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A review on power quality problems and solutions

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ABSTRACT

Modern semiconductor switching devices are being utilized more and more in a wide range of applications These power electronics devices offer economical and reliable solutions to better manage and control the use of electric energy. However, the characteristics of most power electronics circuits, those semiconductor devices present nonlinear operational characteristics, which introduce contamination to voltage and current waveforms at the point of common coupling (PCC) of industrial loads. These devices, aggregated in thousands, have become the main polluters, the main distorters, of the modern power systems. At the Same time rapid development of semiconductor devices in power and control circuits, a new generation of equipments that help maintaining a good level of power quality, namely active power filters, has been developed. Theirs advantages over conventional means are more flexibility and very fast control response. The paper aim is to present the actual Power Quality Problems and solutions by active filters based on state-of-the-art power electronics technology and also their future prospects and directions.

Introduction

SOLID-STATE control of ac power using thyristors and other semiconductor switches is widely employed in do-mestic and industrial loads. Examples of such application such as adjustable speed drives (ASD's), furnaces, diode and thyristor rectifiers, uninterruptible power supplies (UPSs), computers and their peripherals, consumer electron-ics appliances (TV sets for example), among others. Com-puter power supplies as well in , etc. Such controllers are also used in HV dc systems and renewable electrical power generation. As nonlinear loads, these solid-state converters draw harmonic and reactive power components of current from ac mains. In three-phase systems, they could also cause unbalance and draw excessive neutral currents. The injected harmonics, reactive power burden, unbalance, and excessive neutral currents cause low sys-tem efficiency and poor power factor. They also cause disturbance to other consumers and interference in nearby communication networks. Extensive surveys [1]–[7] have been carried out to quantify the problems associated with electric power networks having nonlinear loads. Conven-tionally passive L–C filters were used to reduce harmon-ics and capacitors were employed to improve the power factor of the ac loads. However, passive filters have the demerits of fixed compensation, large size, and resonance. The increased severity of harmonic pollution in power networks has attracted the attention of power electronics and power system engineers to develop dynamic and ad-justable solutions to the power quality problems. Such equipment, generally known as active filters (AF's)

The basic principle of active power filtering is to synthe-size and apply a certain current or voltage waveform at a specified point of a distribution network. Active filters are fundamentally static power converters designed to synthe-size a current or voltage source; alternatively, they can be made to emulate specified impedances, both in magnitude and phase. Advantages of active filters over conventional means (passive filters, special transformer connections and special transformers) are mainly: flexibility in defin-ing and implementing the functions of the filter, a very fast control response, and no additional problems caused by possible resonant frequencies or network configura-tion.

This paper aims at presenting a comprehensive survey on the on power quality problems and solutions by various types of AF's.

Impact of Power Pollution

Unexplained computer network failures, premature motor burnouts, humming in telecommunication lines, and trans-former overheating are only a few of the damages that quality problems may bring into home and industrial in-stallations. What may seem like minor quality problems may bring whole factories to a standstill. Studies by the Canadian Electrical Association indicate that power qual-ity problems, including voltage sags and surges, tran-sients, and harmonics, are estimated to cost Canada about $1.2 billion annually in loss production. Most of the cost of harmonics is not incurred in the power system itself but rather within the customer's facility [8]. While system solutions are being searched and even power quality mar-kets are being formulated in the present deregulated envi-ronments, the solution starts at the individual industrial and commercial facilities. With the risks and costs of pol-lution in mind, researchers and equipment manufacturers are looking for alternatives for protection, while industry and businesses are increasingly investing in sophisticated and innovative devices to improve power quality.

An overview of power quality pro-lems, their causes and effects:

Electrical systems are subject to a wide variety of power quality problems which can interrupt production proc-esses, affect sensitive equipment, and cause downtime, scrap, and capacity losses [1]–[7].

Power Quality Solution

We have seen number of power quality problems, nowa-days there are number of power Quality problems solu-tions

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available. Power Quality problems solved by differ-ent methods like Surge Suppressors, Voltage Regulators, Generators, Passive Filters Active Filters[9-10] etc. Each method has its own merits and demerits Present discus-sion is focused on Power quality solution by use of Active Filters

Active Power Filters

Nowadays various types of Active power filters are avail-able. We will discuss three main topology one by one.

Static Compensator(Statcom)

The shunt active power filter (STATCOM), used for reac-tive power compensation in power transmission systems. Shunt active power filters compensate load current har-monics by injecting equal but opposite harmonic compen-sating current[11][12]. In this case the shunt active power filter operates as a current source injecting the harmonic components generated by the load but phase shifted by 180^o.

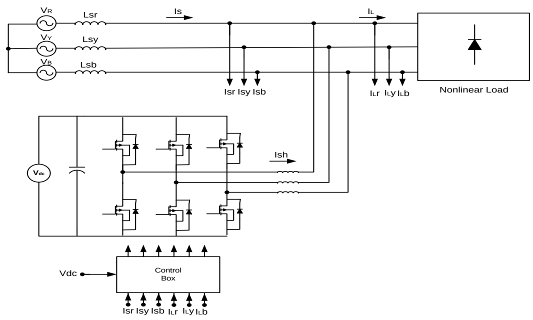

Fig 1.1 Statcom

Fig 1.1 shows the connection of a shunt active power fil-ter and Fig 1.2 shows how active power filter works to compensate the load harmonic currents. The STATCOM is a solid-state synchronous voltage generator, which con-sists of a multi-pulse, voltage-sourced inverter connected in shunt with the transmission line. It can counteract both voltage depression and voltage rises. Although its output characteristics are similar to those of a rotating synchro-nous condenser, the STATCOM [17]is superior in that it provides greater speed of response, does not increase short circuit current in the system and can provide sym-metrical leading or lagging reactive current. The smooth continuous control of the STATCOM minimizes

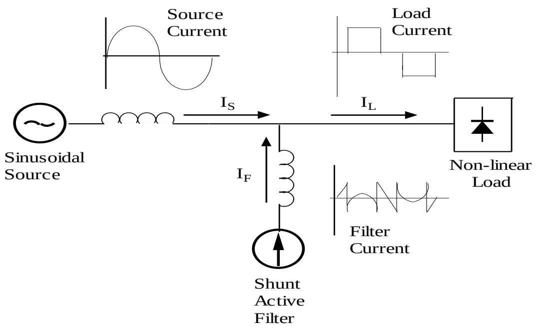

Fig 1.2 Filter current IF generated to compensate load current harmonics

the possibility of large voltage fluctuations which may occur with passive devices. The development efforts of advanced static compensation technology at the power delivery level have resulted in a distribution STATCOM (DSTATCOM) that exhibits high-speed control of reac-tive power to provide harmonics suppression voltage sta-bilization, flicker suppression, and other types of system control. The DSTATCOM utilizes a design consisting of a voltage-source converter connected to the power system via a multi-stage converter transformer.

Static Synchr Series Compensator (Sssc)

Series active power filters were introduced by the end of the 1980s and operate mainly as a voltage regulator and as a harmonic isolator between the nonlinear load and the utility system. The series connected filter protects the consumer from an inadequate supply voltage quality. This type of approach is especially recommended for compen-sation of voltage unbalances and voltage sags from the ac supply and for low power applications and represents economically attractive alternatives to UPS, since no en-ergy storage (battery) is necessary and the overall rating of the components is smaller. The series active filter in-jects a voltage component in series with the supply volt-age and therefore can be regarded as a controlled voltage source, compensating voltage sags and swells on the load side. In many cases, the series active filters work as hy-brid topologies with passive LC filters. If passive LC fil-ters are connected in parallel to the load, the series active power filter operates as a harmonic isolator, forcing the load current harmonics to circulate mainly through the passive filter rather than the power distribution system.

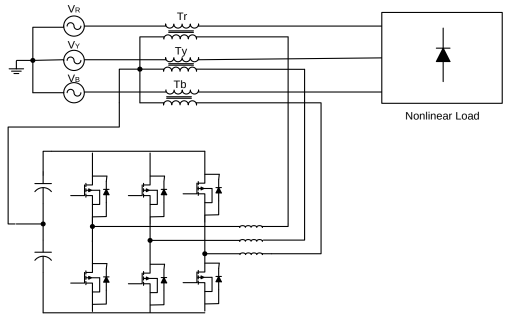

Fig:1.3 Static Synchronous Series Compensator (SSSC)

The main advantage of this scheme is that the rated power of the series active filter is a small fraction of the load kVA rating, typically 5%. However, the apparent power rating of the series active power filter may increase in case of voltage compensation. Fig 1.3 shows the connec-tion of a series active power filter, and Fig 1.4 shows how the series active filter works to compensate the voltage harmonics on the load side. Series filters can also be use-ful for fundamental voltage disturbances. The series filter during an occasional supply voltage drop keeps the load voltage almost constant and only small instabilities and oscillations are observed during initial and final edges of disturbance.

Inverter connected in series with the transmission line through an insertion transformer. This connection allows the SSSC to precisely control power flow in the line with a wide range of system conditions. Although the SSSC can be compared to variable series capacitors in that they both inserta voltage in quadrature with the line current, the SSSC is considerably more powerful. In addition to advancing power flow, the SSSC can operate inductively to retard power flow.

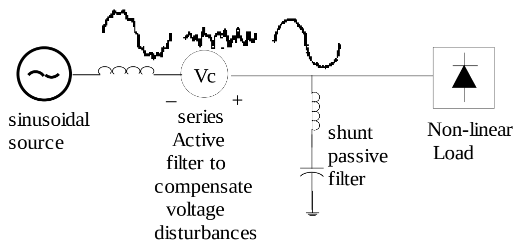

Fig:1.4 Filter voltage generation to compensate voltage disturbances

The SSSC can also reverse power flow like a dynamic phase shifter by overcome pensating the line. Another advantage of the SSSC over passive components (whether fixed or switched) is that the full compensat-ing voltage of the SSSC can be applied irrespective of the current flow through the line. In comparison, the compensating voltage of a series reactive element is directly proportional to the current flow. This allows the SSSC to operate effectively over a much greater range of system conditions. Using active control, the SSSC[11]-[13] has the ability to damp system oscilla-tions over a wide range of frequencies including those associated with sub-synchronous resonance (SSR) phenomena that involves series capacitors losses.

Unified Power Quality Conditionar (UPQC)

As the name suggests, the series-shunt active filter is a combination of series active filter and shunt active fil-ter. The topology is shown in Fig 1.5. The shunt-active filter is located at the load side and can be used to compensate for the load harmonics. On the other hand, the series portion is at the source side and can act as a harmonic blocking filter. This topology is called as Unified Power Quality Conditioner. The series portion compensates for supply voltage harmonics and voltage unbalances, acts as a harmonic blocking filter and damps power system oscillations. The shunt portion compensates load current harmonics, reactive power and load current unbalances. In addition, it regulates the dc link capacitor voltage. The power supplied or absorbed by the shunt portion is the power required by the series compensator and the power required to cover Unified Power Quality Conditioner (UPQC) The UPQC gives power system operators the flexibility to overcome many of the transmission restraints facing the industry today .A UPQC equipped transmission line can independently control real and reactive flow to maximize line utilization and system capability. It also can be used to minimize reactive current flow, enabling users to reduce system losses. The UPQC provides simultaneous, real-time control of all three basic power transfer parameters (voltage, impedance and phase angle) in any combination to optimize the transmitted power. It can handle such conventional functions as reactive shunt compensation, series compensation and phase shifting. The UPQC allows the power delivery system operator to set and independently control the real and reactive flow on a specific power transmission line[14]-[15]-[18].

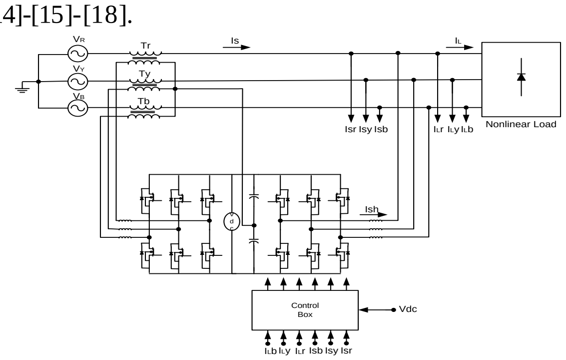

Fig: 1.5 Unified Power Quality Conditioners (UPQC)

Conclusion

Active power filters are offering unprecedented ability to clean the network from harmonics. They eliminate har-monics in a controlled way and can compensate load un-balances and power factor at the same time. Present de-vices can eliminate up to the 50th harmonic, with a pro-grammable filtering strategy and free choice of harmon-ics. With the new semiconductor devices and topologies coming in the near future, active power filters will in-crease their ability to keep the power distribution systems clean and free of dangerous perturbations. However, at the same time, electronic equipment will become more and more sensitive to power quality disturbances. For these two reasons, active power filters have a growing challenge in keeping the system completely free of un-wanted harmonics. Research and development will have to continue for this purpose.

The static shunt compensators, such as STATCOM, are mainly intended for conditioning the current flowing from the load into utility The series compensators, such as SSSC, are used to improve the quality of the voltage sup-plied by the utility to the load Unified Power Quality Conditioner (UPQC) to solve almost all power quality problems To put in nutshell, UPQC aims at the integra-tion of series active and shunt active power filters con-nected through a common DC link capacitor. This led to the development of advanced control techniques for UPQC

References:

[1] T. M. Gruzs, "A survey of neutral currents in three-phase computerpower systems," IEEE Trans. Ind. Applicat., vol. 26, pp. 719–725,July/Aug. 1990.

[2] J. S. Subjak Jr. and J. S. Mcquilkin, "Harmonics-causes, effects,measurements, analysis: An update," IEEE Trans. Ind. Applicat., vol.26, pp. 1034–1042, Nov./Dec. 1990.

[3] M. E. Amoli and T. Florence, "Voltage, current harmonic control of a utility system—A summary of 1120 test measure-ments," IEEE Trans.Power Delivery, vol. 5, pp. 1552–1557, July 1990.

[4] H. M. Beides and G. T. Heydt, "Power system harmonics estimation,monitoring," Elect. Mach. Power Syst., vol. 20, pp. 93–102, 1992.

[5] A. E. Emanuel, J. A. Orr, D. Cyganski, and E. M. Gulchen-ski, "Asurvey of harmonics voltages, currents at the customer's bus," IEEETrans. Power Delivery, vol. 8, pp. 411–421, Jan. 1993.

[6] P. J. A. Ling and C. J. Eldridge, "Designing modern electri-cal systemswith transformers that inherently reduce harmonic distortion in a PC-richenvironment," in Proc. Power Quality Conf., Sept. 1994, pp. 166–178.

[7] P. Packebush and P. Enjeti, "A survey of neutral current harmonics incampus buildings, suggested remedies," in Proc. Power Quality Conf.,Sept. 1994, pp. 194–205.

[8] Hugh Rudnik,Juan Dixon and Luis Moran "Active power filters as a solution to oiwer quality problems in distribution networks"IEEE powe and energy magazine pp 32-40 october 2003

[9] Bhim Singh, Ambrish Chandra and Kamal Al-Haddad "A Review of Active Filters for Power Quality Improvement" IEEE Trans. Ind. Electronics, VOL. 46, NO. 5, pp 960-971 OCTO-BER 1999

[10] H. Akagi, "New Trends in Active Filters for Power Condi-tioning," in IEEE Trans. on Industry Applications, vol. 32, no. 6, pp. 1312-1322, Nov./Dec. 1996.

[11] Stefanescu Silviu, Mircea Chindris, Andrei Cziker "Active Filtering – A Modern Trend in Power Conditioning" WEC Re-gional Energy Forum –FOREN 2004.

[12] Kuang Li, Jinjun Liu, Zhaoan Wang, and Biao Wei "Strate-gies and Operating Point Optimization of STATCOM Control for Voltage Unbalance Mitigation in Three-Phase Three-Wire Systems" IEEE TRANSACTIONS ON POWER DELIVERY, VOL. 22, NO. 1, JANUARY 2007 PP 413-422

[13] Massimo Bongiorno, , Jan Svensson, , and Lennart Ängqu-ist, "Single-Phase VSC Based SSSC for Sub synchronous

Resonance Damping”. IEEE TRANSACTIONS ON POWER DELIVERY, VOL. 23, NO. 3, JULY 2008 PP 1544-1552

[14] Fujita H., Akagi H., "The unified power quality conditioner: the integration of series and shunt-active filters." Power Electronics, IEEE Transactions on, Volume: 13 Issue: 2, March 1998, pp.315 -322.

[15] Yashomani Y. Kolhatkar, and Shyama P. Das,; “Experimental Investigation of a Single-Phase UPQC With Minimum VA Loading” IEEE TRANSACTIONS ON POWER DELIVERY, VOL. 22, NO. 1, JANUARY 2009 PP 373-380

[16] Mohan N., Undeland T. M., and Robbins W. P., Power Electronics:Converters, Application and Design. New York: Wiley, 1989.

[17] Understanding FACTS: Concepts and Technology of Flexible AC Transmission Systems. Narain G. Hingorani, Laszlo Gyugyi. Wiley IEEE press.

[18] Metin Kesler, Engin Ozdemir, " A Novel Control Method for Unified Power Quality Conditioner (UPQC) Under Non-Ideal Mains”, IEEE Conference, 978-1-4244-4783-1/10/$25.00 ©2010 IEEE

Power Problems	Causes	Effects
Voltage Sags	fuse or breaker operation, motor starting, or capacitor switching	short -term reduction in voltage (that are 80-85% of normal voltage), and can cause interruptions to sensitive equipment such as adjustable-speed drives, relays, and robots
Power Interruptions	weather, equipment malfunction, recloser operations, or transmission outages	System crash, System lock-up, Power supply damage, Lost data, Complete shutdown loss of control
Volage Flicker	sudden and large increases in load current, most commonly caused by rapidly varying loads that require a large amount of reactive power such as welders, rock-crushers, sawmills, wood chippers, metal shredders, and amusement rides.	It can cause visible flicker in lights and cause other processes to shut down or malfunction. Data corruption, Data Loss, Reduced performance, Loss of system control
Power Surges	heavy electrical equipment being turned off	Under these conditions, computer systems and other high tech equipment can experience flickering lights, equipment shutoff, errors or memory loss.
Switching Transients	take place when there is an extremely rapid voltage peak of up to 20,000 volts with duration of 10 microseconds to 100 microseconds caused by machinery starting and stopping, arcing faults and static discharge	data errors, memory loss and component stress that can lead to breakdown.
Frequency Variation	Erratic operation of emergency generators or unstable frequency power sources.	For sensitive equipment, the results can be data loss, program failure, equipment lock-up or complete shut down.
Electrical Line Noise	motors, relays, motor control devices, broadcast transmissions, microwave radiation, and distant electrical storms	unwanted effects in the circuits of computer systems, cause equipment to lock-up, and data error or loss.
Harmonics	Switch mode power supplies, Nonlinear loads	High neutral currents, Overheated neutral conductors, Overheated transformers, Voltage distortion, Loss of system capacity
Voltage Spikes and Surges	Lightning, Utility grid switching, Heavy industrial equipment	Equipment failure, System lock-up, Data corruption, Data loss
Power Outage & Interruptions	Blackouts, Faulted or overload, conditions, Back-up generator start-up	System crash, System lock-up, Power supply damage, Lost data, Complete shutdown loss of control