Assuage of Voltage Swell and Sag problems with UPQC Based on AMC Converter

Kamal Mohamed Saied[1], Abdulrahman A.A.Emhemed[2], Suhail M. J. Khattab[3], Mohamed. A. Farag[4]

Abstract- **Voltage swell and sag problems, which most frequently occur and negatively affect power quality, are among the most prominent power quality problems with the incessant outstanding development of electronic devices. Therefore, the purpose of this research is to mitigate voltage sag and swell problem with Unified Power Quality Conditioner (UPQC) using proposed Adaptive Multi Converter (AMC) converter. The proposed device was implemented while rising voltage sag and swell problem in electronic appliance. The results revealed that the controlled reactive source of implemented device infused accurate electric flow during voltage sag and swell problem and restored quickly concerning to any incongruity in the distribution system. The comparisons in this research showed that the developed converter was capable to compensate the voltage sag and the voltage swell at 1-phase, 2-phase, and 3-phase, respectively. As a result, the developed power distribution system was substantiated as a proficient compensator for the reactive power requirement of the load, and in future it can be used as a fancy power distribution system for the protection of dynamic load.**

***Key Words—Voltage Sag, Voltage swell, UPQC, reactive power*.**

I. INTRODUCTION

IN today's global electronic distribution system, the power quality problems are the blazing matter of concern for electric utilities companies and consumers. In fact, poor power quality may consequence into increased power losses, abnormal power and undesirable behavior of equipments, interference with nearby communication lines, and so forth [1]. As a result, it can cause loss of production, damage to equipment and human health [2]. A power quality problem can be defined as [3]: "Any power problem manifested in voltage/current or leading to frequency deviations that results in failure or mis-operation of customer equipment". Power quality problems comprise a wide range of disturbances such as voltage sags/ swells, flicker, harmonics, distortion, impulse, transient and interruptions. Among the above mentioned problem, voltage sag is the most commonly occurring problem in terms of power quality problem. The IEC electro-technical vocabulary, IEC 60050- 604, 1998 defines a voltage sag as any "sudden reduction of the voltage at a point in the electrical system, followed by voltage recovery after a short period of time, from half a cycle to a few seconds". Likewise, in more explicitly, A sag, as defined by IEEE Standard 1159, IEEE Recommended Practice for Monitoring Electric Power Quality, is "a decrease in RMS voltage or current at the power frequency for durations from 0.5 cycles to 1 minute, reported as the remaining voltage". Typical values are between 0.1 p.u. and0.9 p.u. Typical fault clearing times range from three to thirty cycles depending on the fault current magnitude and the type of over current detection and interruption. Actually, Voltage sags are appeared due to faults, motor starting , and transformer energizing [4]. However, voltage swells are not as important as voltage sags because they are less common in the distribution systems. Voltage Swell is denoted by IEEE 1159 as the increase in the RMS voltage level to 110% - 180% of nominal, at the power frequency for durations of ½ cycle to one 1 minute. It is alignmented as a short duration voltage variation phenomena, which is one of the common categories of power quality problems [3]. The term momentary overvoltage is also used as a synonym for swell. Main causes of voltage swells include energizing of capacitor banks, shutdown of large loads, unbalanced faults (one or more phase-to-phase voltages will increase, transients, and power frequency surges [5]. Besides Multi converter-UPQC, there are some types of converter such as single voltage cascade converter, multilevel cascade converter, multi-voltage cascade converter. In case of single voltage cascade converter a single-phase full bridge or "H-bridge" inverter is a fundamental building block and it is called as a "cell." The identical cells are connected in series and the string composes a cascade converter (called as "single-voltage cascade converter"). Since the cascade converter realizes high blocking voltage and low harmonic output voltage, it needs no step-down transformers for medium voltage applications [6][7]. Whereas, a cascaded multilevel converter which has more than two types of cells with different rated voltage. Different cells whose dc voltage ratio is typically 2:1 or 3:1 are connected in series and controlled together to compose low-harmonic output voltage. It can reduce harmonic voltage comparing to the single-voltage cascade converter with the same number of cells. However, the multi-voltage cascade converter has difficulty in maintaining the dc voltage ratio to the predetermined value. Although it is confirmed that the dc sources consisting of isolated power supplies are effective to keep the dc voltages ,

[1], [2], [3] Department of Electrical Engineering, Bright Star University, El – Brega, Libya.

[4]Zwitina OCGT Power Plant Libya , Zuweitna, Libya.

E-mail: kmal_10_100@ yahoo.com[1]

the method needs power supplies in all cells and its configuration becomes complex. High voltage isolation of the power supplies also makes the converter [8][9][10]. To overcome the voltage sag and swell difficulties, UPQC is one of the best custom power device owing to compensate both source and load side problems [11]. It consists of a shunt voltage-source converter (shunt VSC) and two or more series VSCs, all converters are connected to back to back on the DC side and share a common DC-link capacitor. Therefore, power can be transferred one feeder to adjacent feeders to recovery for voltage sag and swell complexities [12]. The importance of this research to resolve voltage swell and sag problem manifested in voltage/current or frequency deviations that result in failure of customer equipment. Modern power systems are of complex networks, where hundreds of generating Stations and thousands of load centers are interconnected through long power transmission and distribution networks. In Power distribution system power should provide with an uninterrupted flow of energy at smooth at the contracted magnitude level to their customers. In distribution network sinusoidal voltage required where consumer uses various non linear, inductive and capacitive load. These load derived from reactive power distorted the power quality of the power system. In order to overcome the reactive power some facts devices (STATCOM, UPQC) were incorporated in power system but these devices leads generation of inconsistence voltage fluctuation in power system. So, the converter used within the UPQC should be able to withstand the increased power levels. So, in order to overcome this problem, the term multi-level is brought out in 1981. The very important thing of multilevel converters is that adding more transformer and to reduce the power quality problems. The energy from transformer is used to maintain the load voltage.

II. RESEARCH METHOD

This paper consists of three part is proposed. First part is main circuit and control methods. Main circuit shows the configuration of the proposed UPQC design using MATLAB/SIMULINK. The function of three-level Bridge is to shunt voltage source. The output of Three-level Bridge connects with AMC converter as shown in Simulation below"A-phase A-MC and B-phase A-phase and C-phase A-MC". This paper the new innovative technique, UPQC with AMC converter, had designed whereas it was expected that the better compensation strategy for voltage swell and sag problems would be developed ever before. Furthermore, globally current highly competitive custom power devices market, customer always looking for a better and proficient electronic devices. With this regard, this proposed approach would be able to fulfill the buyer demands. The network was designed based on UPQC which plays the most vital role to improve the power quality in distribution networks. It was used to compensate the power system disturbances such as voltage sags and swells. This network was consisted of a voltage source (15 kV, 50 hZ) and load (0.35Ω, 200 mH) , DC link voltage (6 kV), three, two, single fault scenario, series transformer ratio (1:1) and injection transformer. It was expected that, if the simulation was apply perfectly UPQC would be able to compensate the sags and swells during single-phase, two-phase and three-phase fault. Additionally, filter (inductance 0.5 mH, and capacitance, 1μF) was introduced to reduce the harmony. At last, to analyze the scenario of fault system, AMC converter controller was applied at single, two and three phase fault on distribution network in order to understand the compensation performance against voltage sag and swell.

Voltage sags/swells caused by unsymmetrical line-to line, single line to ground (SLG), double-line-to-ground and symmetrical three phase faults effects on sensitive loads, the UPQC injects the independent voltages to restore and maintained sensitive to its nominal value. The injection power of the UPQC with zero or minimum power for compensation purposes can be achieved by choosing an appropriate amplitude and phase angle.

At voltage sag stage the UPQC with the help of AMC injected the missing voltage in order to compensate it and voltage swell condition the proposed system absorbed the voltage so that voltage at the load protected from voltage swells problem. The injected voltage that was produced by the AMC based UPQC in order to correct the load voltages and the load voltages maintain at the constant level. The main function of the UPQC is the protection of sensitive loads from voltage sags/swells coming from the network. The UPQC was connected in series between the source voltage or grid and sensitive loads through injection transformer. The energy storages are very important in order to supply active and reactive power to the UPQC. The controller is an important part of the UPQC for switching purposes. The switching converter is responsible to do conversion process from DC to AC. The inverter ensures that only the swells or sags voltage is injected to the injection transformer. The swells voltages occur at the time duration of 0.4 sec to 0.9 sec and the same duration voltage restored back to its normal value. It can be seen from the results, the load voltage was kept at the nominal value with help of the UPQC.

Table 1 System parameter used for simulation

Supply Voltage	15Kv
Series transformer turns ratio	1:1
Line impedance	0.001 Ω, 0.005H
DC Link Voltage	6kV
Filter Inductance	0.5mH
Filter capacitance	1μF
Load resistance	0.35Ω
Load inductance	200mH

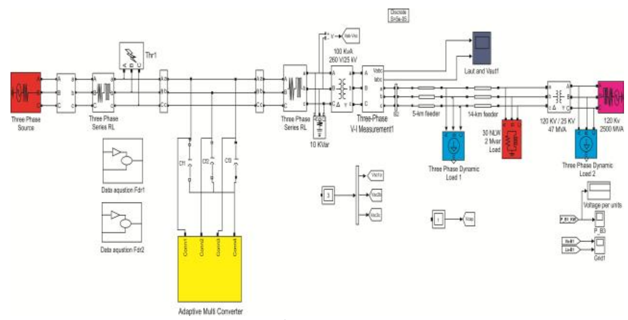

Fig. 1 Simulink Model for UPQC with AMC Converter

From above table 1 it can be reported that these are specification of this study for simulation process. As for instance 15 Kv is used for medium voltage network acting as a source voltage. Besides, it is also mentioned that these are the standard parameters for simulation through UPQC system

The paper was started studying by the literature review. Afterwards, the UPQC using MATLAB was simulated. Subsequently, Control method was applied. Therefore, result of the simulation was analyzed by determining current load and time respond using newly proposed adaptive multi-converter based UPQC. However, during the analysis stage the fault was found then it was started once again from simulation stage. At last, it was ended up with a comprehensive conclusion.

Dynamic load means very first flow of current in the within the large electrical device. Voltage sag or swell can be happened due to dynamic load. As for instance when turn on electrical industrial motor, voltage sag is generated owing to dynamic load. Likewise, during turn off electrical industrial motor voltage swell is produced because of dynamic load.

The Three-Phase Dynamic Load block implements a three-phase, three-wire dynamic load whose active power P and reactive power Q vary as function of positive-sequence voltage. Negative- and zero-sequence currents are not simulated. The three load currents are therefore balanced, even under unbalanced load voltage conditions.

The load impedance is kept constant if the terminal voltage V of the load is lower than a specified value Vmin. When the terminal voltage is greater than the Vmin value, the active power P and reactive power Q of the load vary as follows:

$$P(s) = P_0\left(\frac{v}{v_0}\right)^{n_p}\frac{1+T_{p1^s}}{1+T_{p2^s}} \quad (1)$$

$$Q(s) = Q_0\left(\frac{v}{v_0}\right)^{n_q}\frac{1+T_{q1^s}}{1+T_{q2^s}} \quad (2)$$

Where: V_0 is the initial positive sequence voltage; P_0 and Q_o are the initial active and reactive powers at the initial voltage V_o; V is the positive-sequence voltage; n_p and n_q are exponents (usually between 1 and 3) controlling the nature of the load; T_{p1} and T_{p2} are time constants controlling the dynamics of the active power P; T_{q1} and T_{q2} are time constants controlling the dynamics of the reactive power Q.

III. RESULT AND ANALYSIS

The simulation system of this study began with three phase voltage source carrying 120 Kv. The adaptive multi-converter was located between two three phase series RLC load. The measurement transformer was placed between three phase series RLC load and three-phase V.I measurement, while the power transformer was set up between three phase dynamic load 1 and three phase dynamic load 2. The R and L value of line impedance were 0.001 Ω and 0.005 H. The key components of AMC converter were three phase measurement, three phase series RLC load, discrete 3-phase PLL1, terminator, DC voltage source. Series RC snubber circuits are connected in parallel with each switch device. Vabc and Iabc receive signals from the Goto block with the specified tag. Data aqustion Fdr1 and Fdr2 were placed inside the AMC converter. The figure below illustrates the 1- phase voltage sag fault scenario and competency of AMC converter for the mitigation of voltage sag problem. Here, The X-axis and Y-axis indicates the time (sec) and voltage (volt) per unit, respectively.

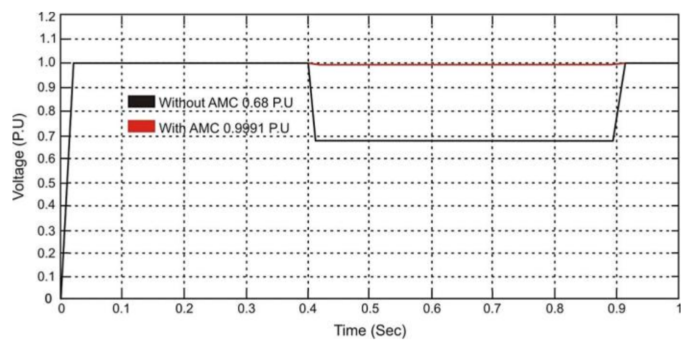

Fig. 2 Voltage sag at one-phase fault scenario with and without AMC converter.

From above figure 2 it is clear that during the first 0.40 second a constant voltage 100 volt per unit was found. Afterwards, the voltage sag was made and dropped the voltage level hugely to 0.68 per unit in case of without having AMC converter. Then, this level was remained unchanged the same position until voltage shifted into 1 per unit value. Subsequently, the rest of the period the voltage level ran the same pace as like as before voltage sag problem. However, due to the application of AMC converter the voltage level was moved to 0.9991 per unit value. As a result, the proposed converter was able to mitigate 99.72% voltage sag problem.

The figure below elucidates the 2- phase voltage sag fault scenario and competency of AMC converter for the minimization of voltage sag problem. Here, The X-axis and Y-axis indicates the time (sec) and voltage (volt) per unit, respectively.

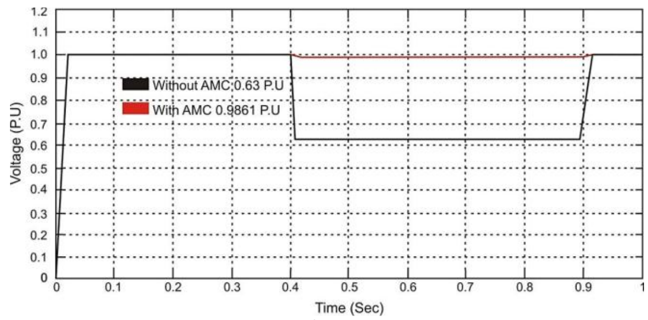

Fig. 3 Voltage sag at two-phase fault scenario with and without AMC converter

From above figure 3 it is transparent that during the first 0.40 second a constant voltage 100 volt per unit was observed. Afterwards, the voltage sag was occurred and changed the voltage level dramatically to 0.63 per unit in terms of without using AMC converter. Then, this level was remained stable the same position until a substantial jump at 0.89 sec. Subsequently, the rest of the period the voltage followed the same tract as like as before voltage sag problem. But, owing to the incorporation of AMC converter the voltage level was injected to 0.9861 per unit. Consequently, the proposed converter was able to compensate 96.24% voltage sag problem.

The figure below shows the 3- phase voltage sag fault scenario and competency of AMC converter for the assuage of voltage sag problem. Here, The X-axis and Y-axis indicates the time (sec) and voltage (volt) per unit, respectively.

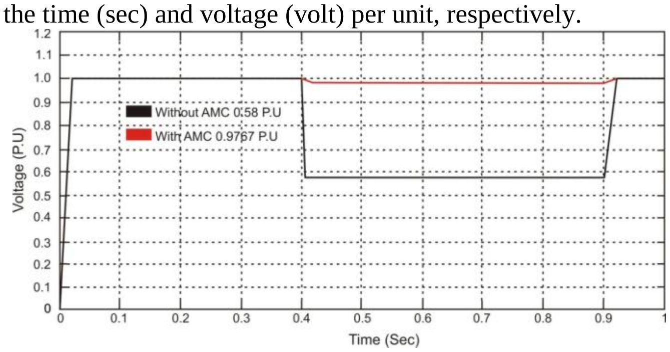

Fig. 4 Voltage sag at three-phase fault scenario with and without AMC converter

From above figure 4 it is obvious that over the first 0.40 second a constant voltage 100 volt per unit was observed. Afterwards, the voltage sag was occurred and changed the voltage level boomly to 0.58 per unit without using AMC converter. Then, this level was remained stable the same position until a voltage level moved to 1 p.u at 0.9 sec. Subsequently, the rest of the period the voltage followed the same tract as like as before voltage sag problem. Nevertheless, owing to the association of AMC converter the voltage level was injected to 0.9767 per unit. Therefore, the proposed converter was able to compensate 94.45% voltage sag problem.

The figure below depicts the 1- phase voltage swell fault scenario and competency of AMC converter for the mitigation of voltage swell problem. Here, The X-axis and Y-axis indicates the time (sec) and voltage (volt) per unit, respectively.

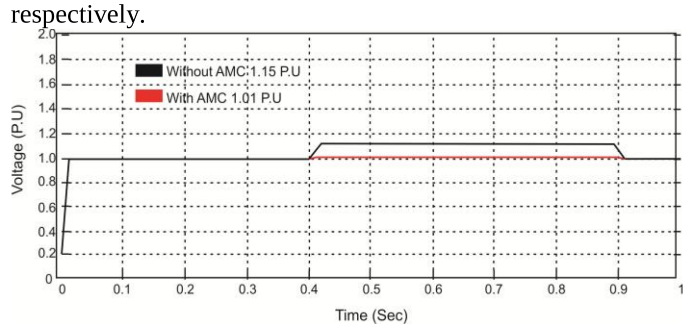

Fig. 5 Voltage swell at one-phase fault scenario with and without AMC converter

From above figure 5 it is transparent that during the first 0.40 second the voltage 1 volt per unit was found. Afterwards, the voltage swell was happened and changed the voltage level substantially to 1.15 per unit without being installed AMC converter. Then, this level was maintained the same position until voltage level shifted to 1 p.u at 0.9 sec. Subsequently, the rest of the period the voltage ran the same pace as like as before voltage swell problem. However, due to the initiation of AMC converter the voltage level was fallen to 1.01 per unit. Therefore, the proposed converter was able to assuage 93.33% voltage swell problem.

The figure below illustrates the 2- phase voltage swell fault scenario and competency of AMC converter for the mitigation of voltage swell problem. Here, The X-axis and Y-axis indicates the time (sec) and voltage (volt) per unit, respectively.

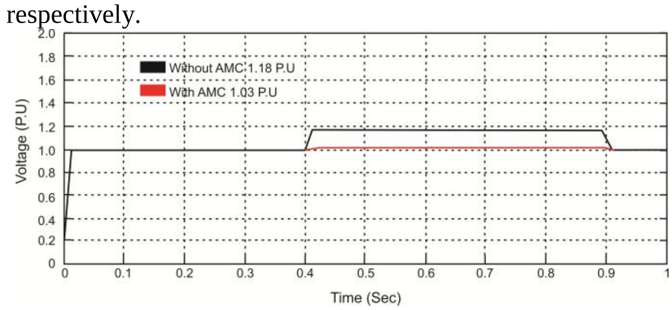

Fig. 6 Voltage swell at two-phase fault scenario with and without AMC converter

From above figure 6 it is clear that over the first 0.40 second the voltage 100 volt per unit was observed. Afterwards, the voltage swell was occurred and switched the voltage level enormously to 1.18 per unit in case of without applying AMC converter. Then, this level was leveled out until a sharp drop at 1 sec. Subsequently, the rest of the period the voltage ran the same pace as like as before voltage swell problem. However, due to the insertion of adaptive multi-converter the voltage level was minimized to 1.03 per unit. As a result, the proposed converter was able to recovery 83.33% P.U voltage swell problem.

The figure below elucidates the 3- phase voltage swell fault scenario and capability of AMC converter for the mitigation of voltage swell problem. Here, The X-axis and Y-axis represents the time (sec) and voltage (volt) per unit, respectively.

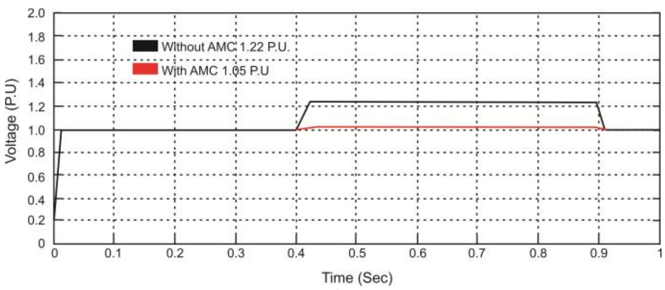

Fig. 7 Voltage swell at three phase fault scenario with and without AMC converter

From figure 7 it is obvious that since the beginning to 0.40 second the voltage per unit was stable 100 volt per unit. Afterwards, the voltage swell was occurred and changed the voltage level dramatically to 1.22 per unit. Then, this level was remained constant until a massive decline at 0.9 sec. Subsequently, the rest of the period the voltage followed the same speed as like as before voltage swell problem. However, due to the usage of AMC converter the voltage level was reduced to 1.05 per unit. Consequently, the proposed converter was able to recovery 77.27% voltage swell problem.

The figure in below compares the importance of AMC converter for mitigating voltage sag problem in the system at dynamic load condition with AMC and without AMC at three phase. The X- axis indicates the time in second and Y – axis represents the voltage per unit value.

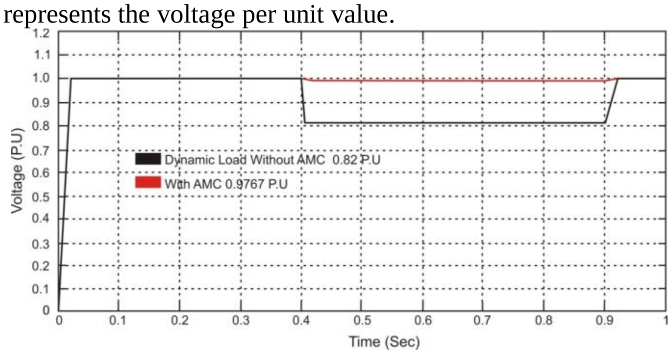

Fig. 8 Voltage sag at three phase dynamic load scenario with and without Adaptive multi converter

From figure 8 it is clear that over the first 0.40 second the voltage 1 volt per unit was observed. Then, the voltage sag was occurred and transformed the voltage level noticeably to 0.82 per unit without applying AMC converter. Then, this level was leveled out until the switch of voltage at 1 p.u at .9 sec. Subsequently, the rest of the period the voltage ran the same pace as like as before voltage sag problem. However, due to the installment of AMC converter the voltage level was moved to .9767 per unit. As a result, the proposed converter was able to recovery 87.06 % P.U voltage sag problem at dynamic load condition.

The figure in below differtiates the importance of AMC converter for solving voltage sag problem in the system at dynamic load condition with AMC and without AMC at three phase. The X- axis indicates the time in second and Y – axis represents the voltage per unit value.

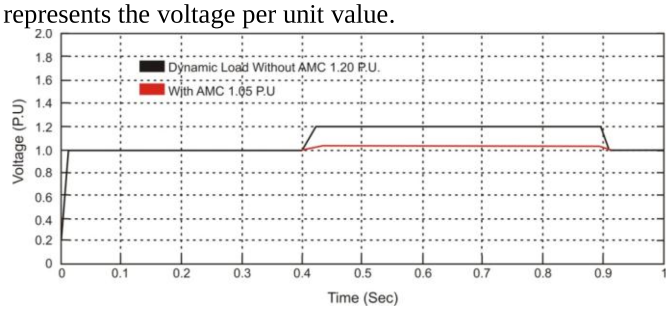

Fig. 9 Voltage swell at three phase dynamic load scenario with and without AMC converter

From figure 9 it is obvious that since the beginning to 0.40 second the voltage per unit was stable 1 volt per unit. Afterwards, the voltage swell was occurred and changed the voltage level dramatically to 1.20 per unit. Then, this level was remained constant until voltage level shifted to 1 p.u. at 0.9 sec. Subsequently, the rest of the period the voltage followed the same speed as like as before voltage swell problem. However, due to the usage of AMC converter the voltage level was reduced to 1.05 per unit. Consequently, the proposed converter was able to recovery 75 % voltage swell problem.

To understand the excellency of this research, the findings of this research can be compared with some other research outcomes which were found with same research area like this experiment. As for instance, the recent research findings such as the Simulation results derive from Nayak and Kumar, 2014 [13] show that the DSTATCOM can compensate the voltage sag and swell conditions. In their thesis work, Voltage Sag condition was mitigated at 0.20 Ω and 0.40 Ω fault resistance by applying DSTATCOM based simulation. As a result, Power Quality was improved significantly. It can be concluded that DSTATCOM promotes the power quality and remove the voltage sag condition in distribution network. Patjoshi and Mahapatra introduced a novel controller for the UPQC and analyzed by using both shunt and series converter based on sliding mode control algorithm and dc-link voltage regulation with a fuzzy logic controller. It was observed that use of SMC (Sliding Mode Control) to the series APF can compensate the both symmetrical and asymmetrical sag and swell in terminal voltages and make the load voltage free from any voltage fluctuations [14]. The work of Dinesh et al., 2012 [11] was mainly to the study of Power Quality problems and its compensation with UPQC. Results obtained from this study provide useful information regarding the behaviour of different controllers used for power quality improvement connected to distribution line. The simulation results showed that the UPQC with fuzzy logic controller Compensates 75% of voltage sag during fault condition. While UPQC with artificial neural network based controller compensates 95% of voltage sag. From simulation results also showed that the DVR compensates the sags/swells quickly and provides excellent voltage regulation.

IV. CONCLUSION

To sum up, it can be attained that the developed UPQC with AMC converter was proved as a efficient power distribution system to maintain the stability of the current in the network. The results revealed that the controlled reactive source of implemented device infused accurate electric flow during voltage sag and swell problem and restored quickly concerning to any incongruity in the distribution system and recovered to voltage sag by 99.72%, 96.24%, 94.45% and the voltage swell by 93.33%, 83.33%, 77.27% at 1-phase, 2-phase, and 3-phase, respectively. Furthermore, it is to be anticipated that in future this proposed device will be recognized as a new effective customer power device with regard to promoting delicate and miniature electronic devices.

V. SUGGESTION

On the basis of findings from this research it can be suggested that the highly potential AMC converter can be installed with some other devices such as Static Synchronous Series Compensator (SSSC), Static Phase Shifting Transformer (SPST), Dynamic Voltage Resistor (DVR), Interphase Power Controller and other FACT devices for reducing the power quality disturbance namely notching, inter-harmonics, voltage fluctuation, power frequency variations greatly.

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