DESIGN AND ANALYSIS OF UNIFIED POWER QUALITY CONDITIONER WITH FUZZY CONTROL OF TEN SWITCH TOPOLOGY

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Abstract: This paper implements a new topological configuration which is known as unified power quality conditioner (UPQC). Normally in the power structure of three-phase-three-wire of the UPQC which may consists of the two back-to-back connected six switch inverters. According to following configuration, among the 12 switches, 6 switches are connected in the series inverter which will be under-utilized many numbers of times. The fuzzy controller is that the best suited for the human decision-making mechanism, providing the operation of associate electronic system with choices of consultants. Moreover the proposed system which have been realized by utilizing the ten switches with the retains all the performance have the advantage of the twelve-switch of the UPQC during the minimizing with its underutilization without increasing the switch VA rating. And this paper has detailed analytical study and evaluation by comparing the proposed topology between the twelve and nine switches which is depend upon the UPQC system configurations. The proposed conditioner is simulated and the results are presented to verify the operating principles.

***Index terms*- Power Quality, ten-switch converter, Unified power quality conditioner (UPQC), Voltage Sag, Zero sequence.**

1. INTRODUCTION

The ever increasing use of solid state technology in industrial and domestic applications is extensively causative towards line current harmonics, resulting in nonlinear voltage drops, cables heating, poor power issue and extra power losses at distribution levels [1]-[2]. To mitigate these issues and maintain the dependability of the delivered power among acceptable margins, demanding power quality standards ar place into observe [3]. The adherence to those standards are often achieved with a custom power device like the unified power quality conditioner (UPQC). Being a flexible and versatile power device, UPQC has become the foremost engaging answer to power quality issues at the distribution level [9]. A UPQC typically consists of 2 voltage supply inverters (VSI), connected in shunt and series configuration with the grid, at the purpose of common coupling (PCC) and share a standard dc link electrical condenser [4]. The series VSI protects the downstream hundreds from sags/swells within the PCC voltage whereas the shunt VSI reduces the upstream line losses by compensating the harmonic distortion and reactive part of the load current, once the voltage at PCC is distorted, the series VSI are often to boot controlled to mitigate and forestall the voltage harmonics from reaching the load [10]. There is an intensive literature offered on UPQC and a close review is often found in [4]. Although succeeding UPQC with twelve switches offers freelance management of each VSIs and wonderful mitigation of grid disturbances, its series VSI is mostly underutilized throughout traditional conditions the series VSI (six out of twelve switches) stay either utterly inactive or operate at terribly low modulation index. This under-utilization of the series VSI might make to procedure issues as addressed in [11]- [12].

Moreover this paper proposes a replacement reduced switch UPQC system topology that contains of 10 switches in total. The most objective is to scale back the switch count of the back-to back UPQC system whereas retentive its operational options with none performance trade-off to take care of the linear modulation vary and uniform shift frequency for all the switches at intervals the projected topology, a carrier based mostly double zero sequence injection theme is additionally developed to attain the seamless operation of the projected UPQC topology below totally different in operation conditions. Therefore the simulation study is administered to validate the performance of the projected topology.

In FLC, basic management action is set by a collection of linguistic rules. These rules square measure determined by the system. Since the numerical variables square measure regenerate into linguistic

3variables, mathematical modeling of the system isn't needed in FC.

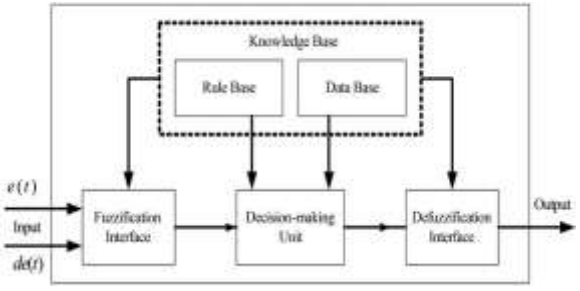

Fig.1.Fuzzy logic controller

The FLC includes of 3 parts: fuzzification, interference engine and defuzzification. The FC is characterised as i. seven fuzzy sets for every input and output. ii. Triangular membership functions for simplicity. iii. Fuzzification exploitation continuous universe of discourse. iv. Implication exploitation Mamdani's, 'min' operator. v. Defuzzification exploitation the peak methodology.

TABLE I: Fuzzy Rules

Change in error	Error						
	NB	NM	NS	Z	PS	PM	PB
NB	PB	PB	PB	PM	PM	PS	Z
NM	PB	PB	PM	PM	PS	Z	Z
NS	PB	PM	PS	PS	Z	NM	NB
Z	PB	PM	PS	Z	NS	NM	NB
PS	PM	PS	Z	NS	NM	NB	NB
PM	PS	Z	NS	NM	NM	NB	NB
PB	Z	NS	NM	NM	NB	NB	NB

Fuzzification:

Membership perform values square measure allotted to the linguistic variables, exploitation seven fuzzy subsets: NB (Negative Big), NM (Negative Medium), NS (Negative Small), ZE (Zero), notation (Positive Small), PM (Positive Medium), and Pb (Positive Big). The Partition of fuzzy subsets and therefore the form of membership CE(k) E(k) perform adapt the form up to acceptable system. the worth of input error and alter in error square measure normalized by associate input scaling issue. In this system the input scaling issue has been designed specified input values square measure between -1 and +1. The triangular form of the membership perform of this arrangement presumes that for any specific E(k) input there's only 1 dominant fuzzy set. The input error for the FLC is given as

$$E(k) = \frac{P_{ph(k)} - P_{ph(k-1)}}{V_{ph(k)} - V_{ph(k-1)}} \quad (1)$$

$$CE(k) = E(k) - E(k\text{-}1) \quad (2)$$

2. Circuit Description:

2.1 Existing Configuration:

For three-phase-three-wire system, generally, the back-toback electrical converter primarily based UPQC system is wide used and is shown in Fig. 1. It contains of twelve power semiconductor switches in total. Switches represent the shunt VSI that is connected at the PCC, whereas, the switches represent the series VSI and is connected between the PCC and cargo. Each inverters share the common dc link capacitance. As shown in Fig. 1, the twelve-switch UPQC deploys 2 dedicated inverters for performing arts the UPQC functionalities.

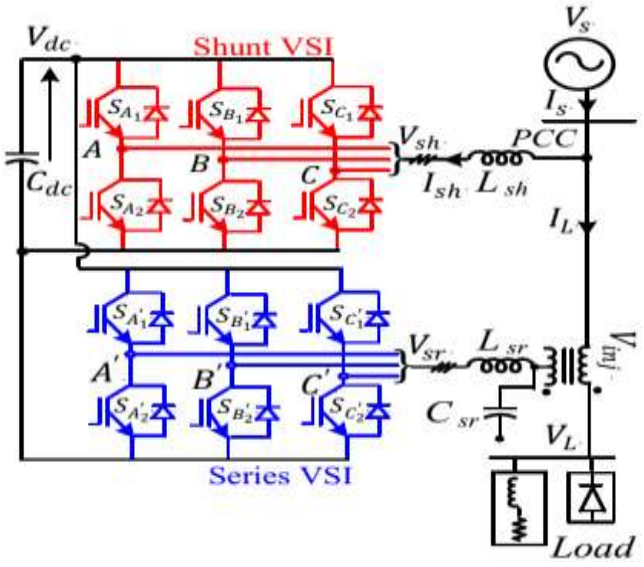

Fig. 1. Twelve-switch UPQC topology.

This feature permits UPQC to possess shunt VSI connected at either the PCC or load with no result on the compensation ability. Recently, there has been a shot to cut back the entire switch count of the UPQC as reported in [13]. By merging the lower 3 switches of the shunt VSI higher 3 switches of the series VSI in Fig. 1, the reduced nine-switch UPQC topology is achieved in [13]. This configuration features a set of 3 shared switches as illustrated in Fig. 2.

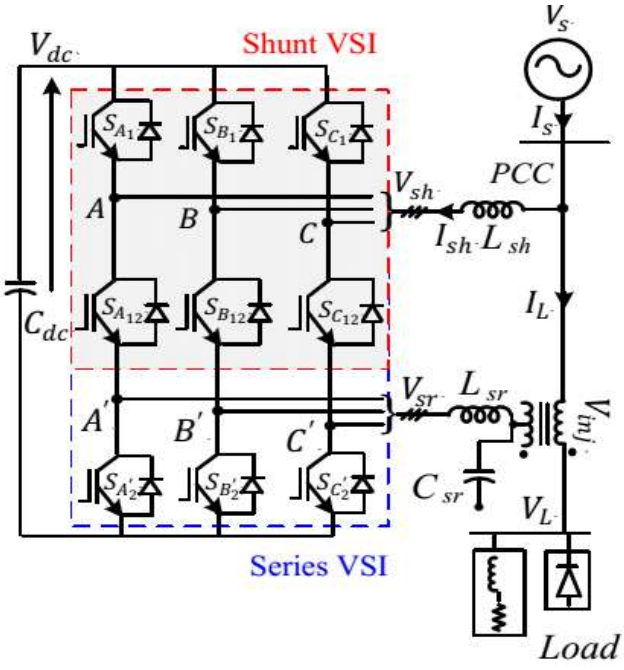

Fig. 2. Nine-switch UPQC topology.

The configuration options saving of 3 switches and performs satisfactorily underneath traditional and sag conditions while not a rise within the dc link voltage. However, it causes sizeable rise within the switch current ratings of 2 switches per part that is principally attributed to the series affiliation of 3 switches in every leg. Therefore, six out of 9 switches should be outsized for adequate operation of the nine-switch UPQC. additionally, all the 9 switches should stay operational regardless of the UPQC compensation mode. Thus, the dependableness of the nine-switch UPQC reduces for one switch malfunction

This paper proposes the utilization of ten-switch configuration because the best suited candidate for shunt-series configuration, such as, UPQC. The principle behind this recommendation is given below.

As shown in Fig. 3, the outputs of the higher VSI ar connected to the PCC constituting the shunt configuration, whereas, the outputs of lower VSI ar connected nonparallel with a similar PCC constituting the series configuration.

Proposed Ten-Switch Topology:

In this paper, a replacement topology of UPQC, supported 10 switches, is projected for power quality sweetening applications. As delineate in Fig. 3, the projected topology is accomplished by combining the section C switches of shunt and series VSI and in Fig. 1, severally, into a typical leg with a shared set of 2 switches and . as yet the ten-switch structure has been used in drives applications with sure limitations. the subsequent segment provides an outline of the ten-switch connected add the literature [14-21].

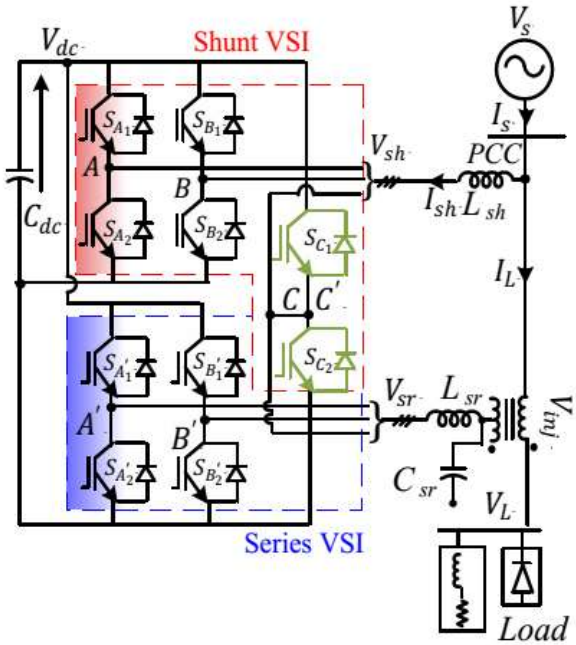

Fig.3 Proposed Ten-Switch Topology

Control for Shunt-VSI

The task of the shunt VSI is to compensate the reactive and harmonic elements of load current and regulate the dc link voltage throughout traditional and sag conditions. to appreciate these objectives, the management theme is shown in Fig. 7. The measured load current i is regenerate to the synchronous organization quantitates i and i that square measure given as.

$$i_{Ld} = \bar{\imath}_{Ld} + \tilde{\imath}_{Ld}$$
$$i_{Lq} = \bar{\imath}_{Lq} + \tilde{\imath}_{Lq}$$

where and correspond to the elemental active and reactive elements of load current, severally. and replicate the harmonic elements of i . The reference current of the shunt VSI are often expressed as

$$i_{ref-sh} = \tilde{\imath}_{Ld} + i_{Lq} + i_{Loss}$$

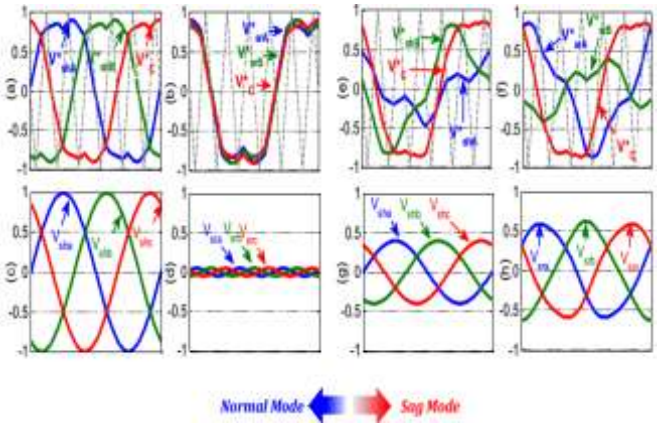

Fig. 4 Representation of modulation indexes and output voltages after second stage for (a),(c) shunt VSI during normal mode (b),(d) series VSI during normal mode (e),(g) shunt VSI during sag mode and (f),(h) series VSI during sag mode.

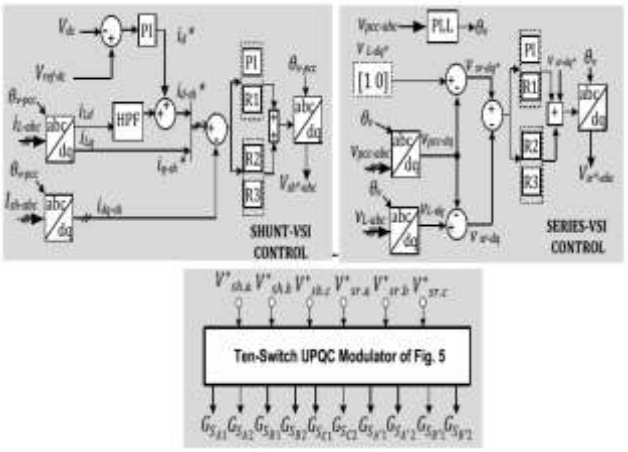

Fig. 5. Detailed control block diagram for the proposed ten-switch UPQC

3. SIMULATION RESULT

Therefore the performance of the projected ten-switch UPQC, associate experimental image is developed. A digital signal processor (DSP), dSPACE DS1103, is employed to manage the shunt and series inverters of the ten-switch UPQC. The developed algorithmic rule needs a sampling time of fifty to execute the code on dSPACE DS1103. each inverters operate at a shift frequency of 10kHz. To emulate the sag and harmonic distortion within the grid voltage, a 3 part programmable supply is employed. The experimental system parameters square measure listed in Table V. Note that all told the experimental results the PCC and cargo voltages square measure shown as line to line voltages, whereas, the series injected voltages square measure shown as part voltages across series transformer).

Table V

UPQC System Data for Simulation Result

Programmable voltage source	Supply voltage: 175 $V_{L-L\,peak}$, 50 Hz Source Impedance: R_g = 0.047 Ω and L_g = 160 μH
UPQC:	DC link capacitors, C_{dc} = 1100 μF Reference DC link voltage = 230 V Series filter, L_{sr} = 2.5 mH C_{sr} =15 μF Shunt filter, L_{sh} = 5 mH Series transformer = 240/240 V (1:1 ratio)
Load	Linear: R = 27 Ω and L = 50 mH Non Linear R = 57 Ω and L = 5 mH Nominal Load voltage $V_{L-L\,peak}$=50V

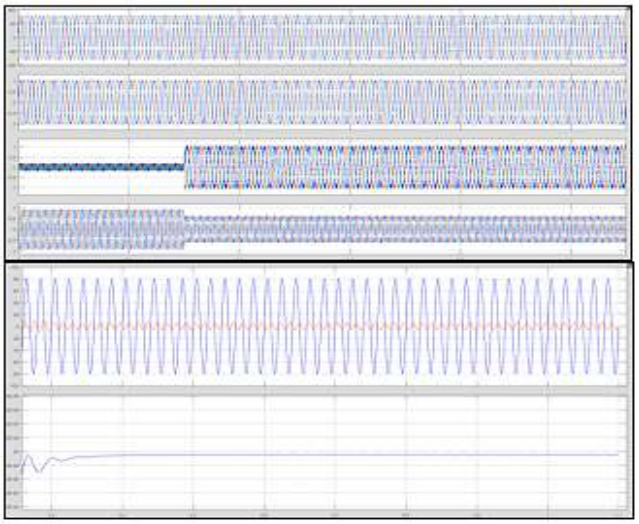

Fig. 6 (a),(b),(c),(d),(e),(f) simulation result: power factor correction during steady state condition.

According to the fig.6 which can depicts the steady state performance of the projected ten-switch UPQC system considering a linear RL load (. Initially, the shunt VSI is maintaining the dc-link voltage by drawing a little current (Fig. 6(c)), whereas, the load reactive power is provided by the grid. As seen from Fig 8(e), the grid current lags the grid voltage by . The reactive compensation starts at time . The shunt VSI injects the mandatory current inflicting the grid to provide solely the load active power (i.e. grid current being inphase with the grid voltage as shown in Fig. 6(e)). On identical system, a fulminant sag condition is obligatory. associate unbalance voltage sag is introduced within the grid voltage as shown in Fig. 7(a). It may be seen from Fig. nine that the projected ten-switch UPQC effectively maintains the dc link further because the load voltage at nominal values (Figs. 7(b) and (c)).

Further, the performance of projected UPQC configuration is valid below worst case situation of most three-phase balanced voltage sag depth of four-hundredth with solely non-linear load (diode bridge rectifier with current ThD of 28%) connected to the system.

As shown in Fig. 8 (c), the load voltage square measure maintained at rated worth during this case further. To boot, the shunt-VSI compensates the harmonics within the load current and maintains the dc-link voltage at reference worth. The supply current ThD is improved from twenty eighth to one.8%. Fig. eleven depicts the performance of projected ten-switch UPQC once the PCC voltage and cargo current square measure distorted. a mixture of linear (RL) and nonlinear load is taken into account with the combined load current ThD of eighteen. The 15 and 17 harmonic voltages square measure accessorial within the grid voltage to realize a ThD of 10%.

Fig.7. (a),(b),(c),(d),(e),(f),(g) simulation result: transition from steady state to unbalanced voltage sag condition (with liner RL load).

Fig.8. (a),(b),(c),(d),(e),(f),(g) simulation result: transition from steady state to balanced voltage sag condition (with non-linear load).

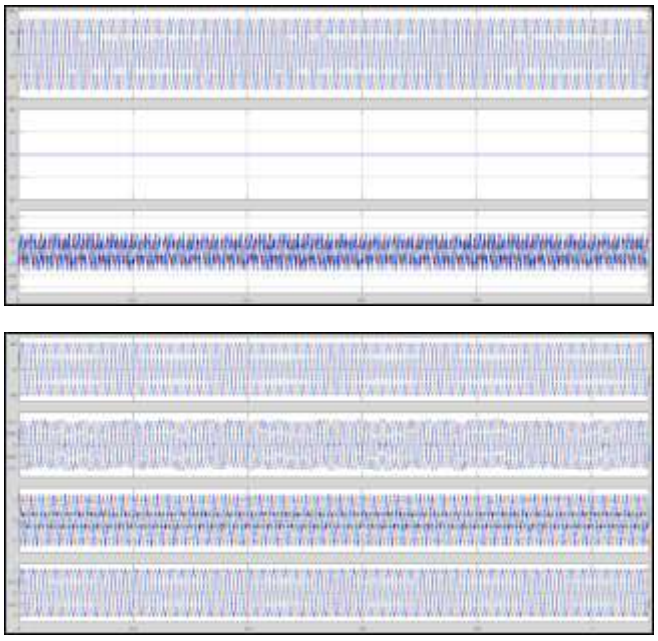

Fig. 9. (a),(b),(c),(d),(e),(f),(g) Simulation result: distorted supply and unbalanced nonlinear load condition.

The series half effectively mitigates the harmonics within the grid voltage. The improved load voltage profile may be noticed from Fig. 9(d) whereby the ThD is reduced to three. at the same time, the shunt controller effectively compensates the load current harmonics achieving curving grid currents with the ThD of two.1%. Thus, the on top of experimental study verifies the feasibleness of the projected ten-switch UPQC topology for sensible applications to enhance the facility quality.

4. Conclusion:

In order to enhance the limitations of the nine-switch that is rely upon the decreases the switch power conditioner, so during this paper we have a tendency to square measure proposes a replacement strategy known as UPQC by utilizing the ten semiconductor switches. They square measure few feature of the planned topology there are capability of maintaining identical power quality sweetening alongside the less variety of switches and conjointly without negative rising within the switch VA rating. Then ever the comparative study square measure conducted and there square measure the results that square measure demonstrate that the planned ten-switch topology can do identical power quality mitigation performance with the smallest amount VA loading of the UPQC system. The fuzzy controlled system is extremely sensitive to the distribution of membership functions however to not the form of membership functions .The performance of the planned topology has been valid simulation underneath numerous operative conditions.

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