A Comparison of Back Propagation and Improved Linear Sinusoidal Tracer Algorithms for DSTATCOM

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Abstract— Distribution Static Compensator (DSTATCOM) is implemented for the compensation of reactive power and unbalance caused by the various loads in distribution system. Back Propagation and ILST are the two types of control algorithm used for the extraction of reference source current. The neural network and fuzzy logic are used to design the alternative control schemes for switching the shunt active power filter. These schemes are simulated under MATLAB environment using SIMULINK. Simulation and experimental results demonstrate the performance of these control algorithms of DSTATCOM.

Key words: Back Propagation (BP), Improved Linear Sinusoidal Tracer (ILST), Active Power Filter

I. INTRODUCTION

Improved power quality is the primary requirement of any electric distribution system. It has many advantages such as maximum utilization of electrical equipments, enhanced loading capability, zero voltage regulation etc. Sources of poor power quality can be divided based on consumer loads and subsystem of a distribution system. These consumer loads can be classified as linear, nonlinear, or mixed type of loads. Power electronics-based shunt custom power device, known as a distribution static compensator (DSTATCOM) or Active shunt filter, is used for the compensation of reactive power, unbalance, and harmonics of these loads in a medium-voltage distribution system [1]-[3]. An active shunt compensator can be operated as a variable conductance for different order of harmonics corresponding to voltage harmonics distortion such that this technology is also useful for suppression of harmonics resonance in the distribution system [4]. Various configurations and topologies of DSTATCOM are used for reduction of distortions with acceptable level of performance according to the IEEE-519 standard with an optimal use of dc bus of a voltage source converter (VSC) used as DSTATCOM and in cost-effective manner [5]. Effective use of DSTATCOM is directly related to the design of power circuit components such as dc-bus capacitor, interfacing inductors, and VSC, control algorithm used for the estimation of reference source currents with increased speed and less calculation, switching scheme for gating pulses, and stability issues of a designed control algorithm [12].

In order to overcome these limitations Back Propagation (BP) and improved linear sinusoidal tracer algorithm (ILST) have been proposed in this paper to achieve harmonic compensation. An improved Back Propagation and linear sinusoidal tracer control algorithm is implemented on a DSTATCOM for the extraction of load currents fundamental components in three phase consumer loads. Internal parameters of this algorithm have clear physical understanding and easy adjustable to optimal value, which show the simplicity of this algorithm. Frequency- and time-domain characteristics of the ILST are not affected due to external environment changes. Detection accuracy and speed of the dynamic response can be tuned after adjusting algorithm internal parameters. In this algorithm, extracted reference source currents exactly follow the actual source currents during steady-state as well as dynamic conditions. For this reason, three-phase source currents have smooth variation during load perturbations. This control algorithm is implemented on a DSTATCOM for compensation of linear and nonlinear loads. The advantages of these systems are as follows, 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, Better response for dynamic system, Voltage Regulation, power factor correction is achieved.

II. SYSTEM CONFIGURATION

The D-STATCOM is a three-phase and shunt connected power electronics based device. It is connected near the load at the distribution systems. The major components of a D-STATCOM are shown in Fig 1.

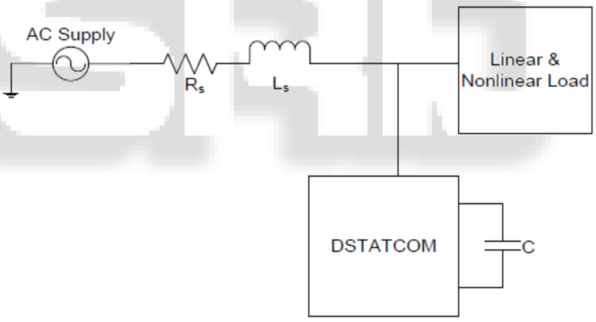


Fig. 1: Basic building blocks of DSTATCOM

It consists of a dc capacitor, three-phase converter module, ac filter, coupling transformer and a control strategy. The basic electronic block of the DSTATCOM is the voltage sourced converter that converts an input dc voltage into a three phase output voltage at fundamental frequency. The controller of the D-STATCOM is used to operate the inverter in such a way that the phase angle between the inverter voltage and the line voltage is dynamically adjusted so that the DSTATCOM generates or absorbs the desired VAR at the point of connection.

III. CONTROL ALGORITHM

The reactive power compensation a DSTATCOM provides reactive power as needed by the load. The source current remains at unity power factor. The real power is being supplied by the source and then the load balancing is achieved by making the source reference current balanced. Reference source current is used to decide the switching of the DSTATCOM thus the references source current.

A. Back Propagation Algorithm:

Back propagation, an abbreviation for "backward propagation of errors", is a common method of training artificial neural networks used in conjunction with an optimization method such as gradient descent[12].The method calculates the gradient of a loss function with respects to all the weights in the network[9]. Back propagation requires a known, desired output for each input value in order to calculate the loss function gradient. Back propagation requires that the activation function used by the artificial neurons (or "nodes").The estimation of weighted value of average fundamental load reactive power components. The input layer for three phases are expressed as the weighted amplitudes of the reactive power components of the load currents (*waq*, *wbq*, and *wcq*) of the fundamental load current are extracted as

$$i_{Laq}=W_o+i_{La}u_{aq}+i_{La}u_{bq}+i_{Lc}u_{cq} \quad (1.1)$$

$$i_{Lbq}=W_o+i_{Lb}u_{bq}+i_{Lc}u_{cq}+i_{La}u_{aq} \quad (1.2)$$

$$i_{Lcq}=W_o+i_{Lc}u_{cq}+i_{La}u_{aq}+i_{Lb}u_{bq} \quad (1.3)$$

The extracted values of *ILaq*, *ILbq*, and *ILcq* are passed through a sigmoid function as an activation function to the estimation of *Zaq*, *Zbq*, and *Zcq*

$$z_{aq}=f(I_{Laq})=1/(1+e^{-I\,Laq}) \quad (1.4)$$

$$z_{bq}=f(I_{Lbq})=1/(1+e^{-I\,Lbq}) \quad (1.5)$$

$$z_{cq}=f(I_{Lcq})=1/(1+e^{-I\,Lcq}) \quad (1.6)$$

The estimated values of *Zaq*, *Zbq*, and *Zcq* are fed to the hidden layer as input signals. The three phase outputs of this layer (*Iaq*1, *Ibq*1, and *Icq*1) before the activation function can be represented as

$$i_{aq1}=w_{o1}+w_{aq}z_{aq}+w_{bq}z_{bq}+w_{cq}z_{cq} \quad (1.7)$$

$$i_{bq1}=w_{o1}+w_{bq}z_{bq}+w_{cq}z_{cq}+w_{aq}z_{aq} \quad (1.8)$$

$$i_{cq1}=w_{o1}+w_{cq}z_{cq}+w_{aq}z_{aq}+w_{bq}z_{bq} \quad (1.9)$$

The extracted values of *Iaq*1, *Ibq*1, and *Icq*1 are passed through an activation function to the estimation of the fundamental reactive component in terms of three phase weights *waq*1, *wbq*1,and *wcq*1 as

$$w_{aq1}=f(I_{aq1})=1/(1+e^{-Iaq1}) \quad (1.10)$$

$$w_{bq1}=f(I_{bq1})=1/(1+e^{-Ibq1}) \quad (1.11)$$

$$w_{cq1}=f(I_{cq1})=1/(1+e^{-Icq1}) \quad (1.12)$$

These equations are developed for the fundamental reactive power component similarly the equations must be developed for the fundamental active power components. Thus fundamental reactive power component equations are developed in MATLAB as a simulink model is represented in the Fig 2.

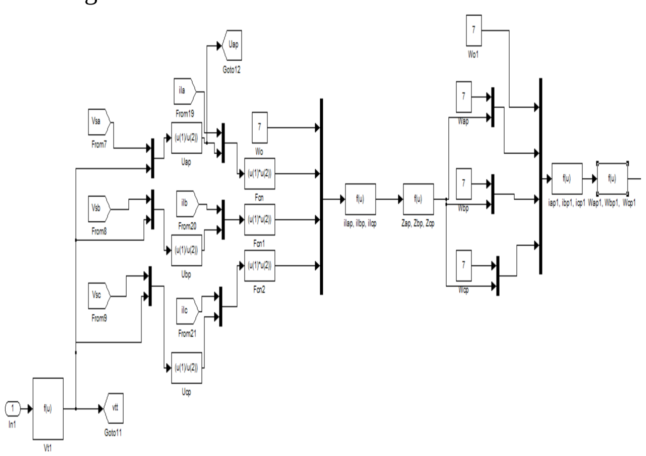


Fig. 2: Simulink model sub system for a reactive component in compensated system.

B. ILST Algorithm:

The Figure 2 gives the block diagram to generate reference source current using ILST algorithm. Three-phase voltages at the PCC are sensed and their amplitude is calculated using PCC phase voltages. The sensed PCC voltages are first passed through band pass filter to eliminate switching noise and any other harmonics present. Simple mathematical operations are applied to convert PCC line voltages to phase voltages, output of which are phase voltages as v_{sa} , v_{sb} , v_{sc}. An amplitude transformation is applied to estimate amplitude of phase voltages. There are two parameters in the proposed control algorithm, α and β, where β is tuning frequency and α decides the bandwidth of ILST-based filter.

In this algorithm, phase PCC voltages (v_{sa}, v_{sb}, and v_{sc}),source currents (i_{sa}, i_{sb} and i_{sc}), load currents (i_{La}, i_{Lb} and i_{Lc}), and dc-bus voltage (v_{dc}) are required for the extraction of reference source currents (i^*_{sa}, i^*_{sb} and i^*_{sc})

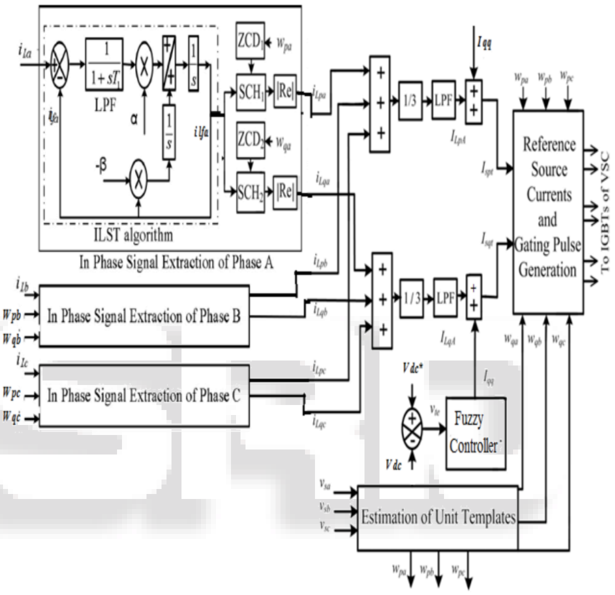


Fig. 3: Generation of reference source currents using ILST control algorithm

IV. SIMULATION AND RESULTS

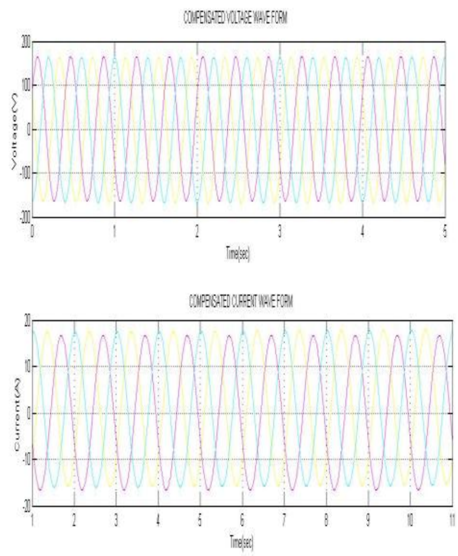


Fig. 4: Compensated voltages and current wave form using BP

The results of three phase source voltage and current waveform for compensated system. The source voltage is 415V and 50Hz and the waveforms here is shown.

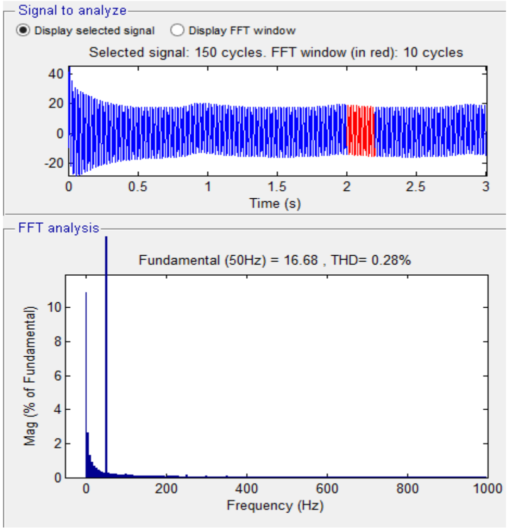


Fig. 5: Current THD for compensated system using BP

Fig. 5 shows the total harmonic current distortion display at the output side for compensated system.The load current is taken as the input. It displays the one cycle of load current in which the distortions obtained is as 0.28% at the fundamental frequency.

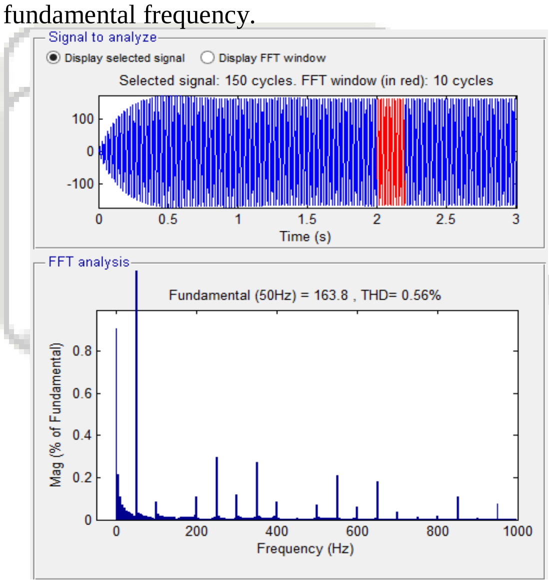


Fig. 6: Voltage THD for compensated system using BP

Fig. 6 shows the total harmonic voltage distortion display at the output side for uncompensated system.The load voltage is taken as the input. It displays the one cycle of load current in which the distortions obtained is as 0.56% at the fundamental frequency.

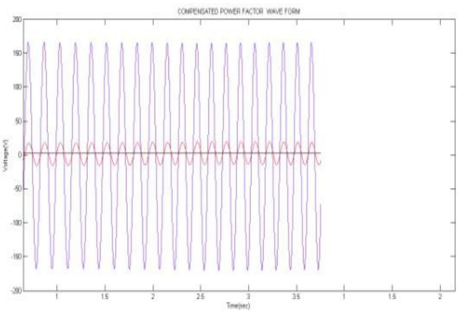


Fig. 7: In phase voltage and current waveform using BP

The below Fig. 8 shows the three phase voltage and current waveform with compensation using ILST Algorithm. The corresponding rules while generating reference currents are framed using Fuzzy controller. The membership functions for input and output variables are depicted in the Fig 9. Also the variations in the output for every change in the error input are also shown in Fig 10.

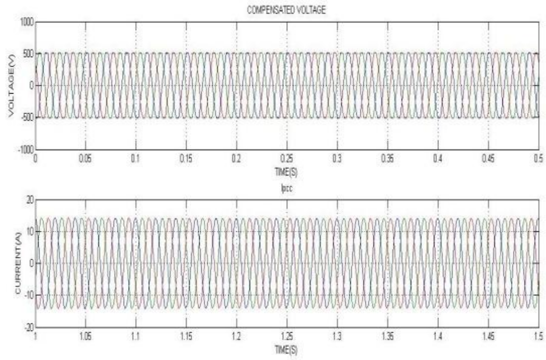
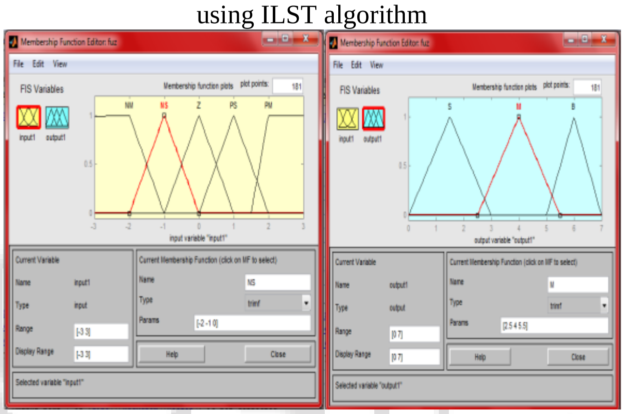


Fig. 8: Compensated output voltage and current waveforms using ILST algorithm



A B

Fig. 9: Input an Output variables in Fuzzy controller for ILST Algorithm

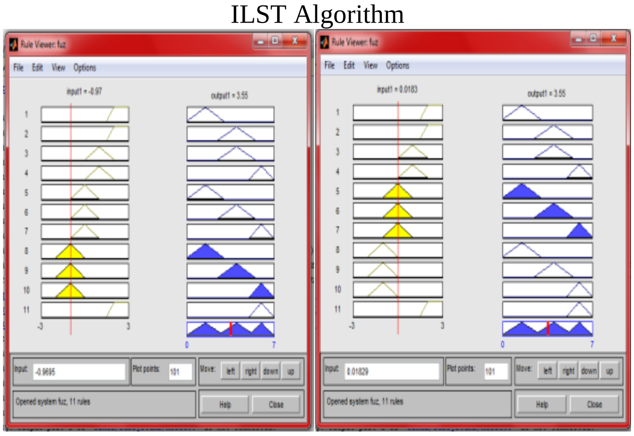


Fig. 10: Variations for input changes in Rule viewer for ILST Algorithm

The ILST algorithm does not need any transformations and the internal tuning parameters (α, β) have physical significance and hence the controller is easy to tune.The overall concept of control of the system is very intuitive and easy.The Back Propagation algorithm will not be affected by the initial gain settings, changes of system conditions, and the limits of human experience and judgment.It also gives better response for dynamic system and its a self tuning process.The below Table 1 gives the comparison of results for both algorithms.

Entity	Without compensation	With compensation Using BP	With compensation Using ILST
i_{sa}	34.24	0.28	2.55
i_{sb}	34.11	0.14	2.53
i_{sc}	35.14	0.20	2.60
v_{sa}	8.21	0.56	3.46
v_{sb}	8.25	0.59	3.48
v_{sc}	8.27	0.55	3.53

Table 1: Comparison of THD Results for Bp and Ilst Algorithms

V. CONCLUSION

The paper presents the comparative study of two control algorithms used for the control of DSTATCOM.BP and ILST control algorithms are described with the help of simulation results under nonlinear loads. It can also be concluded that a DSTATCOM though is conceptually similar to a STATCOM at the transmission level, its control scheme should be such that in addition to complete reactive power compensation, power factor correction and total harmonic distortion are also checked, for achieving improved power quality levels at the distribution end.

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