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POWER QUALITY PROBLEMS, CAUSES AND SOLUTIONS

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I. INTRODUCTION

Power quality problems are manifested by the interruption or distortion of ideal 50/60 Hz sine wave. The term power quality (PQ) problem refers to a set of disturbances, which create sudden deviation of voltage or current from its normal or ideal waveform [1].

Various types of power quality mitigating equipments are available to protect commonly used sensitive electronic equipment against power quality problems.

II POWER QUALITY PROBLEMS, CAUSES AND EFFECTS

The power quality problems can be divided into two classes, according to their duration [2,3]:

A. Momentary Anomalies:-These anomalies are mostly voltage fluctuations of up to 3 sec. in duration.

***Voltage transients*:-**These anomalies (also called spikes and notches) are high amplitude and/or very short duration (µs) voltage disturbances. The switching of inductive loads, power factor correction capacitors, electronic equipment and lightning, causes them. It can damage insulation in motors, cables and transformers, affect microprocessor-based equipment and can cause data loss or permanent damage. Transients can be categorized as either impulsive or oscillatory.

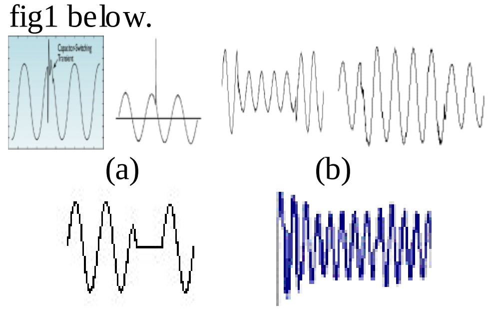
Dips (Voltage Sags):- A *sag* or *dip*, as defined by IEEE Standard 1159-1995, *IEEE Recommended Practice for Monitoring Electric Power Quality*, is a sudden reduction in the r.m.s. voltage, for a period between half cycle to 3 sec, of any or all the phase voltages of a single-phase or a multi-phase supply. Sags account for the vast majority of power problems experienced by end users. Voltage sags are caused by abrupt increases in loads such as short circuit, motor starting, etc.

Surges (Swells):- A voltage swell is defined as an increase in the r.m.s. voltage at the power frequency, for duration from 0.5 cycles to 1 min. The typical magnitudes are between 1.1 and 1.8 pu. Voltage swells are almost always caused by an abrupt reduction in load, switching capacitor banks or loose neutral connection. Although swell occurs infrequently, compared to sag, can cause equipment malfunction, premature wear, stress insulation in transformers and capacitors.

Interruptions:- Interruption is a phenomena that occurs when one or more phases of a supply to a customer are disconnected for a period exceeding 3 sec. A *voltage interruption* is the complete loss of electric voltage usually by the opening of a circuit breaker, line recloser, or fuse.

Flicker:-A waveform may exhibit *voltage flicker* if its amplitude is modulated at frequencies less than 25 Hz, which the human eye can detect as a variation in the lamp intensity of a standard bulb. Voltage flicker is caused by an arcing condition on the power system

All types of momentary anomalies are shown in fig1 below.



(a) (b) (c) (d)

Fig.1. a) Voltage transients b) Sag and Swell c) Interruption d) Flicker

B. Steady-State Anomalies:-These types of anomalies manifest themselves over longer periods of time and can sometimes be semi-permanent.

Voltage deviations:-Long-term over- and under-voltages are caused by overloaded distribution systems, incorrect transformer tap settings, unbalanced phase loading and improper application of power factor correction capacitors as shown in fig2a. It can cause low efficiency, overheating and reduced lights.

Phase unbalance:-This is a 3-phase phenomena caused by unbalanced phase loading, defective transformers or ground faults. It causes premature failure of motors and transformers due to overheating.

Harmonic distortion:- Harmonic Distortion is the deviation of voltage or current from a true sine wave due to the addition of frequencies that are multiples of the fundamental (50/60 Hz) frequency component as shown in fig2b. It is measured as percentage Total Harmonic Distortion (THD). It is caused by non-linear loads, such as static power converters, solid-state switches, variable speed drives, welding equipment, furnaces, battery chargers or saturated transformers. Effects include serious damage to capacitors and transformers, decreased motor performance, and malfunctioning of control equipment.

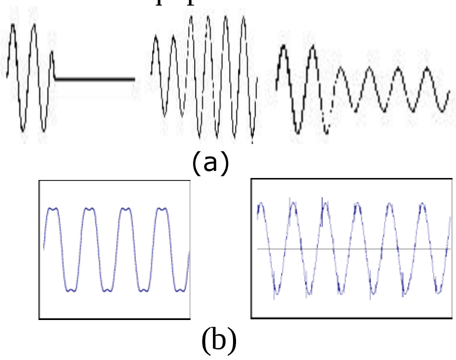


Fig.2. Steady state anomalies a) Voltage deviations b) Harmonic distortion and notching

III POWER QULAITY SOLUTIONS

3.1 Flicker Mitigation:-For flicker mitigation, a number of different methods are available, which differ in performance, feasibility and cost [4]. However, the most used devices for flicker mitigation are by far the static var compensator (SVR) and D- Statcom.

An SVC installed with an arc furnace not only reduces the flicker, but also stabilizes the ac voltage [5]. However, the ability of the SVC to mitigate flicker is limited by its low speed of response.

A shunt connected VSC mounting IGBTs and operated with PWM is normally referred to as “Statcom” or “D-Statcom”. In the study reported in [6,7], the VSC is found to be superior to other flicker mitigation methods.3.2 Harmonics-Mitigation:-In orders to remove harmonics, passive or active filters are used. The passive filter consists of series LC filters tuned for specific harmonics. The drawbacks with passive filter are that they are dependent on the system impedance. This may cause the passive filter to act as a sink for harmonic currents from other sources in the network and can be get overloaded.

The VSC based shunt active filter consists of a dc- link capacitor, power electronics switches and filter inductors between the VSC and the load. Together with active filtering, it is also possible to control the power factor by injecting or absorbing reactive power from the load.

3.3 Mitigation of Voltage sag and Interruptions*: -* According to study conducted the vast majority of offending events were found to be short duration disturbances, primarily voltage sags and momentary loss of power. Different methods to reduce the voltage sags and interruption are described in [8] are basically classified as utility solutions and customer solutions.

Utilities can take two main steps to reduce the detrimental effects of sags and interruptions 1) Prevent faults 2) Improve fault-clearing methods.

Customer solutions:- The installation of power quality mitigation equipments is often the only option for customer to achieve the desired quality of supply.

Traditional PQ mitigating devices include motor generator sets, which use the rotational energy stored in a flywheel to provide power to the load during the sag, and the modern equipments based on advanced power electronics are described.

i) Electronic tap changing transformer (Voltage regulator):-Voltage regulators (shown in fig3a) maintain voltage output within a desired limit during wide fluctuations in the input. They might provide protection against spikes or noise and limited or no protection from rapid voltage changes. Voltage regulators respond best to slow changes in voltage.

ii) Ferro-resonant transformer (CVT):-Ferro-resonant transformers protect sensitive electronic equipment by buffering electrical noise like isolation transformers. This solution is suitable for low-power, constant loads: variable loads can cause problems, due to the presence of this tuned circuit on the output.

Fig.3.a) Electronic tap changing transformer b) Ferro-resonant transformer (CVT)

iii) Inverter based solutions

Uninterrupted power supply (UPS):-It provides power to critical loads at all times. A DC bus backed by a battery provides conditioned power as shown in fig4a. Low cost and simple operation has made the UPS the standard solution for low-power equipment like computers.

Back up power source: - To avoid the losses due to the additional energy conversions in the UPS, a backup power source can be used instead as shown in fig4b. As soon as a disturbance is detected, the sensitive load is isolated from the power system by a static switch and supplied from the stored energy.

Series voltage controller:-It consists of a VSC connected in series with the distribution feeder by means of an injection transformer as shown in fig4a. It can inject voltages of controllable amplitude, phase angle and frequency into the distribution feeder, thus restoring the voltage to critical loads during sags. Even without stored energy, the series controller can provide limited compensation for variations of terminal voltage by injecting a lagging voltage in quadrature with the load current.

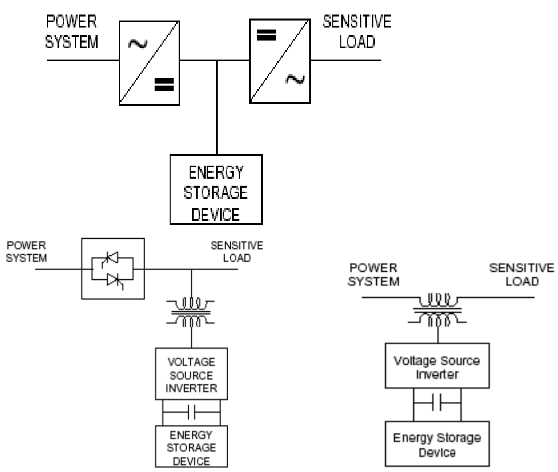
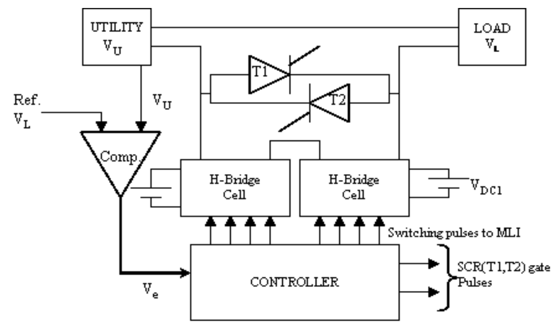


Fig.4 a) UPS b) Backup power source c) series voltage controller

Transformer less series sag compensator:- Due to the difficulties involved with protecting series injection devices under fault conditions as well as the necessity for costly injection transformers the series topologies are not the natural choice for power quality compensators. The use of cascaded multilevel topology makes it possible to implement cost effective series voltage sag compensation by eliminating the injection transformer and output filter components.Fig.5 shows the basic block diagram of series voltage sag compensator using cascaded multilevel inverter with distributed energy sources (DES). It is very suitable for connecting either in series or in parallel on ac grid with renewable energy sources [9,10]. Compensation is initiated when sag is detected.



ries sag
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V. CONCLUSIONS

The installation of mitigation devices at the system equipment interface appears as the most attractive short-term solution for customers. For longer duration sags caused by faults in the distribution system, improvement of system performance may be easier. A cascaded multilevel inverter is a cost effective way of series voltage sag compensation, because it eliminates the bulky series injection transformer and filter components. The cascaded multilevel topology is able to compensate the sags for different loads with relatively fast response. Sags at the larger depth than the specified can also be compensated for to a limited extent.

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