{V} \qquad 23$$

Capacitive reactance Xc

$$X_c = \frac{V}{I_c} \qquad 24$$

$$\frac{1}{2\pi f c} = \frac{V}{Ic} \qquad 25$$

$$c = \frac{Ic}{2\pi f V} \qquad 26$$

Capacitor Cost/KVA = KW (Tanϕ1-Tanϕ2) A 27

If capacitor/KVA is represented by K where A is a fixed amount for loss free capacitor/KVA.

5.2 Depreciation

Depreciation is the loss in value resulting from the use of machinery and equipment during the period. During a specific period, the cost of using a capital good is the depreciation or loss of the value of that good, not its purchase price. The depreciation rate is the rate of such a loss in value [11].

Annual Depreciation Charges =

$$\frac{Original\ Cost - Salvage\ Value}{life\ span\ of\ the\ plant\ (Years)} \qquad 28$$

Percentage annual depreciation charges= x% 29

$$\text{Salvage Value} = \frac{Initial\ Cost x Salvage\ Value}{100} \qquad 30$$

5.3 Interest

Nominal interest rate is the annual percentage increase in the nominal value of a financial asset [12].

Annual interest on capital cost =

$$\text{Initial Cost x } \frac{Interest\ rate}{100} \qquad 31$$

Annual interest on capacitor cost =y% 32

Percentage annual saving in interest and depreciation rate = (x+y) % 33

=Z% 34

Percentage annual saving in interest and depreciation on the capacitor

= Z% KW (Tanϕ1-Tanϕ2) A 35

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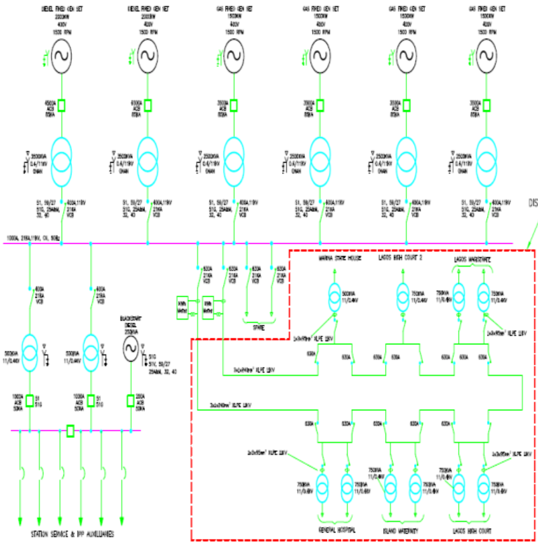


Figure.6: Independent Power plant and the off taker

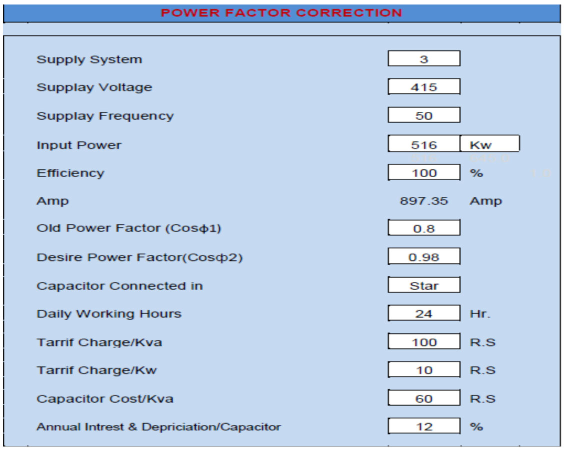
The power plant has a combined installed capacity of 10 megawatts (MW) comprising of 2 units of 2MW diesel reciprocating engines and 4 units of 1.5MW gas reciprocating engines. The 10MW independent power is supplying public utilities based on the agreed tariff regime. The two outgoing feeders have separate energy meters for their respective monthly reading. To reduce the effect of penalty tariff introduced by the by the independent power plant, the off taker had to be operating at a power factor above 0.8, this can only be achieved with the application of power factor device .Hence this paper actually studied the effect of installing power factor correction device in any power system.

6.0 Estimation of KVAR required for power factor improvement.

Estimation of capacitive KVAR required for power factor improvement at a given load can be achieved with application of EEP power factor correction application software as shown in figures 7&8. The static capacitor rating must be carefully selected having considered rated voltage of the power system and the system over voltages.

6.1Main Template

The function of the main template is to accept the necessary data such as frequency, input power, old and new power factor, type of capacitor connection and daily working hours just as it reflects in fig. 7. All this data is required for calculation of annual cost before power factor correction, annual Cost after power factor correction and annual saving.



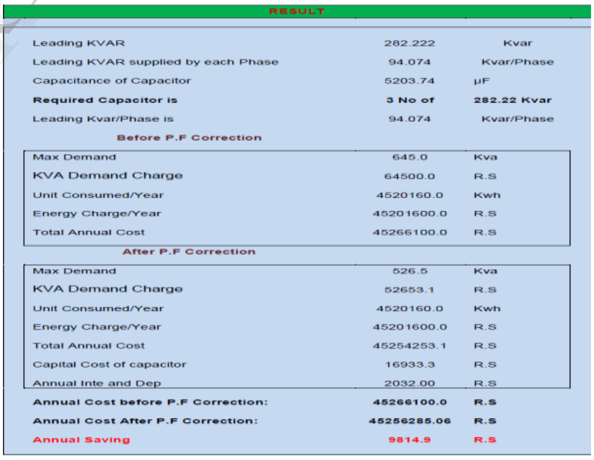
POWER FACTOR CORRECTION		
Supply System	3	
Supplay Voltage	415	
Supplay Frequency	50	
Input Power	516	Kw
Efficiency	100	%
Amp	897.35	Amp
Old Power Factor (Cosϕ1)	0.8	
Desire Power Factor(Cosϕ2)	0.98	
Capacitor Connected in	Star	
Daily Working Hours	24	Hr.
Tarrif Charge/Kva	100	R.S
Tarrif Charge/Kw	10	R.S
Capacitor Cost/Kva	60	R.S
Annual Intrest & Depriciation/Capacitor	12	%

Source:EEP computer application software

Figure.7:Main Template

6.1Result Template

The function of the main template is to accept the necessary data such as frequency, input power, old and new power factor, type of capacitor connection and daily working hours just as it reflects in fig. 8. All this data is required for calculation of annual cost before power factor correction, annual Cost after power factor correction and annual saving.



RESULT		
Leading KVAR	282.222	Kvar
Leading KVAR supplied by each Phase	94.074	Kvar/Phase
Capacitance of Capacitor	5203.74	µF
Required Capacitor is	**3 No of**	**282.22 Kvar**
Leading Kvar/Phase is	94.074	Kvar/Phase
Before P.F Correction		
Max Demand	645.0	Kva
KVA Demand Charge	64500.0	R.S
Unit Consumed/Year	4520160.0	Kwh
Energy Charge/Year	45201600.0	R.S
Total Annual Cost	45266100.0	R.S
After P.F Correction		
Max Demand	526.5	Kva
KVA Demand Charge	52653.1	R.S
Unit Consumed/Year	4520160.0	Kwh
Energy Charge/Year	45201600.0	R.S
Total Annual Cost	45254253.1	R.S
Capital Cost of capacitor	16933.3	R.S
Annual Inte and Dep	2032.00	R.S
Annual Cost before P.F Correction:	**45266100.0**	**R.S**
Annual Cost After P.F Correction:	**45256285.06**	**R.S**
Annual Saving	**9814.9**	**R.S**

Source:EEP computer application software

Figure.8:Result Template

7.0 Power losses in Electrical Power Systems:

Power losses in electrical transmission and distribution systems can be reduced by connecting static capacitors either in star or delta to the system. This will result in an increase in the system power factor. The total power loss in any electrical system is a summation of alternators losses, transformers losses, bus bar losses and cable losses. The reduction can only be achieved by reducing the current flowing in the alternators, transformers, bus bars and cables. The power loss is expressed as shown in equation 36

$$P = I^2 R \tag{36}$$

% Power loss reduction =

$$= \frac{Old\ Power\ Loss - New\ Power\ Loss}{Old\ Power\ Loss} * 100\% \tag{37}$$

$$= \frac{Io^2 R - In^2 R}{Io^2 R} * 100\% \tag{38}$$

$$= (1 - \frac{In^2}{Io^2}) * 100\% \tag{39}$$

$$= \{1 - (\frac{\frac{P}{\sqrt{3}\, xVxPfn}}{\frac{P}{\sqrt{3}xVxpfo}})\ 2\} * 100\% \tag{40}$$

$$= (1 - \frac{Pfo^2}{Pfn^2}) * 100\% \tag{41}$$

$$= \{1 - (\frac{Pfo}{Pfn})^2\} * 100\% \tag{42}$$

$$= \{1 - (\frac{Old\ Power Factor}{New\ Power\ Factor})^2\} 100\% \tag{43}$$

7.1 Current Reduction

Power factor correction reduces the current drawn from the electrical power system and increases the system's capacity by raising the power factor to a certain level. This will allow extra loads to be served by the same power system. Some electrical equipment such transformers, cables, alternators, distribution and transmission lines which might have been thermally overloaded when operating at low power factor will now be operating optimally with application of power factor improvement which is the best option of reducing current flowing through these equipment to a certain level [15]. Power factor improvement is the appropriate and economic way to reduce current and overloading of cables, transformers, alternators, and transmission and distribution lines. This is illustrated by the relationship shown in equation 44

$$I_{NEW} = \frac{New\ Apparent\ power}{\sqrt{3}xV} \tag{44}$$

Current reduction will reduce the sizes of cable and bus bar to be connected in power distribution systems.

7.2 Voltage Improvement

Power factor improvement will optimize a circuit voltage, for this reason it is necessary to install static capacitors in star or delta for power factor improvement. Power factor improvement will affect the voltage drop in any electrical cable, thus this will drastically reduce the terminal voltage at the receiving end i.e. transformers, switchgears and motor control centers. The formula for calculating voltage drop in electrical cable is shown in equation 45.

$$I = \frac{Active\ Power}{\sqrt{3}Vxcos\phi} \tag{45}$$

The size of cables is selected by dividing the rated load current I_B by different correction factors, K1, K2, K3, K4, and K5-------

$$I^1 = \frac{I}{K1*K2*K3*-----} \tag{46}$$

Where K1, K2, K3, K4, K5 ------ are correction factors

K1 is the *Correction factors for ambient air temperatures other than 30 °C to be applied to the current-carrying capacities for cables in the air*
Ground Temperature Correction Factor K2=0. 93
Soil Correction Factor for Air K3 = *1.00*
Group Factor for Ground K4= *1.00*
Cable Laying Depth Factor K5 = *0.98*
Total derating Factor= *0.91*
K1xK2xK3xK4 =1. 0x0.93 x1. 0x1.0x0.91 = 0.91

$$\Delta V = (RIcos\phi + XIsin\phi)L \tag{47}$$

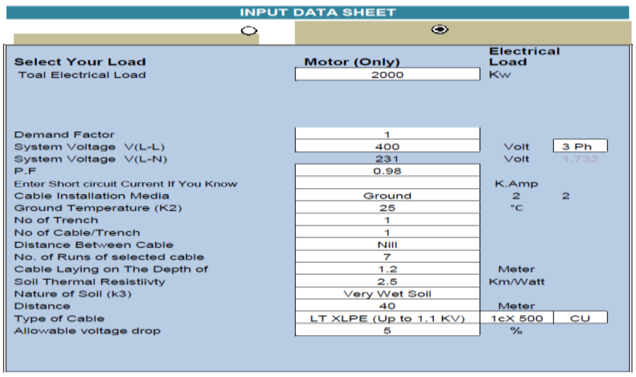
$$\Delta V = I(Rcos\phi + Xsin\phi)L$$

ΔV =IZL

Where Z =Impedance, Ω/km
L=Distance
I=Full load current

Due to power factor improvement, the new voltage drop can be estimated by using equation x

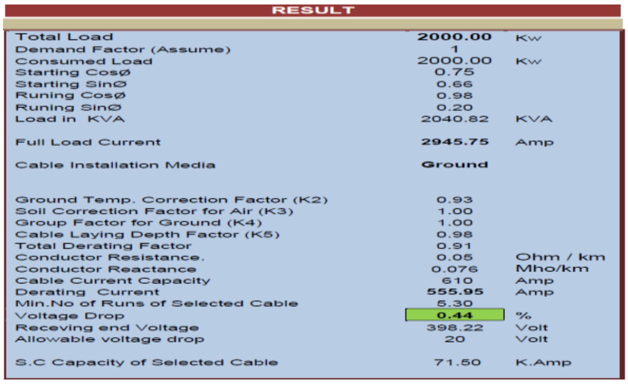
$$\%\ Voltage\ Drop = \frac{\Delta V}{V} x100\% \tag{47}$$



INPUT DATA SHEET

Select Your Load	Motor (Only)	Electrical Load	
Toal Electrical Load	2000	Kw	
Demand Factor	1		
System Voltage V(L-L)	400	Volt	3 Ph
System Voltage V(L-N)	231	Volt	1.732
P.F	0.98		
Enter Short circuit Current If You Know		K.Amp	
Cable Installation Media	Ground	2	2
Ground Temperature (K2)	25	°C	
No of Trench	1		
No of Cable/Trench	1		
Distance Between Cable	Nill		
No. of Runs of selected cable	7		
Cable Laying on The Depth of	1.2	Meter	
Soil Thermal Resistiivty	2.5	Km/Watt	
Nature of Soil (k3)	Very Wet Soil		
Distance	40	Meter	
Type of Cable	LT XLPE (Up to 1.1 KV)	1cX 500	CU
Allowable voltage drop	5	%	

Figure.9 illustrates application of EEP application software for selection of cables.



RESULT		
Total Load	2000.00	Kw
Demand Factor (Assume)	1	
Consumed Load	2000.00	Kw
Starting Cosø	0.75	
Starting Sinø	0.66	
Runing Cosø	0.98	
Runing Sinø	0.20	
Load in KVA	2040.82	KVA
Full Load Current	2945.75	Amp
Cable Installation Media	Ground	
Ground Temp. Correction Factor (K2)	0.93	
Soil Correction Factor for Air (K3)	1.00	
Group Factor for Ground (K4)	1.00	
Cable Laying Depth Factor (K5)	0.98	
Total Derating Factor	0.91	
Conductor Resistance.	0.05	Ohm / km
Conductor Reactance	0.076	Mho/km
Cable Current Capacity	610	Amp
Derating Current	555.95	Amp
Min.No of Runs of Selected Cable	5.30	
Voltage Drop	0.44	%
Receving end Voltage	398.22	Volt
Allowable voltage drop	20	Volt
S.C Capacity of Selected Cable	71.50	K.Amp

Figure.10 illustrates %voltage drop in a cable having considered the different power factor and correction factors.

8.0 Result and discussions

Table1: Total annual cost per year without application of power factor improvement.

Year	2008	2009	2010	2011	2012
Active Power(kw)	6300	6500	7000	7800	8000
Old Maximum KVA	8750	9155	9210.5	10000	10126.6
Old Power Factor (Cosϕ1)	0.72	0.71	0.76	0.78	0.79
KVA Demand Charge (N:K)	8750	6921126.8	6963157.9	7560000	7655696.2
Unit Consumed/Year(Kwh)	55188000	56940000	61320000	68328000	70080000
Energy Charge /Year(N:K)	1931580000	1992900000	2146200000	2391480000	2452800000
Total Annual Cost(N:K)	1938195000	1999821127	2153163158	2399040000	2460455696

Table.1 shows the total annual cost per year without application of power factor improvement.The table illustrates the KVA demand charge,unit consumed ,energy charge and total annual cost per year for an independent power plant as shown in figure6.

Table.2: The annual saving after the power factor improvement device has been applied.

Year	2008	2009	2010	2011	2012
Active Power (Kw)	6300	6500	7000	7800	8000
New Max KVA	6847.8	6989.2	7526.9	8387	8602.2
New Power (Cosϕ2)	0.92	0.93	0.93	0.93	0.93
Tariff Charge/KVA	756	756	756	756	756
Tariff Charge/Kw	35	35	35	35	35
Capacitor Cost/KVA	60	60	60	60	60
Leading Kvar	3388.484	3877.952	3219.557	3175.038	3046.875
Annual Interest & Depreciation	8%	8%	8%	8%	8%
KVA Demand Charge	5176956.5	5283871	5690322.6	6340645.2	6503225.8
Unit Consumed/Year	55188000	56940000	61320000	68328000	70080000
Energy Charged/Year	1931580000	1992900000	2146200000	239148000	2452800000
Total Annual cost	1936756957	1998183871	2151890323	2397820645	2459303226
Capital cost of Capacitor	203309.1	232677	193173.4	190502.3	182812.5
Annual Depreciation /Capacitor	16264.72	18614.17	15453.87	15240.18	14625
Annual Cost before Power factor correction	1938195000	1999821127	2153163158	2399040000	2460455696
Annual Cost after power factor correction	1936773221	1998202485	2151905776	2397835885	2459317851
Annual Saving	1421778.8	1618641.6	1257381.4	1204114.7	1137845.4

Table.2 illustrates the annual saving after the power factor improvement device has been applied by the consumers of the power plant shown figurey. The table also illustrates different parameters that have to do with power factor correction such as Capital cost of the capacitor, annual Depreciation /Capacitor, annual cost before power factor correction, the annual cost after power factor correction and annual saving.

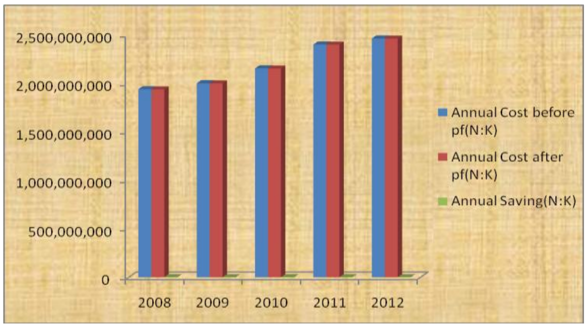


Figure.10:Annual cost before and after application of power factor improvement.

The figure compares and constracts annual cost before and after application of power factor correction.The saving incured from application of power factor improvement is also analysed.

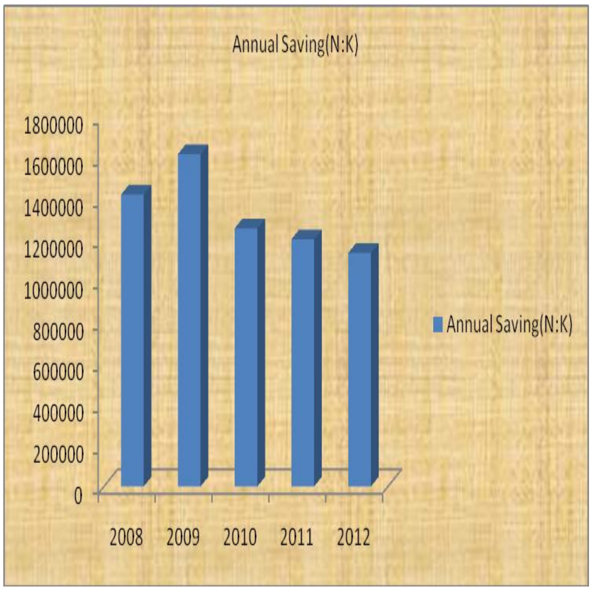


Figure 11 shows the annual saving per year

Time	Old PF	Desired PF	% Power Loss Reductio
0	0.78	0.82	9.518144
2	0.79	0.86	15.61655
4	0.8	0.88	17.35537
6	0.82	0.9	16.98765
8	0.85	0.92	14.63847
10	0.88	0.94	12.35853
12	0.86	0.91	10.68712
14	0.84	0.93	18.41831
18	0.88	0.95	14.19391
20	0.89	0.96	14.05165
22	0.87	0.97	19.55574
24	0.86	0.94	16.29697

Table 3: Hourly reduction of power losses

The table shows the hourly reduction in power losses in the independent power plant shows in figure 6 with application of power factor correction device.

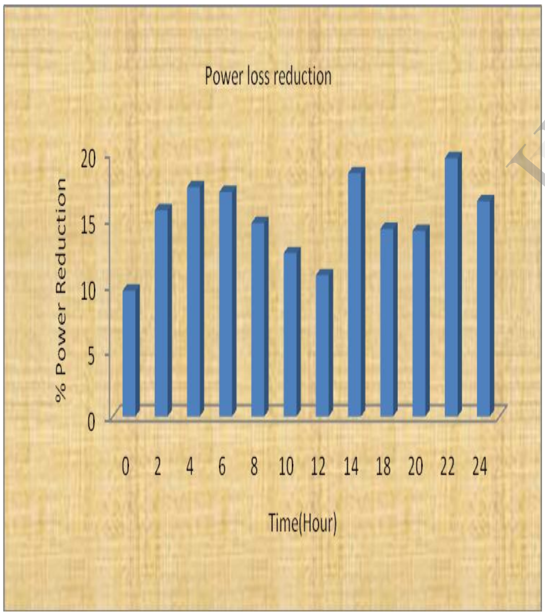


Figure 12 shows the hourly power loss reduction with application of power factor improvement.

Table4: Effect of power factor correction on I and S

Before Application of power factor improvement					
Time	Old PF	P(KW)@415V	Q(Kvar)	S(KVA)	I (A)
0	0.78	6000	4813.7	7692.3	10701.9
2	0.79	5560	4315.1	7038	9791.56
4	0.8	6500	4875	8125	11303.9
6	0.82	6800	4746.5	8292.7	11537.2
8	0.85	7000	4338.2	8235.3	11457.3
10	0.88	7250	3913.1	8238.6	11462
12	0.86	7500	4450.2	8720.9	12133
14	0.84	7800	5038.3	9285.7	12918.7
18	0.88	7900	4264	8977.3	12490
20	0.89	8000	4098.6	8988.8	12505.6
22	0.87	7650	4335.4	8793.1	12233.4
24	0.86	7600	4307.2	8735.7	12153.4

The table shows the effect of power correction on current and apparent power before application of power factor correction.

Table 5: Effect of power factor correction on I and S after application of power factor improvement.

After Application of power factor improvement					
T	P(KW) @415V	Desired PF	Q(Kvar)	S(KVA)	I (A)
0	6000	0.82	4188.07	7317.1	10180
2	5560	0.86	3299.08	6465.1	8994.5
4	6500	0.88	3856.8	7558.1	10515
6	6800	0.9	2896.78	7391.3	10283
8	7000	0.92	2982	7608.7	10586
10	7250	0.94	2631.5	7712.8	10730
12	7500	0.91	3417.2	8241.8	11466
14	7800	0.93	3082.77	8387.1	11669
18	7900	0.95	2596.64	8315.8	11569
20	8000	0.96	2333.21	8333.3	11594
22	7650	0.97	1917.28	7886.6	10972
24	7600	0.94	2758.41	8085.1	11248

Table 6 shows the effect of power correction on current and apparent power after application of power factor correction.

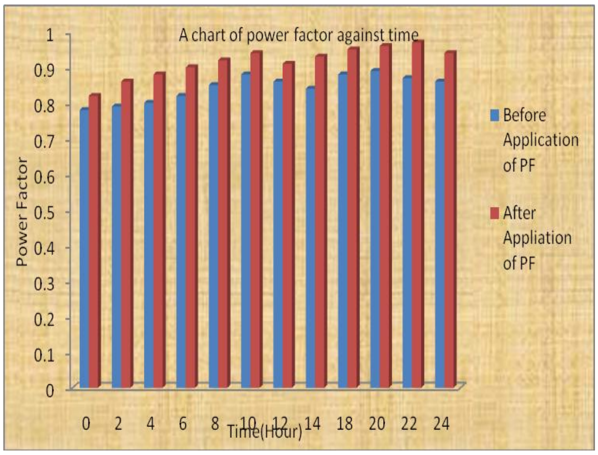


Figure 13 illustrate power factor per hour.

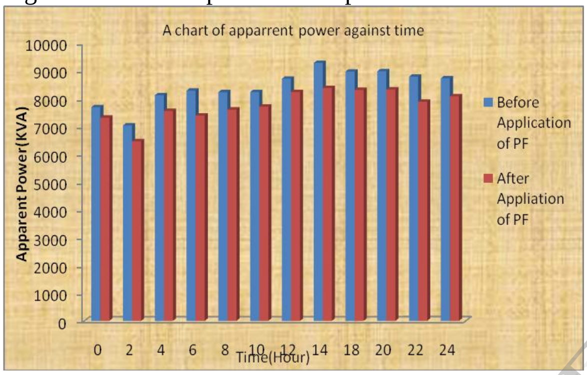


Figure 14 shows the effect of power factor on apparent power.The figure shows that with application of power factor improvement there will be total reduction in apparent power of the power sysytem.

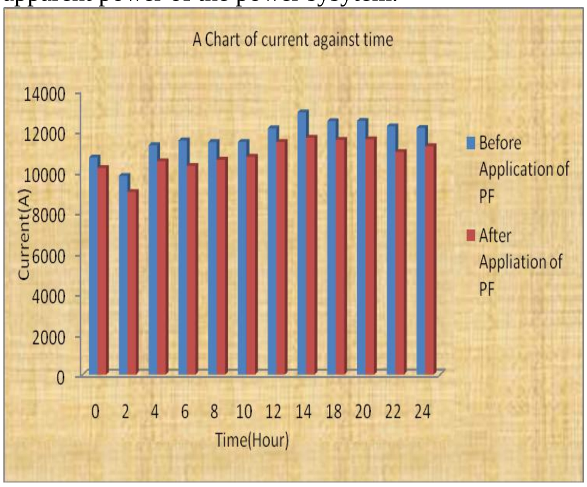


Figure 15 shows the effect of power factor correction on the current drawn from the electrical power system. The figure compares the effect of current before and after application of power factor correction.

Table6: Voltage drops in a cable with application of power factor improvement.

The shows the voltage improvement by considering a unit (2MW) in the power plant as shown in fig. 6. To

Active Power (Kw)	Desired Power factor	Voltage Drop%	Size of cable(XLPE LV)
2000	0.8	0.74	6x500mm2
2000	0.82	0.71	6x500mm2
2000	0.84	0.68	6x500mm2
2000	0.86	0.66	6x500mm2
2000	0.88	0.63	6x500mm2
2000	0.9	0.6	6x500mm2
2000	0.92	0.57	6x500mm2
2000	0.94	0.53	6x500mm2
2000	0.96	0.49	6x500mm2
2000	0.98	0.44	6x500mm2

improve voltage in a power system, the system must be operating at unity or near unity power factor. In order to achieve this, power factor improvement device must be connected in parallel with the system. From Table 3, voltage drop is inversely proportional to power factor.

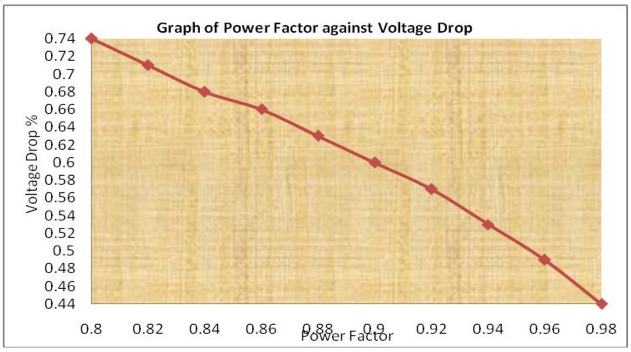


Figure5 shows the percentage of voltage drop in a cable.Voltage drop is inversely proportional to power factor.

9.0 Conclusion

The low power factor in any electrical power system causes an increase in KVA demand charge the electricity consumers by the utilities. Hence, in order to ensure most favorable conditions for a power system in both engineering and economic perspective, it is important for any power system with different equipment such as alternators, transformers, switchgears, and transmission and factory or very close to unity power factor. With this, total reduction in the cost of electricity can be achieved in economic and efficient way. Having analyzed different cases from

this research work, it has been established that in order to have good performance of the electric power system, it is important to operate the system between the power factor of 0.8 and 1.0. This will reduce power losses and improve terminal voltage without the need
To install additional auxiliaries such as transformer cables, switchgears, alternators, bus bars etc. Hence power factor improvement results in:
a) Improve voltage drop.
b) Improved plant efficiency and reliability.
c) Reduced overloading (Current Reduction) of cables, transformers, switchgear, bus bar etc.
d) Reduced power losses in power system
e) Reduced electricity charge per month or annum.

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