Importance of Power Quality Improvement and The Role Of Custom Power Devices

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Abstract

In last couple of decades due to exponential growth in semiconductor integration technology and variety of high-power rating static switches, energy conversion technologies based on power electronic interface have gained tremendous popularity. Due to massive advancement in automation technology, it has necessitated to use power electronics converter based Variable Speed Drives (VSD) for the speed control of ac and dc motors in the industries. In the modern-day industry as well as commercial entities, majority of the machinery and equipment use power electronics interface in one or the other way.

In addition, the low voltage customers like modern households also use a significant amount of power electronic based devices for their daily usage. In most of the residential buildings, modern home appliances like air conditioners, refrigerators and washing machines, microwave ovens, induction cooking range, LED/LCD tv panels, LED lighting and CFL lamps, cell phones and laptops use either single stage fixed ac to fixed dc conversion or two stage fixed ac to variable ac energy conversion with the help of power electronics converters.

Due to concern over environmental pollution and green-house gas emission norms, renewable energy generation has gained a lot of focus by the governments and private industries across the globe. There are various technical issues faced by the renewable energy sources while operating with the grid or in islanding mode. Majority of such issues are resolved when renewable energy source is connected to the grid through power electronics interface. At the same time, with the increase in renewable energy based electric power generation the power quality issues are further complicated due to the intermittent nature of the renewable energy generation along with use of power electronics interface.

The power electronic switches operating at high frequency switching introduce switching harmonics to the system it is connected. The widespread use of power electronic devices in the low voltage network create huge amount of harmonic pollution in the network as those devices emit harmonic current and eventually increase harmonic voltage distortion in the network. The nonlinearity of the electrical equipment like motors and transformers also introduce distortion in the waveform which also contributes to harmonic pollution.

With the distorted supply voltage, most of the devices produce even more harmonic current pollutions. The experiments have revealed that when the supply voltage is distorted, the devices produce significantly large amount of harmonic current pollution. In extreme cases, poor power quality because of high harmonic distortion may damage or decrease the service lifetime of the network components. Considering all these factors and detrimental consequences of the harmonic related problem in the overall low voltage network are to be taken into accounted seriously. Many standards had been devised to reach a common goal of defining power quality standards which concluded with IEEE519 standards which were first defined in 90s and revised to the latest implementation scenario in 2014 that defines all required parameters at different voltage levels in the power system.

To overcome the issue of harmonic there are variety of the harmonics filters available to control and mitigate harmonic pollution in the power system. Mainly they are classified into passive filters, hybrid filters and active filters. Passive filters are inexpensive compared with all other harmonic filters. They are made up of only passive elements like inductances, capacitances, and resistances that are tuned to the harmonic frequencies of the currents or voltages that must be attenuated. Passive filters have better performances when they are placed near to the harmonic producing nonlinear loads. There is a variety of passive filters for single phase and three-phase power systems in series and shunt configurations. Shunt passive filters provide low-impedance paths for the flow of harmonic currents and carries only a fraction of the total load current. Hence shunt passive filters have lower rating with compared to series-connected passive filters as series passive filters have to carry full load current being in the series connection. Shunt passive filters are also desirable as they supply reactive power at fundamental frequency and having low cost compared to series filter. Straightforward design, construction and their implementation, fast response, low maintenance cost and relatively very low cost are the prime merits of the passive harmonic filters. Whereas fixed compensation, detuning due to sensitivity towards temperature effects and hence aging, possible resonance with the supply system impedances at fundamental and/or harmonic frequencies, and no possibilities of stepless control are some of the main drawbacks of passive harmonic filters.

Hybrid power filters are combination of passive filters and active filters. They are used when cost of active power filter is not feasible and passive filters alone are unable to address the filtering needs. Due to operational complexities and decreasing costs of power electronics apparatus, they are rarely used.

The active power filters are also known as custom power devices. The technology of application of the power electronics to power distribution system for the benefit of a customer or a group of customers is called Custom Power through which utilities can supply value added power to these specific

customers. The custom power devices can broadly be divided into two categories (i) network reconfiguring type and (ii) compensating type.

The network reconfiguring type CPD are usually used for fast current limiting and current breaking during faults which generally use either GTO or Thyristor as a switch. To secure a load from voltage sag, swell or fault in the supplying feeder, it can quickly transfer the load to the spare/auxiliary feeder. There are three members namely (i) Solid State Current Limiter (SSCL), (ii) Solid State Circuit Breaker (SSCB) and (iii) Solid State Transfer Switch (SSTS). SSCL inserts a fault current limiting inductor in series in the faulty circuit as soon as the fault is detected and it cuts the inductor once the fault is cleared. SSCB can interrupt the fault current very rapidly and also perform auto-reclose function. This device is much faster than its mechanical counterpart and hence it is ideal for custom power application. SSTS is used for protecting sensitive load from sag and swell. It can perform a sub-cycle transfer of the sensitive load from a supplying feeder to an alternate feeder when a voltage sag/swell is detected in the supplying feeder.

The compensating devices are used for active filtering, load balancing, power factor correction and voltage regulation. The active filters can be connected in series and shunt both. Usually, shunt active filters are preferred over series active filters due to greater ease of protection. In the compensating type devices family there are three members, (i) Distribution STATCOM (DSTATCOM), (ii) Dynamic Voltage Restorer (DVR) and (iii) Unified Power Quality Conditioner. The DSTATCOM is a shunt connected device which can be considered as shunt connected compensating current source which can perform load compensation (power factor correction), harmonic filtering and load balancing when connected at load terminal. It also can perform unbalanced voltage compensation at the bus it is connected. The DVR is a series connected device which can be considered as series connected compensating voltage source which looks after voltage related issues like sag, swell and harmonic distortion at bus it is connected. The UPQC is device which is a combination of DVR and DSTATCOM via dc link capacitor. It can perform both, load compensation as well as voltage control simultaneously. Unified power quality conditioners (UPQCs) can be installed at the load end to overcome these issues and provide complete power quality solution. UPQC is very versatile device having variety of configuration to address different applications. However, UPQC suffer from the only drawback of inability to maintain the supply in case of interruptions. To address this lacuna of UPQC, there are couple of configurations which can complement this issue.

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