Energy conservation in developing countries using green building idea

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Abstract. Green buildings uses processes that are environmentally responsible and resource-efficient throughout a building's life-cycle. In these buildings Certain energy conservative and environment friendly steps are considered and implemented from design, construction, operation, maintenance and renovation. In present era no doubt new technologies are constantly constructed and used in creating greener structures, energy efficient buildings. The common objective is to reduce the overall impact of the built environment on human health using available energy efficiently. To increase the efficiency of the System or the building, Onsite generation of renewable energy through solar power, wind power, hydro power, or biomass can significantly reduce the environmental impact of the building. Power generation is generally the most expensive feature to add to a building. Any how power generation using renewable sources that is Solar system may further enhance energy conservation ideas. Power Factor improvement can also be another source of efficient tool for efficient use of Electrical Energy in green buildings. In developing countries a significant amount of Electrical Energy can be conserved and System efficiency as a whole can be increased by Power Factor correction. The reverse flow of power can be locally engaged instead of creating extra stress and opposition to the existing grid lines.

1. Introduction
Energy crises is appearing to be a bottleneck in the Economic development of countries across the globe. There is enormous increase in the Global demand of Energy because of Industrialization and population growth. Energy crises are more severe because of the deficit in Demand and Supply. In order to cope with the present energy crises in especially in developing countries low energy buildings can be a best solution. To minimize the primary energy consumption, the many passive and active day lighting techniques are the first solution to apply. Day-lighting with light emitting diode-LED lamps, Solar Powered circulation systems can also be employed in houses, Xenon and Halogen lamps can be used in large buildings and industries. In spite of all these the most immediate and more efficient solution to meet the present energy crises in the developing countries is to improve Power Factor. Since the Power Factor is purely frequency dependent hence frequency and transient analysis are the main topics of this research. In this research the green building idea is strongly related with the industries/buildings/houses offering less opposition rather facilitating the incoming power for its efficient usage.
2. Problem statement
Energy is the most important tool in the development of any country. It is just like a blood circulation in the life line of a country. In developing countries mostly the energy crises are because of old energy distribution system. The industrial/household energy receiving systems are unable to receive the required energy efficiently. Since the loads are not purely resistive rather to say are more inductive and hence they become the source of reverse power flow. This reverse Power flow gives a significant amount of resistance to the incoming power and create excess amount of heat and power loss within the power transmission lines and system itself. Their systems work inefficiently and this way the inefficient systems are casting long shadows in the Economic development of Developing countries. This system loss as a whole can be well tackled by analyzing power factor considering its frequency dependence nature.

3. System model
Power is a precious resource. Power transfer to the load is maximum when the load impedance is equal to the complex conjugate of the impedance of the source. The loads of reactive elements give energy back and forth between the load and the source. Because these elements store and release energy, this ability of the reactive elements causes a much pressure/opposition on the energy distribution system. The instantaneous system power is

\[ p(t) = \frac{1}{2} V_m I_m \cos\phi + \frac{1}{2} V_m I_m \cos(2\omega t + \phi) \]  

(1)

When the system is purely resistive the above equation reduces to

\[ p(t) = \frac{1}{2} V_m I_m (1 + \cos 2\omega t) \]  

(2)

This confirms that energy is being transferred constantly from source to load. Power is maximized when \( \cos \phi = 1 \) and the power above is apparent one.

\[ S = \frac{1}{2} V_m I_m = V_{rms} I_{rms} \]  

(3)

When \( \phi = \pm 90^\circ \) and \( \cos \pm 90^\circ = 0 \) the circuit is purely reactive and purely reactive load dissipate no power. In this case the energy transferred to the load during positive alternation is returned to the source during negative alternation. We sum up with the equation

\[ p(t) = \frac{1}{2} V_m I_m \cos(2\omega t \pm 90^\circ) \]  

(4)

It is very much clear that in Load is partly resistive and partly reactive. So the Power factor \( \cos \phi \) lies between 0 and 1. This shows that Power factor is frequency dependent and hence the power is frequency dependent. Power factor is leading when the load is Capacitive and lagging when the load is Inductive. The power delivered to the load is

\[ P_L = \frac{1}{2} R_L \frac{|V_{\infty}|^2}{(R_{eq} + R_L)^2 + (X_{eq} + X_L)^2} \]  

(5)
On average reactances absorb zero power; the reactive term can be eliminated easily. This shows

\[ X_L = -X_{eq} \]  

(6)

This would lead to reduce the power delivered to the load. In this case the above equation clearly shows that for maximum power transfer we are left with the only condition

\[ R_L = R_{eq} \]  

(7)

From equations 6 and 7 we conclude that maximum power to the load to be transferred require the following condition to be valid

\[ Z_L = Z^*_{eq} \]  

(8)

So there will be no reactive power from load to the distribution network and there will be a sufficient power conservation.

For capacity requirements and system efficiency Complex Power plays a vital role. The instantaneous power as per equation (1) can be written as

\[ p(t) = V_{rms}I_{rms}\{\cos\phi + \cos2\omega t\cos\phi - \sin2\omega t\sin\phi\} \]

(9)

\( \phi \) is Phase difference between voltage and current. We can introduce the quantities in equation (9) as following.

\[ P = V_{rms}I_{rms}\cos\phi \]  

(10)

\[ Q = V_{rms}I_{rms}\sin\phi \]  

(11)

From equations (10) and (11) we can get the instantaneous power as

\[ p(t) = p_R(t) - p_X(t) \]  

(12)

and

\[ Q = X(\omega)I^2_{rms} \]  

(13)

When we will get Q as a positive quantity the load to which the power is going to be transferred will be Inductive and if negative the load will be Capacitive. As a power Engineer this can be recognized that inductive load consume while capacitive load produce reactive power. From equations 10 and 11 the Q will be as

\[ Q = P\tan\phi = p\tan(\pm\cos^{-1}pf) \]

(14)

Positive is used when load is inductive with pf lagging and negative when load is capacitive with pf leading. For efficient power transmission the pf is closer to unity. The specifications are given in terms of load Impedance. So in a given industrial/household load \( Z = R + JX \). In this case we are interested to find out \( X_p \). Which means that when it is connected in parallel with \( Z \), the power factor of the composite load will be raised to a new power factor. This way we obtain the required reactance by the following equations as

\[ X_p = \frac{R^2 + X^2}{R\tan(\pm\cos^{-1}pf_{new}) - X} \]

(15)

Positive sign is if \( pf_{new} \) is lagging and –sign if leading. If in above equation multiply by \( I^2_{rms} \), and
placing we will get the equation given below

$$X_p = \frac{V_{rms}^2}{p} \tan(\pm \cos^{-1}(pf_{new}) - \tan(\pm \cos^{-1}(pf_{old}))$$

(16)

Here P is the average power and \( pf_{old} \), \( pf_{new} \) are the power factors before and after corrections. Let us consider Example

Suppose \( \phi = 45^\circ \) and then \( pf = \cos 45^\circ = 1/\sqrt{2} = 0.707 \). Using this value in the equation below

$$I_{rms} = \frac{P}{V_{rms} \times pf}$$

(17)

We obtain \( I_{rms} \) which shows that current capacity of the system have to be increased by 41.4% to accommodate the reactive power exchanges which are present with the low power factor. Moreover if we consider the resistance of the power line as

$$R_{line(pf=0.707)} = \sqrt{2} I_{rms(pf=1)} = 1.414 I_{rms(pf=1)}$$

(18)

$$R_{line} I_{rms}^2 (pf=0.707) = 2 \times R_{line} I_{rms}^2 (pf=1)$$

(19)

This shows that line power losses are double because of the reactive exchanges. The possible Capacitor locations for power factor improvements are shown in figure 1 below.

![Figure 1. Possible capacitor locations for power factor improvements.](image)

4. Results and conclusions

As shown in figure 1 a Hampden type 3-phase motor, 220V, 1.4 Ampere, 1725 RPM and 1/3 HP motor is used. For power factor correction, the Inductor or Capacitor Banks are used. Three basic power factor correction banks in series and parallel with the grid lines respectively. Inductor bank is connected in series with the line terminals and hence it get small current ripples with its characteristic easier to implement. This series Inductor forces the current to have same shape as the input voltage is.
This gives the less input impedance to the incoming power because of the improvement in the Power factor.

To understand how the input voltage influence the Power Factor we have to analyze the Harmonics. The Harmonics of the input voltage create 90˚ lead in the corresponding Harmonic at the Inductor current as shown in figure 2 below.

![Figure 2. Harmonics of input voltages.](image)

When the capacitors are added to proper location to an Industry the resonance current is increased more than twice as shown in the figure 3 below.

![Figure 3. Magnification of harmonic current when standard capacitors are added.](image)
Table 1. Harmonic components in input voltage.

| n | 2    | 4    | 6    | 8    | 10   | 12   |
|---|------|------|------|------|------|------|
| Vrms | 100  | 60   | 12   | 8    | 4    | 3    | 2    |
|     | 250  | 150  | 50   | 30   | 20   | 10   | 6    |

Table above shows that input voltage consists of large number of harmonics. The higher the voltage the more the line current is influenced and hence the power factor.

Figure 4 below shows efficiency of the motor is increased when the power factor is improved. In the beginning the efficiency increased sharply.

![Figure 4](image)

**Figure 4.** Efficiency increased with the improvement in the power Factor.

For power factor improvement of our system Relays are used Relay coils are energized from SATEC meter when the power factor drops below a certain point

- Line current is also monitored to ensure no switching occurs when no load is present
- Capacitors are added to the circuit in parallel with the motor
- Placed in parallel to maintain the same line voltages into the motor

Power factor can be varied over any desired range to avoid electric utility company charges Project system maintains a power factor of above 0.98. The complete sequence is shown in the flow chart below
Figure 5. Sequence of improving power factor.

Figure 6 below shows the relation between source power factor and the motor power factor and in turn the efficiency of the motor.
Figure 6. Motor power factor increasing constantly when the source power factor is unity.

Figure 7 below shows that maximum power will be transferred when power factor will be equal to unity and hence the reverse current flow will be equal to zero as indicated by red line.

Figure 7. Unity power factor restrict zero reverse current flow to power transmission lines.
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