IOSR Journal of Engineering (IOSRJEN) **www.iosrjen.org**
ISSN (e): 2250-3021, ISSN (p): 2278-8719
Vol. 10, Issue 6, June 2020, ||Series -II|| PP 14-18

Neutral Point Clamped Multi Level Inverter Based Unified Power Quality Conditioner

Arundhatee Srivastava[1], Anukirti Srivastava[2], Rakeshwri Agrawal[3], Deepak Agrawal[4]

[1,2]*Research scholar, Department of Electrical and Electronics Engineering, Trinity Institute of Technology & Research, Bhopal, India*

[2,3]*Assistant Professor at Department of Electrical and Electronics Engineering, Trinity Institute of Technology & Research, Bhopal, India*

Received 10 June 2020; Accepted 27 June 2020

Abstract: Unified power qualityconditioner (UPQC) is one of the mostpromisingcustomizeddeviceused to mitigate power quality (PQ) issues particularly at distribution side. There are numerous topologies are available in literature for UPQC control design. In this paper a five-level neutral point clamped UPQC is proposed to mitigate PQ issues. A comparative analysis is alsopesentedwith the conventional PI controllerbased design and the cascaded H-bridge based UPQC controller. The basic approach of UPQC is to regulateloadside voltage and maintain low THD content particularly at grid side. The proposed five-level neutral point clamped UPQC is capable of maintaining low THD at grid side and alsoregulates the load voltages.

I. INTRODUCTION

Power Electronics Devices (PED) based customized power conditioner are the preferred choice for mitigating various PQ issues also they have advantages such as less energy consumption, better efficiency, good quality, less maintenance requirement etc. UPQC is also one such PE device installed at distribution side to mitigate PQ issues generated particularly due to non-linear loading.

Good quality of power is always an essential requirement of supply system since poor quality causes adverse effect to the sensitive equipments. Various devices and control have been reported to improve the quality of utility. The problem has been growing in recent years due to poor quality, specifically owing to the rise in nonlinear loads connected to the system. The prominent affect is the utility voltage distortions at the point of common coupling (PCC). Many more are voltage swell/sag, unbalanced voltages and load and/or source current harmonics affecting the appropriate operation of sensitive devices. The power demanded by the load has to be conditioned in order to upgrade the system performance at all adverse conditions. There have been numerous events reported in literature which witnesses the presence of voltage and current quality issues causing complete failure in the grid. Moreover the presence of PQ issues brings abnormalities in sensitive loads at various levels of distribution system. Owing to this, abundant of research is in progress to mitigate PQ issues. The use of multi-level inverters (MLI) in designing control of UPQC has not been explored much. Broadly MLI are of two types; separately energized DC source and common DC source connected MLI. In separately type cascaded is the popular one and in common DC source type neutral point clamped (NPC) is popularly used.

To obtain higher power, the basic concept of a MLI is to use semiconductor switches in series with many lower level voltage dc sources to do power conversion by synthesizing a stair like voltage waveform. Batteries, capacitors and renewable voltage sources can be used for multiple dc voltage sources. To achieve high voltage at the output the commutation of the power switches plays an important role. Power semiconductor's devices rated voltage depends upon the rating of DC-voltage sources they are connected to.

In this paper comparative analysis of UPQC both for cascaded and NPCMLI topology with 5-level has been presented in designing the UPQC control. The results are obtained when the proposed UPQC topology are connected to distribution system for balanced and unbalanced linear as well as non-linear loadings.

II. MULTI-LEVEL INVERTERS

MLI is now a day used in high power AC supplies and medium to high voltage applications. MLI is made by the series combination of semiconductor switches. As the name suggest there are multiple level of output voltage retrieved by many DC-voltage sources. Moreover voltage quality at output is enhanced because of the increased voltage levels, so the cost and quality of the filter can be reduced. The AC output of the full bridge converters which are in same phase are connected in series and are able to obtain the voltage waveform which is the sum of the converters output. The classification of MLI topologies are presented in Figure-1.

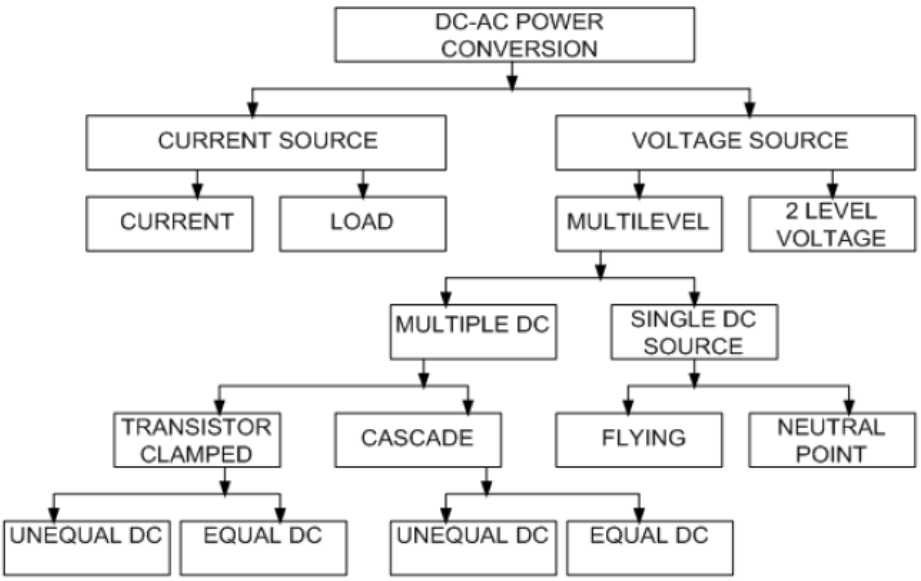

Figure-1 Classification of MLIs

III. UNIFIED POWER QUALITY CONDITIONER

UPQC is a very versatile controller which can be easily customized as per the requirement for mitigating PQ issues. Broadly they could be UPQC-L for left inverter shunted, UPQC-R for right converter shunted, UPQC-Q for reactive power injection, UPQC-P for real power injection, UPQC-S which could inject both active and reactive power and many more like multi-converter based, modular, interline or distributed etc. All these classification are application oriented.

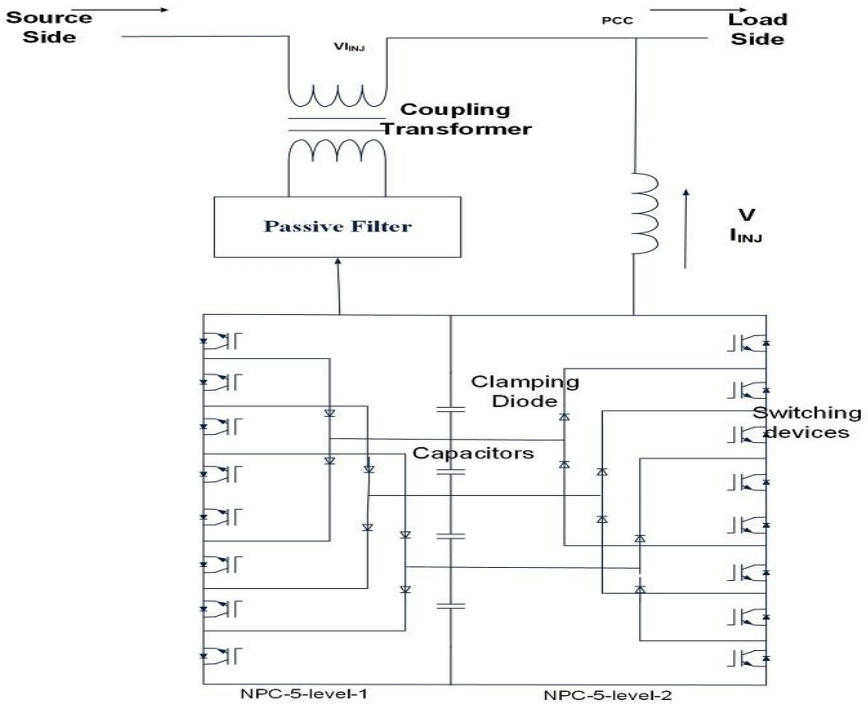

Figure-2 Proposed configuration of NPC-MLI-UPQC.

In this work a new type of UPQC is proposed in which in place of voltage or current source converter as in case of conventional UPQC topology, multilevel inverters are used to control the output at PCC. The multi-level is NPC type with 5-level and the results are verified for the effectiveness of the proposed NPC-UPQC for various non-linear loadings.In literature not much research are sited and which are sited it is not

tested for loading conditions. Here three topologies for UPQC are used namely 5-level neutral point (NPC) inverter, 5-level cascaded (CHB) MLI and conventional PI controller based. All the above mentioned inverter topologies are used to design series and shunt converters for UPQC. Their results are compared for linear and non-linear loading.

IV. MLI BASED UPQC

MLI based UPQC is not evident much since the complication is to control two converters with PWM technique and synchronize to give desired output. MLI topologies based UPQC upto three-level [1]. In this paper 5-level NPC with low component requirement topology is proposed to design UPQC. In basic configuration of UPQC the series converter is connected to source through a coupling-transformer while parallel one is shunted to the load side as shown in fig.2. The series NPC-MLI performs the function of current source while the parallel performs the function of voltage-source. The switching pulses are generated using variable frequency based PWM. The two MLIs are synchronized using PI controller and PLL. The synchronous reference frame signals are obtained using grid voltage reference signals to generate control for PI. The work has been done to test the performance of the UPQC with 5-level NPCMLI, 5-level CHBMLI and conventional P based UPQC. The proposed MLI-UPQC presents tremendous reduction in THD percentage hence PQ of the system is enhanced.

The simulation results are obtained for grid connected MLI-UPQC for balanced linear loading and non-linear loading. The simulation results for all the operating conditions are presented in the next section.

V. RESULT AND DISCUSSION

The MATLAB simulation model has been developed using Simulink platform. Firstly MLI has been designed and performed the simulation for static load. The design parameter for 5-level NPC-MLI is given in Table 3. The output voltage waveform for 5-level NPC is shown in fig. 3.

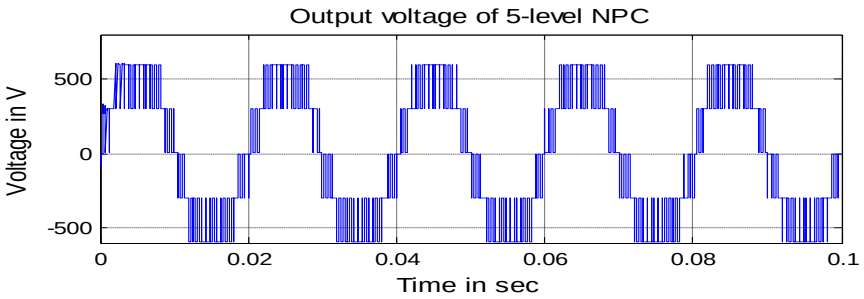

Figure.3. Output Voltage of 5-level single phase NPC-MLI.

Table-1 Component and rating used in the proposed topology.

Parameter	**Values**
Effective nominal voltage of the utility (RMS) VS	415 V
Nominal utility grid frequency f	50Hz
Switching frequency of the converters fch	30khz
Inductance of filter	100e-3 H
Series resistance converter	0.01 ohms
Capacitances of the parallel filters	1000e-6F
Resistances of the converter filter	0.01 ohms
dc-bus voltage Vdc	500V
PI gains	Kp = 0.04; Ki = 500

- **Simulation results for NPC-UPQC source side**

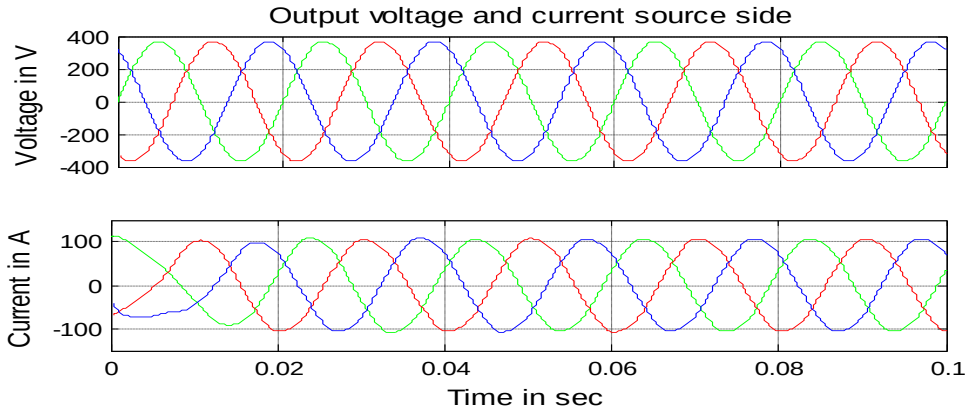

Figure 4 Output Waveforms of 5-level NPC-UPQC source side for non-linear loading

- **Simulation results for NPC-UPQC load side**

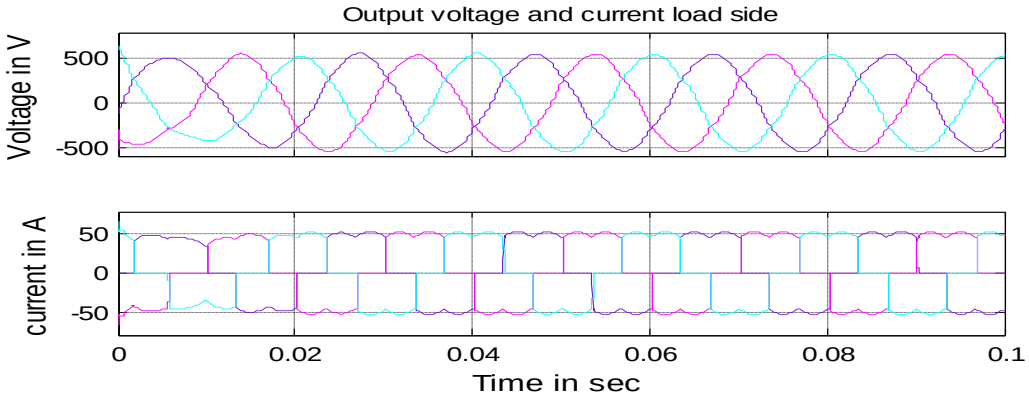

Figure 5 Output Waveforms of 5-level NPC-UPQC load side for non-linear loading

The THD analysis of the output voltage waveform is carried out for non-linear load of 17.7 ohm connected through a three phase rectifier, whose comparative analysis for source and load voltages are presented in Table-2. To reduce the THD a filter component is also added with the converter circuit. The comparative analysis of the various topologies for source and load currents are presented in Table 3. Form the tables it can be evident that the proposed NPC-MLI based UPQC improves the PQ issues much smoothly as compared to other topologies.

Table-2 comparison of THD for output voltage using different PWM techniques

Loading condition	**Phase A**	**Phase B**	**Phase C**	**Phase A**	**Phase B**	**Phase C**
	Source voltage			Load Voltage		
NPC-UPQC	0.0	0.0	0.0	1.1	1.1	1.1
CHB-UPQC	0.01	0.0	0.01	2.0	2.0	2.0
PI based-UPQC	0.01	0.01	0.01	5.1	5.1	5.1

Table-3 comparison of the component requirement for various MLI topologies

Loading condition	**Phase A**	**Phase B**	**Phase C**	**Phase A**	**Phase B**	**Phase C**
	Source current			Load current		
NPC-UPQC	0.2	0.2	0.2	28	28	28
CHB-UPQC	3.26	3.26	3.26	23	23	23
PI based-UPQC	0.5	0.5	0.5	27.6	27.6	27.6

V. CONCLUSION

A versatile topology of NPC-MLI-UPQC is presented in this paper based on MLI. Not of much work is available in literature for MLI-UPQC. Here successful implementation of 5-level NPC-MLI for designing UPQC has been evident for various balanced three phase non-linear loading conditions for three phase distribution system. In distribution system most of the loads are non-linear and they affect adversely the grid profile by injecting harmonics to the system. The comparative analysis of the various topologies for source and load voltages and currents are presented and it is evident that the proposed NPC-MLI based UPQC improves the PQ issues much smoothly as compared to other topologies.

REFERENCES

[1]. Muneer, V., & Bhattacharya, A. (2018, December). Cascaded H Bridge Multi Level Inverter Based Unified Power Quality Conditioner. In 2018 IEEE 8th Power India International Conference (PIICON) (pp. 1-6). IEEE.

[2]. Bhattacharya Avik, C. Chakraborty and S. Bhattacharya, "Parallel-Connected Shunt Hybrid Active Power Filters Operating at Different Switching Frequencies for Improved Performance", IEEE Transactions on Industrial Electronics, vol. 59, no. 11, 2012.

[3]. B. W. Franc¸a, L. F. Silva, M. A Aredes, and M., Aredes, "An improved iUPQC controller to provide additional grid-voltage regulation as a STATCOM," IEEE Trans. Ind. Electron., vol. 62, no. 3, pp. 1345–1352, Mar. 2015.

[4]. R. A. Modesto, S. A. O. Silva, and A. A., Oliveira, "Power quality improvement using a dual unified power quality conditioner/ uninterruptible power supply in three-phase four-wire systems," IET Power Electron., vol. 8, no. 3, pp. 1595–1605, Sep. 2015.

[5]. V. Khadkikar, "Enhancing electric power quality using UPQC: A comprehensive overview," IEEE Trans. Power Electron., vol. 27, no. 5, pp. 2284–2297, May 2012.J. Wang, "Fundamentals of erbium-doped fiber amplifiers arrays (Periodical style—Submitted for publication)," IEEE J. Quantum Electron., submitted for publication.

[6]. V. Khadkikar, and A. Chandra, "A novel structure for three-phase four-wire distribution system utilizing unified power quality conditioner (UPQC)," IEEE Trans. Ind. Appl., vol. 45, no. 5, pp. 1897–1902, Sep./Oct. 2009.

[7]. V.Khadkikar and A. Chandra, "UPQC-S: Anovel concept of simultaneous voltage sag/swell and load reactive power compensations utilizing series inverter of UPQC," IEEE Trans. Power Electron., vol. 26, no. 9, pp. 2414– 2425, Sep. 2011.

[8]. M. Ucar, S. Ozdemir, and E. Ozdemir, "A four-leg unified series–parallel active filter system for periodic and non-periodic disturbance compensation," Electric Power Syst. Res., vol. 81, pp. 1132–1143, 2011.

[9]. Muneer, V., and Avik Bhattacharya. "Cascaded H Bridge Multi Level Inverter Based Unified Power Quality Conditioner." In 2018 IEEE 8th Power India International Conference (PIICON), pp. 1-6. IEEE, 2018.

[10]. Liu, Zhengfu, Jingjing Lu, ZhiguangOu, Ming Ma, Chang Yuan, Xiangning Xiao, and Hao Wang. "The start control strategy design of unified power quality conditioner based on modular multilevel converter." In 2013 International Electric Machines & Drives Conference, pp. 933-937. IEEE, 2013.

[11]. H. Fujita and H. 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.

[12]. H. Awad, M. H.J Bollen, "Power Electronics for Power Quality Improvements," IEEE Symposium on Industrial Electronics, 2003, vol.2, pp. 1129-1136

[13]. Bhim Singh, Kamal Al-Haddad and Ambrish Chandra , "A Review of Active Filters for Power Quality Improvement" IEEE Trans. on Industrial Electronics, Vol.46, No.5, oct. 1999, pp.960-971

[14]. Rosli Omar, NasrudinAbd Rahim, Marizansulaiman "Modeling and Simulation for voltage sags/swells mitigation using dynamic voltage restorer (DVR)" IEEE journal on Power Electronics Drives and Energy System.

[15]. F. Kamran and T. G. Habetler, "Combined deadbeat control of a series parallel converter combination used as a universal power filter," in Proc. Power Electron. Spec. Conf., Jun. 18–22, 1995, pp. 196–201. 2294 IEEE TRANSACTIONS ON POWER ELECTRONICS, VOL. 27, NO. 5, MAY 2012

[16]. H. Fujita and H. Akagi, "The unified power quality conditioner: The integration of series and shunt-active filters," IEEE Trans. Power Electron., vol. 13, no. 2, pp. 315–322, Mar. 1998.

Arundhatee Srivastava, et. al. "Neutral Point Clamped Multi Level Inverter Based Unified Power Quality Conditioner." *IOSR Journal of Engineering (IOSRJEN)*, 10(6), 2020, pp. 14-18.