POWER QUALITY AND RELIABILITY PROBLEMS - A PRACTICAL APPROACH

Prof. (Mrs.) S.A.Kanitkar, A.R. Chudasama, ShailendraSingh Dungar, Vishant Patel, Lakulish Bhatt, Sameer Rohadia.
Department of Electrical Engineering . Faculty of Technology and Engineering. The M.S.University of Baroda.
Vadodara -390 001. Gujarat, India.

B.S.Vaidya. Consultant. 3, Matruka Soc. Subhanpura. Vadodara, Gujarat, India.

Abstract :

The paper focuses on the application of developments in the field of power quality. The paper is an outcome of an extensive survey, wherein industries were specifically probed about power disturbances and their effect. Based on the data available from the survey, a power system ,incorporating power quality solutions, is designed for six industries, which are feasible for accepting 'Custom Power'.

Keywords :

Power Quality, Survey, System Design.

1.0 INTRODUCTION :

The astronomical advancement in technology and engineering has propelled the industries to become complex and diversified in their functions. The pressing need for higher efficiency and productivity has encouraged the development of variety of industrial equipments. The meteoric rise of semiconductor technology has enabled the prolific use of sensitive technology has enabled the prolific use of sensitive power electronic equipment in process control and automation. With the industry on its dream run towards automation, one bug that seems sure to put the brakes on is - 'POWER QUALITY', precisely the lack of it.

In recent years, both industrial and commercial customers of utilities have reported a rising tide of misadventures related to power quality. At fault, there are voltage sags, voltage swells, undervoltages, overvoltages, impulsive transients, oscillatory transients, momentary interruptions, harmonic distortion, voltage modulation, voltage flicker, waveform notching, electrical noise, phase voltage and phase angle unbalance, frequency deviations and outage or sustained interruptions, that have always existed on utility systems.

It is not that the utilities are producing power of quality way back in the century, instead in most cases they are supplying as good or far better quality power today. Rather the same electrical environment is too uneven for the sensitive microprocessor and power electronic equipment being installed these days to control assembly lines, to automate office work and to enhance life at home. So, the electrical utilities need to ask what the present state of affairs is, for they cannot implement better services, until they have determined existing levels of power quality. Premium power cannot be offered to customers unless this baseline is known, nor can this knowledge be obtained without wide scale power quality monitoring projects.

In short, collecting the statistics for phenomena that have been neglected for decades is the first step to a redefinition of electric power reliability. In accordance with this objective, a survey was conducted to determine the existing state of power disturbances in different types of industries and the results were used to simulate a network of industries wherein, solutions were suggested to improve power quality and reliability of the network.

2.0 SURVEY FOR COLLECTING POWER QUALITY DATA - PREPARATION , EXECUTION & RESULTS

2.1 Field Of Survey :

Industries located in the industrial estate of the Gujarat Industrial Development Corporation around Halol (nearly 40 kms from Vadodara city of Gujarat State, India) was selected as the field for survey for collecting power quality data. The selection of field was based on the variety of industries available for analysis viz. Ceramic, chemical, engineering, industrial gases, metallurgical, pesticides, plastic, pharmaceuticals , cement, agro, rubber etc.

2.2 Survey Data :

The face-to-face survey of selected industries was carried out with the help of a questionnaire wherein the industries were probed about (a) The type,capacity & name of product. (b) The maximum & minimum loads (daily load variations) of the industries. (c) Nature of loads.(d) Number of working days per year. (e) Details of Annual shutdown. (f) No. of interruptions/month. (g) Nature of interruptions. (h) Estimated production losses. (i) Effect of varying frequency on the process. (j) Effect of varying voltage on the process. (k) Self - generation details (l) Extra equipment installed for maintaining power quality & reliability. (m) Their perception about existing quality of power supply.

2.3 Survey Results :

On assimilation of survey data, the effect of poor power quality on various industries was brought out which is summarized as under :-

1. **Metallurgical industry** : Fatal accident did occur in one such industry due to power failure. After a power failure for longer duration during melting, furnace is required to cool down & entire metal is allowed to solidify. During restart, if top metal solidifies & metal below the crest is still molten , there can be splash of metal. So, power interruption results into loss of production & increases energy consumption per ton of melt.

2. **Ceramic industry** :- Ceramic bodies require right instant of firing for long hours. Voltage fluctuations may trip any of the ancillary motors & ultimately trip the kiln. Firing of kiln needs interruption free supply. There is a heavy production loss due to it. During forming process, ceramic body is formed with sharp knives. Any interruption results into the deformation and damage to ceramic bodies.

3. **Industrial Gases** :- For cryogenic process, any interruption due to variation of frequency/voltage results in tripping of the system. Thus, for restart, half-an-hour cooling-in period is essential & subsequent start takes another half-an-hour to start production.

4. **Chemical & Rubber industry** :- They use variable speed drives for process controls. Frequency fluctuations causes process interruptions. Restart involves resynchronization of all drives, which causes delays & loss of production.

5. **Engineering & Metal Forming industries** :- Some industries use electromagnets for lifting metal parts. Voltage fluctuations may result into dropping of metal components, thereby causing injuries.

6. **Plastic Industry** :- Plastic injection molding plants can be specially vulnerable to interruptions. These plants frequently employ assembly lines that depend upon the smooth transition of the unfinished plastic from machine to machine during processing. If one component of assembly line shuts down because of voltage interruption, then the plastic may clog in machines behind the shut-down point. If the plastic cools, it may even be necessary to use hammer to remove it. Thus, it may require quite a long time to restore full production after an interruption as short as 0.5 second.

7. **Interruptions** :- Number of interruptions during a month, on an average, by all industries , are 10 to 12.

8. **Back-up Power supply** :- Some industries have gone for wind power to overcome the power supply demand restrictions which can be as high as 30%. However, majority of industries have installed Diesel generator sets.

As things stand, businesses tend to install their own; relatively common surge suppressors (to prevent damage to equipment from overvoltages), uninterruptible power supplies (to protect specific critical loads). alternative feeders with mechanical transfer switches & standby power generators, which are a sizable investment and yet not wholly a satisfactory solution. They incur high capital cost & also result in energy losses as high as 20% in some instances. These expedients tend to evolve out of frustrating experiences, rather than starting out as part of a well designed solution.

So, it is needed to shift the focus from customer side solutions to utility side when it comes to large power users involved in automated production. 'Custom Power', a concept originated by Dr. Narain Hingorani, describes the value added power that electric utilities and other service providers will offer their customers in future. The improved level of reliability of this power, in terms of reduced interruptions and less variations, will stem from an integrated solution to present problems of which, a prominent feature will be the application of power electronics controllers to utility distribution systems and/or at supply end of many industrial and commercial customers and industrial parks. For this purpose, it was decided to carry out a feasibility study to supply 'Custom Power' to six surveyed industries varying in product, process and nature of load. It was started from deciding the capacity of generating/switching station, its location and design of an appropriate network were covered under the solution. These industries have shown a definite preference for good quality power and considering their problems and production losses, they shall appreciate solutions offered for supplying continuous and quality power.

3.0 SYSTEM DESIGN

3.1 Deciding The MVA Capacity Of Generating /Switching Station :

The total MVA demand of the selected industries is 34.6 MVA. The individual load values incorporate the increase in load in few years. They are approximately 10% to 25% depending on expansion plans of the selected industries. Considering a capacity factor of 0.865, the capacity of generating / switching station is kept at 40 MVA. The generation is at 11 kV.

3.2 Location Of Generating/Switching Station :

In a green field situation, the location of generating/switching station for these industries is calculated by the centre of gravity method.

- The x co-ordinate of the centre of gravity of the given loads is given by :

$$X = \frac{\Sigma x Q}{\Sigma Q}$$

- The y co-ordinate of the centre of gravity of the given loads is given by :

$$Y = \frac{\Sigma y Q}{\Sigma Q}$$

where Q is the demand in kVA.

The location of generating/switching station is important from the point of view of future extension of network and superimposition of higher voltage. The location is influenced by cost of land, distance from residential areas, transportation facilities for fuel, topographical conditions and political implications.

3.3 Choice Of System Voltage :-

The system voltage influences power quality to a considerable extent with respect to power losses. Table - I gives approximate percentage values per maximum feeder lengths for a given load & the power losses and construction cost for different voltage levels compared to an 11 kV feeder based on the same conductor cross-sectional area.

Table - I

Voltage (kV)	Feeder Length (%)	Power Losses per Km (%)	Capital Cost per Km(%)
6.6	41	278	93
11	100	100	100
20	331	30	112
33	991	11	131

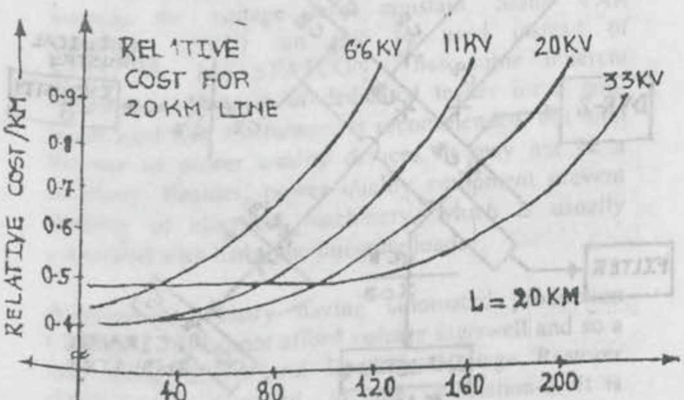
Thus, with higher system voltage.

(1) Load carrying capacity is considerably increased for small increase in capital cost, which is itself offset by reduced power losses.

(2) Early replacement of conductors is eliminated and networks retain their original configuration for long.

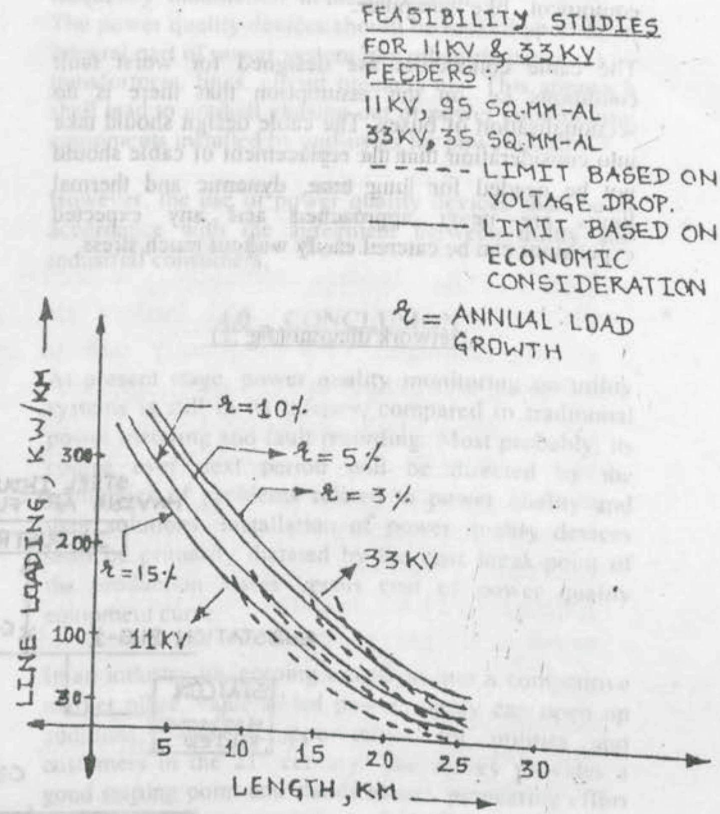
(3) Higher voltage levels leads to a higher percentage per unit length for a given loading, and thus, longer feeder lengths are possible without using booster transformers or capacitors.

The following graphs indicate the advantage for opting for higher voltage levels.



Graph - I

Graph - I indicates that, based on 20 km line, 33 kV is cheaper than 20 kV for line loading above 100 kW/km.



Graph - II

Graph - II shows the profitability of a 33 kV system, compared with an 11 kV system, its sensitivity to the load density, the average length of feeders and the estimated annual load growth. So, for the given sample network the transmission voltage of 33 kV was selected.

3.4 Busbar Arrangement :-

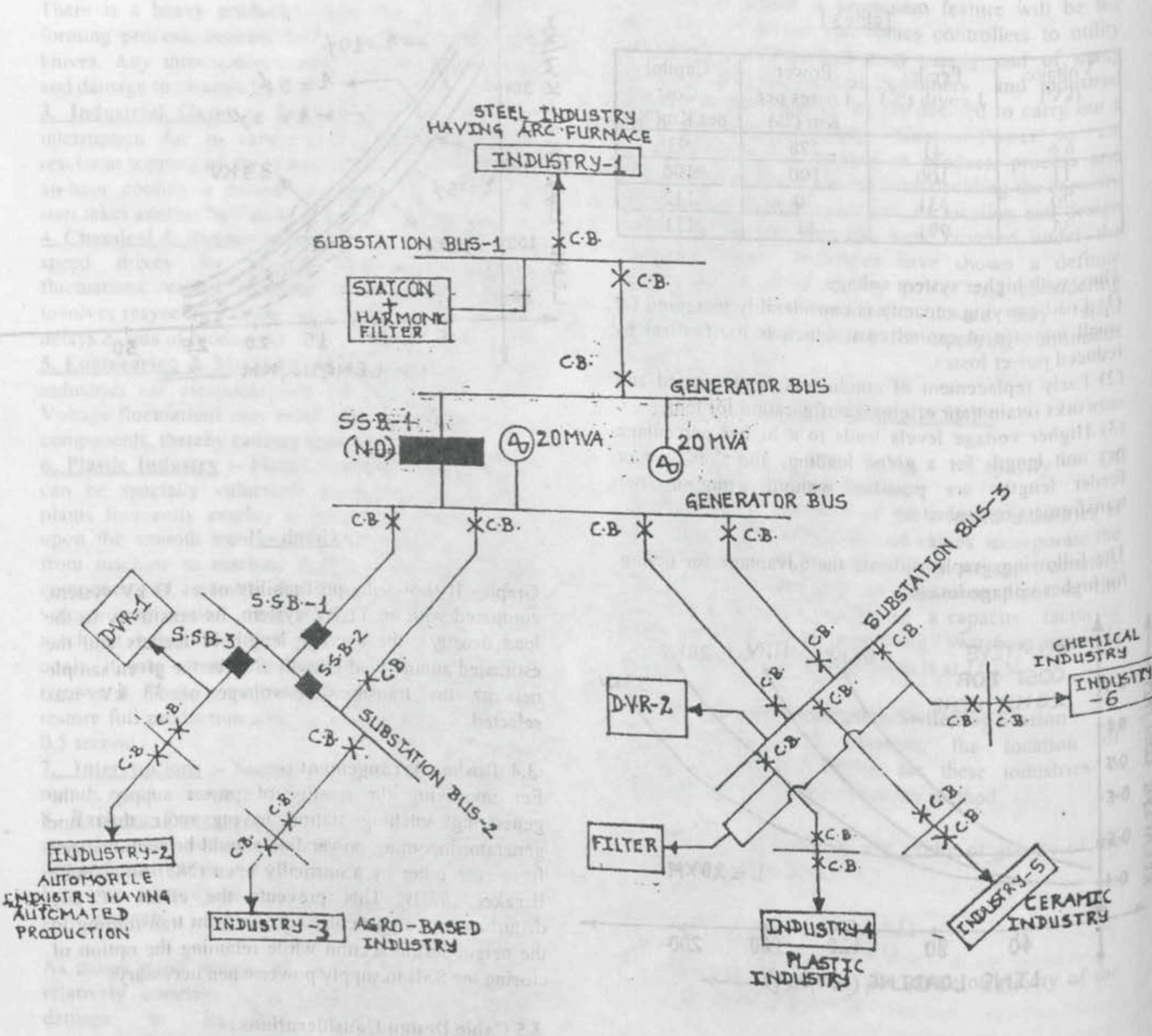
For improving the quality of power supply, the generating/switching station having more than one generator/incoming power line should be sectionalized from each other by a normally open (NO) Solid State Breaker (SSB). This prevents the effect of any disturbance in a particular section from transmitting to the neighbouring section while retaining the option of closing the SSB to supply power when necessary.

3.5 Cable Design Considerations :-

For ensuring good quality of power, underground XLPE cables are used for transmission. Besides the advantages of underground cables like lower inductive reactance, less interference with communication circuits, higher thermal stability, less chances of faults, the underground network systems are ranked the highest in supplying good quality of power, which is confirmed by voltage tolerance envelopes of sensitive equipment like computer.

The cable conductors are designed for worst fault conditions i.e. on the assumption that there is no sectionalisation of buses. The cable design should take into consideration that the replacement of cable should not be needed for long time, dynamic and thermal limits are never approached and any expected expansions can be catered easily without much stress.

Network diagram(fig :1)



3.6 Distribution Network Planning :-

For distribution network planning, non-linear programming approach should be adopted for the optimal sizing and siting of substations and network routing problem.

A cost function F is formulated as -

F = [Substation fixed cost of all the feasible substation locations including the cost of infeed circuits + the cost of constant transformation losses at all the feasible substations + feeder bay costs + feeder segment costs + feeder loss costs]

Now, this function F is solved using Quadratic Mixed Integer Programming (QMIP) approach to arrive at an economically feasible distribution network. The distribution network follows the basic QMIP approach.

The type of distribution network also plays an important role in ensuring good quality power supply. Of the seven types of distribution system networks like simple radial systems, primary autoloop systems, underground residential systems, secondary selective systems, grid network systems and spot networking systems : the spot network system is the best for supplying good quality power. It is considered the best in its ability to prevent spread of harmonics, to supply power conforming to computer voltage tolerance envelope, in its reliability and operating flexibility, in its economics and effectiveness to serve high density load areas with mixture of large and small loads, non-existence of momentary and long duration outages and in having best voltage regulation.

Double circuit lines for transmission improve the reliability of the system while keeping the impedance of transmission at a low value. The thermal limits of transmission lines are seldom approached, thereby increasing their useful life. It increases the power-handling capacity and thus improves power system stability.

3.7 Incorporation Of Power Quality Device As An Integral Part Of The Given Sample Power Network :-

The industries in the sample network have typical nature of loads, so also their process requires good quality of power. Steel industry having arc furnace (Industry - 1) as principal load necessitates power quality device like STATCON with harmonic filter, which shall prevent the spread of harmonics, while keeping the voltage level constant. Static VAR Controller (SVC) can also be used instead of STATCON, but STATCON has some inherent advantages. The use of dedicated feeder for a non-linear load like arc furnace is recommended, but with the use of power quality devices, it may not be a necessity. Besides, power quality equipment prevent derating of electrical machinery, which is usually associated with harmonic injecting loads.

Automobile industry having automated production (Industry - 2) cannot afford voltage sag/swell and so a fast acting SSB-3 and Dynamic Voltage Restorer (DVR-1) are provided in the substation-2. It is sectionalised from Agro-based industry (Industry - 3) through a normal open (NO) SSB-2 on the busbar so that disturbances due to load of Industry- 3 are not affecting it.

Plastic industry (Industry-4), Ceramic industry (Industry - 5) and Chemical industry (Industry-6) need good voltage regulation and so a common DVR-2 is provided in the substation. Plastic and chemical industry have processes, which cannot afford frequency deviations and hence a common filter is provided for frequency modulation in the substation.

The power quality devices should be looked upon as an integral part of power system like other elements viz. transformers, lines, circuit breakers etc. This approach shall lead to gradual phasing out of power conditioning equipments installed by end-users for power quality.

However, the use of power quality devices shall be in accordance with the agreement between utility and industrial consumers.

4.0 CONCLUSION

At present stage, power quality monitoring on utility systems is still in its infancy, compared to traditional power metering and fault recording. Most probably, its course over next period will be directed by the economics of problems related to power quality and their solutions. Installation of power quality devices shall be primarily dictated by the cost break-point of the production losses versus cost of power quality equipment curve.

In an industry undergoing transition into a competitive market place, value-added power supply can open up additional business opportunities for utilities and customers in the 21st century. The survey provides a good starting point and stands as an pioneering effort in India in the perspective of dealing with power quality issues.

5.0 BIBLIOGRAPHY

1. Lythall - J & P Switchgear and Protection Handbook.
2. Electricity Distribution Network Design Handbook.
3. McPortland - Handbook of Practical Electrical Design.
4. Lothar Heinhold - Power Cables and their Application- Siemens Handbook.
5. M.Ponnavaikka,K.S. Prakasa Rao, S.S Venkata - IEEE Transactions on Power Delivery, Vol.2, No.4, Pg.1157-1163, Oct1987.
6. IEEE Committee Report - IEEE Transactions on Power Systems. Vol.4, No.3, Pg.856-861, Aug 1989.
7. IEEE Spectrum - June 1995.
8. IEEE Spectrum - Feb 1993.
9. IEEE Spectrum - April 1993.
10. Sunil S. Rao - Switchgear & Protection.
11. Sudesh L. Uppal - Electrical Power.