

Power Quality, Energy Conservation and the Environment

Introduction

This article outlines the issues relating to Power Quality and their impact on Energy Conservation. Further, the important linkage between Energy Conservation and the environment are also outlined particularly in the context of climate change, the UNFCCC and the carbon dioxide emission issue.

Power Quality

The term Power Quality means different things to different people.

It is therefore necessary that the subject of Power Quality should be addressed as understood within the scope of the relevant international IEC standards. For ex: IEC 61000 -2-4 lays down what is considered as Power Quality criteria with regard to certain types of electrical power distribution systems.

According to this approach Power Quality may be co-related with four topics.

- Voltage
- Frequency
- Harmonic distortion
- Power Factor

Voltage

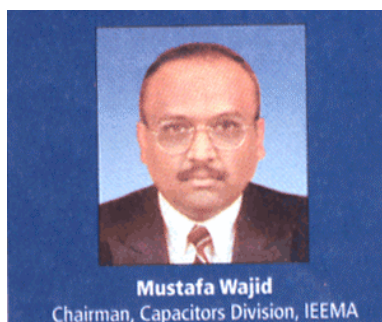
In the Indian context this issue must be viewed from two different directions. The first direction is variation in supply voltage due to the factors arising from transmission and distribution of power. The second direction is variation in voltage within a network due to the characteristics of the loads connected therein.

It is a well known fact in India, as well as in many other developing Countries, that the quality of voltage supplied by the utilities varies widely depending on the type of distribution network and geographical locations of such networks. The problem of voltage variation in this regard becomes more acute in the rural distribution network and in that part of the network which is considered to be the tail end segment of the grid.

To compound this problem further the voltage variation is also a function of the season of the year, for ex: rural feeders experience the lowest voltages when the drawal of power is the highest, which is invariably in a particular time of the year depending on the agricultural output/crop of that area.

Similarly on particular feeders which supply highly fluctuating loads of an industrial nature, it is common to find voltage variations beyond permissible limits.

The impact of such voltage variations is to cause higher energy consumption due to a combination of factors. Some of the important factors are



- For a given MW of power rating, the current drawn goes up inversely in proportion to the voltage. Consequently, a drop in voltage would result in increased current flowing on the network. This increased current then causes increase in I^2R losses of the network. For ex: a 20% drop in voltage would increase the losses in the network by 56%. Further, this increased current will contribute to increasing the voltage drop and thereby intensifying the problem.
- Drop in efficiency of induction motors: It is well known that a substantial part of electrical energy consumption occurs in induction motors. The characteristics of these motors are such that a drop in voltage will mean a higher energy consumption to do the same job. Hence, extra energy is consumed when there is a voltage drop on the network.
- A variety of studies has shown that the variations in voltage are a frequent occurrence in power distribution networks. The voltage drop seen in such studies could be as much as – 40% of the rated value, thereby increasing corresponding I^2R losses by 277%. This results in increased energy wastage and higher power demand from the system, i.e., the power generation equipment has to supply higher MW for the same load.

Considering that most of the power generation is heavily dependent on fossil fuels, this means that there will be a higher quantity of fuel has to be spent thereby directly increasing the amount of carbon dioxide emissions into the environment.

Frequency

While this is also an important factor, it is more stable than the voltage due to the fundamental nature of electricity generation, transmission and distribution. Frequency variations can occur, due to the load levels on the electricity supply system, for ex: a highly overloaded power system will experience a drop in frequency. Further, mismatch of frequency in different sections of a grid can cause power quality and power supply problems particularly, when it is important to have an integrated and interconnected grid. The issues relating to these topics are more relevant in the area of power system stability and load dispatch and are hence, not touched upon in this paper. Impact of this topic on Energy Conservation is less important in comparison with the other three topics stated above.

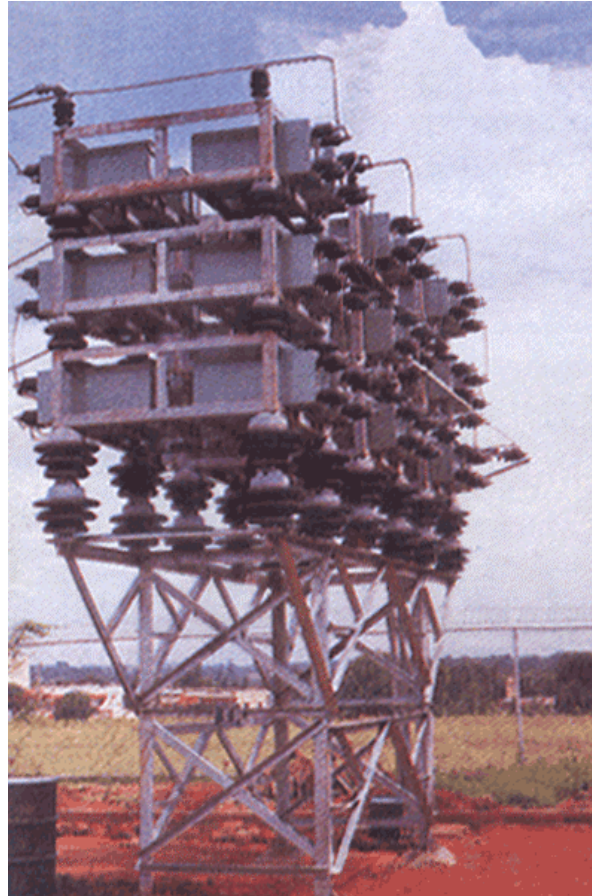
Harmonic Distortion

The problem of Harmonic distortion primarily occurs in modern electrical networks due to feedback of Harmonic currents from nonlinear loads. Harmonic Voltage distortion is created due to interaction of such Harmonic currents with source impedances. Consequently, this can be treated as a form of electrical pollution on the network.

In most part of the World, there is still a lack of clarity about the management of this pollution and hence, enforcement of pollution limits is still an unfolding scenario. This has resulted in a situation where it is not uncommon for a new consumer on the electricity grid to find that the incoming supply voltage consists of a basket of frequencies including the fundamental frequency. This is due to the pollution of the grid by other consumers. The presence of Harmonic distortion has a significant impact in increasing energy consumption. Some of the important reasons for this are listed below:

- All electromagnetic equipment such as transformers, motors etc, have two key constituents of losses namely, iron loss and copper loss. The iron loss is also a function of the power of the frequency. Consequently, presence of higher frequency components such as 5th harmonic, 7th Harmonic etc, will result in a n increase in iron losses. Hence energy consumption will go up and this is a particular importance in the distribution transformers whose All Day Efficiency could be significantly reduced because of this aspect. It is also harmful for the transformers and motors since it causes faster ageing of the insulation due to higher temperature rise in the electromagnetic core.
- The phenomena are skin effect is well known. The flow of Harmonic currents therefore, increase the I^2R losses depending on the occurrence of the skin effect. This phenomena is well

understood and cause over heating of equipment and current carrying parts thereby, increasing the amount of energy consumption for the same network load.



Power Factor

While the theoretical definition of Power factor is the ratio of active power to apparent power, it is well known that in electricity distribution systems this is measured as a ratio of active energy to apparent energy over specified time period.

The ideal power factor is unity. However, this cannot be achieved in reality due to the nature of the loads used. For ex: inductive loads, nonlinear loads etc, a lower power factor means more current drawn for the same load. This causes increase in the apparent power demand i.e. kVA demand as well as increase I^2R losses.

Consequently, more system capacity is needed to supply the same load. In other words a lower power factor results in higher energy consumption.

Further, lowering of power factor also causes a drop in voltage which then brings us back to the ill effects of voltage variation as described earlier.

Impact on the Environment

As outlined above, the combination of voltage variations, harmonic distortion and low power factor can together result in wastage of energy, increased need for resources due to higher demand from the supply system and therefore, reduced efficiency of operation.

It is important to view this phenomena in the context of electricity generation capacity and system losses.

- As on 31.03.2004 the All India Capacity for Power Generation is declared by the Ministry of Power as 1,12,058 MW.
- Of this, almost about 70% is from thermal powers plants which use fossil fuels for generating electricity.
- It is also important to remember that the PLF of thermal stations is estimated at around 72%.
- The total generation of electricity in India is estimated at about 558 billion units during the period 2003 – 2004.
- Of this, approximately 466 billion units are again from thermal power plants i.e., 83% + of the electricity generated is from this segment.
- It is also a fact that the power supply position is one of shortages both in terms of energy and demand.

While it is a complex issue to accurately estimate the total system losses, it is generally felt that this could range from 20% + of the energy generated at an overall national level. Given the fact that this estimate of losses is always a contentious and controversial subject it may not be entirely inaccurate to expect that we as a nation are wasting somewhere in the region of 100 billion units as a wastage due to inefficiencies in the system arising from the aforesaid mentioned factors of voltage variation, harmonic distortion and low power factor.

When seen in the economic context, this translates in to a very large financial figure.

Hence, the need for corrective action cannot be overstated.

However, the focus of this paper is to outline the impact on the environment and hence, the techno-economic issues relating to these energy losses are not dealt with in this article.

The use of fossil fuels to generate electrical energy means that a variety green house glasses is released into the environment.

Of these, the most important one is carbon dioxide.

The negative impact of carbon dioxide on change of climate is a topic which has been globally debated, particularly since the Rio Earth Summit in 1992.

As a result of this there is now a convention on climate change which has been agreed to in the form of “the United Nations Framework Convention on Climate Change (UNFCCC)”.

It is this convention which forms the basis for the global effort to combat and reduce global warming. The objective of this convention is

- “Stabilisation of green house glass concentrations in the atmosphere at a level which would prevent dangerous anthropogenic (i.e., caused by Human activities) interference with the climate system. Such a level should be achieved within a time frame sufficient to allow eco systems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner”.

It can be easily seen that the objective of the UNFCCC is in line with our national priorities.

It is expected that the emissions of green house gasses has already crossed 20 billion tons per year at a global level.

In this context, the technical reality is that in a fossil fuel plant the amount of carbon dioxide emissions for per kWh generated could range from about 0.6 kilo gms to 0.8 kilo gms. This figure is however a function

of the age of the plant, the type of fuel used as well as the mitigation methods used for reducing emissions. Consequently, this figure could also be higher particularly in older plants.

The scope for energy saving by applying the appropriate methods such as, Reactive Power Compensation, Harmonic filtering etc, is quite high. In our National context it is believed that a well coordinated and implemented program could save 50 billion units + of energy per year.

If we convert this saving into carbon dioxide emissions, it would translate into a minimum of 30 million tons of carbon dioxide emissions per year. This is a conservative estimate and the actual benefits could be significantly higher.

The positive impact on the environment and benefits arising thereof to the nation as a whole would be not only significant but an important tool for our progress in the competitive global environment.

The Role of Power Capacitors in Saving Energy and Improving the Environment

As outlined above the problems of voltage drops are primarily due to excessive flow of Reactive Power in the network. The use of Capacitor banks to carry out shunt compensation as well as Series compensation would go a long way in improving the voltage profile and making it more consistent.

Similarly, if all consumers of electricity can improve their power factor closer to unity, the release of system capacity and reduction in losses would be very significant. Power Capacitors are the most well proven and cost effective devices to achieve this objective.

As regards Harmonic distortion it is possible to reduce the same by the use of passive and active harmonic filters. Power capacitors of various types form an essential constituent of such harmonic filtering devices.

Conclusion

The power Quality issues such as voltage variations, Harmonic distortions and power factor combine together to reduce the overall operating efficiency of electrical networks and also result in increased power supply demand and unnecessary wastage of energy.

Considering the fact that a vast majority of energy generated in our country is from fossil fuels, this wastage of energy means that harmful green house gases are emitted and create a negative impact on climate change.

The use of Power Capacitor can go a long way in reducing energy losses and contribute to reduction of such greenhouse gases.

Reference Book:

IEEMA Journal (Energy Conservation Week 14-21 Dec., 2004)
Energy Conservation Special Issue