lighting in case of blackout. However, they do not offer protection against utility power problems such as over voltages and frequency fluctuations. Motor generators [14] are consists of an electric motor driving a generator with coupling through a mechanical shaft. This solution provides complete decoupling from incoming disturbances such as voltage transients, surges and sags.

6.1.8 Static VAR compensator (SVC)

Static VAR compensators (SVC) use a combination of capacitors and reactors to regulate the voltage quickly. Solid-state switches control the insertion of the capacitors and reactors at the right magnitude to prevent the voltage from fluctuating. It is normally applied to transmission networks to counter voltage dips/surges during faults and enhance power transmission capacity on long [14].

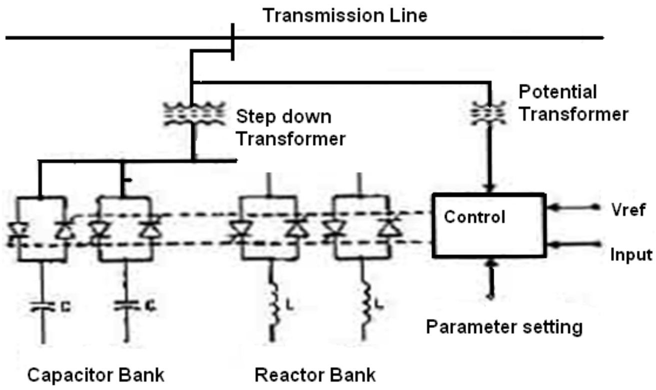

Figure 5: Static VAR compensator using TCR and TSC

6.1.9 Thyristor based Static switch

The static switch is a versatile device for switching a new element into the circuit when voltage support is needed. To correct quickly for voltage spikes, sags, or interruptions, the static switch can be used to switch in capacitor, filter, alternate power line, energy storage system etc. It protects against 85% of the interruptions and voltage sags [18].

6.1.10 Unified Power Quality Conditioner (UPQC)

The UPQC employs two voltage source inverters (VSI) that is connected to a dc energy storage capacitor .A UPQC, combines the operations of a Distribution Static Compensator (DSTATCOM) and Dynamic Voltage Regulator (DVR) together. This combination allows a simultaneous compensation of the load currents and the supply voltages, so that compensated current drawn from the network and the compensated supply voltage delivered to the load are sinusoidal and balanced [18].

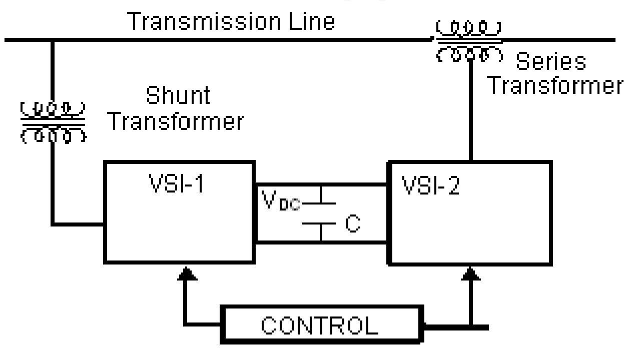

Figure 6: Basic Structure of UPQC

6.2 Energy Storage System

6.2.1 Flywheels

A flywheel is an electromechanical device that couples a rotating electric machine (motor/generator) with a rotating mass to store energy for short durations. The motor/generator draws power provided by the grid to keep the rotor of the flywheel spinning. During a power disturbance, the kinetic energy stored in the rotor is transformed to DC electric energy by the generator, and the energy is delivered at a constant frequency and voltage through an inverter and a control system. Advanced flywheels constructed from carbon fibre materials and magnetic bearings can spin in vacuum at speeds up to 40,000 to 60,000 RPM. The stored energy is proportional to the moment of inertia and to the square of the rotational speed. High speed flywheels can store much more energy than the conventional flywheels. Flywheels typically provide 1-100 seconds of ride-through time, and back-up generators are able to get online within 5-20 seconds [19].

6.2.2 Super capacitors

Super capacitors (also known as ultra capacitors) are DC energy sources and must be interfaced to the electric grid with a static power conditioner, providing energy output at the grid frequency. A super capacitor provides power during short duration interruptions or voltage sags. Medium size super capacitors (1 MJoule) are commercially available to implement ride-through capability in small electronic equipment, but large super capacitors are still in development, but may soon become a viable component of the energy storage field. Capacitance is very large because the distance between the plates is very small (several angstroms), and because the area of conductor surface (for instance of the activated carbon) reaches 1500-2000 m2/g (16000-21500 ft2/g). Thus, the energy stored by such capacitors may reach 50-60 J/g [17].

6.2.3 Super Conducting Magnetic Energy Storage (SMES)

A magnetic field is created by circulating a DC current in a closed coil of superconducting wire. The path of the coil circulating current can be opened with a solid-state switch, which is modulated on and off. Due to the high inductance of
the coil, when the switch is off (open), the magnetic coil behaves as a current source and will force current into the power converter which will charge to some voltage level. Proper modulation of the solid-state switch can hold the voltage within the proper operating range of the inverter, which converts the DC voltage into AC power. Low temperature SMES cooled by liquid helium is commercially available. High temperature SMES cooled by liquid nitrogen is still in the development stage and may become a viable commercial energy storage source in the future due to its potentially lower costs. SMES systems are large and generally used for short durations, such as utility switching events [19].

7. Other Recommendations

Some practices to check/mitigate power quality problems are recommended below:

7.1 Proper Grounding and Bonding

A recent survey of Power Quality experts indicates that 50% of all Power Quality problems are related to grounding, ground bonds, and neutral to ground voltages, ground loops, ground current or other ground associated issues[4].Grounding is one of the most important and misunderstood aspects of the electrical system. It is essential to differentiate the functions of the grounded conductor (neutral) from the equipment grounding system (safety ground). The safety ground protects the electrical system and equipment from super-imposed voltages caused by lightning or accidental contact with higher voltage systems. It also prevents static charges build-up. The safety ground establishes a “zero-voltage” reference point for the system. The safety ground must be a low impedance path from the equipment to the bonding point to the grounding electrode at the service entrance. This allows fault currents high enough to clear the circuit interrupters in the system preventing unsafe conditions. The grounded conductor (neutral) is a current carrying conductor which is bonded to the grounding system at one point. Grounding this conductor limits the voltage potential inside the equipment in reference to grounded parts. Neutral and ground should only be bonded together at the service entrance or after a separately derived source. One of the most common errors in a system is bonding the neutral to ground in multiple locations. Whether intentional or unintentional, these ‘extra’ bonding points should be identified and eliminated. Proper grounding and bonding minimizes costly disturbances.

7.2 Proper Wiring

The entire electrical system should be checked for loose, missing or improper connections at panels, receptacles and equipment. Article 300 of the National Electrical Code (NEC) cover wiring methods and should be followed to ensure safe and reliable operation. There are many types of commonly available circuit testers that can be used to check for improper conditions such as reversed polarity, open neutral or floating grounds. Make certain to isolate panels feeding sensitive electronic loads from heavy inductive loads, or other electrically noisy equipment such as air compressors or refrigeration equipment. Also check neutral and ground conductors to make sure they are not shared between branch circuits.

7.3 Safe Operating Zone

The Information Technology Industry Council (ITIC) has revised the CBEMA curve in 2000. This curve is used to define the voltage operating envelope within which electronic equipment should operate reliably. Equipment should be able to tolerate voltage disturbances in the “no interruption” region of the chart. When the voltage disturbance is in the “no-damage” region, the equipment may not operate properly, but should recover when voltage returns to normal. If voltages reach the “prohibited region,” connected equipment may be permanently damaged. Expensive equipment should be protected from voltages in the prohibited region. Processes which require high reliability should be protected from both the prohibited and no-damage regions.

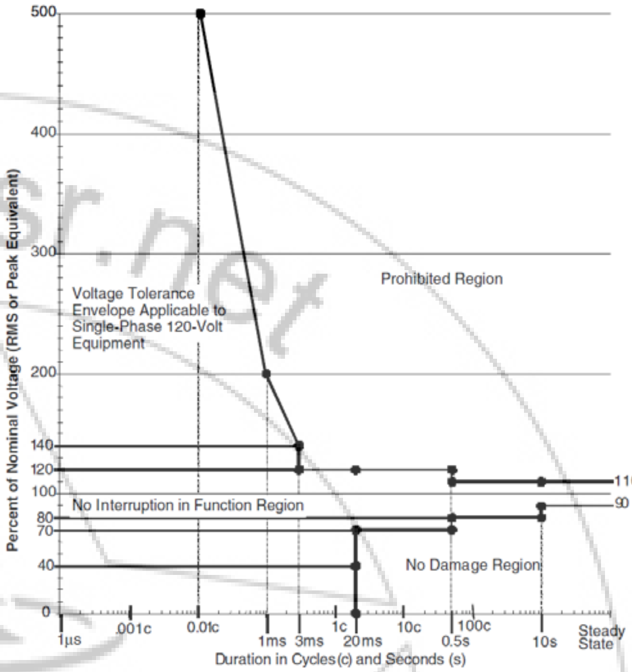

Figure 7: ITIC-CBEMA curve (revised 2000)

7.4 Proper designing of the Load equipment.
7.5 Proper designing of the power supply system.
7.6 Application of passive, active and hybrid harmonic filters, FACTS devices.
7.7 Application of voltage compensators and different power conditioning devices at different stages like generation, transmission and distribution system as per requirement and suitability.
7.8 Reliability on standby power.
7.9 Adoption of hybrid energy system with optimal distributed generations.

8. Conclusions

The availability of electric power with high quality is crucial for the running of the modern society. If some sectors are satisfied with the quality of the power provided by utilities, some others will demand more. When even the most robust equipment is affected, then other measures must be taken, such as installation of restoring technologies, distributed generation or an interface device to prevent PQ problems. Coordination with existing industry practices and international harmonic standards is also considered in this paper. Optimized use of power quality enhancement devices is required as the *cost*, *complexity*, *flexibility* of various techniques is different and this *optimization* issue is under research to find an efficient answer to the power quality problems. So, undoubtedly, this paper has a good *future scope* and will help research workers, users and suppliers of electrical power to gain a guideline about the power quality.

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