Power Quality And Economic Consequences Of Poor Power Quality

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Abstract—The power quality (PQ) problem in power system exist due to variegated reasons and effects function and operation of the various components that exist in the power system. The power quality problem became predominant in the power system studies in early 1990's with the implementation of various power electronic and FACTs devices in the power system operation. The power quality in power systems can be viewed as cumulative effect of current and voltage quality. Power quality includes various phenomenon like voltage sag, voltage swell, flickers, interruptions, sustained interruptions etc. Power quality problems cause many problems and accounts for heavy economic losses in the power system. Various methods have been formulated for the improvement of PQ problems. In this paper, several methods for power quality improvement are discussed and an overview of economics related to these power quality problems is talkedover.

Keywords—Power quality; Undervoltages; Over voltages; surges; Compensators

INTRODUCTION

Power quality is an important subject of investigation in power system operation. Different types of power quality problems arise in the power system due to various reasons. The power quality problems can be due to the electric utilities as well as consumers. As the present day equipments are very sensitive to the power quality problem. The poor quality of electricity leads to the misoperation, malfunctioning and ultimately failure of these equipments. Therefore the power quality problems have many economic consequences. There are certain ways to improve these power quality problems. In this paper certain methods to improve these PQ problems has been discussed. Also the sources that account for these issues and the economics related to these issues have been discussed ondetail.

POWER QUALITY

In power system operation, the voltage varies over a range. The voltage changes vary from small fluctuations to complete outage. The voltage variations can be classified on the basis of magnitude as well as the durations of thevoltage variations.

Under voltages occur when voltage falls in the range of0.9 per unit to 0.1 per unit for a period of not more than 1 minute. While as over voltages can be defined as the voltage variation with magnitudes more than 1.1 per unit for the same time period.

These voltage variations cause sensitive equipments to get damaged. The service providers or companies are trying hard to keep voltage constant but the disturbances that occur from outside like lightning are unpredictable and cannot be detected in advance. The power quality problems that arise due to these outside sources are known as surges, which are more dangerous than the over voltages and the under voltages. These surges vary from few volts to megavolts and last for a time range of few milliseconds to few microseconds.

III. FOUNTAINHEADS OR THE SOURCES OFPOWER QUALITY PROBLEMS

The power quality issues in the power system arise from following main sources;

1. *Externalsources*

The main power quality issues arise due to the external sources that entail lightning surges. These external sources are also known as unpredictable events. The other causes that are classified as unpredictable events are faults, resonance and ferroresonance etc.

TABLE I - Transient cataloging

Disturbance Category	Origins	Effects
Oscillatory Transient	Capacitive or inductiveloadsSwitching.	Loss of data, possible damage.
Impulsive Transient	Utility fault clearing,switching impulses lightning,.	Possible damage, Loss of data, and system halts.

2. *Serviceproviders*

Power quality issues or problems arise due to utilities also. The following are the sources of the power quality complications injected from the utilityside;

2.1.Generating system

The synchronous generators generate voltage waves. These voltages although being sinusoidal contain some harmonics with it. The disturbances are due to various activities going on in the power system like maintenance, activity, expansion, limitations and load shifting from one station to another.

2.2Transmissionsystem

The transmission system although does not introduce muchofthepowerqualityproblems.Howeverpowerquality problems introduced by the transmission system may be the effect of high wind conditions causing faults and interruptions, transient over voltages due to the lightning, plannedoutages,overvoltagescausedbythecapacitors,lack of voltage regulation devices, corona, inefficient FACTs devices, converter devices for HVDC transmission, electromagneticeffectscausedbythenearbyline,broadband over power line and communicationline

2.3Distributionsystem

Power quality complications in the distribution system may be like voltage sags, spikes, slow changing variations of voltage, feck-less assignment of voltage regulation devices etc.

3. *Customer*

Handsome amount of power quality complications in power systems are catalyzed by customer loads. The nonlinear loads such as electronic devices, adjustable speed drives and computers generate harmonics. Poor power quality is caused by the inductive loads such as induction motors and furnaces, graceless grounding and misoperation of the appliances are the major origins of power quality problems due to customers.

4. *Manufacturers*

The power quality problems arising due to the manufacturing regulations may be due to the two sources;The accumulation of sensitive power electronic devices like computers also inject the power quality problems into the power systems

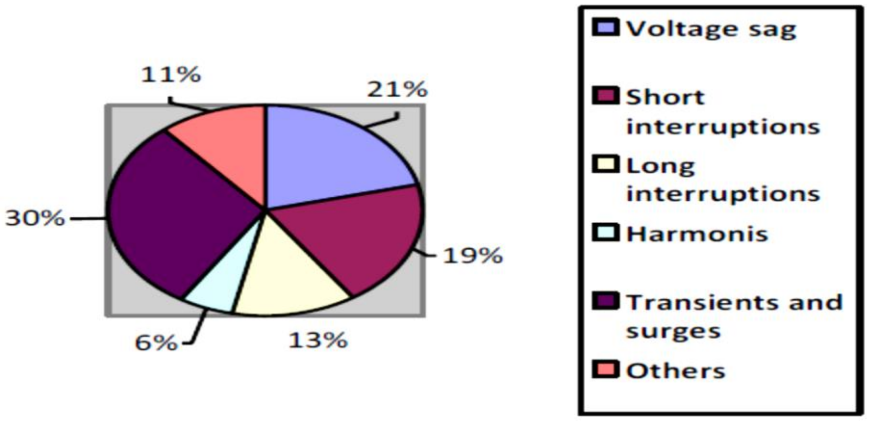

Figure 1: Power quality disturbances

TABLE II - Short period voltage deviationorganization

DisturbanceCategory	Origins	Effects
Voltage Sag	Start-up loads, faults.	Shutdown, Loss of data, system halts.
Voltage Swell	Load changes, Utility failure.	Tripping of circuitbreaker Damages equipment.
Interruptions	Switching, utility faults, componentletdown.	Shutdown, loss of data and damages.

TABLE III -Long duration voltage variation classification

Disturbance Category	Causes	Effects
Over Voltage	System loadchange, utility faults.	System shutdown,Loss of data,and system halts
Under Voltage	System load changes, utilityfaults.	Reducedlife ofequipmentEquipment damage,.
Sustained Interruption	Component failure,Utility faults, tripping of breaker.	System shutdown, loss of data and damages.

TABLE IV – Waveform alterationgrouping

DisturbanceCategory	Causes	Effects
DC Offset	Power supplies, faulty rectifier.	Transformerheating,Ground fault, current nuisance tripping,.
Harmonics	to Nonlinear loads.	Loss in machines efficiency,Measurement error, Equipment overheating, communicationinterference.
Interharmonic	Induction motor, faultyequipment, arcingdevice.	Communication interference, Heating, light flicker etc.
Noise	Improper grounding, electromagneticinterferences.	Data processing errorsand Data loss.
Notching	Lightdimmers, Arc welders, variable speed drive etc.	System halts,Loss of system data.

TABLE V – Waveform distortion duration

Categories	Typical Spectral Content	Typical Duration	Typical Voltage Magnitude
1.Transients			
1.1 Impulsive			
1.1.1nanoseconds	5 ns rise	< 50 ns	
1.1.2microseconds	1 µs rise	50 ns-1 ms	
1.1.3milliseconds	0.1 ms rise	> 1 ms	
1.2oscillatory			
1.2.1Low frequency	< 5 Khz	0.3-50ms	0-4 pu
1.2.2medium frequency	5-500KHz	20 µs	0-8 pu
1.2.3High frequency	0.5-5MHz	5 µS	0-4 pu
2.0 Short duration voltage variation			
2.1 Instantaneous			
2.1.1 Sag		0.5-30 cycles	0.1-0.9 pu
2.1.2 Swell		0.5-30 cycles	1.1-1.8 pu
2.2 Momentary			
2.2.1 Interruption		0.5-3s	< 0.1 pu
2.2.2 Sag		30 cycles-	0.1-0.9 pu
		3s	
2.2.3 Swell		30 cycles-3s	1.1-1.2 pu
2.3 Temporary			
2.3.1 Interruption		3 s -1 min	< 0.1 pu
2.3.2 Sag		3 s -1 min	0.1-0.9 pu
2.3.3 Swell		3 s -1 min	1.1-1.2 pu
3.0 Long duration Variations			
3.1 Interruption Sustained		> 1 min	0.00pu
3.2 Undervoltages		> 1 min	0.8-0.9 pu
3.3 Overvoltages		> 1 min	1.1-1.2 pu
4.0 Voltage imbalance		steady state	0.5-2%
5.0 Waveform Distortion			
5.1 DC offset		steady state	0-0.1%
5.2 Harmonics	0-100th H	steady state	0-20%
5.3 Interharmonics	0-6KHz	steady state	0-2%
5.4 Notching		steady state	
5.5 Noise	Broad band	steady state	0-1%
6.0 Voltage fluctuation	<25Hz	intermittent	0.1-7%

IV. ECONOMIC SIGNIFICANCE OFPOWERQUALITY

The industrial equipments have to be strong enough to operate under the normal flaws of the electrical supply. The cost for the correction of these problems is not so huge if the corrective measures are taken while designing the equipment. However that requires the knowledge of complexion and frequency of the problem.

Some of the equipment manufacturers cognize these problems, but the market competition makes them only to respond to the customer demand. The manufacturers will not improve till the customer realizes theproblems.

Following are the consequences of the power quality problems, like poor power factor and harmonics.

- The line current increases with the decrease in the power factor which leads to increase inlosses.
- As in the line, equipment currents also increases leading to the increase in capitalinvestment.
- The losses increase, leading to high temperatures, and hence reduction in the life span of theequipments.
- Early failure of the equipments due to the increased electrical and thermal stresses.
- Quality of production also getsdecreased.
- The equipments do not workproperly.
- Planned outages lead to the complete loss ofproduction.

4.1 Benefits of the power quality improvement

The improvements in the power quality lead to the following advantages;

- Improvement in power quality leads to reduction of currents through lines and equipments, and hence energy bills arelowered.
- The capital investment is alsoreduced.
- The improvement in voltage quality leads to the efficient operation of powerequipments.
- This will lead to reduction in harmonics, which results in reduction oflosses.
- Malfunctioning of equipments can beprevented.
- Loss of production can beavoided.
- Elimination of unplanned outages, hence increase in the revenue.
- The operating life of equipment is enhanced significantly.

V. METHODS FOR POWER QUALITYIMPROVEMENT

Several methods have been proposed for the power quality improvement as it is a wide research area where advancements are taking place day by day. Power quality can be understood as the capability to maintain almost sinusoidal voltage ate predetermined voltage and frequency. The different parameters that account for the power quality problems are frequency, voltage and harmonics etc. Therefore power quality improvement methods for the problems are addressed differently for different parameters. The Improvement techniques are discussed below:

5.1.Compensators

This improvement scheme integrally uses a proportional resonant compensator to keep vigil on fundamental current component and resonant harmonic compensator removes the current harmonics.

However under the abnormal conditions, the sophisticated control scheme is required.

5.2 Filters

Filters have been classified into two categories; active filters and passive filters. To reduce the harmonics or the harmonic distortion which are introduced into the power systems due to the nonlinear loads are eliminated using filters.

5.3 Factdevices

With the advancements in the engineering, FACT devices have been developed which are basically power electronic devices used to enhance the power quality problems. Number of FACT devices have been developed depending upon the purpose and installation in the system. Following are the various FACTdevices.

5.3.1 Series FACTdevices

Series FACT controllers or devices are connected in series to the power system. The series controllers inject voltage into the line. As long as the voltage controller is in phase quadrature with the line voltage, it will consume reactive power.

5.3.2 Shunt FACTdevices

Shunt FACT devices are connected in parallel with the transmission line. The shunt FACT devices inject current into the system as long as the current by the controller is in phase quadrature with the line voltages. These behave as variable impedances and regulate voltages.

5.3.3 Combined FACTdevices

Combined FACT devices are the combinations of both series and shunt FACT devices. They compensate both real and reactive power in the line.

5.3.4 Static Varcompensator

Static var compensators are actually shunt connected devices. It generally consists of bank of capacitors or reactors which are controlled by thyristors.

5.3.4 STATCOM

The static compensator STATCOM is a shunt connected device and consists of voltage source inverter with transformer and control connected to a transmission line. The change in the reactive power is achieved by the voltage sourceconverter.

However all the FACT devices suffer from the problem of introduction of harmonics.

CONCLUSION

Modern day power electronics devices that are very sensitive to the power quality are being manufactured. The extensive use of automatic appliances both for the industrial as well as domestic purposes has made the power quality problem a prominent issue to be addressed with the utmost care. The customers also are becoming knowledgeable day by day about these power quality issues. These problems not only make the appliances malfunction but also deteriorate the appliance material and ultimately leads to the complete failure of the appliances. Hence pose different kind of economic issues in the power system operations. Power quality problems, although seems not so hazardous but sometimes these problems may prove hazardous and may take lives as well as property. In this paper several power quality problems have been discussed along with the economics related to the power quality. Therefore the power quality needs to be improved. For that several possible solutions are discussed in this paper.

REFERENCES

[1] Siemens STEP 2000 "Basics of Power Monitoring"www.sea.siemens.com/step

[2] Ewald Fuchs and Mohammad Masoum, Introduction to Power Quality, Academic Press,2008.

[3] P. M. Anderson, and A. A. Fouad, Power Systems Control and Stability,IEEE Press, New York, 2003. Arrillaga, N. R. Watson, and S. Chen. Power System Quality Assessment,Wiley, Chichester, 2000.

[4] R. Arseneau, and M. Ouellette, The effects of supply harmonics on the performance of compact fluorescent lamps, IEEE Transactions on Power Delivery, 8(2): 473–479, April1993.

[5] M. T. Aung, J. V. Milanovic, and C. P. Gupta, Propagation of asymmetrical sags and the influence of boundary crossing lines on voltage sag prediction, IEEE Transacions on Power Delivery, 19(4): 1819–1827, October2004.

[6] H. Awad. Vector control of static series compensators for mitigation of voltage dips, Licentiate thesis, Department Research on Economic Impact of Poor Power Quality of Electric Power Engineering, Chalmers University of Technology, Gothenburg, Sweden,2002.

[7] H. Awad, J. Svensson, and M. H. J. Bollen, Tuning software phase- locked loop for static series compensator, IEEE Transactions on Power Delivery, 20(1):300–308, January2005.

[8] P. Axelberg, Measurement Methods for Calculating the Direction to a Flicker Source, Licentiate thesis. Chalmers University of Technology, Gothenburg, Sweden, March 2003.

[9] Y. Baghzouz (chair), Time-varying harmonics: Part II—harmonic summation and propagation, IEEE Transactions on Power Systems, 17(1): 279–285, January2002.

[10]G. Ban, L. Prickler, and G. Banfai, 750 kV reactive power control, automatic reclosing and overvoltage protection, Paper presented at the IEEE Bologna Power Tech Conference, Bologna, Italy, June 2003.

[11]P. P. Barker, Determining the impact of distributed generation on power systems, Paper presented at the IEEE PowerEngineering Society Summer Meeting, Seattle, WA, July2000.