Power Quality using Energy Interface DSTATCOM with General Control Scheme

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Abstract- *An implementation of a three phase distribution static compensator (DSTATCOM) for compensation of loads in a distributed system using learning vector quantisation (LVQ) control algorithm. The distribution static compensator used for harmonic elimination, reactive power compensation and load balancing of the distributed system. This LVQ control algorithm produced output is combination of fundamental limit values of active and reactive power component of load currents and required for estimation of reference supply currents. It is based on a double supervisory system each weighted vector is modified by input limits. The input limits are trained outputs of the first stage learning limits. It is needed for accurate estimation of compensation currents for the Voltage Source Converter (VSC) used in DSTATCOM. This type DSTATCOM is developed using a digital signal processor to the proposed control approach and its performance is studied under a steady state and dynamic conditions. This performance of the DSTATCOM is satisfactory with the proposed control algorithm under linear and non-linear loads are commonly used in the distribution system.*

Keywords- Power quality, LVQ control method, DSTATCOM

I. INTRODUCTION

Power quality can be analysed based on voltage and current qualities as it is defined in terms of voltage and current. Poor power quality has undesirable effects on electrical equipment. The continuity and reliability degrade with the poor power quality of supply power. One of the major components for degrading the power quality is harmonics because of spreading of non-linear loads which are variable in nature. Improvement of poor power quality used on facts devices. Facts devices are power electronics family and it have different types. One of the distribution static compensator (DSTATCOM) is the reliable solutions for the current related power quality problems according to the international standards. This device control algorithm can implemented in real time using embedded controllers, digital signal processors (DSPs), and field programming gate arrays(FPGAs)for fast, accurate and reliable performance.

The DSTATCOM can be operated in power factor correction (PFC), zero voltage regulation (ZVR), and load compensation. The performance of DSTATCOM depends upon the control algorithm used for estimation of reference supply currents. Applied control algorithms for compensating devices such as the DSTATCOM, are classified as classical control, adaptive control, neural network, fuzzy logic and other knowledge–based control. Main considerations for selection of a neutral network are weight initialization, number of hidden layers, learning rate, training cycle and type of activation function for desired performance. It can be applied for harmonics detection, dc bus controller and current control and so on. A diagnosis of the PQ problems consists of development of PQ indices to quantify the quality of power supply and detection of power line disturbances such as sags, swells, waveform distortion and so on.

In the present paper, an LVQ control algorithm is implemented in the shunt connected compensating custom power device known as DSTATCOM, for extraction of weighted values of load active power and reactive power current components in three-phase linear and non-linear loads. It is a standard statistical clustering technique which is also known as special case of competitive network. In the LVQ algorithm, the desired values are extracted through training of weighed values of load currents using the gradient descent method. In the training process, the desired signals are at the position of the learning stage. After training, LVQ network classifies the supply current vector by assigning it to the same class as the output stage. It has its weighted vector closest to the input vector.

The structure of this algorithm is similar to the self-organizing neural network without a topological structure considered for the output units. In the LVQ network, each unit has a known value or elements and used supervised learning which differed from the self-organizing map. It is used for reactive power compensation, harmonics suppression and load balancing with a self-supporting dc bus of voltage source converter (VSC) used as DSTATCOM. This control algorithm on a DSTATCOM is implemented for compensation of linear and non-linear loads.

II. SYSTEM CONFIGURATION AND CONTROL ALGORITHM

A VSC-based DSTATCOM is connected to a three-phase ac mains feeding three-phase linear/non-linear load with internal grid impedance (Zs) which is shown in Fig. 1. The steady state and dynamic performances of DSTATCOM depend upon the accuracy of detection of harmonics currents or disturbances. Interfacing inductors (Lf) are connected at ac output of the VSC to limit the ripple in compensating currents. A series combination of capacitor (Cf) and a resistor (Rf) represents the shunt passive ripple filter which is connected at the point of common coupling (PCC) to suppress the high frequency noise because of switching of the VSC.

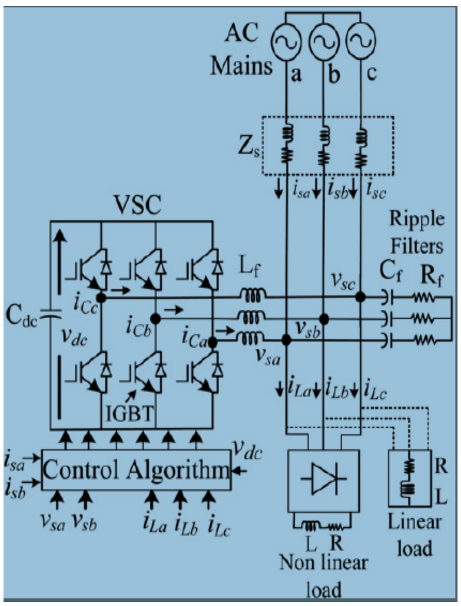

Fig. 1 Schematic diagram of the VSC-based DSTATCOM

The DSTATCOM currents (iCabc) are injected as required compensating currents to cancel the reactive power components and harmonics of the load currents so that loading because of reactive power component/harmonics is reduced on the distribution system. Fig. 2 shows the block diagram of the LVQ algorithm for estimation of reference supply currents through the weighted values of load active power and reactive power current components. Its output layer has a matching pattern with the load current as input signal. In this algorithm, PCC voltages (vsa, vsb and vsc), supply currents (isa, isb and isc), load currents (iLa, iLb and iLc) and dc bus voltage (vdc) are required for extraction of reference supply currents (i∗sa, i∗sb,i∗sc). Amplitude of reactive power components of the reference supply currents is considered zero in the case of PFC mode.

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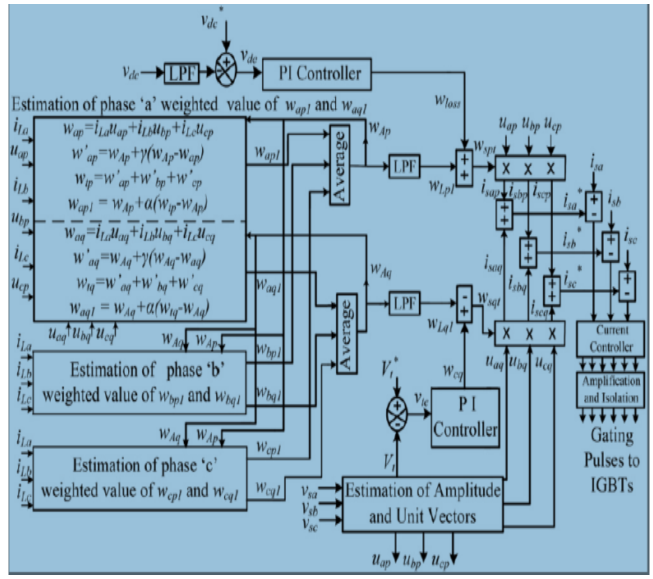

Fig. 2 LVQ control algorithm for DSTATCOM

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III. RESULTS AND DISCUSSION

A VSC-based DSTATCOM is developed to validate the proposed control algorithm. Five ABB make Hall effect current sensors (EL50P1 BB) and three voltage sensors (EM010 BB) are used for sensing PCC voltages, dc bus voltage and currents signals according to DSP compatibility. The LVQ control algorithm is implemented for the control of DSTATCOM using a TMS320F240 DSP. An isolation and amplification circuit is connected between the PWM port of the DSP and the gating port of the VSC of the DSTATCOM to maintain the amplified amplitude of the gating pulses. The opto-coupler IC 6N136 and 2N2222 transistor are used for optical isolation and amplification purposes. A Fluke (43B) power analyzer and Agilent make digital oscilloscope (DSO-6014A) are used for recording of steady state and dynamic tests results, respectively, on a developed DSTATCOM under linear and non-linear loads.

STEADY STATE, LOAD BALANCING AND DYNAMIC PERFORMANCES OF DSTATCOM UNDER LINEAR LOADS

The power factor at ac mains is improved after load reactive power compensation using DSTATCOM. It is shown in Figs. 3a and b where the supply power factor is improved to close to unity (0.98) when the load power factor is 0.85 (lagging), respectively. The compensator power (Pc), is shown in Fig. 3c under a balanced linear load. Measurement of power has been done with line voltage and phase current using Fluke power analyzer. Figs. 4a–i show the waveforms of supply currents (isa, isb and isc), load currents (iLa, iLb and iLc) and compensating currents (iCa, iCb and iCc) along with PCC line voltage (vab) under unbalanced linear loads where phase 'a' load is not connected. This shows the function of the DSTATCOM as a load balancer. Figs. 5a and b show the waveforms of three-phase supply currents (isa, isb and isc) and load currents (iLa, iLb and iLc) under dynamic conditions. Changes in supply current (isa), load current (iLa) and DSTATCOM current (iCa) are shown with dc bus voltage (vdc) under varying load conditions. It shows the fast action and effectiveness of the compensator.

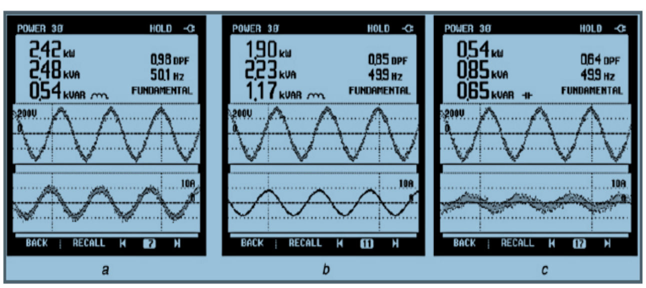
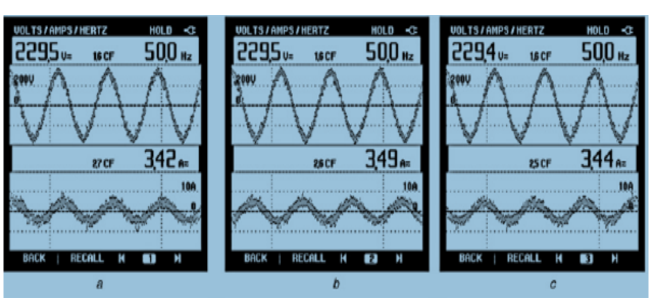


Fig. 3 Performance of the DSTATCOM under linear loads



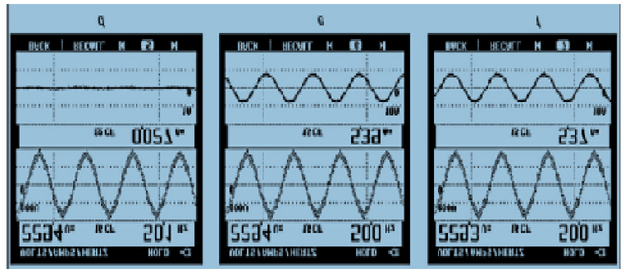


Fig. 4 Performance of the DSTATCOM under unbalanced linear loads

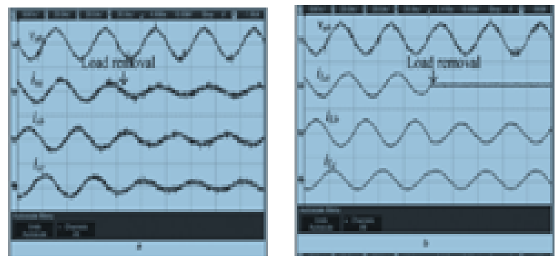


Fig. 5 Dynamic performance of the DSTATCOM during injection of phase 'a' in linear loads

PERFORMANCE OF THE DSTATCOM UNDER NON-LINEAR LOADS

Figs. 6a–c show the waveform of the PCC line voltage (vab) with supply current (isa), load current (iLa), and compensating current (iCa) under non-linear load. In these waveforms, the PCC line voltage (vab) is considered as reference voltage. In Figs. 6d–f, harmonic distortions of 'a' phase supply current, load current and PCC voltage are observed as 4.6, 26.2 and 2.9%, respectively. These results show the satisfactory performance of the LVQ control algorithm of DSTATCOM for harmonics suppression according to the IEEE-519 guidelines in order of less than 5%.

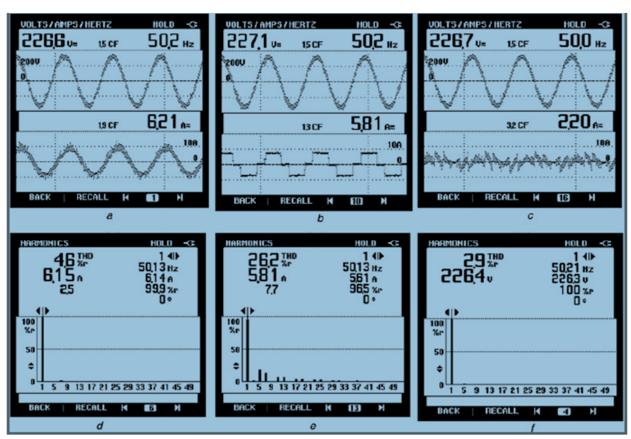


Fig. 6 Performance of the DSTATCOM under non-linear loads

LOAD BALANCING USING DSTATCOM

Figs. 7a–i show the waveforms of three-phase supply currents (isa, isb and isc), load currents (iLa, iLb qnd iLc) and DSTATCOM currents (iCa, iCb and iCc) with PCC line voltage under unbalanced non-linear loads. An unbalanced load condition is created by removal of load from phase ‘c’. It shows the balanced supply currents when one of the phase loads is thrown out-of-service. These results demonstrate the satisfactory performance of the control algorithm under unbalanced loads.

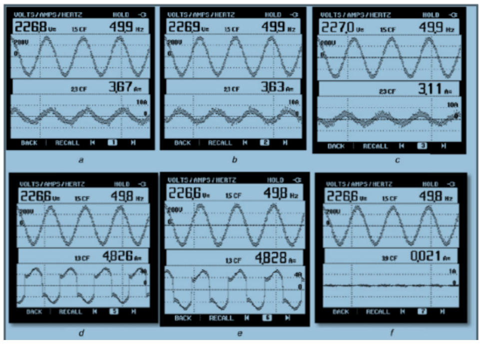


Fig. 7 Performance of the DSTATCOM under unbalanced non-linear loads

DYNAMIC PERFORMANCE OF THE DSTATCOM

Figs. 8a and b show the waveforms of the supply currents (isa, isb, isc) and the load currents (iLa, iLb, iLc) with PCC line voltage (vab) under unbalanced non-linear loads. The unbalanced loads can be observed after removal of phase ‘c’ loads. Variation of dc bus voltage (vdc) with supply current (isc), load current (iLc) and compensating current (iCc). It shows balanced supply currents when the load currents are not balanced and it proves the fast action of the proposed control algorithm after load removal. These results show the acceptable level of the performance of the proposed control algorithm of the DSTATCOM under unbalanced non-linear loads.

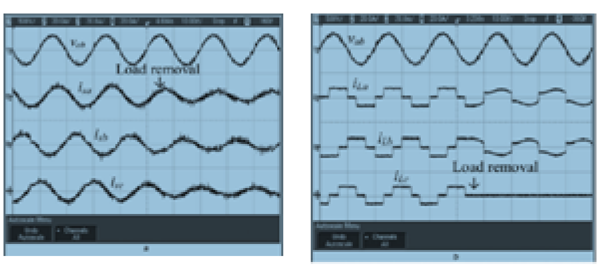


Fig. 8 Dynamic performance of the DSTATCOM during removal of phase ‘c’ in non-linear loads

IV. CONCLUSION

A three phase DSTATCOM has been implemented for compensation of linear and non-linear loads using the LVQ control algorithm. The proposed LVQ control algorithm has been used for extraction of reference supply current to generate the switching pulses for IGBTs of the VSC used as DSTATCOM. Various functions of the DSTATCOM such as, reactive power compensation, harmonic elimination and load balancing have been demonstrated with self-supporting DC bus of VSC. From the results, it is concluded that the DSTATCOM and its control algorithm have been found quite suitable for compensation of linear and non-linear loads.

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