Bidirectional converter with hybrid UPQC implementation for power quality improvement

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Abstract. This paper presents a power quality enhancement strategy based on an energy storage device using the active power line cleanser in energy systems. The PQ challenges can be fixed in this framework by using the efficiency of the power compensation. For distributed generators, the transmission line is used to preserve the shunt inverter's DC connection capacitor and dynamic voltage regulator. The renewable power source is used to provide the supply for bidirectional converter which controlled by using MPPT method. This proposed system consists of dynamic voltage restorer, bidirectional power flow converter, PV arrays, shunt inverter, shunt active power filter control, and super capacitor energy storage system. The PQ troubles of sag and swells are addressed at distribution system and achieve the compensation. The simulation designs are carried out in order to validate the proposed system topology results with their performance.

Keywords: Dynamic voltage regulator, UPQC, MPPT, Shunt inverter, Shunt active power filter, Bidirectional DC-DC converter, sag and swells, and PV source

1. Introduction
In The characteristics changes in the load which connected with the power systems are a resulting of technology development and increasing the electricity demand that introduces power quality problems. The voltage and current variations, deviations in frequency and distortions in the waveform which directs to consumer load damages and equipment issues that is power quality issues [1]. The compensation devices of traditional systems have low performance which is leads to develop advanced technology for power quality issues compensation devices based on the power electronics components [2]. Normally, the unified power quality conditioner which made up of dynamic voltage restorer and it is interfaced with the shunt inverter [3]. The mentioned above system is advanced system to compensate the problems in the current, overvoltage, reactive power compensations and distortions and voltage and current imbalances [4]. Commonly used in between the both shunt inverter is DC link which compensating the current and the dynamic voltage restorer that is directly connected in series to compensate the voltage.

In recent years various circuit topologies for different purposes has been increased and developed. The interline UPQC system and voltage source inverter connected multi converter system is used for the power compensation in the feeders of distribution network [5]. In conventional systems, the open UPQC system is used, in that The DC connection capacitor is fed to the boost converter and voltage quality restorer and there is no dc side connection. To decrease the system load in the system, the PV supply is fed to the DC connection capacitor [6]. The singular inverter and three-phase structures are
used in the transformer less UPQC control device[7]. To sustain the DC connection capacitor with adequate power, the PV system is used. The strength of the PV module is increased by using the methods of MPPT [8]. The power converters are used to convert the power from one part from another. The voltage improvement is achieved through the various DC-DC converters that developed by the less number of semiconductor components [9].

The three phase inverters are using the improved DC link voltage that stored in the capacitor as a input supply. The dynamic voltage restorer is compensating the grid connected system disturbed voltages and currents when the source DC supply is maintained. In the series compensation, the DVR is used to achieve the voltage compensation in distributed line system. The converters of operating under the renewable energy sources are increasing the system output voltage and control the performance of the system [10]. The energy storage system (ESS) is used to control the system performance when the period of power absence from resources. The energy storage is done through the power converters as buck, bidirectional converter, boost etc. The battery or super capacitor is used as a energy storage system to store the power from the source supply [11]. The ESS is performing the power supply in power system to compensate the problem in power quality through the power compensation devices such as UPQC, DVR etc. The power inverters used in the UPQC can be controlled by the different controllers to mitigate the power system-based power quality problems.

In this paper, the energy storage system of super capacitor with UPQC system is to control PQ issues and to mitigate the equipment failures [12]. The DC link voltage is maintained perfectly by using the bidirectional converter which is achieving the both directions energy flowing. The shunt active filter is used to control the shunt and DVR system to provide the switching signals for the power switches for the both inverters [13]. The results of the system are validated through simulations in using MATLAB/Simulink.

2. Methods and Materials

In this proposed system, the ESS based UPQC is designed to compensate the line power in distribution system network which having the three wire three phase system. As seen in figure 1, the block diagrams of the proposed ESS with UPQC framework. The symmetric transformer is linked back-to-back with the popular point dynamic voltage restore (DVR) and shunt alternator at the DC reference voltage [14]. In order to sustain the DC link resistor, the PV arrays provide power in the form of a DC supply. In the DVR device, the volt source inverter, filter and DC communication capacitors devices are integrated in series-by-series injection transmission lines with circuit breakers transmission lines.

The filter in the inverter side used to control the harmonics in the switching. The shunt inverter is interfaced in parallel with the unbalanced loads and sensitive loads at the feeder end. The sensitive and non linear loads are including the inductive loads and the rectifiers which have RC load supply. The super capacitor is used to store the energy in it from the PV supply through the bidirectional converter which regulates using MPPT method [15]. The converter duty cycles is controlled and providing high power to maintain the DC link voltage and supplying reduced power to the super capacitor energy storage system.
3. **Control Method**

SAPF in parallel is generated by non-linear load, the current of which must be compensated. From figure 2 to monitor the block diagram of the shunt filter. The shunt control is used in the reverse compensation to fill current compensation with the current.

![Block diagram of Active Power Filter](image)

**Figure 2**: Block diagram of Active Power Filter

Shunt APF operating theory is focused on the development of new harmonics comparable in magnitude except in process opposition.

The active three phase instantaneous power is given as,
Where, \( v_a, v_b \) and \( v_c \) are the phase voltages.

Three phase average power is given by,

\[
P_{3\phi} = 3V + I \cos \phi
\]  

(2)

Clarke transformation is given by,

\[
\begin{bmatrix}
    v_0 \\
    v'_a \\
    v'_b \\
    v'_c
\end{bmatrix} = \begin{bmatrix}
    1 & 1 & 1 \\
    \sqrt{2}/2 & \sqrt{2}/2 & \sqrt{2}/2 \\
    1 & -1/2 & -1/2 \\
    0 & \sqrt{3}/2 & \sqrt{3}/2
\end{bmatrix} \begin{bmatrix}
    v_a \\
    v_b \\
    v_c
\end{bmatrix}
\]  

(3)

In Similar manner, three-phase line currents can be converted into two phase by using Clarke Transformation derived as below,

\[
\begin{bmatrix}
    i_0 \\
    i'_a \\
    i'_b \\
    i'_c
\end{bmatrix} = \begin{bmatrix}
    1 & 1 & 1 \\
    \sqrt{2}/2 & \sqrt{2}/2 & \sqrt{2}/2 \\
    1 & -1/2 & -1/2 \\
    0 & \sqrt{3}/2 & \sqrt{3}/2
\end{bmatrix} \begin{bmatrix}
    i_a \\
    i_b \\
    i_c
\end{bmatrix}
\]  

(4)

The phase voltages and currents are shown as below

\[
\begin{bmatrix}
    p_0 \\
    p \\
    q
\end{bmatrix} = \begin{bmatrix}
    v_0 & 0 & 0 \\
    1 & v_a & v_b \\
    0 & v_b & -v_a
\end{bmatrix} \begin{bmatrix}
    i_0 \\
    i_a \\
    i_b
\end{bmatrix}
\]  

(5)

\[
P = v_a i_a + v_b i_b
\]

\[
q = v_b i_a + v_a i_b
\]

(6)

Where the \( p \) is - active power and \( q \) is - reactive power.

The average and oscillatory components are obtained by using the decomposition of power. The main sinusoidal and balanced supply conditions are considered to represent the positive sequence current. The oscillatory components are compensated by the shunt filter. The stationary reference frame is used for the compensation of both voltages and currents in the system.
4. Simulations and Results
The current UPQC is built on the basis of the peak power ESS system, as seen in figure 3. Using the symmetric transformer, which is used to increase the energy source from the PV source and control the DC link capacitor, the DC connection voltage can be preserved and modified. To obtain both voltage mitigation, the DC connection capacitor is the source of energy for the UPQC system. Using the d-q comparison control process, the UPQC device adjustment is accomplished.

![Figure 3: UPQC based ESS Simulink model](image)

The under voltage is occurred in the transmission line which carrying to grid connected system. The voltage sag in power system and the power compensation achievement is done by using the proposed UPQC based super capacitor as shown in figure 4. The current injection in the grid system and the voltage of the bidirectional power flow converter is represented in figure 5.

![Figure 4: Proposed UPQC with ESS system voltage sag, injected voltage, and load voltage](image)
Figure 5: The injected current and DC link voltage of the proposed system

5. Conclusions
The proposed UPQC mechanism based on ESS is accomplished by power compensation in the linked system of the grid. For power electronic converters, the dc voltage is often used to preserve the shunt inverter’s DC connection capacitor and dynamic voltage regulator. The renewable PV power source is improved to provide the supply for bidirectional converter which controlled the DC link voltage by using MPPT method. The PQ problems are addressed in the distribution system and the compensation is achieved successfully and the results are verified.

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