A Comparative Study of PI, Fuzzy and Neuro-Fuzzy Controller in UPQC to Improve Power Quality

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***Abstract*— For the development and improvement of dynamic performance of the distribution system, Custom Power Devices are used. The quality of the Electrical power is affected by different factors like- the presence of harmonics in the system, voltage swell and voltage sag due to switching of loads, current flickering etc. A Custom Power Device, Unified Power Quality Conditioner (UPQC) can provide controllable compensating voltage and current simultaneously. Different controllers used in UPQC are studied in this paper. The research work is fabricated as a project and after getting satisfactory results, it is implemented in distribution system to improve power quality.**

***Keywords*- Harmonic, Voltage sag, Voltage swell, UPQC.**

I. INTRODUCTION

In day to day life there is a great importance of electrical energy as it is our basic need and all are largely dependent on it. Also the quality and continuity of the electric power supplied is very important for the efficient functioning of the customer equipment. Many industrial loads require high quality of undisturbed and constant power. Thus maintaining the quality of power is very necessary in today's world.

Due to power electronics devices, there is serious effect on quality and continuity of electric supply. Because of power electronics devices, Programmable logic circuits (PLC), semiconductor devices and adjustable speed drives there is uninterrupted power supply, voltage flickers, harmonics, voltage fluctuations etc. There are also PQ problems such as voltage rise/dip due to network faults, lightning, switching of capacitor banks. With the excessive use of non-linear loads (computer, lasers, printers, rectifiers), there is reactive power disturbance and harmonics in power distribution system. It is very essential to overcome these types of problems to improve power quality. Active Power Filters are used for power quality enhancement. Active power filters are classified according to the system configuration as series and shunt. Combining both series APF & shunt APF, we get a device known as UPQC. UPQC eliminates the voltage and current based distortions.

II. POWER QUALITY ISSUES:

Power quality problem embodies deviation in voltage, current or frequency that culminate into a failure of equipment. Power quality problems often accompany loss of production, damage to appliances, higher power losses, communication interference and so on. It is, therefore, significant to establish and maintain higher standard of power quality. The frequently encounter problems related to power quality are discussed below:

A. Short duration voltage variation:

Due to the 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 and location of the fault. The duration is around 1 min for short voltage variation.

B. Long- Duration voltage variation:

The long duration voltage variations are caused because of sustained interruptions, under voltages and over voltages.

(i) Sustained interruption:- When there is zero supply voltage for a interval of time more than 60 sec, it is considered as sustained interruption in case of long duration voltage variation.

(ii) Under voltage:- It is the reduction in rms ac voltage to lower than 90 % at power frequency for a time interval 60 sec or may be greater than it. The switching off of capacitor banks and switching on of loads cause under voltage

(iii) Over voltage:- It is the rise in rms ac voltage to more than 110 % at power frequency for a time interval of more than 60 sec. Over voltages are caused due to the wrong tap settings of transformers and switching of loads.

C. Transients:

Transients are sudden & small changes in current and voltage signals for a very small period of time.

(i) Impulsive transients:- Impulsive transients are variations in current, voltage or both on power line in one direction (unidirectional). The causes of impulsive transients are switching in power distribution systems, inductive loads switching, lightning. The impulsive transients can be removed with help of Zener diode which suppresses the transient voltage.

(ii) Oscillatory transients:- Oscillatory transients are transients which have swing (bidirectional) i.e. rapid change of polarity of current , voltage or both on power line. It is

caused due to the Capacitors switching which help in power factor correction.

D. Waveform Distortion:

A power system network tries to generate a sinusoidal voltage and current waveform. But due to certain problems, it is not able to generate the sinusoidal waveform and the distortions occur.

III. COMPARISION WITH OTHER CUSTOM POWER DEVICES

A. DSTATCOM :

Distribution Static Compensator is a shunt connected compensator to compensate the load current. Being a shunt connected device, it mainly injects reactive power to the system. The device needs to be installed closer to the sensitive load as possible to maximize the compensating capability.

B. Dynamic Voltage Restorer (DVR):

DVR is a solid state power electronic switching device which is connected in series in the distribution system. It detects the presence of voltage sags and operates to mitigate the voltage dip. It comprises of energy storage unit, voltage source inverter, transformer and control unit.

C. Unified Power Quality Conditioner (UPQC):

UPQC is an effective custom power solution to improve power quality. UPQC combines the operation of a Distribution Static Compensator (DSTATCOM) and Dynamic Voltage Restorer (DVR) together. It consists of back to back connected Active Power Filter with a common DC link. A UPQC operates in simultaneous voltage and current control modes.
In the voltage control mode it can make bus voltage at load terminal sinusoidal against any unbalance, harmonic or flicker in the source voltage or unbalance or harmonic in the load current. In the current control mode, it draws a balanced sinusoidal current from the utility bus irrespective of unbalance and harmonic in either source voltage or load current.

IV. BASIC CONFIGURATION OF UPQC

Unified Power Quality Controller (UPQC) consists of series and shunt active power filters (APF) connected back to back on the DC side and commonly sharing a DC link. The two shunt APF and series APF are connected back to back through a DC link. DC link provides a DC voltage for working of both the active power filter. The DC link also provides a real power difference between source and load during the transient period and also acts as a energy storage device. During steady state, real power supplied by source should be equal to the sum of real power demand of load and a small amount of power which compensates for active filter. DC capacitor voltage should be equal to reference value but due to disturbance in real power balance between source and load due to change in load conditions the DC capacitor value is changed from reference value.

A Shunt APF predominantly mitigates all kind of current related problems like current harmonic, reactive power, poor power factor. It injects current into the system so as to maintain balance sinusoidal currents in phase with the source voltage. A Series APF compensates voltage sags/swells, voltage flickers, voltage unbalance and harmonics so that voltage at load side is perfectly regulated. It inject voltage in series so as to maintain a desired level of load voltage which is balanced and free from distortion.

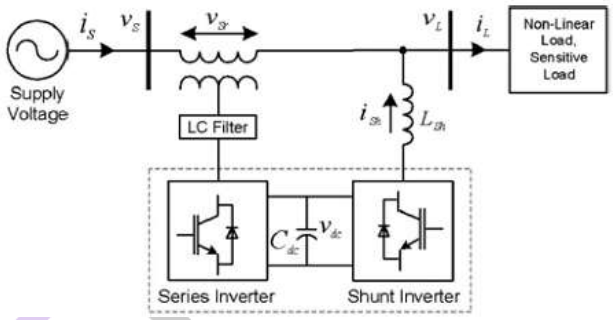

Fig 1. Basic configuration of UPQC

V. CONTROL TECHNIQUES

A. PI-CONTROLLER:

In the proposed control scheme, the supply currents are directly measured and regulated to be sinusoidal by an effective harmonic compensator which is developed based on a PI plus VPI controllers. Owing to the effectiveness of the proposed PI-VPI controller, the harmonic currents produced by the nonlinear load can be accurately compensated without the demand of a load current measurement and harmonic detector. The absence of the harmonic detector not only simplifies the control scheme but also significantly improves the accuracy of the shunt APF since the control performance is no longer affected by the performance of the harmonic tracking process. Moreover, the total cost to implement the shunt APF is lower, owing to the minimized current sensors cost. The PI controller is popularly employed for current/voltage control in power converters due to its fast dynamic response and zero steady-state error in regulating a DC signal.

B. NEURO-FUZZY CONTROLLER (NFC):

A neuro-fuzzy system is a fuzzy system that uses a learning algorithm derived from or inspired by neural network theory to determine its parameters (fuzzy sets and fuzzy rules) by processing data samples. NFC is the combination of Fuzzy Inference System (FIS)and Neural Network(NN). The fuzzy logic is operated based on fuzzy rule and NN is operated based on training data set. The neural network training data set are generated from the fuzzy rules. If more than two Active Power Filters are sharing a common DC link then the discharging time of DC link is very high. To eliminate this problem, an enhanced Neuro-fuzzy controller (NFC) based multiconverter UPQC is used for improving power quality.

C. FUZZY LOGIC CONTROLLER

Fuzzy control system is a control system based on fuzzy logic –a mathematical system that analyzes along input values in terms of logical variables that take on continuous values between 0 and 1. Controllers based on fuzzy logic give the linguistic strategies control conversion from expert knowledge in automatic control strategies. Professor Lotfia Zadeh at University of California first proposed in 1965 as a way to process imprecise data its usefulness was not seen until more powerful computers and controllers were available . In the fuzzy control scheme, the operation of controller is mainly based on fuzzy rules, which are generated using fuzzy set theory.

Fuzzy controller plays an important role in the compensation of PQ problem. The steps involved in fuzzy controller are- fuzzification, decision making, and defuzzification. Fuzzification is the process of changing the crisp value into fuzzy value. The fuzzification process has no fixed set of procedure and it is achieved by different types of fuzzifiers. The shapes of fuzzy sets are triangular, trapezoidale and more. The fuzzified output is applied to the decision making process, which contains a set of rules. Using the fuzzy rules, the input for bias voltage generator is selected from FIS. Then, the defuzzification process is applied and the fuzzified calculated voltage (Vdc)is determined. Fuzzy logic contoller is a complex controller and is useful for multiconverter based UPQC.

VI. PROPOSED CONFIGURATION OF UPQC

The UPQC is capable of compensating voltage distortions at the supply side as well as current harmonics at the load side to make the load voltage and the supply current become purely sinusoidal. In order to fulfill these control targets, many different approaches have been developed in the literature. As shown in Figure 2 in order to compensate harmonics, the harmonic components in the supply voltage (vS) and load current (iL) are first extracted by harmonic detectors. Then the reference voltage and current for the series and shunt APFs are generated, and the voltage/current controllers are executed to regulate the filter voltage (vf) and filter current (iF). In these control methods, along with the voltage/current controllers, harmonic detectors also play vital roles affecting to the dynamic response as well as the steady-state performance of the UPQC.

The system operates at normal mode if the source voltage is held at 1.0pu. If the source voltage falls to a value in between 0.5 and 1.0 pu, voltage sag creeps into the system. On the contrary, if the source voltage rises above 1.0pu, the system operates in voltage swell mode. The complete system interruption occurs if the value of source voltage drastically reduces below 0.5pu.

The two Active Power Filters are connected back to back through a DC link. The DC link also provides a real power difference between source and load during the transient period and also acts as a energy storage elements. During steady state real power supplied by source should be equal to the sum real power demand of load & a small amount of power which compensates for active filter. DC link voltage should be equal to reference value but due to disturbance in real power balance between source and load due to change in load conditions the DC link value is changed from reference value.

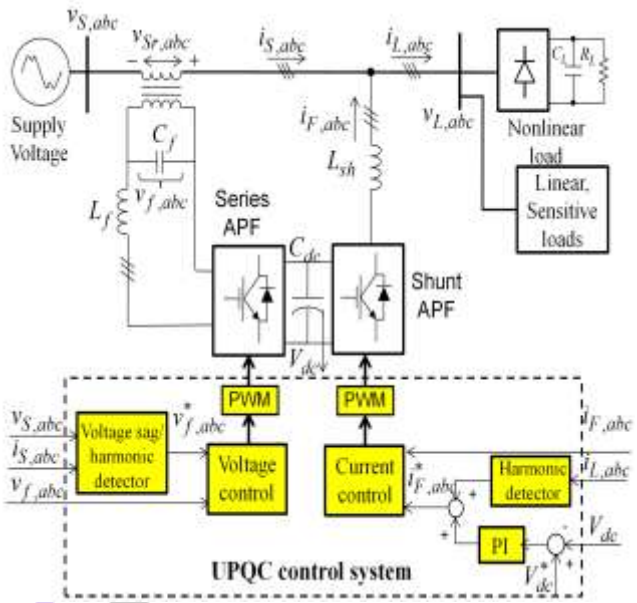

Fig 2. Proposed configuration of UPQC

VII. CONCLUSION

The custom power device, Unified Power Quality Conditioner and its control strategy have been proposed to improve the power quality of distribution network. This paper presents a comparative study of different controllers such as PI controller, FUZZY Controller and Neuro Fuzzy Controller. Also Unified Power Quality Conditioner is compared with other power devices such as DVR and DSTSCOM. Unified power quality conditioner was studied and investigated in this paper for power quality enrichment. UPQC is a type of advance hybrid filter which uses series APF for removal of voltage related problems like voltage dip/rise, fluctuations, imbalance and shunt APF for removal of harmonics in current harmonics. Different types of problems in power quality are studied and discussed.

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