Different Controllers of UPQC for Power Quality Evolution

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Abstract

This paper presents the Power system consists of electrical, electronical and power electronic equipment used in industries. Hence they behave as a nonlinear load and inject harmonics in distribution system, one of the solution is the active power filter. The combination of series and shunt active power filter is UPQC. It not only eliminates harmonics, and also alleviates any type of voltage and current fluctuations and compensates reactive power in distribution system. In these paper, the compensation code and different control plan (PI, FUZZY, ANN) are proposed and compared by using SIMULATION/MATLAB. The thyristor rectifier feeding an RL load acts as a source of harmonics. The performance is observed under utility disturbances such as sag, swell, flicker and spikes. Different control strategies are compared and the simulation results are listed.

Keywords: Power quality, harmonics, voltagesag, voltageswell, pi controller, fuzzy, neural networks

1. Introduction

In electric power supply system use of electronic controllers has become more common. These behave as a nonlinear load and and root severe distortion in distribution system and bring in unwanted harmonics in the supply system. LC passive filters may not solve the problem but Active filters can determine this problem. The APF acts as a power conditioning device such as load balancing, harmonic filtering, and reactive power control for power factor correction. The modern explore focuses on use of unified power quality conditioner to reimburse for power quality problems. Voltage sag is the factor undergo huge loss in industries. Loads which are nonlinear in nature of fast acting switches and they influence the distribution utility in some tremendously objectionable ways. The solution is the custom power devices for power Quality related issues in distribution system to mitigate sag, swell, at the point of coupling. Out of these available power quality enhancement devices, the UPQC has better sag/swell compensation capability.

It consists of two back to back igbt voltage source bidirectional converters with a common dc link. Source side inverter called series inverter is connected through a transformer and load side inverter called the shunt inverter with the nonlinear load. Shunt coupling inductor \( L_s \) is used to border the shunt inverter to the network. It helps in smoothing the current wave shape. A dc link can be shaped by using a capacitor and an inductor. The dc link is realized by means of a capacitor which interconnects the two inverters and also maintains a steady self-supporting dc bus voltage across it. LC filter serves as a passive low-pass filter (LPF) and to eradicate high-frequency switching ripples on generated inverter output voltage. Series injection transformer is used to unite the series inverter in the network. An appropriate turn ratio is often measured to condense the current or voltage rating of the series inverter. The fig is shown below.

Fig. 1. Block diagram of UPQC

2. Control strategy of UPQC

2.1 PI Control

A PI controller calculates an error value as the difference between a measured process variable and desired set point. The controller attempts to minimize the error by adjusting the process control inputs. Vdc is sensed and compared with its reference \( v_{dc}^* \). Error signal is processed in a PI controller. The output of the PI controller is denoted as...
Artificial neural nets are multiplied results in reference in phase with the three phase supply currents, \(i_{sb}\) are fed to the pwm current controller, multiplied by amplitude \(I_{sp}\) gives \(I_{sp}(\mathbf{i}_{sb})\). The magnitude \(I_{sp}\) with acted from three phase reference \(i_{sb}\) for the load and also the reactive power. The inductor which is connected parallel to the load gives the reactive current to compensate harmonic current and also provides the reactive power to the load and improves power factor.

### 2.2 Fuzzy Logic

The word Fuzzy means vagueness. Fuzzy set theory is for solving the uncertainty in the problem. It is an extension of set theory where elements have varying degrees of membership. It uses interval between 0 and 1 for human reasoning. Fuzzy sets are sets whose elements have degrees of membership. fuzzy set theory permits the gradual assessment of the membership functions valued in the real unit interval \([0, 1]\). The process of converting the crisp input to a fuzzy value is called as “fuzzification.” The output of the Fuzzy is interfaced with the rules. The basic operation of FLC is constructed from fuzzy control rules utilizing the values of fuzzy sets in general for the error and the change of error and control action. The results are combined to give a crisp output controlling the output variable and this process is called as “DEFUZZIFICATION.” The sign of the error signals and the output from linguistic codes given in the table.

### 3. Artificial Neural Networks

The quick detection of the signal and fast response of signal are the requirements of desired compensation in upqc. The ANN based controllers give fast dynamic response maintaining stability of the converter. It is the interconnecting of artificial neurons. Neurons are used to store knowledge. ANN is a powerful technique which uses to solve many real world problems. ANNs are being used to explain AI problems without essentially creating a model of a real dynamic system. Artificial neural nets are a type of non-linear processing system that is ideally suited for a wide range of tasks, especially tasks where there is no existing algorithm for task completion. ANN can be trained to solve certain problems using a teaching method and sample data. This way, identically constructed ANN can be used to perform different tasks depending on the training received. With proper training, ANN are capable of generalization, the ability to recognize similarities among different input patterns, especially patterns that have been corrupted by noise.

### 4. Generating compensating current

#### 4.1 Shunt control

The output of controller has a limit ensures that the source provisions active power of the load and dc bus of the UPQC. A self supported dc link of the UPQC is supplied by the activepower. Thus, the dc voltage of the UPQC has a proper current.

### 5. Model equations of UPQC

#### The supply voltage from three phase values are

\[
v_{sm} = \sqrt{\frac{1}{2}(v_{sa}^2 + v_{sb}^2 + v_{sc}^2)}^{1/2}
\]

Three phase unit vectors are

\[u_{sa} = \frac{v_{sa}}{v_{sm}}; u_{sb} = \frac{v_{sb}}{v_{sm}}; u_{sc} = \frac{v_{sc}}{v_{sm}}\]

Unit vectors are multiplied by amplitude \(I_{sp}\) gives reference currents as

\[i_{sa} = i_{sp}u_{sa}; i_{sb} = i_{sp}u_{sb}; i_{sc} = i_{sp}u_{sc}\]

Load currents are subtracted from three phase reference

Suppy currents gives reference currents

\[i_{shu} = i_{sa} - i_{la}; i_{shb} = i_{sb} - i_{lb}; i_{shc} = i_{sc} - i_{lc}\]

Iref and iact are compared to obtain signals for the inverter.

Equations of Series Inverter:
The injected voltage of supply voltage and load voltage is as follows:

\[ \text{vinj} = v_l - v_l \]

Magnitude of injected voltage is

\[ \text{vinj} = |\text{vinj}| \]

Injected voltage of the phase is

\[ \delta_{\text{inj}} = \tan(\text{Re}[v_{pq}]/\text{Im}[v_{pq}]) \]

Following inequalities are followed or reducing harmonics:

\[ \text{vinj} / \text{vinj}_{\text{max}} \text{; magnitude} ; \]
\[ \Omega / \delta_{\text{inj}} / 360^\circ \text{; phase control} ; \]

The injected voltages of three phase reference are

\[ v_{la}^* = \sqrt{2} \text{vinj} \sin(wt + \delta_{\text{inj}}) \]
\[ v_{lb}^* = \sqrt{2} \text{vinj} \sin(wt + 2\pi/3 + \delta_{\text{inj}}) \]
\[ v_{lc}^* = \sqrt{2} \text{vinj} \sin(wt - 2\pi/3 + \delta_{\text{inj}}) \]

Series inverter of the here phase reference currents iref as

\[ i_{sea}^* = \frac{v_{la}^*}{z_{se}} ; \]
\[ i_{seb}^* = \frac{v_{lb}^*}{z_{se}} ; \]
\[ i_{sec}^* = \frac{v_{lc}^*}{z_{se}} ; \]

The iref and iact are compared to obtain signals for series inverter.

Case Study:

A three phase supply of 230v,60hz is considered feeding a thyristor rectifier Rl load with rating of 2KVA. Rs and Rl values are 0.1ohm and 0.1mh.

Shunt values

Rsh=1ohm, Lsh=30Mh, Csh=700

Series values

Rsh=0.1ohm, Lse=12Mh

Passive filter values:

Rpsh=3ohm, Lpsh=15Mh

**Basic Circuit of UPQC Using PI Controller**

**Fig.2 Transmission line without UPQC**

**Fig. 3 Transmission line using UPQC**

**Fig.4 UPQC with PI Controller**

**Load current compensation:**

**Case 1:** Ideal three phase sinusoidal supply voltage of 230v,60hz is applied to the nonlinear load injecting harmonics in the system supply voltage without upqc is shown in 1(a). The load current 1(b) is THD is establish to be 27% before compensation condensed to 10.53% in 1(c). The shunt current 1(d) hold harmonics of load but with opposite polarity, such that the harmonic content of supply current is reduced. At the reference voltage capacitor is charged, the charging current is drawn by VDC from supply 1(e) using pi controller it is charged to a required value and held constant . Load current harmonics are compensated by the shunt inverter. The dc side after compensation of the load current is shown in fig1(f).

**Case 2:** A voltage sag and voltage swell of 20% is applied to nonlinear load. The immediate existence of flicker 10% and spike of 15% are forced to study the sensible condition of one or more of them. To reimburse the dip and swell upqc used to organize detects and calculates the necessary value by injected in series. The swell and sag of 40% in fig 2(a) is compensated by the supply voltage.
supplied by the load. In fig 2(b) Dc link voltage more or less reflects in the supply voltage. After compensation of Vdc the voltage tries to come back to the reference voltage. In case of sag compensation the supply voltage in fig 2(c) is 180 out of phase shows the series compensating current required to generate compensating voltage, in case of swell it is in phase with supply voltage. The dc side acts as a nonlinear load on the load before compensation is current.

**Load Current Harmonics**

**Case 1:**
Ideal three phase sinusoidal supply voltage of 230v,60hz is applied to the nonlinear load injecting harmonics in the system. The load current 3(a) in THD is establish to be 27% before compensation condensed to 10.84% in 3(b). The shunt current 1(d) hold harmonics of load current but with opposite polarity, such that the harmonic content of supply current is reduced. At the reference voltage capacitor is charged, the charging current is drawn by vdc from supply 3(c). Using fuzzy controller it is charged to a required value and held constant .Load current harmonics are compensated by the shunt inverter .the dc side of the inverter before compensation is fig.13(d) and after compensation of the load current is shown in fig.3(e).

**Case 2:** A voltage sag and voltage swell of 20%is applied to nonlinear load. The immediate existence of flicker 10% and spike of 15% are forced to study the sensible condition of one or more of them. To reimburse the dip and swell upqc used to organize detects and calculates the necessary value by injected in series. The swell and sag of 40%in fig 4(a) is compensated by the supply voltage supplied by the load. In fig 4(b) Dc link voltage more or less reflects in the supply voltage. After compensation of Vdc the voltage tries to come back to the reference voltage. In case of sag compensation the supply voltage in fig 4(c) is 180 out of phase shows the series compensating current required to generate compensating voltage in case of swell it is in phase with supply voltage. The dc side acts as a nonlinear load on the load before compensation is current.
Case 1:
Ideal three phase sinusoidal supply voltage of 230v ,60hz is applied to the nonlinear load injecting harmonics in the system. The load current in THD is established to be 27% before compensation condensed to 9.04% in 5(a). The shunt current5(b) hold harmonics of load current but with opposite polarity, such that the harmonic content of supply current is reduced. At the reference voltage capacitor is charged5(c), the charging current is drawn by Vdc from supply5(c). Using fuzzy controller it is charged to a required value and held constant .load current harmonics are compensated by the shunt inverter .The dc side of the inverter compensation in fig.15(d) After compensation of the load current is shown fig3(d))

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In In case of sag compensation the supply voltage in fig 6(c) is180 out of phase shows the series compensating current required to generate compensating voltage .in case of swell it is in phase with supply voltage. Line to line compensating voltage of series Inverter in fig 6(d).
Comparison of three different Controllers of UPQC

<table>
<thead>
<tr>
<th>FACTOR</th>
<th>PI</th>
<th>FUZZY</th>
<th>ANN</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Utility side THD</td>
<td>6.78%</td>
<td>3.69%</td>
<td>0.00%</td>
</tr>
<tr>
<td>2. Line current THD with UPQC</td>
<td>10.30%</td>
<td>10.17%</td>
<td>6.79%</td>
</tr>
<tr>
<td>3. Charging of DC link</td>
<td>Slower</td>
<td>Faster</td>
<td>Faster</td>
</tr>
<tr>
<td>4. Time taken for capacitor reach overshoot</td>
<td>0.04s</td>
<td>0.0195s</td>
<td>0.0145s</td>
</tr>
<tr>
<td>5. Sag,swell,flicker in supply voltage</td>
<td>Eliminated</td>
<td>Eliminate d</td>
<td>Eliminated</td>
</tr>
<tr>
<td>6. Powerfactor</td>
<td>0.85</td>
<td>0.9</td>
<td>1</td>
</tr>
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</table>

Conclusion

A simple control technique based on unit vector templates, generation is proposed for UPQC. Proposed model has been simulated in MATLAB. The result after simulation compensates the input voltage harmonics and current harmonics caused by non-linear load effectively by the control strategy. The closed loop control schemes of direct current control, for the proposed UPQC have been described. A suitable model of the UPQC has been developed with different shunt controllers (PI FUZZY and ANN) and simulated results are compared. The load current in these cases is found to be content of all odd harmonic minus triplen providing a total harmonic distortion (THD) of 27.82%. It is observed from the figure. After compensating the THD is reduced to 6.79% in ANN. Thus by seeing the result obtained through the simulation of UPQC with the controllers PI, FUZZY and ANN it can be conclude that for the ANN same load the THD obtained is less as compared to the FUZZY and PI controller. Hence the ANN controller is better option than the fuzzy and Pi controller.

References


Ambra Sannino and Jan Svensson. Static series compensator for voltage sag mitigation supplying non-linear loads.