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Improvement of Power Quality by using Injection Super Capacitor UPQC for BLDC Motor

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ABSTRACT

This paper presents the operation of unified power quality conditioner (UPQC) as a universal active power conditioning device to mitigate both current as well as voltage distortions at a distribution end of power system network. The UPQC is designed by combining a series active power filter and shunt active power filter which shares a common DC link capacitor and series active filter mitigate the voltage related harmonics in power supply side and shunt active filters are mitigate the current related harmonics of non linear loads. UPQC mitigate the harmonics and other harmonic sensitive loads. Among from them unified power quality conditioner was widely studied by different controllers and we applied to BLDC motor for updating of load characteristics that improve the power quality in distribution side.

KEYWORDS: *Power quality, unified power quality conditioner (UPQC), phase locked loop (PLL), fuzzy logic controller.*

I. Introduction

In electric power system the power quality mostly effected by voltage and current variation these are caused by harmonic content in the supply due to non-linear loads, such as large thyristor power converters, rectifiers. These are also affected by switching of loads and removing of loads in the form of sags and swells. The above number of factors are mainly effects the power system quality. These number of factors issues to maintaining the fixed voltage at point of common coupling for various voltage distribution levels and finally to maintaining the unity power factor drawn from the electric power supply ,stop unbalance currents and voltages from different distribution levels , voltage and current harmonics reduction in the system [1]. In the distribution system using of number of non-linear loads so want to be maintaining the quality of power. Hence power quality varies with the different sources of generations. The conditioning of power supply by injecting the specific values of voltage and current by concentrated the UPQC.

In our power system using single phase loads, three phase loads it's all are linear or non-linear but our final criterion is to eliminate the voltage and current variations to maintain the system at exact levels. The receiving of AC supply is converted into DC by using inverters. The converted DC supply strictly is clearly stored by one device is called a battery. The energy is stored in the form of battery or flywheel etc. These are artificial type of because of its have slower rate charge/discharge time by the reason of slower chemical process. The proposed UPQC presents super capacitors it require small amount of current for charging [1]. Power transfer is high and it is very less weight, efficiency is more when compare to conventional batteries.

In our electric power system using different types of loads which are linear and non-linear loads. In case of linear loads there is no problem from the harmonics and when there is an using non-linear loads like 3-phase four were bridge-rectifier and diode-bridge rectifier with RC load in the DC side. If using of non linear loads it will presents the harmonics it may more than 45% is observed. In paper [6] using bi-directional full bridge DC-DC converters are used in UPQC. In this paper concentrated only on voltage variations, current variations using the series inverter and parallel inverter. The UPQC is a custom power device and it contains series and parallel active filters which are used to compensate voltage and current related problems. In voltage problems like voltage swell, sags and flicker, voltage harmonics, in current related problems like reactive power generation and poor power factor. The improvement of power factor and reactive power is neglected so the entire system is protected to connected the UPQC at the load end side.

II. POWER QUALITY PROBLEMS IN DISTRIBUTION NETWORK WITH HIGH PENETRATION OF DGS

In distribution network with high penetration of DGS output of the power is fluctuated. The power could be supplied by energy storage technology, which includes two aspects: one is high efficient mass storage, and the other is fast and efficient energy conversion. Energy storage is useful for the future demand for the critical load. Meanwhile, it would provide technical support for reducing network power loss and improving power quality. Super capacitor storage is normally used for smoothing the power of short duration, high power load or used in high peak power situation such as high power DC motor starting and dynamic voltage restorer. When it comes to voltage sags or instantaneous disturbance, Super capacitor storage technology is able to improve the power supply and quality. Thus, this technology is suitable for solving power quality problems in distribution network with high penetration of DGs [12]

Custom power technology, based on power electronic technology, could provide power supply up to reliability and stability level which users required in MV/LV distribution network system. UPQC, with feature of series compensation and parallel compensation being integrated together, has been considered as the most full featured and effective one of all DFACTS technologies so far. To improve power quality of distribution network with the high penetration of DGs, developing custom power technology based on UPQC, which can inject active power during the voltage regulation and integrate to reactive compensation, is a feasible strategy.

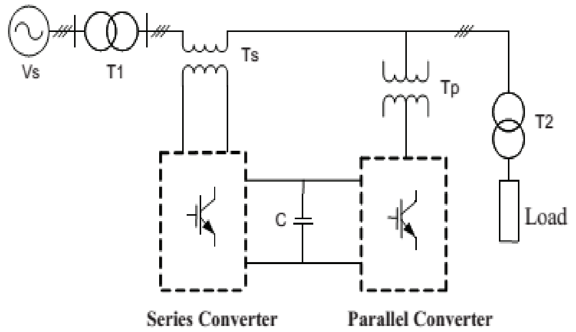

Fig.1. Structure scheme of UPQC.

Traditional UPQC used in power distribution system, integrating series compensation voltage principle and parallel compensation voltage principle in one device, can compensate three-phase asymmetric and harmonicon both mains supply voltage and nonlinear loads. UPQC is composed of the main circuit shown in Fig.1, including series and parallel PWM converter, and the control circuit. There are two basic control strategies, i.e. direct control scheme and indirect control scheme. Direct control scheme means series converter is controlled as sinusoidal current source to isolate voltage disturbance comes from grid and load. And parallel converter is controlled as sinusoidal voltage source to avoid load reactive power, load harmonic current and unbalance from being injected into grid. On the other side indirect control scheme means series converter works as a non-sinusoidal voltage source, outputting compensation voltage which offsets grid voltage distortion and fundamental deviation, accordingly it ensures load voltage being rated sinusoidal voltage.

Meanwhile, parallel converter works as an non-sinusoidal current source, outputting reactive power and harmonic current which offset reactive load power and load harmonic current, accordingly it could make the injected current be sinusoidal and running under unit power factor by compensating reactive power and harmonic current[13]. Indirect control scheme by researched more common is mainly discussed in this paper. With the series and parallel PWM converter topology, three phase four-leg circuit structure implements both three-phase and single phase structure, as a result, it is more flexible and versatility. And three-phase control systems can drive unbalanced loads as a result of three phases being mutually independent [14]. Therefore, it chooses the three-phase four-leg circuit structure as the topology of power quality improving device.

In view of the above, this paper presents a kind of three phase four-wire power quality conditioning device based on fast energy storage named Energy-storage UPQC (EUPQC) aiming for power quality problems in distribution network with high penetration of DGs.

III. SUPERCAPACITOR BASED UPQC

The block diagram representation for the proposed system is shown in fig (2). The DC link of both these active filters is connected to a super capacitor through a common DC link capacitor. The source side as well as load side maintain the stable voltages and currents so using series active filters and shunt active filters are used, when series active filters are used to inject the voltage when sag appears and to consume voltage when swell appears in the line. The shunt active filter is reduces the harmonics from source side, load side and also improve the power factor. These transformers are also used to filter the ripple content in the series active filters.

The super capacitor bank consists of number of series and parallel capacitors. The UPQC is solve the problem simultaneously, by using UPQC in the line harmonic reduction and compensation of voltage and current, but UPQC has the capability of voltage imbalance compensation and regulation also harmonic compensation at the consumer end. The UPQC is one of the best solutions for the large capacity loads sensitive to supply voltage imbalance. The UPQC system with DC/DC converter is to control the voltage at capacitor end and also performance of the system is improved.

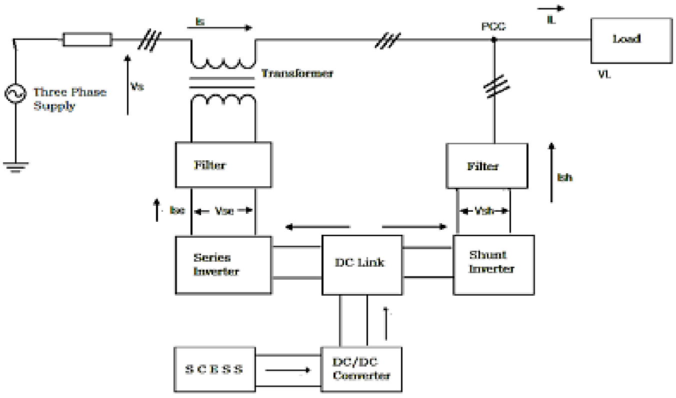

Fig 2. Proposed Block Diagram of UPQC with Super capacitor.

The super capacitor bank consists of number of series and parallel capacitors. The UPQC is solve the problem simultaneously, by using UPQC in the line harmonic reduction and compensation of voltage and current, but UPQC has the capability of voltage imbalance compensation and regulation also harmonic compensation at the consumer end. The UPQC is one of the best solutions for the large capacity loads sensitive to supply voltage imbalance. The UPQC system with DC/DC converter is to control the voltage at capacitor end and also performance of the system is improved. In the proposed control method, load voltage, source voltage, and source current are measured, evaluated, and tested under unbalanced and distorted load conditions using MATLAB/Simulink software.

IV. STRUCTURE OF EUPQC

As shown in Fig.3, the main circuit system structure of EUPQC includes series converter, parallel converter, booster and discharge unit which consisting of super capacitor energy storage and DC/DC converter, outputting power transformer TsA~TsC of series converter, output filters Ls and Cs of series converter and inductance L_P , of parallel converter [5]. The electric interfaces A1, B1, C1, and N1 connect distribution network source and the A2, B2, C2, and N2 connect various loads. Two sets of three-phase four-leg converter respectively compose the series and parallel converters of the EUPQC. The series converter output enters into distribution network via LC filter and transformer in series, while the parallel device output enters into distribution network with filter inductance in parallel.

When EUPQC accesses to distribution network and sets to work, the DC bus voltage equals to that of the super capacitor bank. Then close contactors KMp2, 380V AC power supply charges to the dc side via pre-charge resistance R1 and parallel converter. When charging completes, close KMp1, and break KMp2 and DC/DC converter starts to work. Adjust the DC side voltage to nominal reference level 690V. Detect unbalanced degree and harmonic content of mains supply voltage and load current in load side, in order that parallel converter could be put into operation when over ranging problem happens when voltage problems like voltage sag and swell happen to mains supply, series converter will be put into operation and output compensation voltage until the problems are solved. Then series converter quits working and the SCRA, SCRB and SCRC bypass.

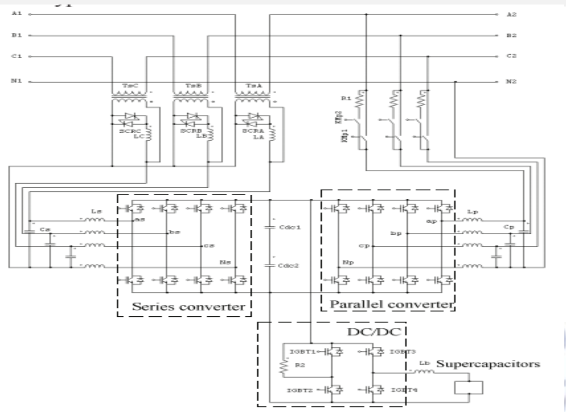

Fig.3. Main circuit system structure of EUPQC.

The single phase structure schematic diagram of EUPQC is illustrated in Fig. 4. Series converter output voltage vector to compensate voltage unbalance and harmonic of power supply side. Parallel converter is used to solve power quality problems in load side, such as unbalance and harmonic of nonlinear load including reactive compensating and current harmonic. Super capacitor energy storage and DC /DC converter buffer reactive power, exchange and provide energy for voltage compensation. As a result, decoupling series converter and parallel converter is implemented. Moreover, voltage quality problems of power interruption, which beyond the reach of traditional UPQC, can be resolved successfully.

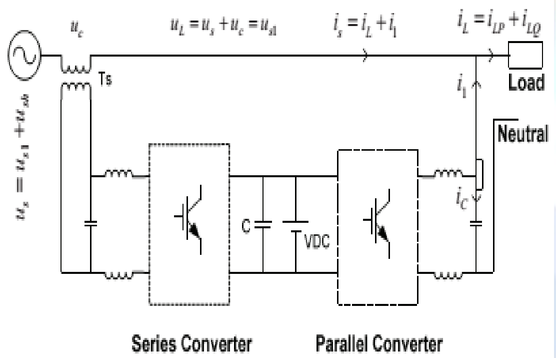

Fig. 4.The single phase structure schematic of EUPQC

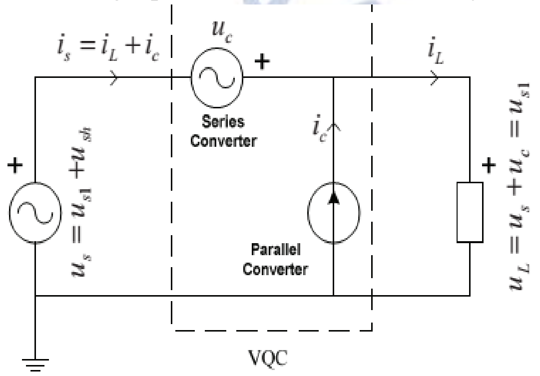

Fig.5.Control schematic of EUPQC

The ultimate purpose of EUPQC control is to keep load voltage on a constant level and be sinusoidal feature, compensate load reactive power and harmonic and ensure power supply has unity power factor characteristic in all circumstances. In this control schematic of EUPQC shown in Fig.5, series converter works as a non-sinusoidal voltage source, outputting compensation voltage u_c , which offsets grid voltage distortion and fundamental deviation, accordingly it ensures load voltage u_L , being rated sinusoidal voltage.

Meanwhile, shunt converter works as a non-sinusoidal current source, outputting reactive power and harmonic current I_c , which offset reactive load power and load harmonic current, accordingly it could make the injected current I_s , be sinusoidal by compensating reactive power and harmonic current. And the angle between the injected voltage us and the injected current I_s is zero at the moment, namely the power factor in grid side is unity.

V.THE CONTROL STRATEGY OF EUPQC

The control of EUPQC mainly includes three aspects: the control of series converter, the control of parallel converter and the control of DC bus voltage. In control strategy diagram of series converter shown in Fig.5 u_{sa} , u_{sb} , u_{sc} are distribution network three-phase voltage respectively. Through software phase-locked loop, we could get t ω sin and t ω cos, which is essential to d-q rotary transformation. After that then we perform d-q transform and d-q inverse transform on three phase standard voltage to make it in-phase with mains supply voltage. Then subtract the distribution network unbalance voltage from this standard voltage to get three phase reference compensation voltage Compare reference voltages with three phase actual compensation voltage u_{ca} , u_{cb} , u_{cc} , and constitute closed loop control by using a PI regulator. Specifically, in SPWM mode three phase driving signal of series converter is generated, consequently series converter is controlled to output corresponding voltage vector to compensate. The control of the forth leg of series converter is aiming to keep load zero sequence voltage to zero, which function is implemented through closed loop control with feed-forward control for voltage constituted by a PI regulator, symbols u_{La} , u_{Lb} , u_{Lc} , in Fig.6. Represent three-phase load voltage respectively.

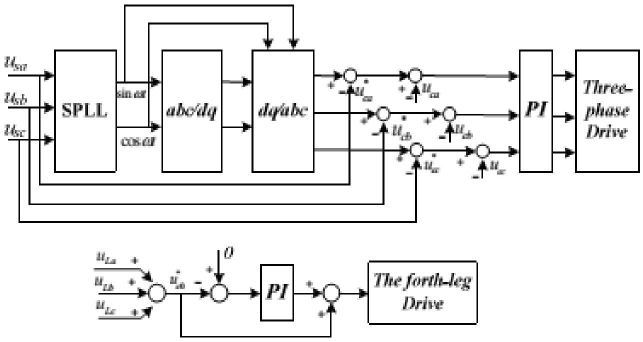

Fig. 6. Series converter control strategy diagram

As parallel converter control strategy diagram shown In Fig.6, perform d-q transform on three phase load current i_{La}, i_{Lb}, i_{Lc}.
Then let the transformed current pass low-pass filter to generate active component i_d and reactive component i_q. Perform d-q inverse transform on these two components to get fundamental component of three phase load current. Subtract load current from this standard current to get three phase reference compensation current. Compare the reference currents with three phase actual compensation current i_{ca}, i_{cb}, i_{cc}, and constitute closed loop control by using a PI regulator. The same as the series converter control mode, in SPWM mode three phase driving pulse signal of parallel converter is generated, consequently parallel converter is controlled to output corresponding current vector to compensate. The control of the forth leg of shunt converter is aiming to keep load zero sequence current to zero, which function is implemented through closed loop control constituted by a PI regulators symbols i_{sa}, i_{sb}, i_{sc}, in Fig.7. Represent three-phase power supply current respectively.
Parallel converter can realize reactive compensation by controlling reactive component iq . If i_q=0, then all reactive power of the load is provided by parallel converter.

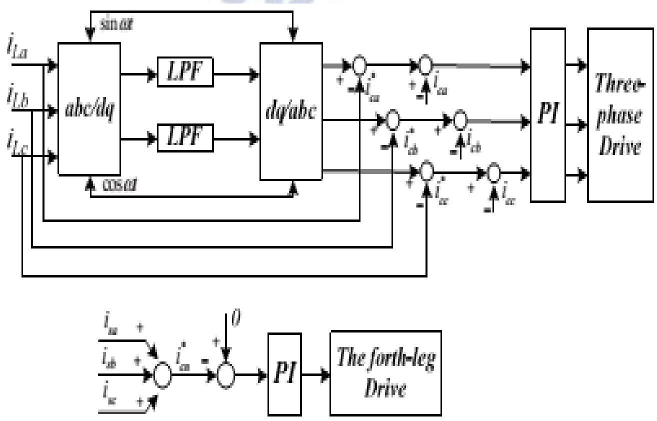

Fig.7.Parallel Converter Control Strategy Diagram.

DC side of EUPQC, consisting of bi-directional DC-DC converter based on super capacitor fast energy storage, is able to solve problems of deeper voltage sag and voltage instantaneous interruption. Fig.8. Illustrates control strategy of DC/DC converter. After comparing reference voltage u_{def}, with DC bus voltage u_d the two voltages pass through closed loop PI control and then compared by limited driver to generate PWM signal. They could drive IGBT3 and IGBT4 respectively to implement the control of DC/DC converter and then use the output to maintain u_d at a desired level. The function of discharge circuit comprising IGBT1 and IGBT2 could avoid over tension happens to DC bus voltage u_d.

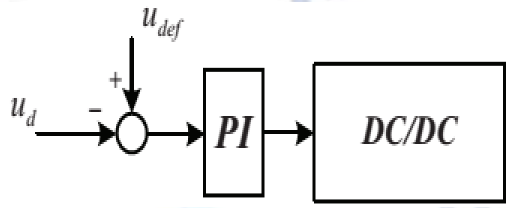

Fig.8. DC/DC converter control strategy diagram.

VI. BLDC MOTOR

Permanent magnet motor is one of the load in electrical power system. The motor consists of stator and rotor. These are used in mid power applications such as robotics, adjustable speed drives and electric vehicle. In light of the rotor position, the force gadgets are commutated consecutively every 60 degrees. The electronic compensation takes out the issues connected with the brush and the commutator plan, in particular starting and destroying of the commutator brush course of action, along these lines, making a BLDC engine more rough contrasted with a dc engine. Fig.9 demonstrates the stator of the BLDC engine and fig.10 shows rotor magnet plans.

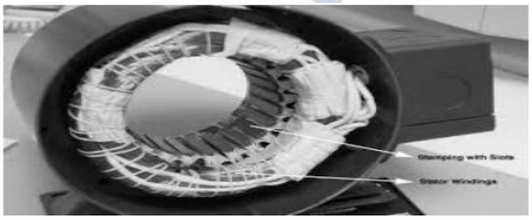

Fig.9. BLDC motor stator construction

Fig.10. BLDC motor Rotor construction.

The brush less dc engine comprise of four fundamental parts Power converter, changeless magnet brushless DC Motor (BLDCM), sensors and control calculation. The force converter changes power from the source to the BLDCM which thus changes over electrical vitality to mechanical vitality. One of the remarkable highlights of the brush less dc engine is the rotor position sensors, in view of the rotor position and order signals which may be a torque charge, voltage summon, rate order etc; the control calculation s focus the entryway sign to every semiconductor in the force electronic converter.

The structure of the control calculations decides the sort of the brush less dc engine of which there are two principle classes voltage source based drives and current source based drives. Both voltage source and current source based commute utilized for perpetual magnet brushless DC machine. The back emf waveform of the engine is demonstrated in the fig. 11. Be that as it may, machine with a non sinusoidal back emf brings about diminishment in the inverter size and lessens misfortunes for the same influence level.

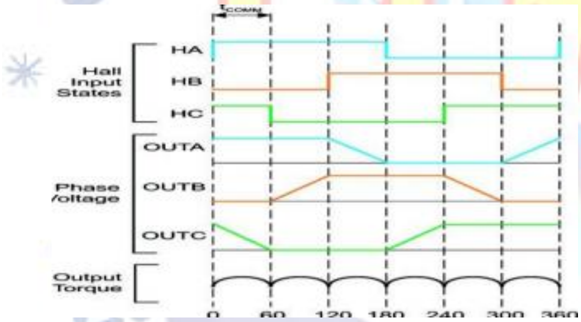

Fig.11 Hall signals & Stator voltages.

VII. MATLAB/SIMULINK RESULTS

Case 1: Proposed UPQC Converter

Voltage Waveforms:

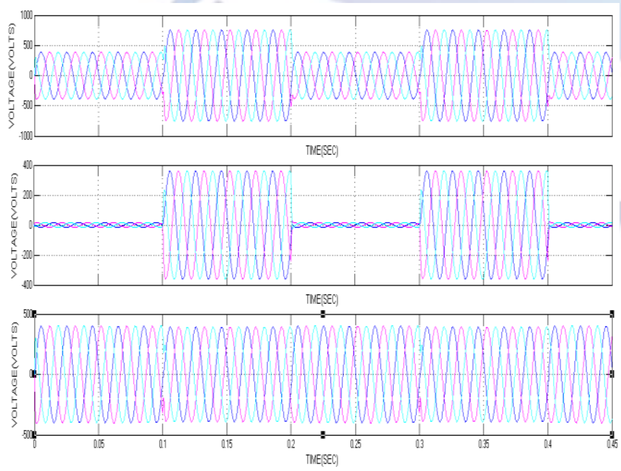

Fig.12.Shows load Voltage, DVR Voltage and Source Voltage.

Fig : 12 Illustrates the output Load voltage, DVR Voltage and Source Voltage after introducing proposed technique. Here the UPQC module with super Capacitor is used for power quality improvement instead of the conventional injecting transformer and Injection Capacitor Methods. The voltage and current waveforms are as shown in Fig 12 and Fig: 13 respectively. The system minimized the power quality issues to further level. Here the sag elimination was more effective and instantaneously than the transformer.

Currents Waveforms:

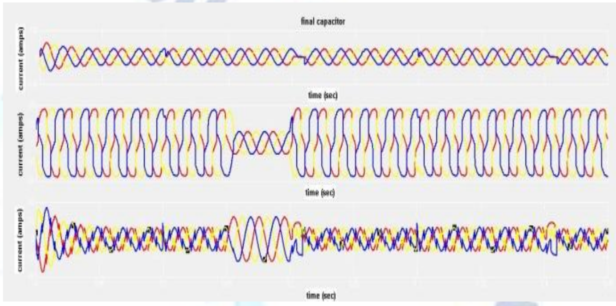

Fig.13. Source Current, Load Current and Compensating Current.

Case 2: Proposed UPQC Converter with BLDC Motor

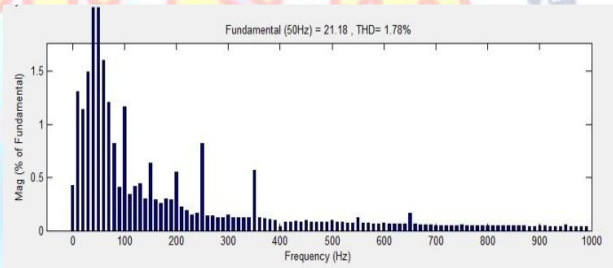

Fig.14.Total harmonic distortion of BLDC motor drive

Fig: 14 illustrates that the total harmonic distortion is improved by using the UPQC with super capacitor to minimize the power quality issues generated by the different types of faults. The proposed system concludes the total harmonic distortion (THD) as 1.78%which is more improvement as the conventional methods, in which the THD is 18.82%.

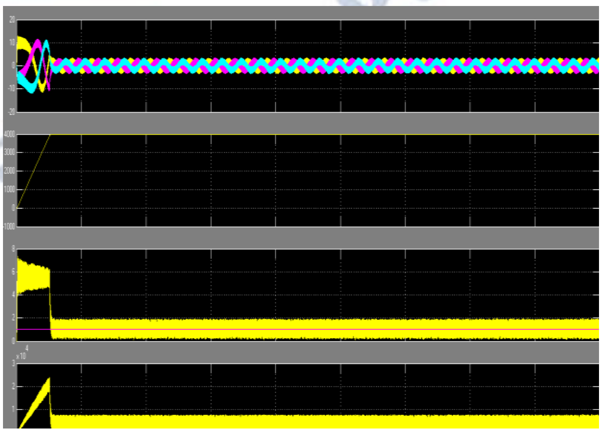

Fig.15.Simulation results for Stator Current, Speed, and Torque.

Fig: 15 Illustrates the speed torque characteristics along with stator current which shows the variation of all the parameters with respect to time. At the time of starting of a BLDC motor, it requires a high starting torque so that the speed of the motor attains a constant speed with respect to time.

VIII. CONCLUSION

This paper proposes a new configuration of UPQC that consists of the DC/DC converter and the super capacitor. The proposed UPQC compensated the reactive power, harmonic currents, voltage sag and swell, voltage unbalance, and the voltage interruption. This paper demonstrated for compensation of reactive power, voltage sag & swell, neutral currents, unbalanced for voltage and currents, and elimination of current harmonics and voltage regulation & correction of power factor, as per IEEE standard the total harmonic distortion will be equal to 5% and less than 5%. In our proposed UPQC converter with BLDC having THD only 1.78%, so that the harmonics are eliminated and also power factor is improved. Rotor movement regulated by speed controller & by varying frequency of the pulse based on feedback from the hall sensors. The application of this paper is used in the distribution side, so the consumer gets reliable and accurate power without any losses.

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