PHOTOVOLTAIC BASED POWER QUALITY IMPROVEMENT

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Abstract: *This paper proposes a new configuration of PV-UPQC (Photovoltaic Unified Power Quality Conditioner) that consists of the Photovoltaic array, DC/DC converter and UPQC for compensating the voltage interruption. The proposed PV-UPQC can compensate the voltage sag and the voltage interruption. The performance of proposed system was verified through simulation. The proposed system can improve the power quality at the common connection point of the non-linear load, the sensitive load and voltage interruption.*

Key words
DC/DC Converter, Voltage interruption, photovoltaic array, UPQC (Unified Power Quality Conditioner)

1. Introduction

As more sensitive loads, such as computers, automation equipments, and communication equipments, have come into wide use, power quality is a big issue in both customer and utility company. Since these equipments are very sensitive for the input voltage disturbances, the inadequate operation or the fault of these loads brings about huge losses [1]-[3]. The elimination or mitigation of disturbances propagated from the source side and the other loads interconnected is critical for improving the operational reliability of these critical loads. PV-UPQC has been widely studied to eliminate the disturbances propagated from the source side and the other loads interconnected [4]-[6]. PV-UPQC has two voltage-source inverters of three-phase four-wire or three-phase three-wire configuration. One inverter called the series inverter is connected through transformers between the source and the common connection point. The other inverter called the shunt inverter is connected in parallel with the load. The series inverter operates as a voltage source, while the shunt inverter operates as a current source. PV-UPQC can simultaneously mitigate the voltage disturbance in source side and the current disturbance in load side. PV-UPQC can compensate voltage sag, voltage swell, harmonic current, and harmonic voltage, and control the power flow and the reactive power. However, it cannot compensate the voltage interruption because it has no energy storage in the dc link. This paper proposes a new configuration of PV- UPQC that consists of the DC/DC converter and the capacitors for compensating the voltage interruption. The operation of proposed system was verified through simulation.

2. Configuration of PV-UPQC

Fig.1 shows the configuration of proposed PV-UPQC, which additionally has a DC/DC converter and photovoltaic arrays for compensating the voltage interruption. The energy in the DC link charges the capacitors through the DC/DC converter when the system is in normal operation. The energy in the capacitors is released to the DC link through the DC/DC converter when the voltage interruption occurs.

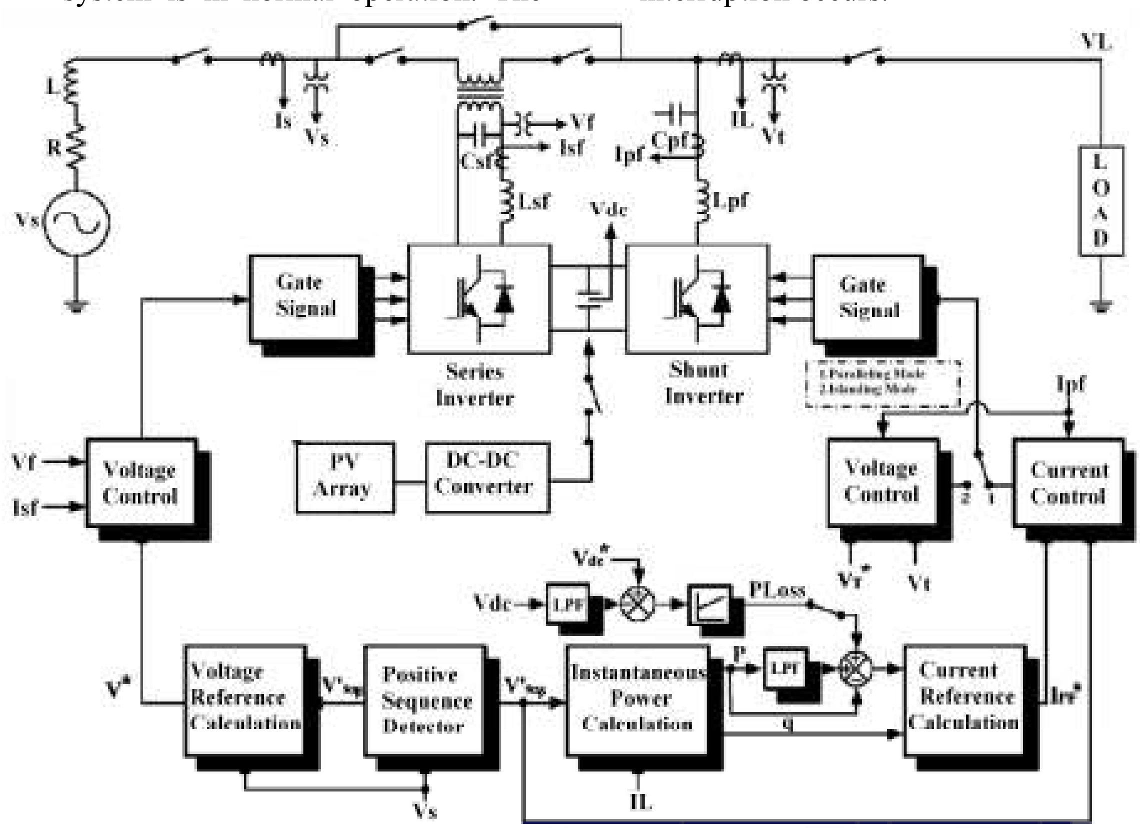

Fig. 1 Block diagram of proposed configuration PV- UPQC

The control system has five major elements, which are system manager, positive sequence detector, shunt inverter control, series inverter control, and DC/DC inverter control.

The system manager determines the operational mode depending on the level of source voltage, which was measured by the positive-sequence detector. The system works in normal mode when the level is maintained as 1.0 pu, and works in voltage sag or swell mode when the level is between 0.5 and 1.0 pu or higher than 1.0 pu. It works in interruption mode when the level is lower than 0.5 pu. In normal mode, the series inverter injects the zero voltage and the shunt inverter absorbs the current harmonics generated by the load. The DC/DC converter works in charge mode or standby mode depending on the voltage level of the photovoltaic arrays.

In voltage sag or swell mode, the series inverter injects the compensating voltage to maintain the load voltage constant. The shunt inverter absorbs the current harmonics generated by the load and the DC/DC converter works in standby mode. In voltage interruption mode, the series inverter is disconnected from the line and the circuit breaker is opened to isolate the source side. The shunt inverter starts to work as an AC voltage source. The DC/DC converter works in discharge mode to supply the energy stored in the photovoltaic arrays to the load. The positive-sequence detector extracts the positive-sequence component from the disturbed three-phase source voltage. The algorithm for detecting the positive-sequence component is described in reference [7].

The series inverter control compensates the voltage disturbance in the source side due to the fault in the distribution line. The series inverter control determines the reference voltage to be injected by the series inverter, using the algorithm described in reference [7]. The shunt inverter control has two functions to compensate the current harmonics and the reactive power in normal operation, and to supply the active power to the load during the voltage interruption. The first function was described in reference [7]. The second function is same as that of the power converter used in power system interconnection. The shunt inverter control has a selective switch which works in current control mode or voltage control mode under the control of system manager.

In charge mode, the system manager monitors whether the voltage level of the capacitors exceeds the maximum operating voltage or not. If the voltage level reaches the maximum value, the DC/DC converter works in standby mode. In discharge mode, the system manager monitors whether the voltage level of the photovoltaic arrays drops lower than the minimum operation voltage or not. If the voltage level reaches the minimum value, the DC/DC converter shuts down to stop supplying power to the load.

3. DC/DC Converter

Converter Design

The DC/DC converter can operate in bi-directional mode using soft-switching scheme [8, 9]. The operating voltage of the photovoltaic array bank is in the range between 115-135V, while the dc link voltage is about 700V. The ground point in dc link should be isolated from the ground point in the photovoltaic array bank. The converter should have high current rating in bank side and high voltage rating in DC link side. Considering these requirements, DC/DC converter as shown in Fig. 2

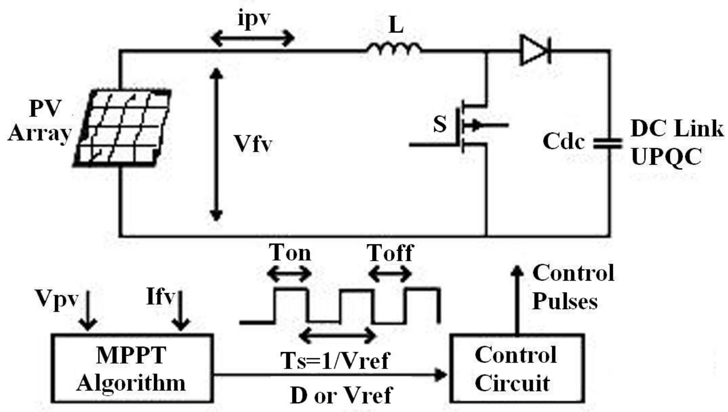

Fig.2. PV Array with DC/DC converter

A filter reactor is inserted between the bank and the full-bridge to reduce the ripple of charging and discharging current, which can reduce the lifetime of photovoltaic arrays due to unwanted heat generation. The full-bridge in bank side works as a current-fed type, while the full-bridge in dc link side works as voltage-fed type. The DC/DC converter boosts the photovoltaic array voltage up to the nominal dc link voltage in discharge mode. The photovoltaic array voltage is controlled between 115-135V, In design point of view it is not effective to build a 20kW DC/DC converter in a single module due to the restriction in power rating of switching unit. Since photovoltaic arrays operate at low-voltage large-current, the switching frequency is limited by the critical value of di/dt which depends on the leakage inductance of the coupling transformer. So, when the converter is designed in a single module, the switching ripple of charging or discharging current is high. Therefore, the proposed DC/DC converter has four modules of 5kW converter connected in parallel as shown in Fig. 2. When the multi-module is used, it is possible to expand the system rating and to increase the operation reliability. Also, the switching ripple of the charging or discharging current can be extremely reduced using the interleaving scheme of PWM switching.

All the circuit parameters are used in computer simulation. A simulation condition shows the compensation of harmonic current in the shunt inverter. Although there are some high-frequency harmonics, the simulation result is very close to the power quality standards.

In the circuit shunt inverter is operated in the active power filter mode. The Fig.3 shows the current waveform of the source, The Fig.4

shunt inverter current and Fig.5 load current and the load, which confirms

4. RESULTS

Simulation parameters

Source	Voltage	400V, 50Hz
	Impedance	R=0.001Ω, L=0.01mH
DC-Link	Capacitor	C1=6600uF, C2=6600uF
	Reference Voltage	700V
Shunt Inverter	Filter L, C	600uH, 40uF
	Switching Freq.	10kHz
	Filter L, C	600uH, 40uF
DC/DC Converter and PV-array	Boost Inductor Lf	100uH
	Capacitor Ch	35uF
	Switching Freq.	35kHz
Load	Linear Load	3.27KVA
	Non-Linear Load	17.54KVA

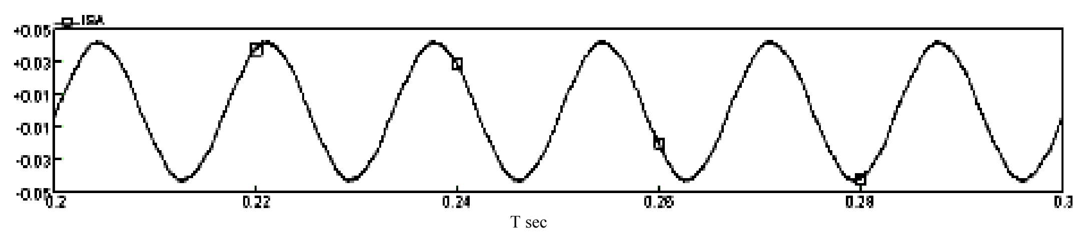

Fig.3 Source current

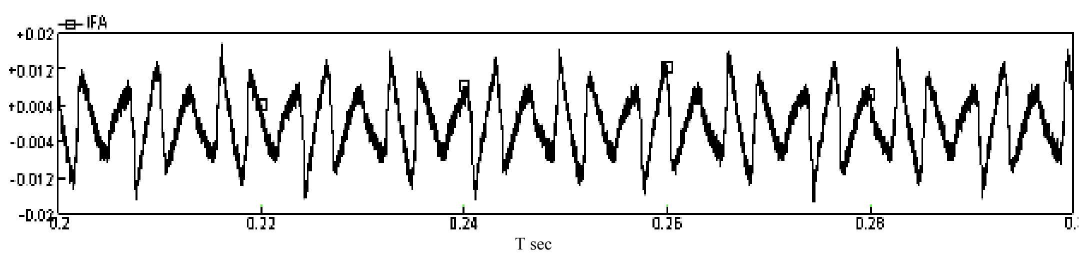

Fig.4 Shunt inverter current

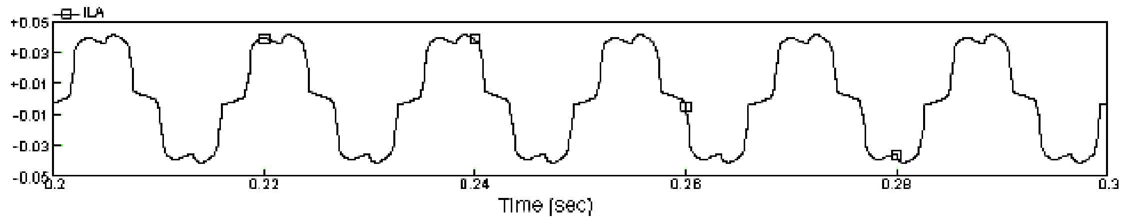

Fig.5 Load current

the operation of the active power filter.

Sag Compensation.

The result when the voltage sag occurs on the source side, it is assumed that phase A and B has 30% of sag voltage and phase C has no sag voltage as shown in the graph fig.6 source voltage. The Fig.7 graph indicates the output voltage of the series inverter. The Fig.8 graph displays the load voltage compensated by the PV-UPQC.

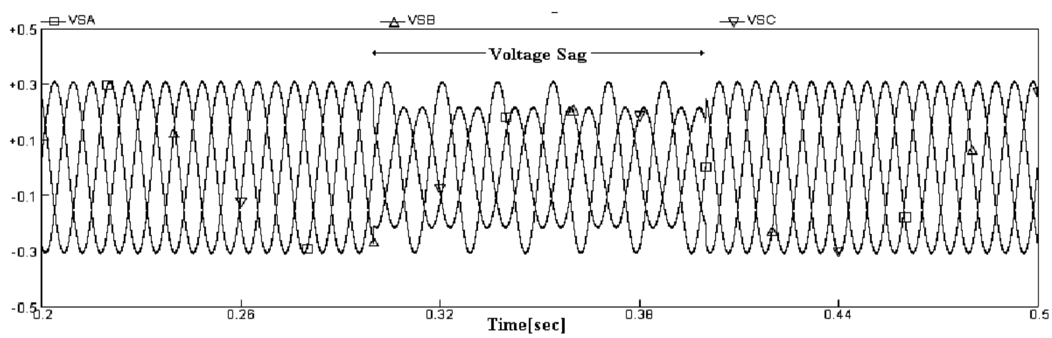

Fig.6.Source voltage

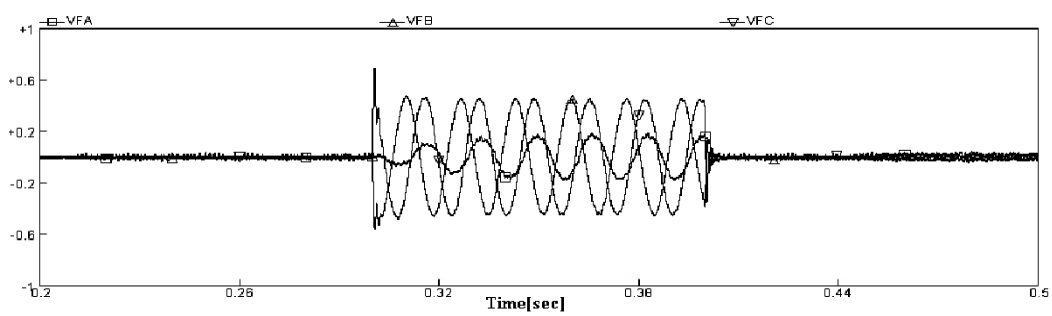

Fig.7. Series inverter voltage

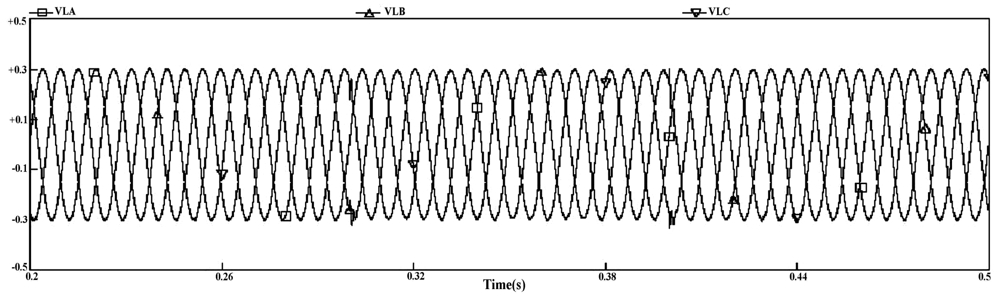

Fig.8. Load Voltage
PV-UPQC Operation during voltage sag.

Interruption mode

In this interruption mode, it is assumed that three-phase fault takes place for 100ms as shown in the fig.9. The fig.10 indicates the output voltage across the load compensated by the PV- UPQC. The output current supplied by the PV Array DC-DC converter.

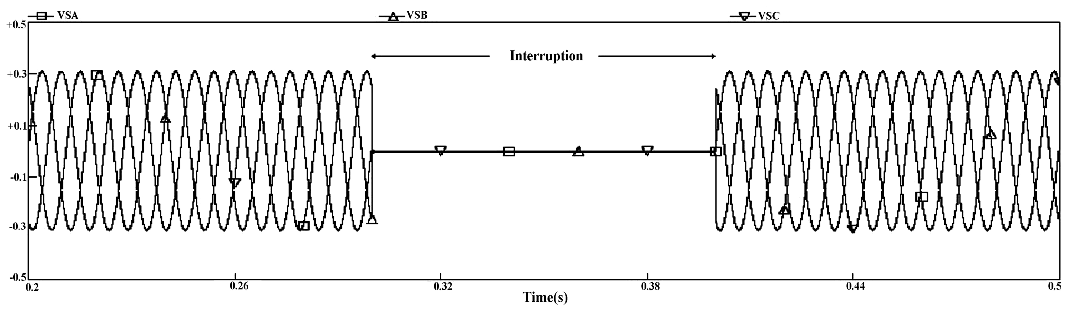

Fig.9. Source voltage

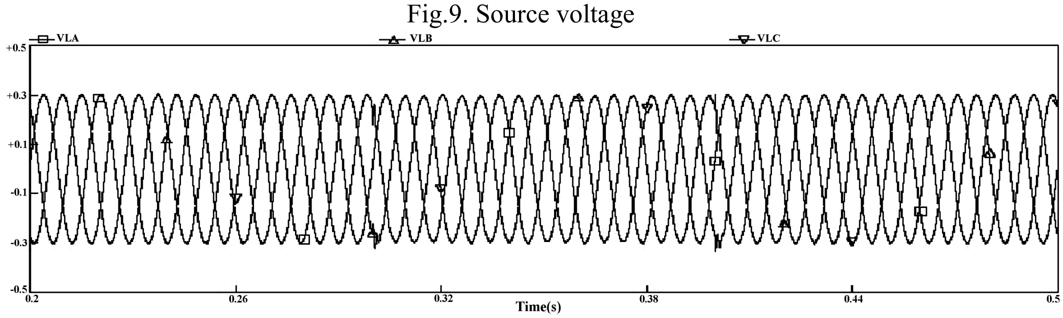

Fig.10. Load Voltage
PV-UPQC Operation during voltage interruption

5. Conclusion

This paper proposes a new configuration of PV-UPQC that consists of the DC/DC converter and the photovoltaic arrays for compensating the voltage interruption. The proposed PV-UPQC can compensate the voltage sag and the voltage interruption. The control strategy for the proposed PV-UPQC was derived based on the instantaneous power method. The operation of proposed system was verified through simulation

The proposed PV-UPQC has the ultimate capability of improving the power quality at the installation point in the distribution system. The proposed system can replace the UPS, which is effective for the long duration of voltage interruption, because the long duration of voltage interruption is very rare in the present power system.

References

1. Prodanovic. M, Green. T. C, "Control and filter design of three-phase inverters for high power quality grid connection", IEEE Trans. on Power Delivery, Vol. 18, No. 1, Jan 2003, pp. 373-380.
2. Han.B, B. Bae, S. Baek, G. Jang, "New Configuration of UPQC (Unified Power Quality Conditioner) for Medium voltage Application," IEEE Trans on Power Delivery, Vol. 21, No. 3, pp. 1438-1444, July 2006.
3. N. G. Hingorani, "Introducing Custom Power," IEEE Spectrum, June 1995, pp. 41-48.
4. Hideaki Fujita, Hirofumi Akagi, "The Unified Power Quality Conditioner:The Integration of Series- and Shunt- Active Filters", IEEE Transactions on Power Electronics, Vol. 13, No. 2, March 1998
5. Yunping Chen, Xiaoming Zha and Jin Wang, etc. "Unified Power Quality Conditioner (UPQC): The Theory, Modeling and Application", PowerSystem Technology, 2000 proceedings. Power Con 2000. International Conference on, vol. 3, pp. 1329-1333, 2000.
6. M. Aredes, K. Heumann, E. H. Watanabe, "An universal active power line conditioner", IEEE Trans. on Power Delivery, Vol. 13, No.2, Apr 1998, pp.545-551.
7. Jos Arrillaga, Math H. J. Bollen, Neville R. Watson, "Power Quality Following Deregulation", Proceedings of the IEEE, Vol. 88, No. 2, Feb 2000.
8. A. Bendre, S. Norris, D. Divan, I. Wallace, R. Gascoigne, “New high power DC/DC converter with loss limited switching and lossless secondary clamp”, IEEE Trans. on Power Electronics, Vol. 18 , No. 4 July 2003, pp.1020-1027.
9. J. Jacobs, A. Averberg, R. De Doncker, “A novel three-phase DC/DC converter for high-power applications”, IEEE Conf. on PESC 04, Vol. 3, 20-25 June 2004, pp.1861-1867.