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Power Quality Analysis of Indo Japanese Industrial Park

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Abstract

The increased requirements on supervision, control, and performance in modern power systems make power quality monitoring a common practice for utilities. Large databases are created and automatic processing of the data is required for fast and effective use of the available information. This paper is a treatment of the concerns being addressed especially as they relate to new technologies of energy control, energy conservation, and modern power conversion. This paper illustrates the power quality analysis of Indo Japanese Industrial Park. The study is expected to yield recommendatory suggestions for specific usages and their merits and difficulties.

Introduction

Reliability and quality of power has become one of the most critical issues facing business today. For critical loads, such as transformers, motors, computer hardware components, instrumentation and control systems and protective devices, anything less than high quality power and reliability means possible equipment malfunction and system downtime[1-5]. All the sources of electrical energy are basically designed on the consumption of balanced three phase loads at fundamental frequency (50 Hz). Therefore the performance of the equipments and system elements to other frequencies has not been given great importance[6-8]. The main objective of the analysis is the identification of the event origin (event classification). It is shown that event classification can be achieved by considering the voltage magnitude of the three phases. Emphasis is given on fault-induced events that present different stages of magnitude and transformer saturation dips.

Power quality monitoring objectives

The term power quality refers to a wide variety of electromagnetic phenomena that characterize the voltage and current at a given time and at a given location on the power system. A power system event is a recorded (or observed) current or voltage excursion outside the predetermined monitoring equipment thresholds. A power disturbance is a recorded (or observed) current or voltage excursion (event) which results in an undesirable reaction in the electrical environment or electronic equipment or systems. The term power problem refers to a set of disturbances or conditions that produce undesirable results for equipment, systems or a facility. The term event is typically used to describe significant and sudden deviations of voltage or current from its normal or ideal waveform. The increased requirements on supervision, control, and performance in modern power systems make power quality monitoring a common practice for utilities. Power quality monitoring is necessary to characterize electromagnetic phenomena at a particular location of the network. The objective of monitoring can be[9]:

- The diagnosis of incompatibilities of the power system with the load.
- The evaluation of the electric environment at a part of the system in order to refine modeling techniques or to develop a power quality baseline.
- The prediction of future performance of load equipment or power quality mitigating devices.

Power Quality Problems

Any power problem that results in failure or disoperation of customer equipment, manifests itself as an economic burden to the user, or produces negative impacts on the environment. The power issues which mainly degrade power quality include[10, 11]:

- Power Factor
- Harmonic Distortion
- Voltage Transients
- Voltage Sags or Dips
- Voltage Swells
- Frequency Unbalancing

Power Factor

The power factor of an AC electric power system is defined as the ratio of the real power flowing to the load to the apparent power in the circuit. Real power is the capacity of the circuit for performing work in a particular time. Apparent power is the product of the current and voltage of the circuit. In an electric power system, a load with a low power factor draws more current than a load with a high power factor for the same amount of useful power transferred. The higher currents increase the energy lost in the distribution system, and require larger wires and other equipment. Because of the costs of larger equipment and wasted energy, electrical utilities will usually charge a higher cost to industrial or commercial customers where there is a low power factor.

Harmonic Distortion

The ac power system harmonic problems are mainly due to the substantial increase of non-linear loads due to technological advances, such as the use of power electronics circuits and devices, in ac/dc transmission links, or loads in the control of power systems using power electronic or microprocessor controllers. Such equipment creates load-generated harmonics throughout the system. The significant harmonics (above the fundamental, i.e., the first harmonic) are usually the 3rd, 5th, and 7th multiples of 50/60 Hz, so that the frequencies of interest in harmonic studies are in the low audible range. The most damaging frequencies to power devices and machines appear to be the lower-below 5 KHz-frequency range.

Voltage Transients

A transient voltage is a time varying voltage value. Transient says that the voltage value changes, especially from a steady state, to a new value, then back again. These are faults which cause the voltage of the power supply to go outside normal limits for a period of time. Many transients are capable of causing immediate equipment failures. But, most of the time they cause minor damage to semiconductors, degrading their performance. This damage is cumulative and eventually reaches a point where sudden failure of the component results.

Voltage Sags or Dips

Voltage sags -- or dips which are the same thing -- are brief reductions in voltage, typically lasting from a cycle to a second or so, or tens of milliseconds to hundreds of milliseconds. Voltage swells are brief increases in voltage over the same time range. Voltage sags are caused by abrupt increases in loads such as short circuits or faults, motors starting, or electric heaters turning on, or they are caused by abrupt increases in source impedance, typically caused by a loose connection.

Voltage Swells

Voltage swells are almost always caused by an abrupt reduction in load on a circuit with a poor or damaged voltage regulator, although they can also be caused by a damaged or loose neutral connection. Voltage Swell is defined by IEEE 1159 as the increase in the RMS voltage level to 110% - 180% of nominal, at the power frequency for durations of ½ cycle to one (1) minute. It is classified as a short duration voltage variation phenomena, which is one of the general categories of power quality problems mentioned in the second post of the power quality basics series of this site. Voltage swell is basically the opposite of voltage sag or dip. Despite of these common terms described here, there are also some extra parameters which degrade the power quality. Our main work is to identify study and find the new ways to suppress and reduce them. The power quality analysis of Indo Japanese Industrial Park is a small step towards it. Indo Japanese Industrial park is powered by 220KV GSS established in the campus. The data to shown below resembles to that GSS.

Power Quality Analysis

In this paper it is explained about the power quality problems, its causes and effects previously. The analysis was done using the three phase power quality analyzer in the technical college. This 3- phase power quality measurement not only lead to the analysis of frequency balancing, crest factor, fundamental varying voltages, but also helps in analyzing the harmonics up to 11th term. The measurement was done for seventy five hours continuously and the observed data can be studied by considering the figures and tables shown below.

Table1: observed voltage, avg. frequency, THD V.

Phase Voltage	fundamental Average (V)	Average Frequency (Hz)	THD V Average
L1	238.922	49.73	1.404
L2	239.078		1.674
L3	240.213		1.480
N	0.735		142.87

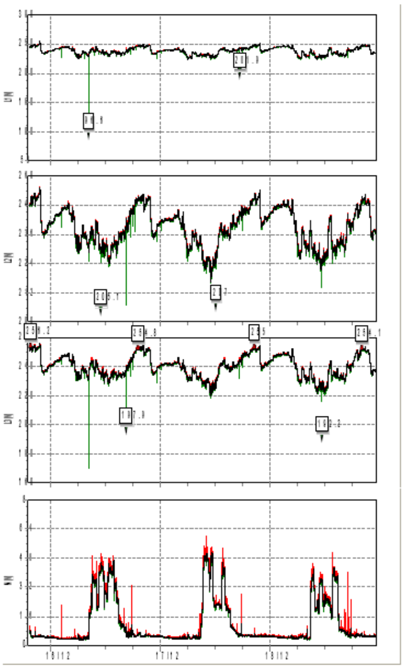

Figure 1. Waveform showing fundamental voltage.

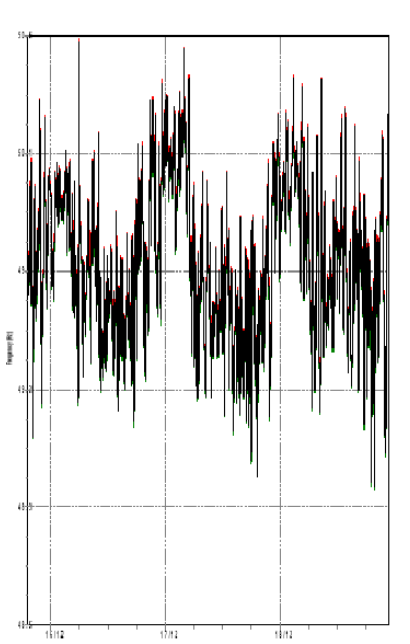

Figure 2: Average Frequency Unbalancing.

The above waveform shows the fundamental voltage present in the park. The average frequency unbalancing is found to be 49.73Hz and the concerned graph was found to be as shown below in Fig 2. Despite of the combine line voltage shown in Fig 1, the individual line voltage graph gives a sound knowledge of the voltages present and varying at the time under supervision. The individual line voltages are shown in Fig 3 to Fig 6 respectively. These graphs represent to the individual voltage variation in seventy five hours at the time of monitoring the power quality in Indo Japanese Industrial Park. It can be clearly observed that the Line-1, Line-2, Line-3, Line-N has voltage variation from 224-258V, 216-257V, 220-257V, 0-5V respectively. The average voltage present during the whole duration of monitoring is shown in table 1 and is followed by table2, shown below.

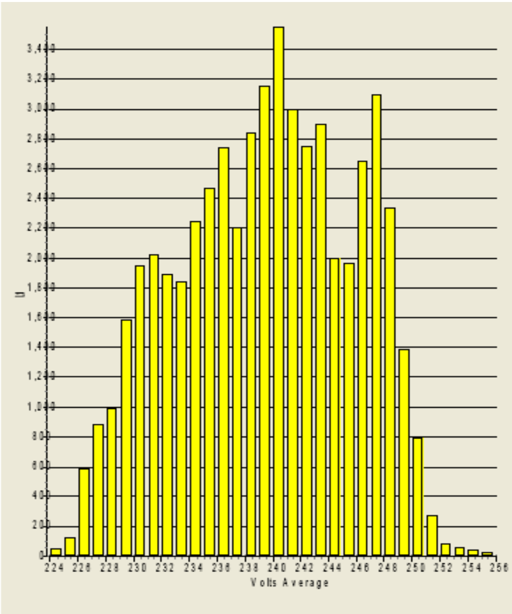

Fig3. Line 1 voltages

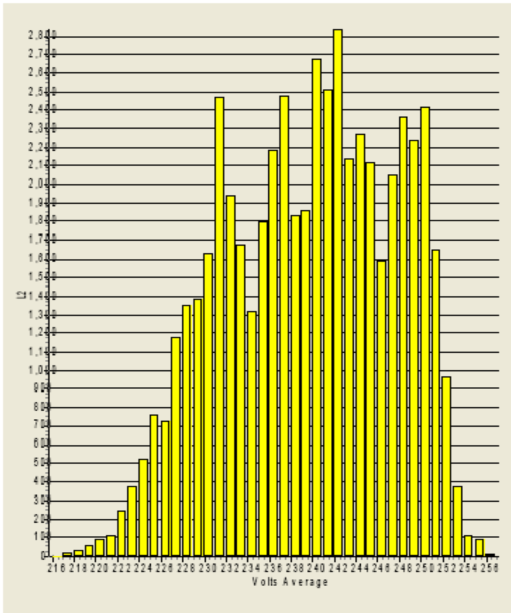

Fig4. Line 2 voltages

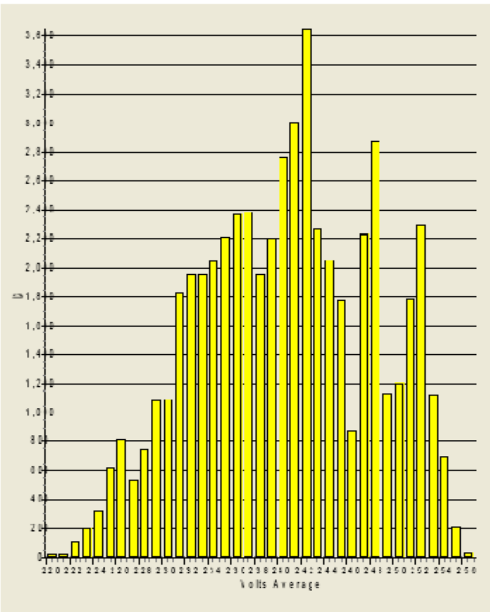

Fig5. Line 3 voltages

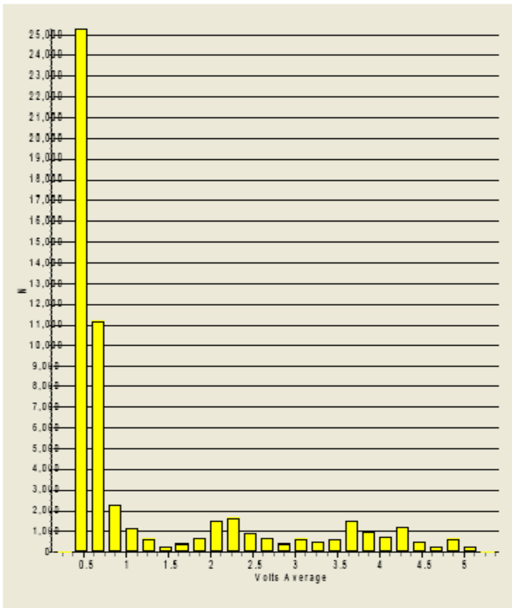

Fig6. Line N voltage

Table 2: Data observed for Crest Factor and avg. line voltage

Phase	Voltage fundamental Crest Factor	Average line Voltage (V)
L1	1.402	238.95
L2	1.395	239.12
L3	1.409	240.24
N	266.95	1.145

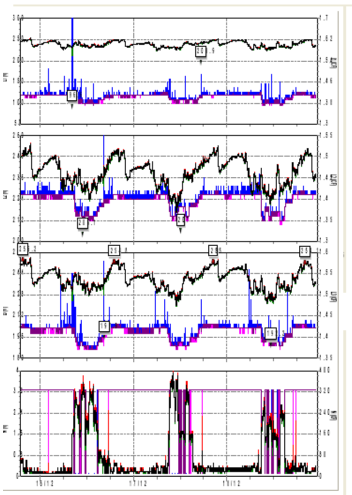

Fig.7 Crest Factor

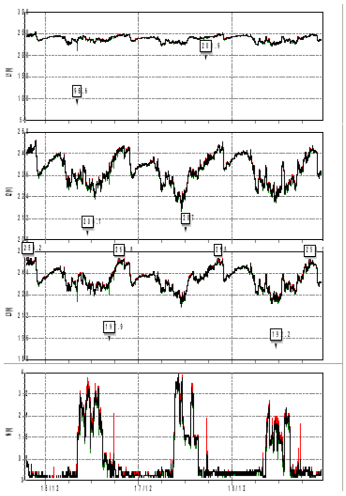

Fig.8 Graph for V&I negative

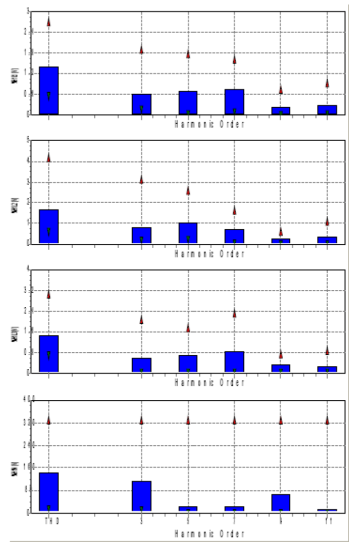

Fig.9 Graph re[resenting volts harmonics up to 9th level

Table 3: Values observed up to 9th harmonics.

Phase	Volts Harmonics 3rd	Volts Harmonics 5th	Volts Harmonics 7th	Volts Harmonics 9th
L1	0.618	0.692	0.740	0.232
L2	0.770	1.087	0.698	0.252
L3	0.588	0.698	0.583	0.356
N	112.871	22.665	22.420	68.559

The Fig 10 illustrated diagram gives the idea of the power quality measures. These results were not found to be theoretically correct. Our research is underway to find a new and effective method for minimizing all the losses, increasing the power quality parameters.

Proposed Method for Accurate Calculation for Power Quality Parameters.
Series compensation is a means of improving the performance of transmission line as well as distribution circuits. The application of series compensation makes the line or circuit appear electrically shortly because it reduces the total effective reactance. A new series compensation technique is proposed, a series capacitor is used for reactive power compensation in transmission line. Here a method is suggested for maximizing the net saving due to power factor correction at the load sides and at the receiving end of power. By using LC compensator a concern can also compensate reactive power. Basic circuit of single line diagram of power system is presented here.

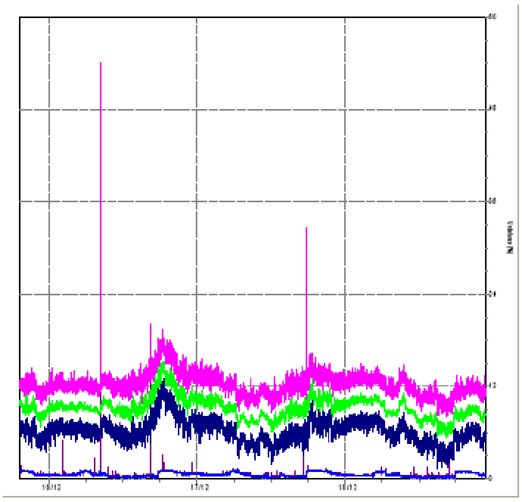

Fig10.Unbalanced V&I Negative

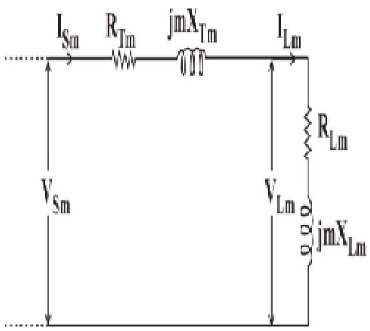

Fig. 12: Single line diagram of power system

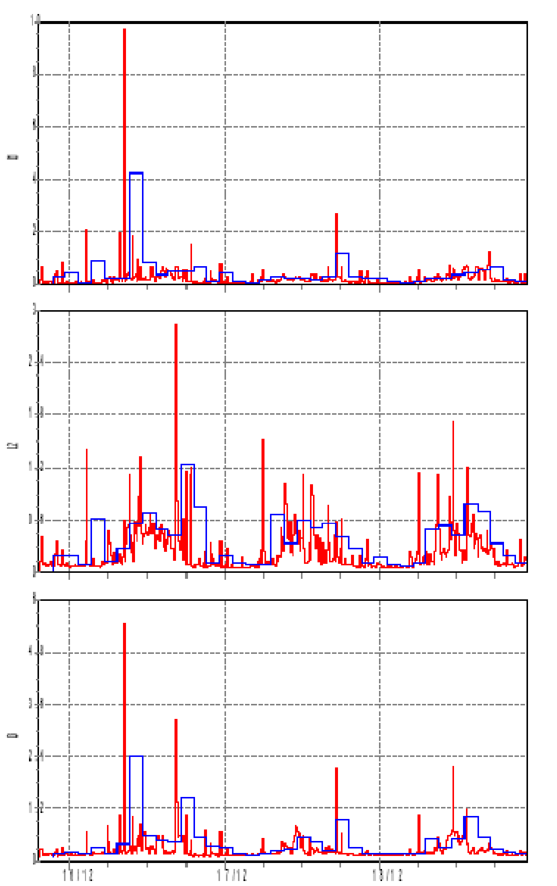

Fig11. Flicker present in line voltages

From above Fig 12
ZTm = RTm + jmXTm and ZLm = RLm + jmXLm
ZTm and ZLm are parallel to each other Therefore

$$Z_{TLm} = \frac{Z_{Tm} Z_{Lm}}{Z_{Tm} + Z_{Lm}} \qquad R_{TLm} = \left(R_{Tm} \; R_{Lm}^{2} \; m \right)$$

$$X_{TLm} = \left(m X_{Tm} \; R_{Lm} \; R_{T} \right); \qquad Z_{TLm} = \frac{R_{TLm} + jX_{T}}{Z_{Tm} + Z_{Lm}}$$

We know that Series capacitors are also used for control of voltage in power system. The series capacitors also provide reactive power compensation. So, now system is compensated by series capacitor and LC compensation as shown in Fig 13. Further the final calculated value for efficiency, power factor, and power loss is shown which is depicted from Fig 13.

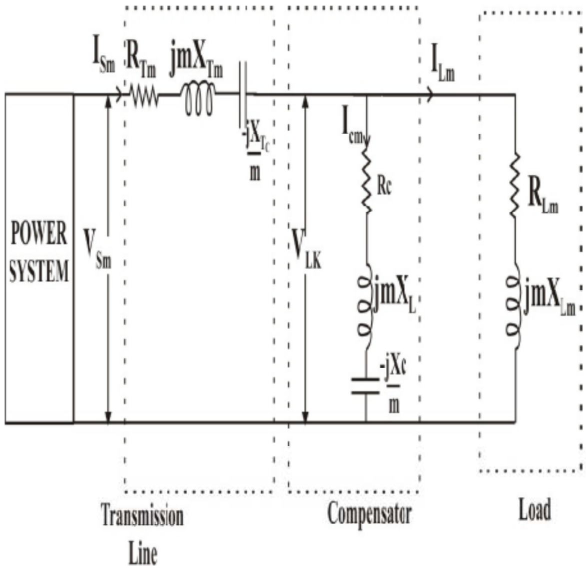

Figure 13: Single line circuit of power system with series capacitor and LC compensation

From Fig 13 it is clear that ZCm is parallel to ZLm Therefore,

$$Z_{CLm} = \frac{Z_{Cm} Z_{Lm}}{Z_{Cm} + Z_{L}} \qquad Z_{Lm} = R_{Lm}$$

$$Z_{CLm} = \frac{\left\{ R_{C} + j\left(mX_{L} \frac{X_{C}}{m} \right) \right\} R_{Lm} \; jm}{Z_{Cm} + Z_{Lm}}$$

Using the above defined equation, the values has been calculated and found to be very satisfactory. The graph has also been plotted to give an illustrative idea of the values that has been calculated using this equation. The brief summary of all the values are given here in tabular form shown in table1. It comprises of XL, XC, P.F, IS, power Loss, Efficiency and VTHD. Using this previous discussed equations for power factor, power loss and efficiency, a java based computational program is developed for better and most efficient and accurate calculation of power factor, power loss, efficiency and etc. Fig14 shows some of the snapshots of that java based application software. Fig 14 shows the main dialog box where provision for providing the inputs like XL XC, RL, RT and etc is given, finally after entering the input values, calculate button is to be clicked for getting the output like power factor, power loss, efficiency etc. Fig15 and Fig16 shows the output dialog box. This application software consists of earlier discussed equation in form a java program. The values are summarizes and shown in table4.

Table 5. Values calculated sung the previous equations.

X_L	X_C	P.F.	IS (Amp)	POWER LOSS (KW)	Efficiency (%)	VTHD
0.30	1.00	0.2497	3132.021	113.20	95.163	0.0364
0.34	1.20	0.3185	2355.478	64.027	97.012	0.0389
0.38	1.40	0.3906	1866.376	40.197	98.012	0.0409
0.42	1.60	0.4648	1536.693	27.250	98.605	0.0425
0.46	1.80	0.5390	1304.993	19.652	98.964	0.0439
0.50	2.00	0.6124	1137.992	14.944	99.195	0.0452
0.54	2.20	0.7229	955.143	10.527	99.414	0.0464
0.58	2.40	0.7829	881.462	8.966	99.495	0.0470
0.62	2.60	0.8354	827.563	7.902	99.537	0.0478
0.66	2.80	0.8796	788.401	7.172	99.595	0.0484
0.70	3.00	0.9156	760.409	6.672	99.610	0.0490
0.74	3.20	0.9579	731.59	6.170	99.642	0.0496
0.78	3.40	0.9753	721.528	6.007	99.653	0.0501
0.82	3.60	0.9873	715.392	5.906	99.654	0.0506
0.86	3.80	0.9949	712.193	5.853	99.655	0.0510

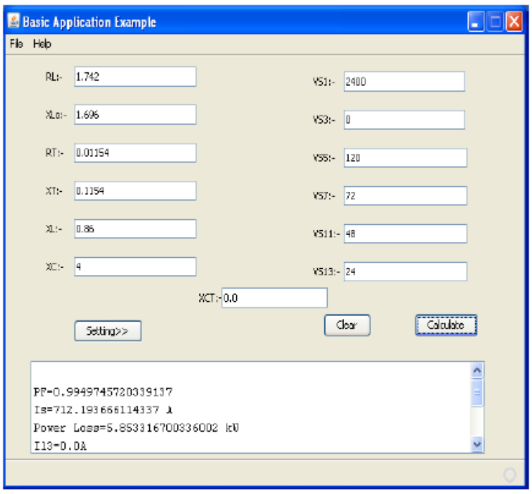

Fig. 14 Main Diolog box showing input and output

Fig15. Output dialog box showing VTHD parameter

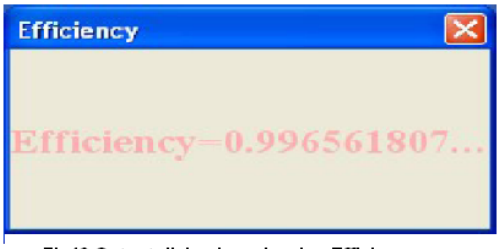

Fig16 Output dialog box showing Efficiency

Considering the parameters given in tabular form shown in table 5, the following graphs are plotted.

From the Fig 17 we conclude that the power factor increase tends up to unity as the value of XL & XC is being altered. Here the final value of Power factor rises till the 0.9995. In The next figure will see that the same case happens for the graph plot of XL & XC and Power loss. Here the power loss starts decreasing with the increase in value of XL & XC . Initial the value of power loss was 113.202KW and finally for the last value the power loss decreases and come to the point of 5.853.B Same thing happens in case of efficiency, the efficiency starts increasing when the values of XL & XC are altered and is found to be 99.65% for the value of XL & XC to be 086 & 0.4 respectively. It can easily be observed from the Fig18. Similarly the next graph plot (Fig 19) shows the variation of the VTHD and Efficiency in respect to the value of XL XC.

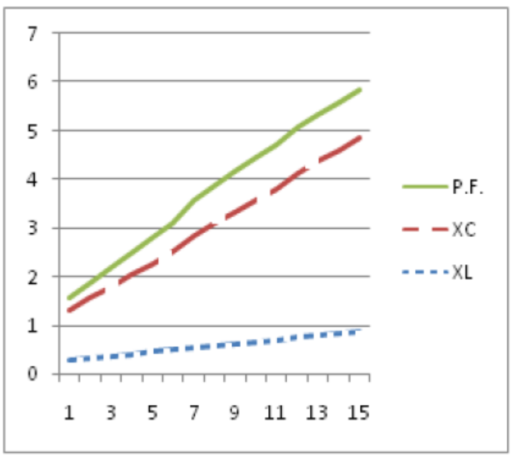

Fig 17 Graph plot of XL XC and PF

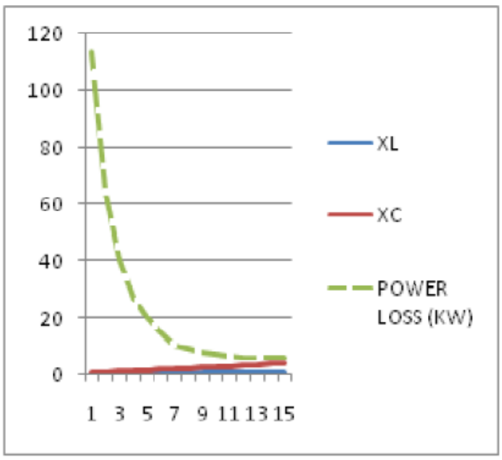

Fig 18 Graph plot of XL XC and Power loss

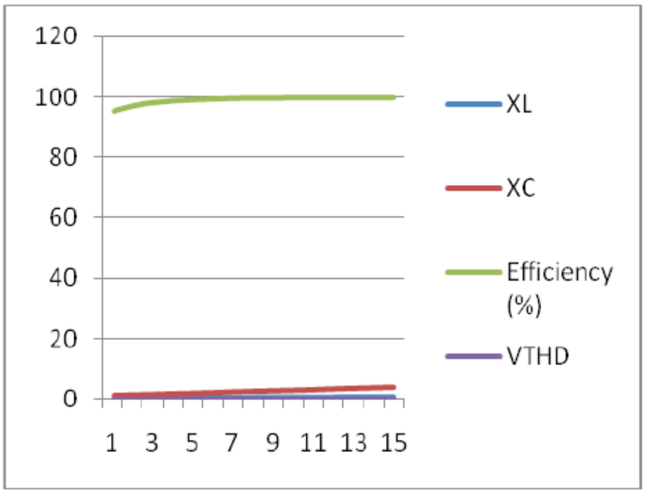

Fig 19 Graph plot of XL XC and VTHD and Efficiency

Conclusions

This work is designed to give the reader a comprehensive understanding of the Optimal Reactive power Compensation. This method attempts to optimize power quality, system power factor and to minimize system losses. This work also gives the idea about the development of software for most efficient and accurate calculation of power factor through a computational program based on JAVA Enterprises. The results found this way is found to be very satisfactory. Efforts are presently underway to develop the new and better ideas for more accurately calculation of power quality parameters.

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