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POWER QUALITY IMPROVEMENT ADOPTING DSTATCOM USING IMMUNE FEEDBACK CONTROL ALGORITHM

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ABSTRACT

This work presents a three-phase distribution static compensator (DSTATCOM) immune feedback control technique. A three-phase voltage source converter (VSC) that is adequately managed as a shunt compensator to carry out these functions is the basis for a configuration that was selected for DSTATCOM. Immune feedback uses adaptive control to estimate fundamental reference grid currents from nonlinear load currents. This DSTATCOM control method has been shown to maintain a power factor of unity, balance the load, and reduce supply current harmonics. To compensate for nonlinear loads, this application puts the proposed control method for a DSTATCOM into operation. MATLAB/SIMULINK served as the platform upon which the simulations were carried out.

Keywords: voltage source converters, power quality, grid current, total harmonic distortions.

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1. INTRODUCTION

Power industry buzzwords have included "power quality" since the late 1980s. It is a general notion that encompasses a wide variety of specific kinds of disruptions that can occur in power systems. The problems that are covered by this category are not always brand-new ones.

The unrelenting push toward greater productivity for all utility customers is the unifying factor that connects all of these many aspects that contribute to the rising level of worry regarding the quality of electric power. The machinery that manufacturers use needs to be quicker, more productive, and more efficient. Because it helps their customers become more lucrative and because it helps defer big expenditures in substations and generation by employing more efficient load equipment, utilities encourage this endeavour because it helps their customers become more profitable. It's interesting to note that the machinery that's built to boost production is frequently the machinery that suffers the most when there's a regular disturbance in the power supply. In addition, the equipment might occasionally be the cause of other issues with the power quality. When entire processes are automated, the efficient operation of equipment and the controls they use becomes increasingly dependent upon the quality of the power supply.

The cost-effective supply of high-quality power affects industrial and domestic sectors and national economic development [1]. Electronic systems are worse. Reactive power demand and harmonics demand are popular bus utility distortion measurements [2]. The indirect matrix converter-based current estimation and gating pulse generation system are among the innovative topologies mentioned in the literature. Classical control algorithms include Fryze power theory, Budeanu theory, p-q theory, SRF theory, Lyapunov-function-based control, and nonlinear control [12–16]. With the application of soft computing techniques, such as fuzzy logic, neural networks, adaptive neuro-fuzzy, etc. [17]–[20], several non-replicating and training-based substitute direct methods have been developed. Major advantages of these algorithms include fault tolerance, self-organization, Adaptive learning, and real-time functioning through redundant information.

Under the presumption that the power frequency is already known, the control algorithm of a neural network-based system, such as the Hopfield-type neural network, is also used for the estimation of the amplitude and phase angles of the fundamental component [21]. This is done with the assumption that the power frequency is already known. The voltage that has been severely distorted is used to accomplish this. In an enhanced adaptive detecting strategy for the extraction of the error signal with variable learning parameters, one has the option of choosing whether to have a quick response to improve tracking speed or to have a low value to improve accuracy. Both of these options are available to the user. It is possible to accomplish this [22]. Choosing the right learning parameter combination is the way to go about accomplishing this goal. In their paper, Wu *et al.* [23] propose a novel control method that combines inverse control with a neural network interface. This approach to control is based on inverse control. In a digital setting, the immediate computation of switching on-off time was accomplished by the application of this strategy.

[24] Gives a summary of iterative learning control, sometimes known as ILC, and breaks it down into several different subcategories within the broad scope of applicability. ILC is based on the principle of finding an input sequence that will bring about an output for the system that is as close as it can come to the intended result. This is the underlying notion of ILC. The quantized Kernel least mean square algorithm [25], radial basis function (RBF) networks [26], and feed-forward training [27] are all examples of control approaches that can be utilised for the management of CPDs. These techniques

are all documented in books that are now in circulation. An immune RBF neural network is produced when the immune algorithm is incorporated into the RBF neural network. This results in the creation of an immune RBF neural network. Because of the implementation of this technology, both the rate of learning and the precision of the astringent signal have been significantly enhanced [28-29]. It can identify the harmonics of the current in the power network in a fast and precise manner as a result of this, giving it the ability to recognize harmonics of the current.

Utilizing a multilayer perceptron neural network can be useful for the identification of nonlinear aspects of the load. This can be the case because of the complexity of the load. The key advantage of utilizing this method is the fact that all that is required to do so is the waveforms of the voltages and currents being measured. Utilizing a neural network that is equipped with memory allows for the identification of the nonlinear load admittance. After only one round of training, the neural network can reliably anticipate the correct harmonic of the load current when it is presented with a clean sine wave. This ability was achieved after the network was given the input of the sine wave. The SRF hypothesis is used in this form of application, and the explanation for doing so is provided. The Feedforward BP artificial neural network (ANN) is made up of numerous layers, the input layer, the hidden layer, and the output layer being the most notable of these layers. This pedestal on feed-forward back propagation has a higher capability to contract with compound nonlinear challenges, and it is presented below. The BP control active compensator possesses a place from which the dc-link capacitor can be detached [10]; the BP control active compensator. Other novel arrangements are based on stacked multi-cell converters. These converters have several advantages, the primary ones being an increase in the number of output voltage levels, the ability to function without a transformer, and natural self-balancing of the voltage across flying capacitors. [11]. The performance of any custom power device is extremely reliant on the control algorithm that is implemented for the reference method that is implemented to propose the pattern categorization model pedestal on verdict support for the system. This is because the control algorithm is implemented to propose the pattern categorization model pedestal on verdict support for the system. The traditional Back Propagation model has been utilized, and the full connection of every node in the layers to the output from the input layers has been maintained throughout the process. This connection has been kept up during the entirety of the procedure. This method has a multitude of applications, some of which include the identification of user faces, industrial processes, data analysis, mapping data, and the control of power quality improvement devices. These are only a few of the many possible uses for this algorithm.

Power industry professionals are becoming increasingly concerned as a result of the rapid development in power quality (PQ) problems and solutions at the distribution level. Even in underdeveloped nations, consumers are coming to understand the significance of high PQ and are willing to pay more money as a result. PQ issues in distribution systems can be attributed to several factors, including an extraordinary increase in the number of power electronics loads. These loads encompass a wide variety of devices, including converters, switch-mode power supplies (SMPS), variable frequency motors, electric arc furnaces, and computers, amongst others. Unbalanced loads, improper voltage control, the introduction of harmonics into the grid supply, and low power factor are typical examples of power quality issues [1]. In the IEEE-519 standard, [2] guidelines are defined for limiting harmonics as well as other concerns connected to power quality. Using a variety of specialized power devices, such as a DSTATCOM (distribution static compensator), can result in an improvement in the power's overall quality [3]. This is one of the more contemporary shunt compensating devices available. It is utilized to mitigate power quality issues that are associated with currents, such as the reduction of harmonics in grid currents, the compensation of reactive power, and the balancing of unbalanced load at the distribution level. Additionally, it is capable of being controlled in a variety of different modes of operation.

2. VOLTAGE SOURCE CONVERTERS

VSCs that make use of PWM control are the foundation of modern power electronics controllers such as STATCOM, DVR, and HVDC-VSC stations [7], [5]. PWM-controlled voltage source converters (VSCs) have several benefits, one of which is the ability to generate quasi-sinusoidal voltage waveforms. Because of this, these waveforms can govern the direction and magnitude of the active and reactive power that is exchanged with the AC system. The phase relationship between these waveforms and the waveform of an existing AC system can have nearly any phase relationship needed. In actual practice, one might eliminate the high harmonic frequencies produced by the VSC by employing a high-frequency harmonic filter [10]; however, the operation of such filters will not be optimal, and it is possible that they will not even be operational. In practice, the VSC will generate high harmonic frequencies. In addition, there will invariably be harmonic interactions taking place between the VSC and the electric network. Because of this interaction, harmonic resonances may be created, which can only be predicted using accurate models of the voltage source converter (VSC) and the electric network. There are detailed models of power converters that can be found in the published research. The incorporation of the commutation period of the thyristors into the switching functions has led to the broad acceptance of switching functions in the modelling of converters based on thyristors in research about the harmonics of power systems. Switching functions have also been utilized in the modelling of converters based on GTOs or IGBTs, where they have shown even higher adequacy than they did in the previous application. This is an extension of the previous use. In this chapter, switching functions are represented as harmonic transfer matrices to describe

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three-phase PWM variable speed drives (VSCs) for steady-state harmonic analysis. To better understand the models, harmonic equivalent impedances have been provided. In these models, both the capacitor and its effects on the alternating current (AC) and direct current (DC) sides are taken into explicit consideration. The model is derived to use it as the primary building block with which different power electronics controllers can be created. As a result, a modular strategy is employed in the construction of the model.

3. CONTROL ALGORITHM

Figure-1 displays the MATLAB model that was used to calculate the weights of the active and reactive components for Phase a.

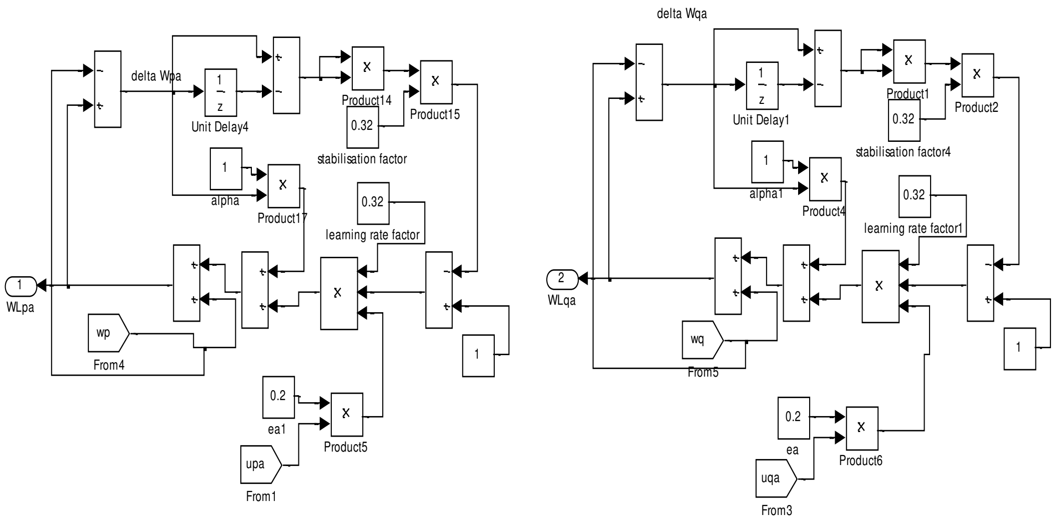

Figure-1. MATLAB model for weights of Phase 'a'.

The calculated reference currents (i.sa, i.sb, and i.sc) are compared with the grid currents that have been sensed by the current sensors (i_{sa}, i_{sb}, and i_{sc}). This results in the generation of the currently occurring errors (i_{sa*}, i_{sb*}, and i_{sc*}). Following the production of these error signals, they are sent through a PWM current controller to generate six switching pulses for the six IGBT switches that make up the VSC.

4. SIMULATION RESULTS

Both the simulation model of a DSTATCOM and the control method for it were developed using MATLAB in conjunction with the SIMULINK and Sim-Power System toolboxes. MATLAB was also used to create the model of the simulation of a DSTATCOM. Figure-2 depicts the simulation that was run to complete the simulation job. The effectiveness of the control method in the time domain for the three-phase DSTATCOM in both the PFC and VR modes of operation, while the system is being subjected to nonlinear loads, is evaluated using simulation. This evaluation takes place while the system is being driven by nonlinear loads. It is determined how well the control mechanism works when nonlinear loads are applied to it, and then observations are made about that performance.

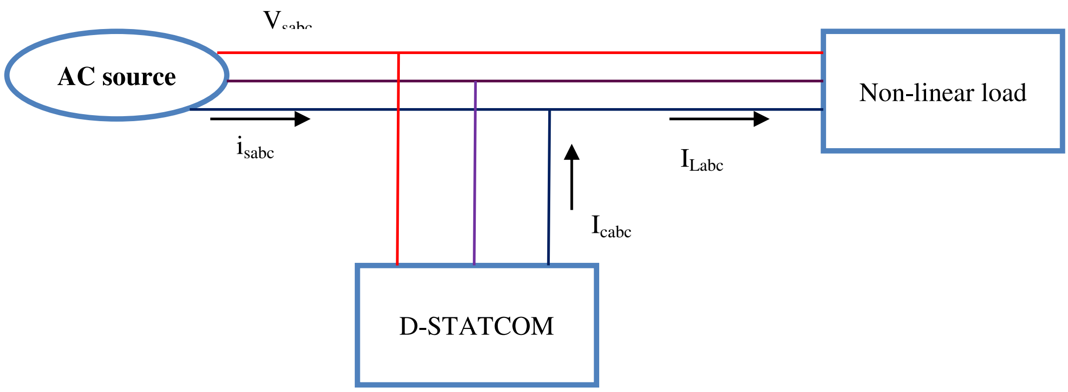

Figure-2. Block diagram of D-STATCOM.

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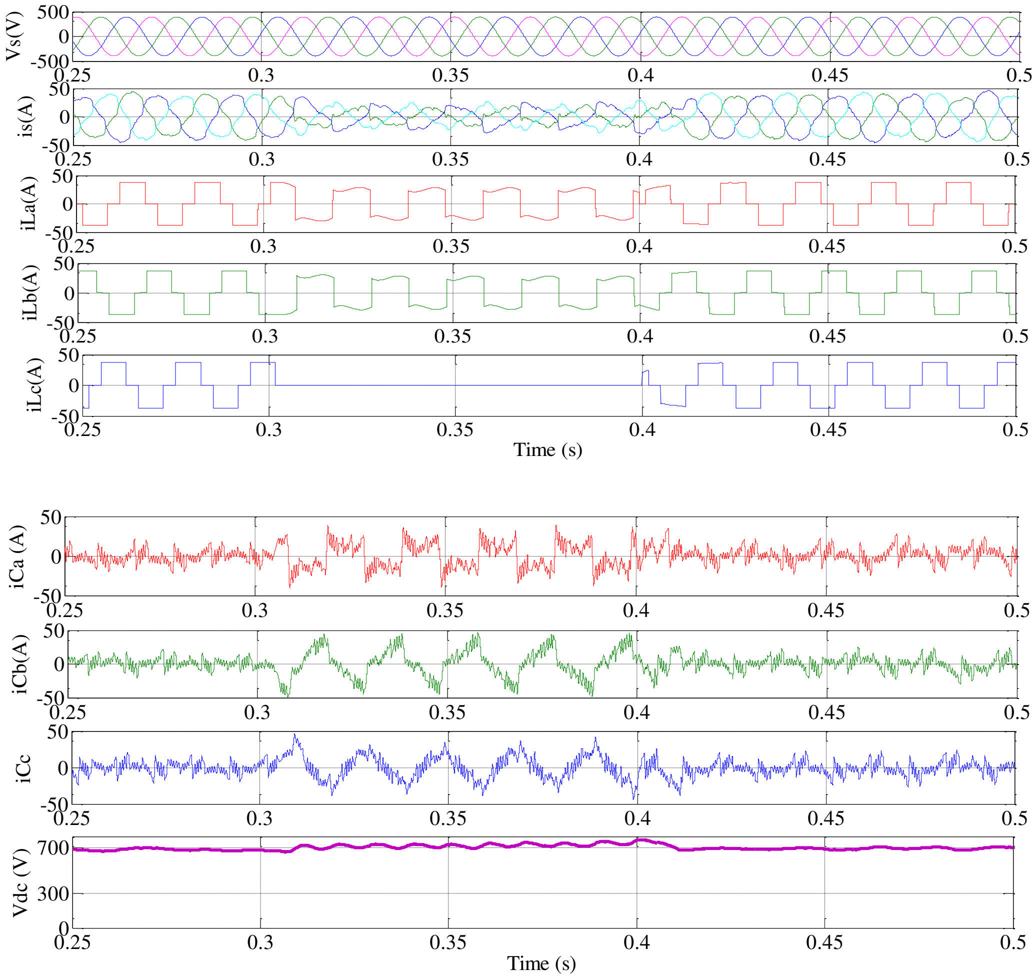

Figure-3. Shunt compensator behaviour using immune feedback in PFC mode.

The precision of the harmonic current detection is directly proportional to the level of performance achieved by DSTATCOM. To minimise ripple in compensating currents, the tuned values of interface inductors (Lf) are coupled at the output of an AC Voltage Source Converter. The shunt passive ripple filter is a three-phase series combination of a resistor (Rf) and a capacitor (Cf) that is associated at a point of common coupling (PCC) to lower the high-frequency switching noise of the VSC. This combination is associated with a point of common coupling (PCC) to reduce the high-frequency switching noise. DSTATCOM's currents, denoted by i_{Cabc}, are injected as necessary compensating currents to eliminate the load currents' reactive power components and harmonics. Because of this, the loading that is placed on the distribution system as a result of the reactive power component and harmonic loading is decreased, which leads to a reduction in the loading.

Figure-3(a) and Figure-3(b) illustrate the operation of a shunt compensator when operating in PFC mode (b). Waveforms of PCC voltages (vs), grid currents (is), load currents (i_l), DSTATCOM currents (i_C), and dc bus voltage (V_{dc}) are displayed here as a result of these results. It is clear from looking at Fig.2 (a) and (b) that the system is running in a steady state (before t = 0.3 s), and that the PI controller is keeping the value of the dc bus voltage at a reference voltage of 700 V. This is something that can be observed. It is now observed that the load currents have become unequal and unbalanced when one phase of the load (phase "c") was shut off (t = 0.3 s to t 0.4 s), which occurred between those two times. The work of DSTATCOM has ensured, however, that the currents in the grid continue to be balanced. The results of simulations show that when there is an imbalanced load state, the greatest overshoot that can occur in the dc bus voltage is somewhere about 25 V. This was observed. However, in a matter of cycles, a PI controller operation brings it down to the reference value of 700V where it is then controlled.

Figure-4 is a representation of the harmonic spectra of the grid current (isa) after correction and the load current (i_{la}) when operating in PFC mode. The total harmonic distortions (THDs) of the grid current and the load current are measured to be 4.69% and 30.54%, respectively. These values are observed to be observed. Based on these data, it is possible to conclude that the harmonic distortion of isa is lower than the limit of 5% which is established by international standards like IEEE-519. The performance of DSTATCOM is evaluated under nonlinear load conditions to determine whether or not the

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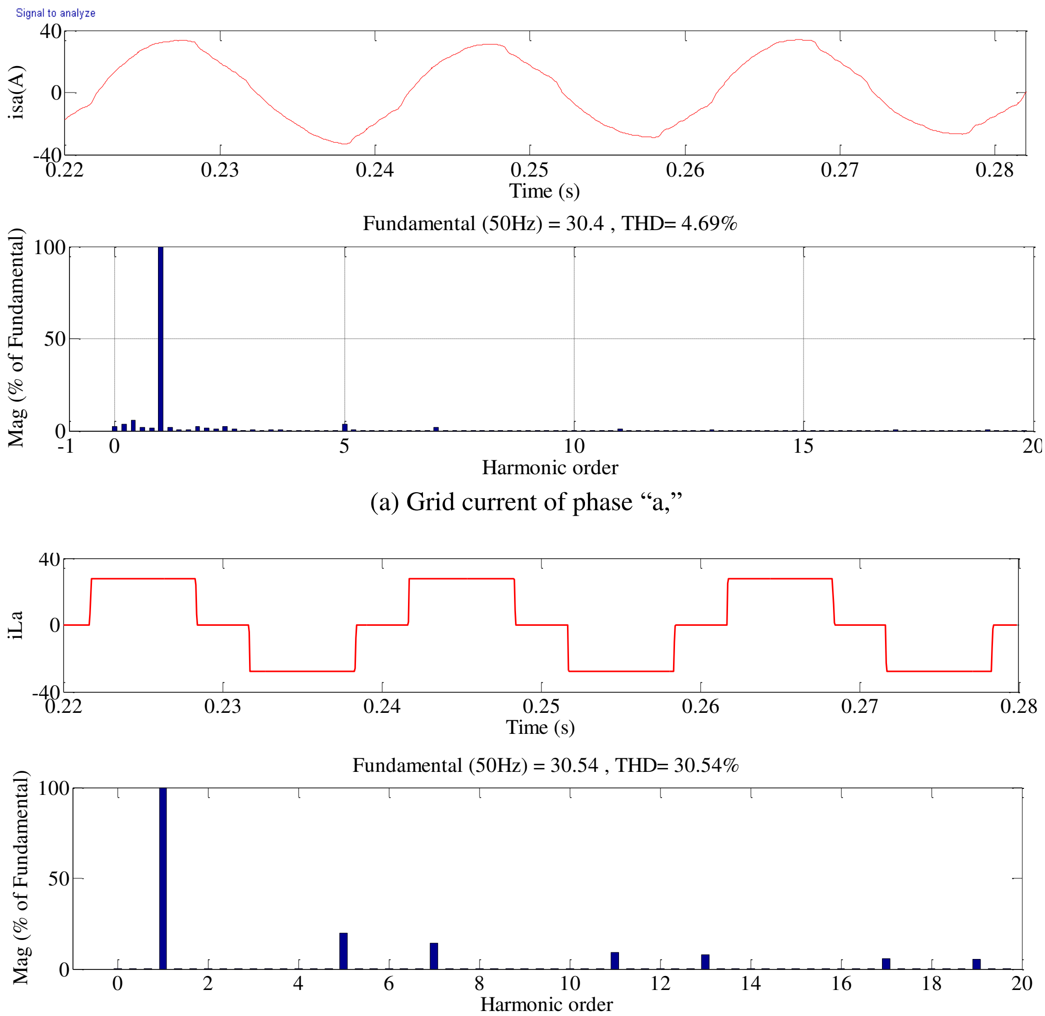
suggested control algorithm is successful in regulating the voltage at PCC. Figure-3 is a representation of the harmonic spectra of the grid current (isa) after correction and the load current (ila) when operating in PFC mode. The total harmonic distortions (THDs) of the grid current and the load current are measured to be 4.69% and 30.54%, respectively. These values are observed to be observed. Based on these data, it is possible to conclude that the harmonic distortion of isa is lower than the limit of 5% that is established by international standards like IEEE-519. The performance of DSTATCOM is evaluated under nonlinear load conditions to determine whether or not the suggested control algorithm is successful in regulating the voltage at PCC. The waveforms shown in Figure-5(a) and (b) represent three-phase voltages at PCC (vs), three-phase grid currents (i_s), three-phase load currents (i_l), compensator currents (i_C), self-sustained dc bus voltage (V_{dc}), and voltage at the VSC and PCC voltage magnitude (V_t).



(a) Grid current of phase “a,”

(b) Load current of phase “a” in PFC mode

Figure-4. Waveforms and harmonic spectrum.

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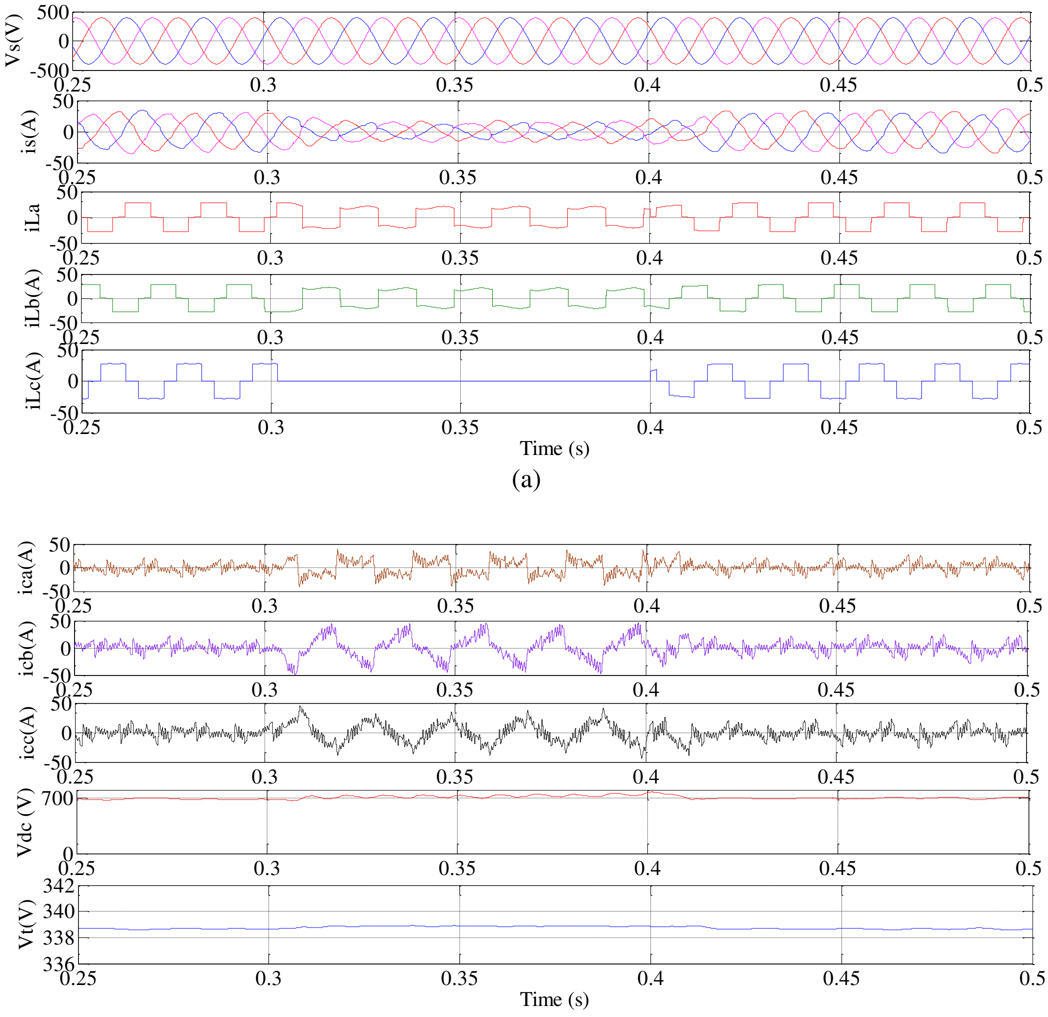

Figure-5. Dynamic performance of DSTATCOM under varying nonlinear loads in Voltage Regulation mode.

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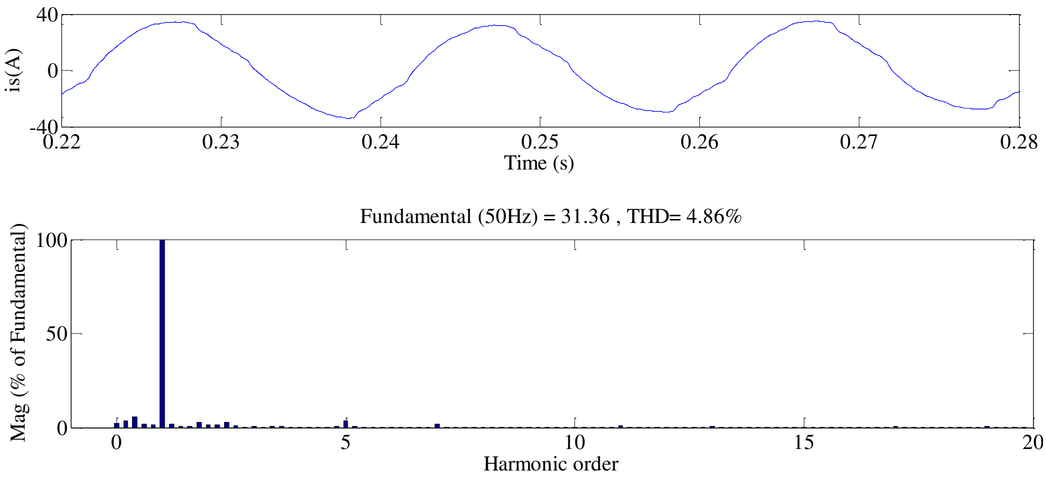
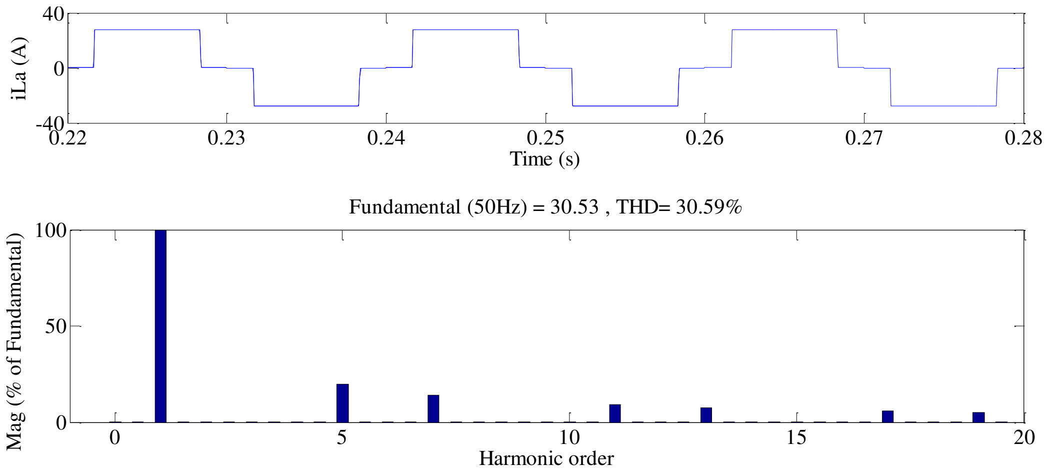


(a) source current of phase "a,"



(b)Load current of phase "a" in VR mode

Figure-6. Waveforms and harmonic spectrum.

Although DSTATCOM operation causes a 120-degree phase shift between the peak magnitudes of the grid currents, it is still possible to see them as completely sinusoidal. Both the PCC voltage and the dc bus voltage are kept at 338 V and 700 V, respectively, by the two PI controllers. So, the immune-feedback-based control algorithm adaptively extracts weights, adjusting to varying loads, including imbalanced loads. Through the use of a PI controller, the voltage can be stabilised in a matter of cycles.

The harmonic spectra of the compensated grid current (isa) and the regulated load current (ila) are displayed in Figure-5. When the distortion in the load current is 30.59%, the distortion in phase "a" of the grid current is just 4.86%. Clearly shown in Figure-5 is that the phase "a" of the grid current is kept sinusoidal after compensation, and that the distortion limitations of isa from the harmonics point of view adhere to a limit of less than 5% as stated by an IEEE-519 standard.

The system stabilises, with the desired 700 V at the dc bus Vdc and 338.89 V at the VSC and PCC voltage magnitude Vt, as desired by the control algorithm. At t = 0.3 s, an imbalance is introduced into the load, and phase "c" of the load is quickly thrown out of the system from t = 0.3 s to t = 0.4 s, resulting in a dynamic load change.

5. CONCLUSIONS

It has been determined that a VSC-based DSTATCOM is the solution that is most favoured for improving the power quality as a PFC and for maintaining the rated voltage of the PCC. A control algorithm has been utilised to validate the efficacy of a three-phase DSTATCOM that has been constructed for the compensation of nonlinear loads. To control DSTATCOM, an algorithm for control that is based on the immunological feedback principle has been devised. At the distribution level, it has been built and put into operation with the intention of addressing and resolving multiple PQ issues. The proposed control method has been supported by extensive test results and simulation data that have been given. The control algorithm that was developed and put into action to provide switching pulses for the VSC has now been completed. This was necessary to finish the project. The performance of an algorithm for immune feedback control was shown to be superior in terms of convergence speed, harmonics correction, error minimization, and computational complexity.

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