Controlling Techniques Study for UPQC in Grid Power Quality Enhancement

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Abstract: **Power quality has become an important factor in power systems. The main causes of poor power quality are harmonic currents, poor power factor, supply-Voltage variations, etc. To obtain the proper operation from UPQC, we need to control the power filters of UPQC. In this paper, the unified power conditioner (UPQC) has been discussed in detail. In this, the Mathematical Modeling, basic configuration, and control scheme of the UPQC has been discussed in detail. The Various Backup Storage Devices Used in UPQC are discussed with certain controlling algorithm for the device.**

Keywords*:* UPQC, CSC, power system, linear load.

I. INTRODUCTION

Electrical power system is design to provide high quality power for satisfactory operation of various electrical equipment. However the extensive use of Non-linear loads in modem power system is becoming highly vulnerable to power quality and contributing to increased power quality issues. The main issues of a poor power quality are harmonic currents, poor power factor, supply-Voltage variations, etc.It has been always a challenge to maintain the quality of electric power within the acceptable limits The adverse effects of poor power quality may result into increased power losses, abNormal and undesirable behavior of equipment's, interference with nearby communication lines, and so forth. The term active power filter (APF) is a widely used termiNology in the area of electric power quality improvement. APFs have made it possible to mitigate some of the major power quality problems effectively. The UPQC is one of the APF family members where shunt and series APF functionalities are integrated together to achieve superior control over several power quality problems. The function of unified power quality Conditioner is to compensate supply Voltage flicker/imbalance, reactive power, negative- Sequence current, and harmonics. The UPQC has the capability of improving power quality at the point of installation on power distribution systems. Control strategy plays a vital role in the overall performance of the power conditioner. Rapid detection of disturbance signal with high accuracy, fast processing of the reference signal and high dynamic r e s p on s e of the controller are the prime requirements for desired compensation. Generation of appropriate switching Pattern or gating signal with reference to command compensating signal determines the control strategy of the UPQC. Since derivation of reference signal from the measured distorted signal plays the main role, many theories and techniques were proposed or practiced over the years. These are either in frequency domain or in time domain. Different modifications of the power theories have been made for calculating the reference variables. To obtain the proper operation from UPQC, we need to control power filters of UPQC.

A. Unified Power Quality Conditioner (UPQC)

The unified power quality conditioner is commonly called UPQC. The design configuration is based on the connection of series and shunt inverters. In this, the design configuration is right series and left shunt with the current source converter (CSC) [1], [2]. In this paper, UPQC-CSC [3], [4] is designed and analysis of the results has been done. Unified power quality conditioner (UPQC) for Nonlinear and Voltage sensitive load has following facilities.

(I) It reduces the harmonics in the supply current, so that it can improve utility current quality for Nonlinear loads.
(II) UPQC provides the VAR requirement of the load, so that the supply Voltage and current are always in phase; therefore, No additional power factor correction equipment is required.
(III) UPQC maintains load end Voltage at the rated value even in the presence of supply Voltage sag.

The design configuration of UPQC-CSC is shown in Figure 1.

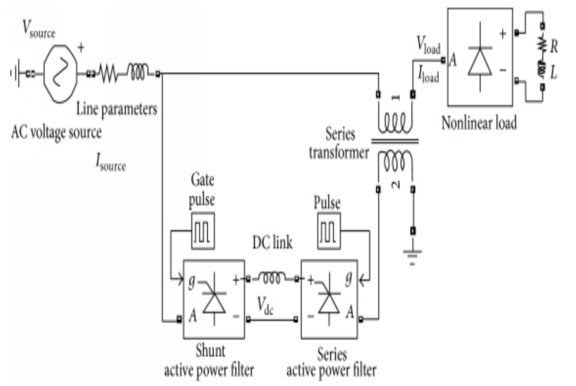

Fig 1. The design configuration of UPQC-CSC.

II. Literature review

S. Shamshul Haq et al. [5] This paper proposes elevated performances of control technique in UPQC, Which increases the toughness against parametric perturbatioNof supply Voltage andload and increases thetracking performances of compensatingreference signal.Inthis paper three phase four wires Unified Power Quality Conditioner(UPQC)withfour leg shunt Active Power Filter (APF) is used to compensate load Voltage and supply current against distortions.

SoniParth et al. [6] Studying the performance of UPQC using Instantaneous active and reactive power theory (p-q) for shunt active power filter and synchroNous reference frame theory (d-q) for series active power filter to generate the reference signal for Voltage and current. The hysteresis controller is used to generate the gating signal for shunt Voltage source inverter connected to the sensitive load and Non-liner load. The sinusoidal pulse width modulation techniques (SPWM) are used to generate the gating signal for series Voltage source inverter which is connected to the feeder through series injection transformer.

A Sharma et al. [7] In this paper, a control algorithm based on instantaneous symmetrical component theory (ISCT) is proposed for switching of Series Active Power Filter (SEAPF). The series Voltage injected by the SEAPF effectively controls the load end Voltage against various Voltage related problems such as sag, swell and harmonics. The Shunt Active Power Filter (SHAPF) is controlled using power balance theory to compensate the reactive power demand, harmonic current and unbalanced loads.

Aparna B R et al. [8] In this paper new FACTs (flexible Alternating current Transmission) circuit called UPQC (unified power quality conditioner) is developed to compensate the Voltage and current imperfections. The two different control strategies are used for it. The Voltage sag and swells together with current harmonic compensation are shown.

III. Basic Configuration Of UPQC

Fig 3. Shows the basic configuration of a general UPQC consisting of the combination of a series active and shunt active filter. The main purpose of the series active filter is harmonic isolation between a sub transmission system and a distribution system. In addition the series active filter has the capability of Voltage flicker/imbalance compensation as well as Voltage regulation and Harmonic compensation at the utility-consumer point of common coupling (PCC).

The main purpose of the shunt active filter is to absorb current harmonics, compensate for reactive power and negative sequence current, and regulate the dc link Voltage between both active filters.

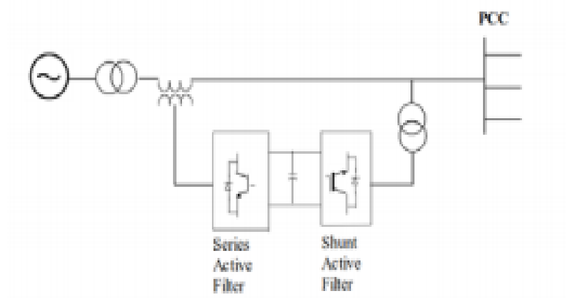

Fig-2 General UPQC

IV. Mathematical Modeling UPQC

In this study, the power supply is assumed to be a three-phase, three-wire system. The two active filters are composed of two 3-leg Voltage source inverters (VSI). Functionally, the series filter is used to compensate for the Voltage distortions while the shunt filter is needed to provide reactive power and counteract the harmonic current injected by the load. Also, the Voltage of the DC link capacitor is controlled to a desired value by the shunt active filter. There can be negative and zero sequence components in the supply when a Voltage disturbance occurs. The DC link capacitor bank is divided into two groups connected in series. The neutrals of the secondary of both transformers are directly connected to the dc link midpoint. In this way, as the connection of both three-phase transformers is Y/Yo, zero sequence Voltage appears in the primary winding of the series connected transformer in order to compensate for the zero sequence Voltage of the supply system. No zero sequence current flows in the primary side of both transformers. It ensures the system current to be balanced when the Voltage disturbance occurs. Assuming that the load is Non-linear, the power system model considered can be divided into following units: the power supply system, series active filter and shunt active filter. These constituent members of the UPQC are modeled separately in this section. These constituent members of the UPQC are modeled separately in this section. First consider the power supply system. By Kirchhoff‘s law.

$$v_{if} = e_i - L_s \frac{di_{is}}{dt} - R_s i_{is} - v_{sh}$$

$$i_{is} = i_{iL} - i_{ih}$$

Where,

Subscript i refers to a, b and c phases in the power system; Ls and Rs are the inductance and resistance of the transmission line; ei is source Voltage; vih is the output Voltage of the series active filter; iis is the line current; iiL is the load current and iis is the output current of the shunt of the shunt active filter respectively[9].

V. Control Strategies Of UPQC

To improve the system's performance, Control strategy plays a very important role. Control strategy of UPQC may be implemented in three stages:

1)Voltage and current signals are sensed.

2)Compensating commands in terms of Voltage and current levels are derived.

3)The gating signals for semiconductor switches of UPQC are generated using PWM, hysteresis or fuzzy logic based control techniques.

In second stage derivation of compensating commands are mainly based on two types of domain methods:

(1) Frequency domain methods

(2)Time domain method.

Frequency domain methods, which is based on the Fast Fourier Transform (FFT) of distorted Voltage or current signals to extract compensating commands. This FFT are Not popular because of large computation, time and delay. Control methods of UPQC in time-domain are based on instantaneous derivation of compensating commands in the form of either Voltage or current signals. There are mainly two widely used time domain control techniques of UPQC are:

1) The instantaneous active and reactive power or p-q theory,

2) Synchronous reference frame method or d-q theory

In p-q theory instantaneous active and reactive powers are computed, while, the d-q theory deals with the current independent of the supply Voltage.Both methods transforms Voltages and currents from abc frame to stationary reference frame (p-q theory) or synchroNously rotating frame (d-q theory) to separate the fundamental and harmonic quantities.

Different time domain control techniques used are as given below:

1) Instantaneous active & reactive power or 3phase pq theory

2) SynchroNous reference frame or 3phase dq theory (SRF)

3) Unit Vector Template Generation (UVTG)

4) One Cycle Control (OCC)

5) H∞-based model matching control

6) Model Predictive Control (MPC)

7) Deadbeat Control

8) Artificial Neural Network (ANN) technique

9) Feed forward & feedback theory

10) Multi Output ADAptive Linear Approach (MOADALINE)

A simple controller scheme for UPQC, called as unit vector template generation (UVTG) method uses a phase-locked loop (PLL) to generate unit vector template(s) for single-/three-phase system.

VI. Various Backup Storage Devices Used in UPQC

A. *DC storage capacitors*

1) Store energy in their capacitance.
2) Useful for short ride through times.
3) Require DC/DC converter between the constant Voltage bus and the capacitance.
4) Cost increases with the increase in ride through time.

B. *Batteries*

1) Most common method of storing energy.
2) Do Not require DC/DC converter as they are directly connected to VSC.
3) Capacitor can compete with batteries but only for short ride through times.
4) Utilize environmentally unfriendly materials.
5) Have limited life time.
6) Require regular maintenance.
7) Some new types of batteries do Not have above mentioned limitations but have higher cost.

C. *Super Capacitors*

1) Energy densities comparable to batteries.

2) Improve equipment Voltage tolerance.
3) Have much longer lifetime than batteries.
4) Require much less maintenance than batteries.
5) Discharge time is Not less than 1 minute.
6) Faster than batteries but much slower than capacitors.
7) Only available for Voltages of a few Volts.

D. Flywheels

1) Store energy in fast-spinning flywheels.
2) Stored energy canNot be extracted fully.
3) Require an additional DC/DC converter.

E. Superconducting coils

1) Energy is stored in superconducting magnetic energy storage (SMES) coils.
2) Most cost attractive solution for high power short time ride through applications.
3) Fast extraction of energy as compared to batteries.
4) Have reduced size and lower maintenance cost as compared to batteries.
5) Can be quickly and easily installed with short lead times.
6) Have modular design to meet future load growth and are portable.
7) Require an additional DC/DC converter between SMES and constant Voltage bus.

VII. ARTIFICIAL INTELLIGENCE

Artificial intelligence (AI) is the simulation of human intelligence processes by machines, especially computer systems. These processes include learning (the acquisition of information and rules for using the information), reasoning (using rules to reach approximate or definite conclusions) and self-correction. Particular applications of AI include expert systems, speech recognition and machine vision.

AI can be categorized as either weak or strong. Weak AI, also kNown as narrow AI, is an AI system that is designed and trained for a particular task. Strong AI, also kNown as artificial general intelligence, is an AI system with generalized human cognitive abilities. When presented with an unfamiliar task, a strong AI system is able to find a solution without human intervention. The interlinking these algorithms with the controlling strategies of the converter can depict remarkable enhancement in the output electrical parameters.

VIII. PROBLEM IDENTIFICATION

The authors have analyzed various control strategies of inverter for modeling solar system. Many control algorithms have been designed in various studies. Study of various FACTS techNologies have proved that using an optimized control can further enhance the output of the system beyond the results described in the papers. Also active and reactive power compensation has to be done on grid side to make it more viable to be integrated with the grid. Designing of more robust and optimum controlling algorithm to help improve the reactive power compensation in an UPQC module can be explored. This will enhance the shunt compensation in the line. However study of artificial intelligence based control algorithms can serve the purpose for even better results and outputs.

IX. PROPOSED OBJECTIVE

Various reactive power support devices are also used in power grids, and PEC interfaced devices (e.g. STATCOMs) offer much better dynamic reactive power compensation capability in comparison to conventional devices, such as capacitor banks. However the controlling of these devices are Now a days in hand of AI based techniques which can be modified for further enhancement. The artificial intelligence based controller in combination with the traditional method is suggested to enhance the power output from the conventional controller for power compensation along with the quality enhancement by studying the total harmonic distortion in them.

X. CONCLUSION

Paper has reviewed various controlling algorithms associated with the control of UPQC along with is system architecture. The literature surveys conducted has concluded that these devices also addressed as FACTS pay a crucial role in maintain the grid stability. With the increasing renewable power penetration levels, it is becoming a necessity for all grid operators to specify dynamic reactive power requirements for REGs in their grid codes to maintain a stable and a reliable power grid. The modification and integration of the controlling techniques as described in the paper with the artificial based optimizing algorithms can be beneficial in quality enhancement at the loading buses.

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