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To Study, Analysis and Implementation of Power Quality Improvement Using DSTATCOM with ANN (Back Propagation Algorithm)

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ABSTRACT

This project illustrates the execution of a three-stage delivery static compensator (DSTATCOM) by using a back propagation (BP) control algorithm for its capacities, such as load balancing and zero voltage management of reactive power compensation under non-linear loads. We use BP-based control algorithm to obtain the critical dynamic weight estimate here. And the BP-based control algorithm is often used for estimating the receptive power portions of the load streams necessary for estimating the reference source streams. Regulation of power efficiency devices through neural networks is the new area of study in the field of power engineering. The extraction of the harmonic components defines the output of the balancing instruments. Here we use DSTATCOM and UPFC as balancing instruments. A DSTATCOM model is developed using a computerized signal processor and its implementation is focused on various working conditions. The execution of DSTATCOM is found to be suitable for various kinds of burdens with the proposed control algorithm. The BP-based control algorithm is used to derive the fundamental weighted value of the active and reactive power components of the load present. Back propagation algorithm trained by the sample will detect the power quality signal issue in real-time. Continuity, differentiability, non-decreasing momotomy are the key features of this algorithm. The process of UPFC is close to that of DSTATCOM, although the only difference is that it does not have the device shut down in worse circumstances. The simulation model is developed with ANFIS and its output is studied under different operating conditions. The output of ANFIS is found to be satisfactory with the proposed control algorithm for different types of loads. The suggested method shall be checked by the results of MATLAB/Simulink.

KEYWORDS: *ANN (BP control algorithm), Harmonics (THD), Loadbalancing, Weights, Power quality and ANFIS, DSTATCOM, VSC MATLAB/Simulink*

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I. INTRODUCTION

The major problem today the distribution system facing is power quality. The quality of power that is given to the end users is not up to the mark. Because of this there is a failure in the devices. In order to overcome this problem that means to improve the quality of the power we are implementing certain devices in the transmission system. Power converter based custom power devices (CPDs) are useful for reduction of power quality problems such as power factor correction, harmonics compensation, reduction in transients, voltage sag/swell compensation, resonance due to distortion, voltage flicker reduction within specified time and range. These CPDs include DSTATCOM, DVR and UPQC in different Configurations. Many non-model and training based alternative control algorithms are reported in the literature with application of soft computing technique such as neural network, fuzzy logic and adaptive neuro-fuzzy etc. A VSC based DSTATCO Mhas been introduced for better power quality improvement and thereby improving power factor correction and maintaining rated PCC voltage. For power quality improvement as power factor correction and to maintain rated PCC voltage a voltage source converter (VSC) based DSTATCOM has been preferred in the distribution systems. A three phase DSTATCOM has been implemented for compensation of nonlinear loads using BPT control algorithm to verify its worthiness. For the extraction of reference source currents to generate the switching pulses for IGBTs of VSC of DSTATCOM has been made by the proposed BPT algorithm. Various functions of DSTATCOM are as follows, harmonic elimination and load. MATLAB with SIMULINK and Sim Power System (SPS) toolboxes are used for the development of simulation model of a DSTATCOM and its control algorithm. By examining the simulation results the performance of the DSTATCOM with BPT algorithm has been found satisfactory for this application because extracted reference source currents performed well in tracing the sensed source currents during steady state as well as under dynamic conditions. The DC bus voltage of the DSTATCOM has also been regulated to rated value without any overshoot or undershoots during load variation that is under varying loads. This paper presents minimum conditions for the losses in distribution systems and experimentally achieving them by using UPFC. The main advantage of UPFC here is that we can independently control the active and reactive powers when needed. Enhanced power quality improvement is the essential necessity of any electrical equipment. Almost all power quality problems originate from disturbances in the distribution networks. The most common problem that is reported in low and medium level distribution system is harmonic resonance. So we have to overcome this by using certain filters. It has numerous points of interest, for example, most extreme use of electrical types of gear, improved stacking ability, zero voltage regulation, and power factor correction and so on. Wellsprings of poor power quality can be separated in view of purchaser burdens also, subsystem of a conveyance framework.

These purchaser burdens can be named straight, nonlinear, or blended sort of loads. So to overcome the problems that are neglected by DSTATCOM we are using UPFC. UPFC consists of a series and a shunt converter which is connected back –to-back through a common DC link. In order to overcome these limitations Back Propagation (BP) has been implemented. An improved Back Propagation control algorithm and linear sinusoidal tracer control algorithm is implemented on a DSTATCOM for the extraction of load currents and fundamental components in three phase consumer loads that is on the consumer side. Internal parameters of this algorithm have clear physical understanding and easy adjustable to optimal value that is to our required value. It is obtained by continuously training the algorithm, which shows the simplicity of this algorithm. Frequency and time-domain characteristics of the ILST are not affected due to external environment changes and this is another advantage of using artificial neural networks on the distribution system. Detection accuracy and speed of the dynamic response can be tuned after adjusting the algorithm's internal parameters. In this algorithm, extracted reference source currents from the trained network exactly follows the actual source currents that are in the nonlinear distribution system during steady state as well as dynamic conditions. For this reason, three phase source currents have smooth variation during load perturbations which is a preferable condition. This control algorithm is implemented on a DSTATCOM which is on the distribution system lines for compensation of linear and nonlinear loads. The advantages of these systems are as follows, (i) This method will not be affected by the initial gain settings, changes of system conditions, and the limits of human experience and judgment, Self-tuning process, (ii)Better response for dynamic system, Voltage Regulation, power factor correction is achieved. (iii)Power quality issues are gaining significant attention due to the increase in the number of sensitive loads on the end user side. Many of these loads use equipment that are sensitive to distortions or dips in supply voltages. So it may cause a failure in the system or complete shutdown of the grid which is not acceptable. Regulations is applied in many places on the distribution system which limit the distortion, transients and unbalanced conditions that a customer can inject into a distribution system. These regulations may require the installation of compensators(filters) on customer premises. It is also expected that a utility will supply a low distortion balanced voltage to its customers, especially those with sensitive loads because increase in distortions leads to burning of the systems on customer side. A distribution static compensator (DSTATCOM) is a voltage source inverter (VS1) based power electronic device. Usually, this device is supported by short-term energy stored in a DC capacitor. Because we know that a capacitor is a energy storing device. So it is connected back to back in the system. When a DSTATCOM is associated with a particular load, it can inject compensating current they are also called as injection currents. Because we are injecting these currents in the place where the system is unbalanced. So that the total demand meets the specifications for utility connection. The shunt converter is also connected in parallel with the transmission line by transformer which allows to control the UPFC's bus voltage shunt reactive power and the DC capacitor voltage. Apart from this, it can also clean up the voltage of a utility bus from any unbalance, overshoots, transients and harmonic distortion. The mitigation of power quality problems can be achieved in two ways. It can be done from either the customer side or utility side. First approach used is load conditioning and other is line conditioning.

II. SYSTEM CONFIGURATION AND CONTROLALGORITHM

One of the major considerations while using DSTATCOM for load compensation is the generation of the reference compensator currents that are taken from the load line. There are several training methods that have been developed for the use of the compensator when it tracks these reference currents, and thereby injecting these three-phase currents in the AC system to cancel out the disturbances caused by the load in the distribution system. The execution of DSTATCOM depends upon the exactness of music streams, tuned esteem of interfacing conductors (Lf) are joined at air conditioning yield of the VSC>For all the methods are present for suppression of harmonics there is a common belief that the voltage at the point of common coupling is tightly regulated and cannot be influenced by the currents injected by the shunt device which is connected externally on the distribution system. The DSTATCOM employs an inverter to convert the DC link voltage of adjustable magnitude and phase i.e.to an alternating one. It is basically connected near to the load because we can inject dc components on to the load. So here we are employing inverter which converts DC to AC and vice versa. The schematic diagram of a VSC based DSTATCOM is shown on the below fig which is connected in shunt to the distribution network along with the controller.

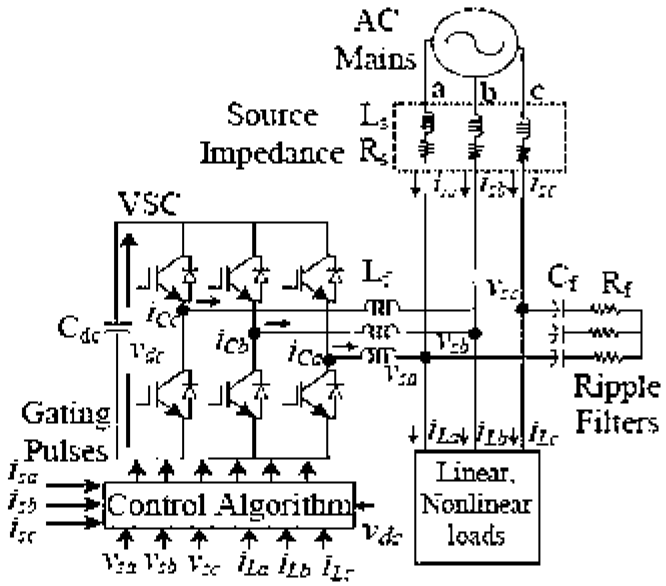


Fig 1 chematic diagram of VSC based DSTATCOM

There are two different modes in which a DSTATCOM can operate. They are (1) voltage mode and(2) current mode. The basic operation that is carried out in a voltage control mode is the DSTATCOM is connected at a utility bus to maintain a balanced voltage at that bus, irrespective of unbalance or distortion on either side of the bus. In this mode, responsibility of the utility is the operation and maintenance of the DSTATCOM effectively. In a voltage control mode, it can make the voltage of the bus to which it is connected a balanced sinusoid, irrespective of the unbalance and distortion in voltage in the supply side or line current. Alternatively, in the current control mode, the DSTATCOM compensates for any unbalance or distortion in the load. Ideally, it should draw a balanced load current from the system, irrespective of any unbalance or harmonics in either the source or load side. Similarly when operated in a current control mode, it can force the source side currents to become balanced sinusoids. It is also assumed that the DSTATCOM is placed at a utility bus on customer. The phase of the output voltage of thethyristor-based inverter, vi is controlled in the same way as the distribution system voltage V_s

A DSTATCOM is capable of compensating either bus voltage or line current. Three load buses. It is assumed that consumers are supplied from these buses. A DSTATCOM can be connected in any of these buses, depending on whether it belongs to the utility or a particular customer. For example, if the voltage at bus 3is distorted, it affects customers both at buses 3 and 4.The utility may then install a DSTATCOM at this bus to clean up its voltage. On the other hand, suppose that the consumer at bus 4 has loads that draw unbalanced and distorted current from the supply. In order to avoid a penalty, one option for the consumer is to install a DSTATCOM on its premises, so that the current drawn from bus 4 is a balanced. VSCs using PWM controllers are the mainstay of modern power electronics controllers, such as STATCOM, DVR and HVDC-VSC stations. One of the many advantages of VSCs using PWM control is that they can produce quasi-sinusoidal voltage

waveforms, having almost any desired phase relationship with an existing AC system waveform, thus dictating the direction and magnitude of the active and reactive power exchanged with the AC system. In practice, the high harmonic frequencies generated by the VSC could be filtered out by high frequency harmonic filter [101, but in real time the operation of such filters will not be perfect or they may not even be operating. Moreover, harmonic interactions between the VSC and the electric network will always take place. This interaction may produce harmonic resonances which can only be predicted with realistic models of the VSC and the electric network Comprehensive models for power converters have been reported in the open literature. In power systems harmonic studies, switching functions have found widespread acceptance in the modeling of converters based on thyristor, where the commutation period of thethyristors has been included in the switching functions. As an extension, switching functions have also been used in the modeling of converters based on GTOs or IGBTs, showing even greater adequacy than in the former application.

III. CONTROL ALGORITHM

The back propagation algorithm looks for the minimum of the error function in weight space using the method of gradient descent. This numerical method was used by different contexts. The combination of weights which minimizes the error function is considered to be a solution of the learning problem. Since this method requires computation of the gradient of the error function at each iteration step, we must guarantee the continuity and differentiability of the error function. Obviously we have to use a kind of activation function other than the step function used in perceptron's because the composite function produced by interconnected perceptron's is discontinuous, and therefore the error function too. Since this method requires computation of the gradient of the error function at each iteration step, we must guarantee the continuity and differentiability of the error function. Obviously, we have to use a kind of a activation function. Here we are using sigmoid function as activation function. Multilayered networks are capable of computing a wider range of Boolean functions than networks with a single layer of computing units. However the computational effort needed for finding the correct combination of weights increases substantially when more parameters and more complicated topologies are considered. In this chapter we discuss a popular learning method capable of handling such large learning problems - the back propagation algorithm. This numerical method was used by different research communities in different contexts, was discovered and rediscovered, until in 1985 it found its way into connectionist AI mainly through the work of the PDP group. It has been one of the most studied and used algorithms for neural networks learning ever since.

A. Estimation of weighted value of average fundamental load active and reactive power components

The back propagation algorithm looks for the minimum of the error function in weight space using the method of gradient descent. This method is not only more general than the usual analytical derivations, which handle only the case of special network topologies, but also much easier to follow. The combination of weights which minimizes the error function is considered to be a solution of the learning problem. Since this method requires computation of the gradient of the error function at each iteration step, we must guarantee the continuity and differentiability of the error function. Obviously we have to use a kind of activation function other than the step function used inperceptron's, because the composite function produced by interconnected perceptron's is discontinuous, and therefore the error function too.

A **BP training** algorithm is used to estimate the three phase weighted value of load active power current components (W_{ap},W_{bp},W_{cp}) and reactive power current components (W_{aq},W_{bq},W_{cq}) from polluted load currents using the feed forward and supervised principle. In this estimation, the input layer for three phases (a, b, and c) is expressed as

The detail application of this algorithm for the estimation of various control parameters is given as follows.

$$I_{lap}=W_O+i_{La}u_{ap}+i_{Lb}u_{bp+}+i_{Lc}u_{cp} \quad (1)$$

$$I_{lbp}=W_O+i_{La}u_{ap}+i_{Lb}u_{bp+}+i_{Lc}u_{cp} \quad (2)$$

$$I_{lcp}=W_O+i_{La}u_{ap}+i_{Lb}u_{bp+}+i_{Lc}u_{cp} \quad (3)$$

Where Wo is the selected value of the initial weight and (u_{ap},u_{bp},u_{cp}) are the in-phase unit templates. In-phase unit templates are estimated using sensed PCC phase voltages (V_{sa},V_{sb},V_{sc}) It is the relation of the phase voltage and the amplitude of the PCC voltage (V_t). The amplitude of sensed PCC voltages is estimated as

$$V_t = \sqrt{2(v_{sa}^2 + v_{sb}^2 + v_{sc}^2)/3} \qquad (4)$$

The in-phase unit templates of PCC voltages (u_{ap},u_{bp},u_{cp}) are estimated as

$$u_{ap} = \frac{v_{sa}}{v_t} u_{bp} = \frac{v_{sb}}{v_t} u_{cp} = \frac{v_{sc}}{v_t} \qquad (5)$$

The extracted values of I_{Lap}, I_{Lbp},$I_{Lcp}$are passed through a sigmoid function as an activation function, and the output signals Z_{ap},Z_{bp},$Z_{cp}$of the feedforward section are expressed as

$$z_{ap} = f(I_{lap}) \qquad (6)$$

$$z_{bp} = f(I_{lap}) \qquad (7)$$

$$z_{cp} = f(I_{lap}) \qquad (8)$$

The estimated values of Z_{ap},Z_{bp},$Z_{cp}$are fed to a hidden layer as input signals. The three phase outputs of this layer I_{Lap1}, I_{Lbp1}, I_{Lcp1} before the activation function are expressed as

$$\mathbf{I_{lap1} = W_{O1} + W_{ap} Z_{ap} + W_{bp} W_{bp+} + W_{cp} u_{cp}} \qquad \mathbf{(9)}$$

$$\mathbf{I_{lap1} = W_{O1} + W_{ap} Z_{ap} + W_{bp} W_{bp+} + W_{cp} u_{cp}} \qquad \mathbf{(10)}$$

$$\mathbf{I_{lap1} = W_{O1} + W_{ap} Z_{ap} + W_{bp} W_{bp+} + W_{cp} u_{cp}} \qquad \mathbf{(11)}$$

Where (W_{01}, W_{ap},W_{bp},W_{cp}) are the selected value of the initial weight in the hidden layer and the updated values of three phase weights using the average weighted value (W_p) of the active power current component as a feedback signal, respectively. The updated weight of phase "a" active power current components of load current "W_{ap}" at the *n*th sampling instant is expressed as

$$w_{ap} = w_p(n) + \mu\{w_p(n) - w_{ap1}(n)\} f'(I_{ap1}) z_{ap}(n)$$

where (*n*) and (n) are `the average weighted value of the active power component of load currents and the updated weighted value of phase "a" at the *n*th sampling instant, respectively and $w_{ap1}(n)$ and $Z_{ap}(n)$ are the phase "a" fundamental weighted amplitude of the active power component of the load current and the output of the feed forward section of the algorithm at the *n*th instant, respectively. $f(I_{ap1})$ and μ are represented as the derivative of I_{ap1} components and the learning rate. Similarly, for phase "b" and phase "c," the updated weighted values of the active power current components of the load current are also expressed as same. The extracted values of I_{ap1}, I_{bp1}, and I_{cp1} are passed through a sigmoid function as an activation function to the estimation of the fundamental active components in terms of three phase weights w_{ap1}, w_{bp1}, and w_{cp1} as

$$z_{ap1} = f(I_{lap1}) \qquad (13)$$

$$.z_{bp1} = f(I_{lap1}) \qquad (14)$$

$$z_{cp1} = f(I_{lap1}) \qquad (15)$$

IV. SIMULATION RESULTS AND DISCUSSION

A neural network-based control technique using Back propagation (BP) algorithm for a three phase two level distribution static compensator (DSTATCOM) to perform the functions such as harmonic mitigation, power factor correction under reactive loads, which further reduces the DC link voltage across the self-supported capacitor of voltage source converter (VSC). The weighted values of fundamental active and reactive components of load currents are extracted using the proposed control technique to generate the reference source currents. Furthermore, these currents are used to trigger the VSC of the DSTATCOM. The effectiveness of this control technique is demonstrated through simulation using MATLAB/SIMULINK and sim power system tool boxes. The real-time implementation of DSTATCOM is also realized by real-time digital simulator. These results reveal the robustness of the proposed DSTATCOM as it is showing outstanding harmonic compensation capabilities under the various loading conditions and keeping the total harmonics distortion of the source current well <5%, the limit imposed by IEEE-519 standard.

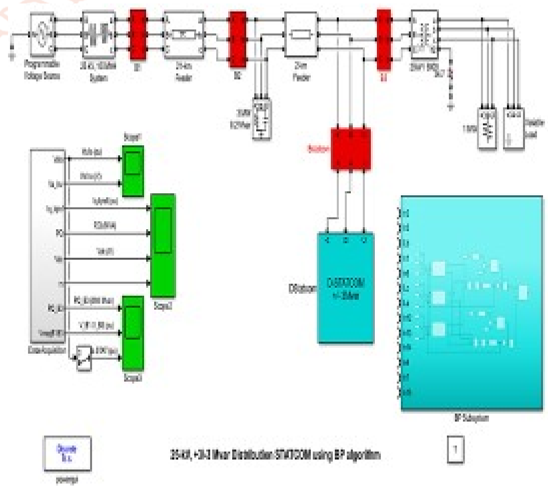


Fig2.DSTATCOM using BP algorithm

Results under varying load condition.

- nominal load [3000 0.9] [current (RMS) power factor]
- modulation [2000 5] [amplitude current (RMS) frequency (Hz)]
- nominal voltage 600 [volts (RMS)Phase to phase]

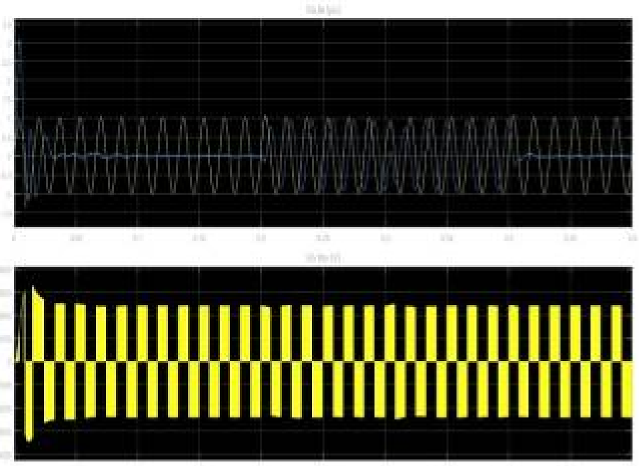


Fig3.DSTAT voltage and current

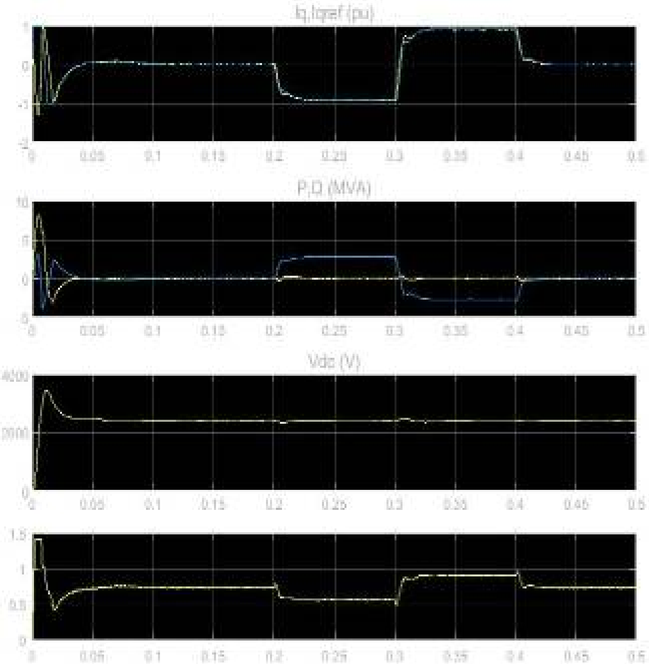


Fig4.active/reactive power, Vdc Voltage

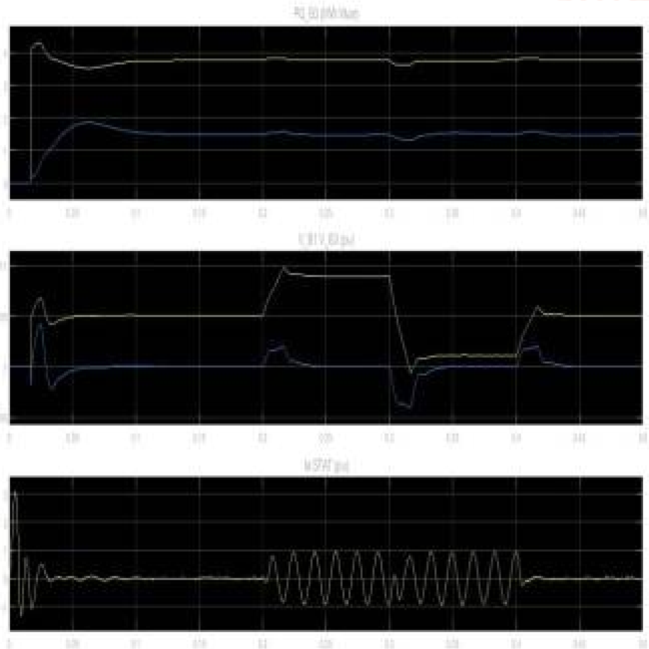
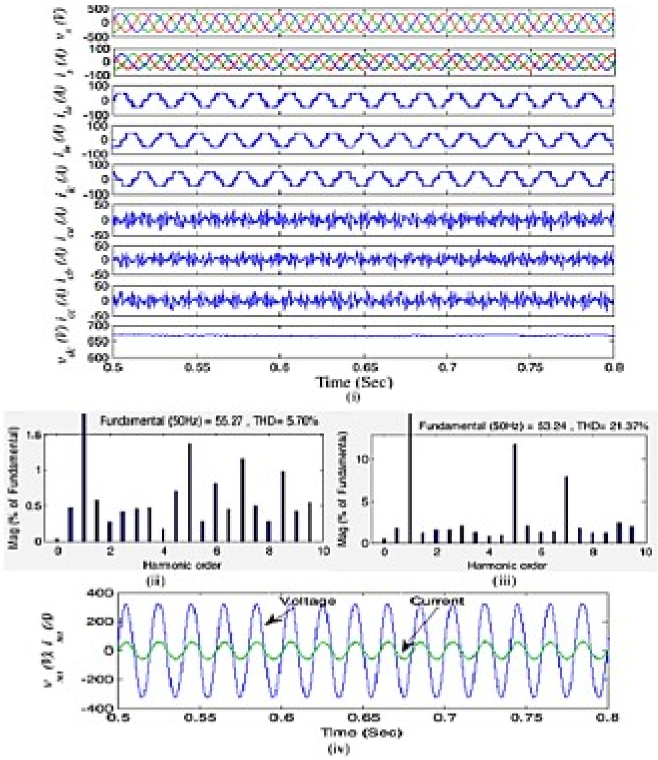


Fig5.power, voltage and current after DSTATCOM



MATLAB results for (i) System performance using BP control technique-based DSTATCOM, (ii) Harmonic spectra of source current, (iii) Harmonic spectra of load current and, (iv) Waveform of a-phase source voltage and source current.

V. CONCLUSION

VSC-based DSTATCOM was recognized as the most desired control quality control approach for power factor correction and maintenance of rated PCC voltage. A three-phase DSTATCOM has been introduced to compensate for non-linear loads using The BPT control algorithm is used to check its usefulness. The proposed BPT control algorithm was used to remove reference source currents to produce switching pulses for DSTATCOM VSC IGBTs. Various DSTATCOM features, such as harmonic exclusion and load balancing, have been demonstrated in the PFC and ZVR modes with DC voltage control of DSTATCOM. Out of the simulation and implementation performance, it is inferred that DSTATCOM and its control algorithm have been found to be appropriate for nonlinear load compensation. The simulation model is developed with ANFIS and its output is studied under different operating conditions. The output of ANFIS is found to be satisfactory with the proposed control algorithm for different types of loads. Its efficiency was found to be satisfactory for this application because the extracted reference source currents reliably monitor the sensed source currents under steady state as well as dynamic conditions. DC bus voltages of the DSTATCOM were also controlled at the rated value without any overshoot or undershoot during load variance. Significant training periods in the implementation of a complex method, the collection of the number of secret layers in the system are the drawback of this algorithm.

- The other transformation methods like linear, Walsh and coordinate methods can be implemented for pre-processing stage in expert system. It can be applied for any industries that require power quality monitoring system.
- Various evolutionary algorithm can be implemented for the tuning process of the controller implemented in the custom power devices.
- At micro grids, the Power quality issues can be assessed and mitigated using various energy storage systems.
- Energy storage system like super capacitors, fly wheel storage systems can be implemented in custom power devices to have a better performance.

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