A Brief Survey on Power Quality Control in LV Distribution Network

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Abstract- In the progressing time frame power electronic and electronic hardware is winding up progressively increasingly delicate when stood out from their accomplice's couple of years back. The hardware which is especially vulnerable to this variety or debasement of power quality is the touchy burdens. Unadulterated sinusoidal voltage is required for its suitable undertaking. On account of augmentation being utilized of force equipment contraptions in the power framework and due deficiencies in the system the electric power supply gets hindered and power quality is especially influenced. There are symphonious substance in voltages and flows. There are deficiencies like glint, increase in variances of voltage. The media transmission, endeavors, and semiconductor creating ventures are continuously touchy to control quality issues as they need high caliber of power. Right now expansive review of composing has given a record of power quality trim in LV distribution networks.

Keywords- Harmonics, Smart Grid, UPQC, Power Quality, LV (Low Voltage), Distribution System.

I. INTRODUCTION

Power quality mainly deals with the interaction among the customers and the utility or it can be also said that it provides an interaction between the power system and the respective load. The ultimate goal of power system is the supply of electric energy to its customers. In the last 50 years or so, because of the extensive growth of industries electricity demand has tremendously increased which has led to establishment of many power generation and distribution grid. The demand for large amount of power for industrial and domestic use increased the burden on the generation. Electrical utilities working today are working as a subsystem of a large utility network that are tied together in order to form a complex grid. All these factors have put the power system under the requirement of a power quality. A high power quality is the main aim of the commercial facility design, along with "wellbeing," "trustable service" and "low beginning and working expenses". Problem in power quality is usually referred to any electrical problem faced in the frequency, voltage or current deviation which leads to mal-operation of the customer’s equipment. Often when talk of quality of power actually mean the quality of voltage because it is the voltage which is controlled most of the times. The term power quality can be related with reliability of the system by the electrical utilities. The most difficult thing is maintenance of the electrical power quality so that it will lie within the acceptable limits. There are many disadvantages of poor and low power quality. It may lead to higher power losses, abnormal and unusual behavior of electrical equipment, and interference with the nearby communication lines, poor voltage profile, harmonics, sag and swells in the voltage, poor and low distortion and displacement factor.

Custom power devices and FACTS devices are used widely in order to overcome these problems and in order to assure a high and better power quality. Custom power devices refer to the power electronic controllers used in the distribution systems to get a higher level of power quality. They act as power conditioning equipment that helps in mitigating the distorted voltage and current. DVR, DSTATCOM, active filters etc. are utilized as a part of request to enhance the quality of voltage and current to a better standard.

Unified Power Quality Conditioner (UPQC) is a very effective step in improving these power quality problems. It is a combination of parallel-Active Power Filter and Series-Active power Filter. Both of these filters are associated through the same dc link. Parallel active filter is connected parallel with the load. It helps in compensating the harmonic current flowing through the load, compensates reactive power demand of the load and helps in maintenance of a constant dc link voltage. On the other hand, series active power filter is connected in series with the utility voltage by the help of series transformer and helps in maintenance of a sinusoidal the load voltage. So as a whole it helps in a simultaneous compensation of the delivered load voltage and source side currents.

Due to faults there is voltage rise (swells), voltage dip (sag), or complete loss of voltages (interruptions) which are temporary for certain interval of time depending upon the type of fault occurred and location of fault. The duration is around 1 min for short voltage variation. Also if duration of fault is for few milliseconds then it is short duration voltage variation.

II. UNIFIED POWER QUALITY CONDITIONER

In the context of up gradation of quality of power UPQC plays a very vital role. It provides blessings of parallel and series active power filter both. Being a multitasking power conditioner UPQC can be utilised for compensation of numerous voltage disturbances, voltage flicker and it also provides prevention to the harmonics in the load current and doesn't allow them to enter into the power system and contaminate the quality of power. This custom power equipment has the ability of mitigation of the problems affecting the working of sensitive equipment or loads. UPQC provides compensation to harmonics in current (shunt part) as well as that to the voltage (series part), controls the flow of power and also overcomes the disturbances in voltage like voltage swell, sag etc. The essential parts of unified power quality conditioner are shunt inverter, series inverter, Dc link capacitor, Shunt coupling inductor and series transformer.

UPQC Configuration

UPQC mainly consists of following parts-

Shunt Inverter: A shunt connected voltage source inverter acts as shunt inverter. It is helpful in cancellation of current distortions i.e. compensates the harmonic current of the load. It also provides assistance in keeping up a steady value for the DC link capacitor voltage and also helps in improvement of system power factor. Furthermore it is also helpful in compensation of load reactive current. Usually hysteresis band controller is employed for controlling of the shunt inverter output current. By adjusting the semiconductor switches reference current can be made to follow the output current and stays within the particular hysteresis band.

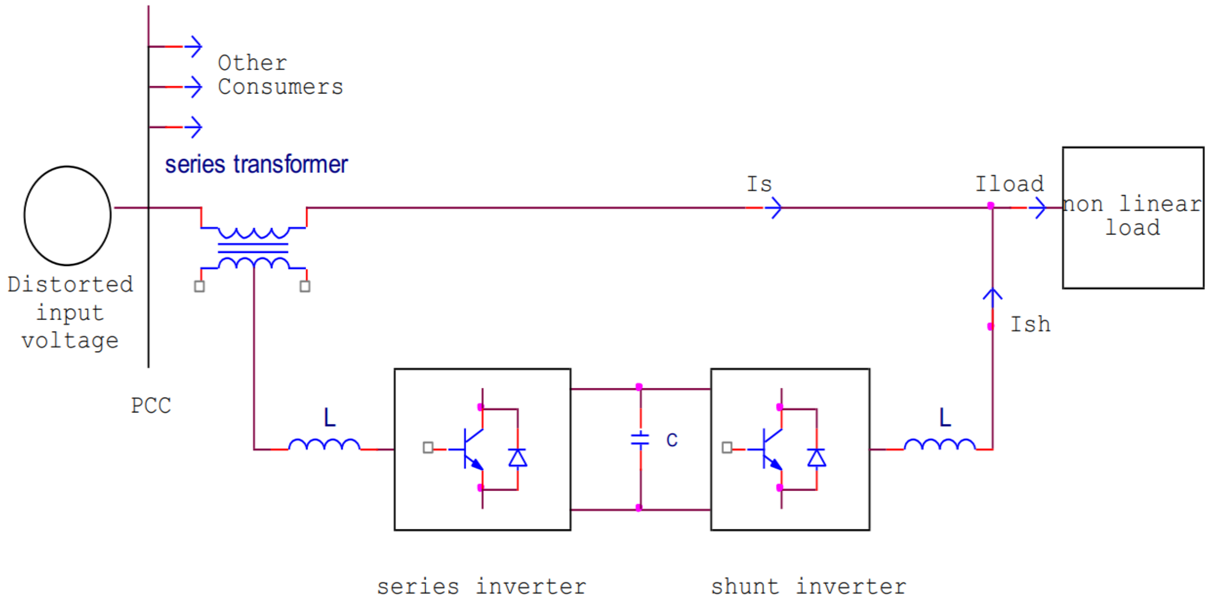

Fig. 2.1 Basic block diagram of UPQC.

Series Inverter: It is a series connected VSI (voltage-source inverter) acting as a source of voltage. Its connection is in series with the line by using a series transformer. It helps in overcoming the voltage based distortions. It helps in maintaining a sinusoidal load voltage by eliminating the load voltage imbalances and the flickers in the terminal voltage. PWM techniques are used for controlling the series inverter. Mostly hysteresis band technique of pulse width modulation is used. There are many advantages of using this PWM technique. It provides a better and faster response speed, easy to implement and it can work properly even without having the knowledge about the parameters of the system.

DC Link Capacitor: It is used for back to back connection of the series and shunt VSIs. The DC voltage developed across the capacitor acts as a constant voltage and helps in proper operation of both shunt and series inverters. If regulated properly the voltage provided by this capacitor can be used a source for both active and reactive power and the use of any outer DC source e.g. battery etc. can be eliminated.

Shunt coupling inductor: It is helpful in interfacing of the shunt inverter to the network. The main benefit of this is to smoothen the wave shape of the current by elimination of the ripples produced in the current.

LC Filter: It is present near the series inerter output of UPQC. Acting as a low-pass filter (LPF), it is helpful in attenuation of high-frequency voltage components of the output voltage of the series inverter.

Series Transformer: The series inverter generates a voltage for maintenance of load voltage sinusoidal at a particular required value. Series inverter helps in injection of this voltage through the series transformer. It is required to maintain a particular turn's ratio in order to maintain a low current flow through the series inverter.

III. LITERATURE REVIEW

SR. NO.	TITLE	AUTHOR	YEAR	APPROACH
1	Power Quality Conditioning in LV Distribution Networks: Results by Field Demonstration	H. Hafezi, G. D'Antona, A. Dedè, D. Della Giustina, R. Faranda and G. Massa	2017	An interesting solution is represented by the open unified power quality conditioner (Open UPQC) proposed within the present work
2	Dynamic Voltage Conditioner: A New Concept for Smart Low-Voltage Distribution Systems	H. Hafezi and R. Faranda	2018	The examination introduces a new control method of a single-phase DVC system able to compensate these long duration voltage drifts.
3	Reactive power flow control of a Dual Unified Power Quality Conditioner	S. M. Fagundes and M. Mezaroba	2016	A way to balance the reactive power processed between series and parallel active filters that compose the Dual Unified Power Quality Conditioner (iUPQC) through the power angle control (PAC).
4	Reactive Power Management in Islanded Microgrid—Proportional Power Sharing in Hierarchical Droop Control,	A. Milczarek, M. Malinowski and J. M. Guerrero,	2015	The novel reactive power sharing algorithm is developed, which takes into account the converters parameters as apparent power limit and maximum active power.
5	Primary Frequency Control Contribution From Smart Loads Using Reactive Compensation	Z. Akhtar, B. Chaudhuri and S. Y. Ron Hui	2015	This examination describes additional contribution to primary frequency control based on voltage-dependent noncritical (NC) loads that can tolerate a wide variation of supply voltage
6	A Simplified Control Technique for a Dual Unified Power Quality Conditioner	R. J. Millnitz dos Santos, J. C. da Cunha and M. Mezaroba	2014	Presents a simplified control technique for a dual three-phase topology of a unified power quality conditioner-iUPQC.
7	Multi-Objective Planning for Reactive Power Compensation of Radial Distribution Networks With Unified Power Quality Conditioner Allocation Using Particle Swarm Optimization	S. Ganguly	2014	Presents a particle swarm optimization (PSO)-based multi-objective planning algorithm for reactive power compensation of radial distribution networks with unified power quality conditioner (UPQC) allocation
8	SmartDomoGrid: Reference architecture and use case analyses for a grid-customer interaction	G. Accetta, D. Della Giustina, S. Zanini, G. D'Antona and R. Faranda	2013	The work is focused on the architecture and several use cases proposed and analyzed within the project.

H. Hafezi, G. D'Antona, A. Dedè, D. Della Giustina, R. Faranda and G. Massa, [1] Power quality in LV distribution networks is already a concern in many European countries especially where there is a strong presence of renewable energy generation. Therefore there is a growing interest in new solutions able to improve the power quality level of such a system. Among them, an interesting solution is represented by the open unified power quality conditioner (Open UPQC) proposed within the present work. The system consists of a single or three-phase ac/dc power converter installed at customer's premises and a main single or three-phase ac/dc power converter in the MV/LV substation. The examination discusses the design, simulation and implementation phases related to an Open UPQC installed in a real LV distribution grid in the city of Brescia (Italy) within the smart domo grid project, co-funded by the Italian Ministry of Economic Development. Results from the field installation show the effectiveness of the proposed solution to face power quality issues in distribution networks.

H. Hafezi and R. Faranda, [2] Power Quality (PQ) improvement in distribution level is an increasing concern in modern electrical power systems. One of the main problems in low voltage (LV) networks is related to load voltage stabilization close to the nominal value. Usually this problem is solved by smart distribution transformers, hybrid transformers and solid-state transformers, but also dynamic voltage conditioners (DVC) can be an innovative and a cost effective solution. The work introduces a new control method of a single-phase DVC system able to compensate these long duration voltage drifts. For these events, it is mandatory to avoid active power exchanges so, the controller is designed to work with nonactive power only. Operation limits for quadrature voltage injection control is formulated and reference voltage update procedure is proposed to guarantee its continuous operating. DVC performance for main voltage and load variation is examined. Proposed solution is validated with simulation study and experimental laboratory tests. Some simulation and experimental results are illustrated to show the prototype device's performance.

S. M. Fagundes and M. Mezaroba [3] thisexamination presents a way to balance the reactive power processed between series and parallel active filters that compose the Dual Unified Power Quality Conditioner (iUPQC) through the power angle control (PAC). The proposed new methodology divides equally the reactive power between the filters according of load demand. It will be presented a review of the iUPQC operation, the concept of power angle control, the mathematical deduction of the power angle control used for reactive power equalization, the analysis of power flow between iUPQC filters and simulations to validate the proposed control.

A. Milczarek, M. Malinowski and J. M. Guerrero, [4] A microgrid (MG) is a local energy system consisting of a number of energy sources (e.g., wind turbine or solar panels among others), energy storage units, and loads that operate connected to the main electrical grid or autonomously. MGs provide flexibility, reduce the main electricity grid dependence, and contribute to changing large centralized production paradigm to local and distributed generation. However, such energy systems require complex management, advanced control, and optimization. Moreover, the power electronics converters have to be used to correct energy conversion and be interconnected through common control structure is necessary. Classical droop control system is often implemented in MG. It allows correct operation of parallel voltage source converters in grid connection, as well as islanded mode of operation. However, it requires complex power management algorithms, especially in islanded MGs, which balance the system and improves reliability. The novel reactive power sharing algorithm is developed, which takes into account the converters parameters as apparent power limit and maximum active power. The developed solution is verified in simulation and compared with other known reactive power control methods.

Z. Akhtar, B. Chaudhuri and S. Y. Ron Hui, [5] Frequency-dependent loads inherently contribute to primary frequency response. This examination work describes additional contribution to primary frequency control based on voltage-dependent noncritical (NC) loads that can tolerate a wide variation of supply voltage. By using a series of reactive compensators to decouple the NC load from the mains to form a smart load (SL), the voltage, and hence the active power of the NC load, can be controlled to regulate the mains frequency. The scope of this work focuses primarily on reactive compensators for which only the magnitude of the injected voltage could be controlled while maintaining the quadrature relationship between the current and voltage. New control guidelines are suggested. The effectiveness of the SLs in improving mains frequency regulation without considering frequency-dependent loads and with little relaxation in mains voltage tolerance is demonstrated in a case study on the IEEE 37 bus test distribution network. Sensitivity analysis is included to show the effectiveness and limitations of SLs for varying load power factors, proportion of SLs, and system strengths.

R. J. Millnitz dos Santos, J. C. da Cunha and M. Mezaroba [6] This examination presents a simplified control technique for a dual three-phase topology of a unified power quality conditioner-iUPQC. The iUPQC is composed of two active filters, a series active filter and a shunt active filter (parallel active filter), used to eliminate harmonics and unbalances. Different from a conventional UPQC, the iUPQC has the series filter controlled as a sinusoidal current source and the shunt filter controlled as a sinusoidal voltage source. Therefore, the pulse width modulation (PWM) controls of the iUPQC deal with a well-known frequency spectrum, since it is controlled using voltage and current sinusoidal references, different from the conventional UPQC that is controlled using nonsinusoidal references. In this work, the proposed design control, power flow analysis, and experimental results of the developed prototype are presented.

S. Ganguly, [7] This examination work presents a particle swarm optimization (PSO)-based multi-objective planning algorithm for reactive power compensation of radial distribution networks with unified power quality conditioner (UPQC) allocation. A UPQC consists of a series and a shunt inverter. The UPQC model based on phase angle control (UPQC-PAC) is used. In UPQC-PAC, the series inverter injects a voltage with controllable phase angle in such a way that the voltage magnitude at load end remains unchanged. Due to the phase angle shift, the series inverter participates in load reactive power compensation along with the shunt inverter during healthy operating condition. In the proposed approach, the optimal location, the optimal reactive power compensation required at the location, and the optimal design parameters of UPQC are determined by minimizing three objective functions: 1) the rating of UPQC, 2) network power loss, and 3) percentage of nodes with undervoltage problem. These objectives are simultaneously minimized to obtain a set of non-dominated solutions using multi-objective PSO (MOPSO). The performances of two MOPSO variants are compared and the better one is used in all subsequent studies. A load flow algorithm including the UPQC-PAC model is devised. The performance of the proposed algorithm is validated with different case studies.

G. Accetta, D. Della Giustina, S. Zanini, G. D'Antona and R. Faranda [8] The evolution of the electrical energy system toward a smart model has already started. Smart metering, electric vehicles, renewable resources, transmission and distribution advanced grid automation are some example of this ongoing change. A further step in this process is the interaction between final customers often residential and the distribution grid. Those customers shall provide new services to the distribution utility which can help them to better and more safely manage the grid. The SmartDomoGrid project - cofounded by the Italian Ministry of Economic Development - is aimed at designing, implementing and testing a possible scheme for the grid-customer interaction in a real operation environment. The work is focused on the architecture and several use cases proposed and analyzed within the project.

IV. PROBLEM STATEMENT

In today’s world there is great importance of electrical energy as it is the most famous from of energy and all are massively relying on it. Without supply of electricity life cannot be imagined. At the same time the quality and continuousness of the electric power supplied is also very important for the efficient functioning of the end user equipment. Many of the commercial and industrial loads require high quality undisturbed and constant power. Thus maintaining the qualitative power is topmost important in today’s world.

Due to power electronics devices there is serious effect on quality and continuousness of electric supply. Because of power electronics devices there is uninterrupted power supply, flicker, harmonics, and voltage fluctuations etc. There is also PQ problems such as voltage rise/dip due to network faults, lightning, switching of capacitor banks. With the excessive uses of non-linear load (computer, lasers, printers, rectifiers) there is reactive power disturbances and harmonics in power distribution system. It is very essential to overcome this type of problems as its effect may increase in future and cause adverse effect.

V. CONCLUSION

This study represents an brief survey of literature based on past work on power quality and quality control enhancement. Monitoring of the power quality (PQ) is essential for all generation, transmission and distribution of the electricity grid all over the world for supplying the continuity of the service. There are various PQ monitoring devices developed for all system levels. As the supply voltage gets distorted it leads to mal-operation of protection, control, and the metering equipment. So the necessity for maintenance of the power quality standards arises and to achieve a voltage that will be purely sinusoidal, the use of compensation technique is very much important. Many consumers are also there whose need of power quality is high than what provided by the electrical networks. So it’s very much essential to obtain a higher quality of electrical power.

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