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Power Quality Enhancement Using UPFC as an Active Power Filter for Renewable Power Generation

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ABSTRACT: In this project ANN based control scheme has been proposed for a UPFC to be used as an active power filter. The objective is to guarantee power to the load at the required power quality. The ANN control unit monitors the voltage at the point of common coupling. UPFC enables improved power quality by maintaining power factor nearer to unity Rapid response time, the ability to provide reactive power at low voltage and to provide voltage compensation can be obtained. For unbalanced voltage compensation, two unbalanced controllers using the phase voltage amplitude and negative sequence component are proposed. Shunt active filter with UPFC proves to be an effective solution for active power filter applications. The system employs discrete PWM technology to provide higher Power Quality. Non-linearity in renewable power system affects power quality. By using ANN active power filter performance is enhanced. The power generation is non-uniform which affects voltage regulation and creates voltage distortion in power system. Thus the unbalance created by single phase non-linear loads and harmonic currents are effectively compensated. Using MATLAB/Simulink, simulations are carried out and output results are shown.

KEYWORDS: Active power filter, Artificial Neural Network, Power quality, Unified Power Flow Controller

I. INTRODUCTION

Increasing electrification of daily life causes growing electricity consumption, rising number of sensitive/critical loads demand for high-quality electricity, the energy efficiency of the grid is desired to be improved, and considerations on climate change are calling for sustainable energy applications. Renewable generation affects power quality due to its non-linearity, since solar generation plants and wind power generators must be connected to the grid through high-power static PWM converters. The non-uniform nature of power generation directly affects voltage regulation and creates voltage distortion in power systems. This new scenario will require new compensation techniques.A number of active shunt power filters have been implemented in to compensate nonlinear loads under unbalanced and distorted supply voltages. The development of power electronic equipment, the intensive use of static converters, and the great number of domestic electronic-based applications have deteriorated the quality of the power mains system. These nonlinear loads generate current harmonics that can be asymmetric and can cause voltage drops on the supply network impedance resulting in unbalanced conditions. These effects can be worse in the case where the loads change randomly. Conventional solutions like passive filters for reducing the current harmonic pollution are ineffective.Active power compensation is normally achieved with the help of switching power converters connected to the network as an active filter. With the great progress of power electronics, active filters have been focused in a large number of published works. The behavior of the active filters under unbalanced conditions has been already studied and analyzed.

Control schemes applied to the control of active power filter under unbalanced three-phase systems have also been introduced. These strategies have been used mostly by considering fixed harmonic compensation for balanced or unbalanced loads. Besides the problems of harmonic distortion, there exist also low power factor and unbalanced load currents at the point of common coupling (PCC) due to the power delivered by the nonlinear loads. Control algorithms for compensating all these power quality problems simultaneously have also been introduced. An important component of a shunt active power filters (SAPF) is the current controller, which has the task of making the controlled current tracking its respective reference. In conventional control strategies applied for SAPF, these current controllers are employed for controlling output filter currents. These currents are composed of a fundamental component for compensating reactive power and harmonic components. Normally, the standard solution is to use linear proportional-integral (PI) current controllers however, the use of these controllers has resulted in steady-state errors and their bandwidth limitation turns into a less than completely satisfactory quality of compensation.

The resonance-based control has the advantage of selective compensation, but in conventional SAPF, it requires the use of one controller for the fundamental frequency and for others specific harmonics, which could be expensive. These solutions are based on controllers designed for SAPF whose dynamic model has fixed parameters. However, the interaction between the load and line impedances may modify the dynamic model of the SAPF system. Moreover, the model parameters can vary especially when the load has random behaviour. Therefore, a suitable solution for compensating these power quality problems consists in the use of current controller whose gains are adjusted by adaptation. Recently, some adaptive approaches have been introduced for dealing with the load parameters variation. A typical power distribution system with renewable power generation is given. It consists of various types of power generation units and different types of loads. Renewable sources, such as wind and sunlight, are typically used to generate electricity for residential users and small industries. Both types of power generation use AC/AC and DC/AC static PWM converters for voltage conversion and battery banks for long term energy storage. These converters perform maximum power point tracking to extract the maximum energy possible from wind and sun. The electrical energy consumption behaviour is random and unpredictable, and therefore, it may be single or three-phase, balanced or unbalanced, and linear or nonlinear. An active power filter is connected in parallel at the point of common coupling to compensate current harmonics, current unbalance, and reactive power.

AIM AND SCOPE OF THE PROJECT

The main aim behind the development of this project is to propose UPFC as a reactive power compensation device to maintain the power factor near unity and to implement the UPFC as shunt active power filter.The proposed system can be applied in a transmission line in order to maintain the power quality of the grid. Unbalanced voltage compensation can be achieved more effectively.The primary objective of the project is to minimize the THD value of current across feeders and to maintain the power factor nearer to unity. The other objectives are to improve the power quality and to provide improved current tracking capability with faster dynamic response.These objectives are achieved using UPFC as a shunt active power filter as well as ANN for providing compensation effectively. The active power filter is one of the major components used in renewable power generation systems. They are used for reactive power compensation, power factor correction and power quality improvement. The use of UPFC as a shunt active power filter will provide better solutions for active power filter applications. The usage of UPFC for shunt active power filtering is a recent development that will be used for many projects in the future.

II. LITERATURE SURVEY

Analyse the harmonics generated by a STATCOM and thereby lowering the harmonic content, a STATCOM controller comprising an AC voltage regulator, a current regulator, a steady state modulation index regulator and a transient modulation controller has been proposed. [1]

ANFIS is found to be very effective in controlling power flow losses in the UPFC system. UPFC is used to control the power flow and reduce the power oscillations in the power that flows through a transmission line. MATLAB/Simulink is used to design the proposed methodology. [2]

Characteristics of a transmission line compensated by series capacitor with the STATCOM provided at the electrical centre of the transmission line have been reviewed. [3]

Closed loop control technique based on ANN to control reactive power generated by the long transmission line is presented. ANN technique and multilevel VSC topology helps in eliminating the harmonics. [4]

Effective load current control, better dynamic response and low switching frequencies is obtained with a predictive current control method has been presented. Flexible model predictive control algorithm for cascaded H bridge inverter including balancing of the power sharing among all cells and reduction of switching frequency has been proposed. [5]

Identify and remove fault module to provide compensation without exceeding total harmonic distortion allowances, various methods of fault detection and their mitigation strategy has been reviewed. [6]

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Improve the performance of STATCOM under static and dynamic operation, a Non-linear optimal predictive control scheme was presented. [7]

Artificial neural network controller is designed based on multilayer perceptron model for the control of STATCOM that is shunted with power system used to absorb/deliver reactive power from/to power system. Peak time, fault time, peak value, fall value and rise time are the control parameters chosen for analysis. [8]

III.PROPOSED METHOD

With increased power transfer, transient and dynamic stability is of increasing importance for secure operation ofpower systems. Facts devices with a suitable control strategyhave the potential to significantly improve the transient stabilitymargin. This allows increased utilization of existing networkcloser to its thermal loading capacity, and thus avoiding the need to construct new transmission lines. Amongst the availablefacts devices, the UPFC (unified power flow controller) isthe most versatile one and can be used to enhance system stability.

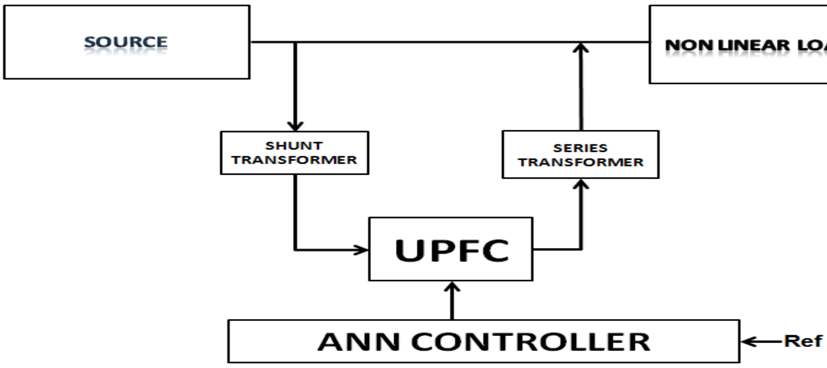

FIGURE 1: BLOCK DIAGRAM OF THE PROPOSED SYSTEM

a. UPFC

The UPFC is the most versatile FACTS controller developed so far, with all-encompassing capabilities of voltage regulation, series compensation, and phase shifting. It can independently and very rapidly control both real- and reactivepowerflows in a transmission line. The UPFC is capable of both supplying and absorbing real and reactive power and consists of two ac/dc converters. One of the two converters is connected in series with the transmission line through a series transformer and the other in parallel with the line through a shunt transformer. The dc side of the two converters is connected through a common capacitor that provides dc voltage for the converter operation. The power balance between the series and shunt converters are a prerequisite to maintain a constant voltage across the dc capacitor. As the series branch of the UPFC injects a voltage of variable magnitude and phase angle it can exchange real power with the transmission line and thus improves the power flow capability of the line as well as its transient stability limit.

Theshunt converter exchanges a current of controllable magnitudeand power factor angle with the power system. It is normallycontrolled to balance the real power absorbed from or injectedto the power system by the series converter plus the losses byregulating the dc bus voltage at a desired value.Various control strategies to control the series voltage magnitudeand angle and the shunt current magnitude have been presented. The series converter voltagephasor can be decomposed into in-phase and quadrature componentswith respect to the transmission line current. The in-phaseand the quadrature-voltage components are more readily relatedto the reactive and real power flows in thetransmission system.During short-circuit and transient conditions, the decrease inreal power can be stopped by controlling the quadrature componentof the series converter voltage and hence the improvementin transient stability. The series voltage in phase component iseither controlled by the reactive power flow deviation or voltagedeviation at the injected bus where the UPFC is located.

UPFC is configured as shown in and comprises two VSCs coupled through a common dc terminal. One VSC converter 1 is connected in shunt with the line through a coupling transformer; the other VSC converter 2is inserted in series with the transmission line through an interface transformer. The dc voltage for both converters is provided by a common

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capacitor bank. The series converter is controlled to inject a voltage phasor, V_{pq}, in series with the line, which can be varied from 0 to V_{pqmax}. Moreover, the phase angle of V_{pq} can be independently varied from 0 to 360. In this process, the series converter exchanges both real and reactive power with the transmission line. Although the reactive power is internally generated/ absorbed by the series converter, the real-power generation/ absorption is made feasible by the Dc energy storage device that is, the capacitor.

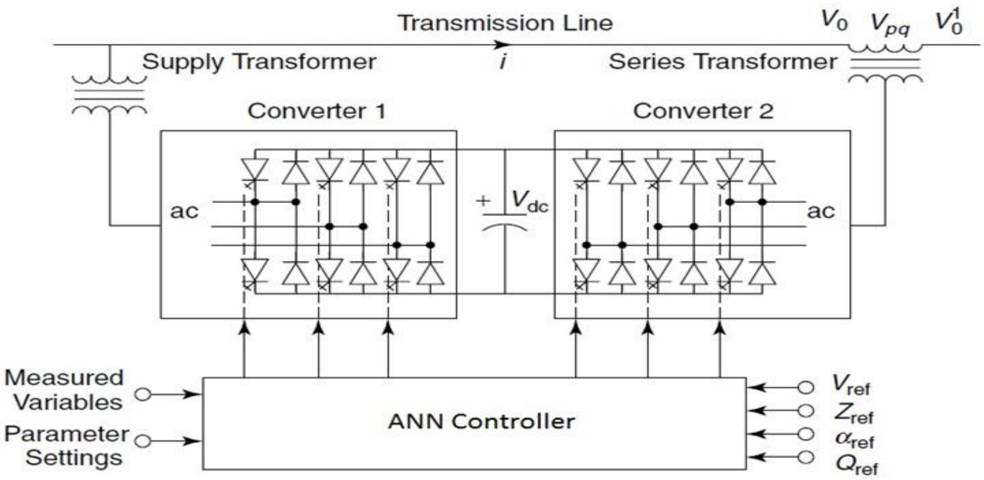

FIGURE 2: CIRCUIT DIAGRAM OF UPFC

The shunt-connected converter 1 is used mainly to supply the real-power demand of converter 2, which it derives from the transmission line itself. The shunt converter maintains constant voltage of the dc bus. Thus the net real power drawn from the ac system is equal to the losses of the two converters and their coupling transformers. In addition, the shunt converter functions like a STATCOM and independently regulate the terminal voltage of the interconnected bus by generating/ absorbing a requisite amount of reactive power.

b. ANN

Use of ANNs (artificial neural networks) for plant identification and control is gaining interest. A potential advantage of the ANN is its ability to handle the nonlinear mapping of the input–output space. The output of the proposed ANN controller is a neuron output, which may be either the quadrature or the real voltage component of the series inverter of the UPFC. The single neuron output will be either a function of the change in real power or change in the bus voltage or reactive power. This provides a nonlinear facts controller, which can significantly improve the transient performance of the power system. Similar neuron controller is used for a shunt current if both series and shunt circuits are controlled in shunt filter applications.

In machine learning and related fields, artificial neural networks (ANNs) are computational models inspired by an animal's central nervous systems (in particular the brain), and are used to estimate or approximate functions that can depend on a large number of inputs and are generally unknown. Artificial neural networks are generally presented as systems of interconnected "neurons" which can compute values from inputs, and are capable of machine learning as well as pattern recognition thanks to their adaptive nature.

For example, a neural network for handwriting recognition is defined by a set of input neurons which may be activated by the pixels of an input image. After being weighted and transformed by a function (determined by the network's designer), the activations of these neurons are then passed on to other neurons. This process is repeated until finally, an output neuron is activated. This determines which character was read. Like other machine learning methods - systems that learn from data - neural networks have been used to solve a wide variety of tasks that are hard to solve using ordinary rule-based programming, including computer vision and speech recognition.

ANN FOR THE CONTROL OF POWER SYSTEMS

The most significant disturbances in electrical supplies are caused by the proliferation of the nonlinear loads, such as rectifiers, computer equipment's, air-conditioning apparatuses or lightings containing fluorescent tubes. These devices

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absorb non sinusoidal currents and introduce harmonic pollutions inthe currents and the voltages. These harmonics circulate in the electrical supply networks, can disturb the performance of the electrical devices, and moreover can destroy them.For several years, Active Power Filters (APFs) have been recognized as advanced techniques for harmonic compensation. Their objective is to recover balanced and sinusoidal source currents by injecting compensation currents. APFs are very able to suppress the current harmonics and to compensate for the power factor, especially with fast-fluctuating loads, in comparison to other compensation devices. In addition to their performances, APFs can favourably be inserted in existing power systems and are thus widely used in practical applications. Since a few years, Artificial Neural Networks (ANNs) techniques have been applied with success in the control of APFs and are very promising in the field. Indeed, the learning capacities of the ANNs allow an on-line adaptation to every changing parameter of the electrical network, e.g., nonlinear and time-varying loads.

The first success in applying ANNs to power systems is incontestably the case of the control of motor drives. ANN is also efficiently used for reactive power/voltage control in power systems. The efficient use of neural networks for the identification and control of nonlinear dynamical systems has firstly been demonstrated. While basic concepts and definitions are introduced, this work investigates above all static and dynamic back propagation learning for MLP architectures. Simulation results reveal that the suggested identification and adaptive control schemes are practically feasible. A MLP is developed to follow any desired reference signal. Indeed, the neural network associated to the reference model of the trajectory, identifies the nonlinear dynamics of the motor and the load. ANNs can also be used as observers for the control of induction machines and inverter drives. More recently, an experimental study of a decentralized neural network control scheme of the reference compensation technique applied to control a 2-degrees-of-freedom inverted pendulum is found. Each axis of the pendulum is controlled by two separate neural network controllers to have a decoupled control structure. The decoupled control structure can compensate for uncertainties and cancel coupling effects. This has been successfully applied with experiments. ANNs based approaches are more and more efficient in active power filtering. Indeed, lots of works show that ANNs can be used to implement the different parts of an APF.

Inverters are used in APF schemes to inject reference currents in the electrical power lines. APF schemes rely on the identification of the distortion harmonics from the measures of the voltages and currents of the power lines. This results in reference currents which must be injected phase-opposite in the electrical power systems. The inverter, generally associated to an output filter implemented by analog circuits, is thus controlled by the reference currents. Different high-level control strategies can be used for this. In practice, a pulse width modulation (PWM) implementation is required. PWM is a well-known and powerful technique for controlling analog circuits and systems with a processor's digital outputs. For example, in an optimized PWM inverter control, the control is based on ANNs and produces optimum switching signals for the voltage and harmonic control of DC/AC bridge inverters using ANNs. Results obtained from an experimental implementation illustrate the performance of the approach. Different neural strategies can be compared. These Neuro-controllers, i.e., direct, inverse, and direct-inverse are compared to PID and RST regulators. Applied to the control of an APF, the ANNs produce the PWM switching signals of an inverter. Reference currents are thus efficiently injected in the power lines to cancel the unwanted harmonics.

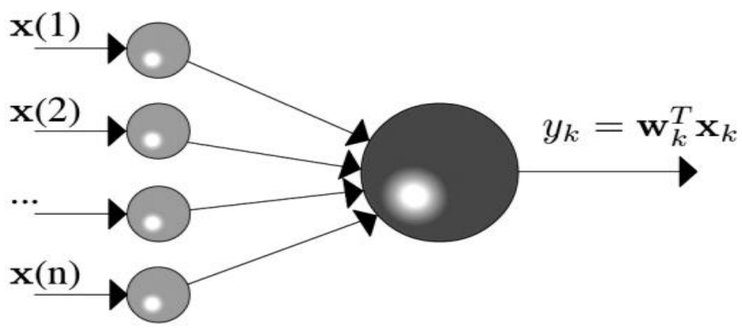

FIGURE 3: BASIC STRUCTURE OF ANN

The ANN is found to be more advantageous than the conventional PI controller due to the fact that it proved to be more efficient in many ways. In the conventional PI, PID controller, the response time is found to be 51 ms for 5th and 7th

harmonics order and the artificial neural network controller gives a response time of 31ms for the same order of harmonics.

IV. CIRCUIT SIMULATION

The simulation models are designed and explained in matlab/simulink. The simulation models are given as follows; the overall matlab simulation circuit along with UPFC & ANN. The simulation circuit of UPFC, ANN, pulse generation and reference wave generation was also given.

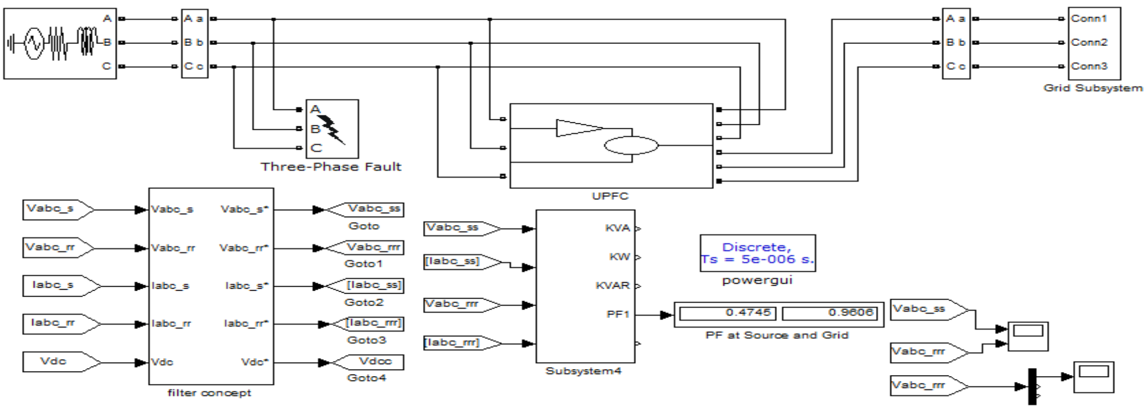

FIGURE 4: SIMULINK DIAGRAM

Figure 4 shows the overall simulation circuit of active power filter for renewable power system. Reactive power compensation is done by connecting UPFC at the PCC. The simulink diagram is discussed and analysed through simulation results. The real and reactive power compensation can be effectively done using UPFC as active power filter in renewable power generations. The power factor is maintained nearer to unity, thus achieving good power quality.

V. SIMULATION RESULTS

Simulated results of the project are shown and discussed. It also ensures the proper working of the model.The chapter is explained as follows; the matlab simulation results were given in this chapter. The THD value with and without UPFC was analysed to understand the improvement while adding UPFC. The voltage waveforms at source side and grid side were simulated and analysed. The current waveforms at source and load side were also simulated and analysed. The THD value of voltage and current waveforms at source side with and without UOFC is simulated to understand the improvement while adding UPFC. The ANN further adds to the improvement and maintains the power factor to unity.

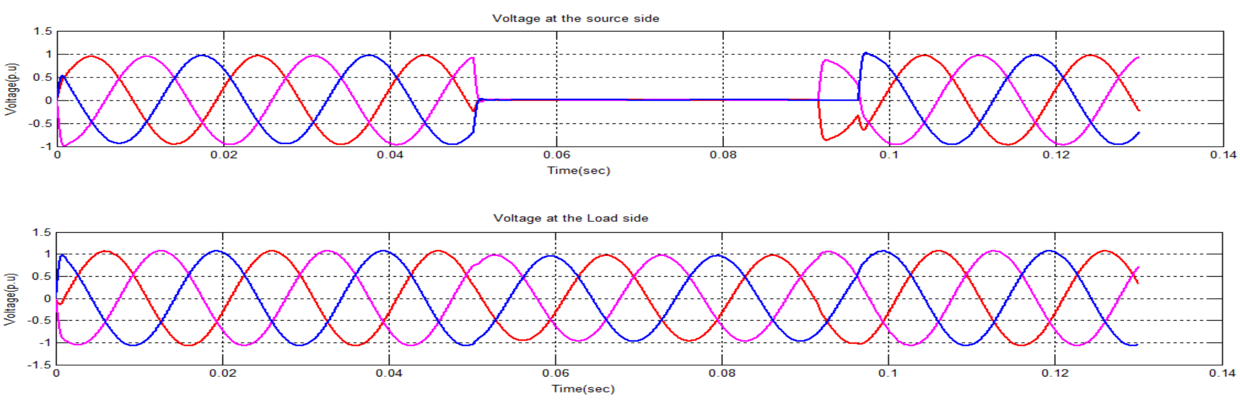

FIGURE 5 VOLTAGE WAVEFORMS AT SOURCE & GRID

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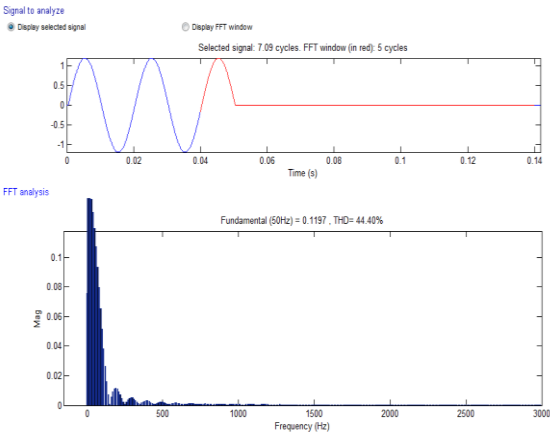
Figure 5 shows the waveform of voltages at source and grid side. The AC voltage fluctuates with the magnitude of 2 volt. Figure 6 shows the waveform of currents at source and load side. The AC value fluctuates with the magnitude of 2 volt. Its value reaches the maximum value at 0.25 ms.



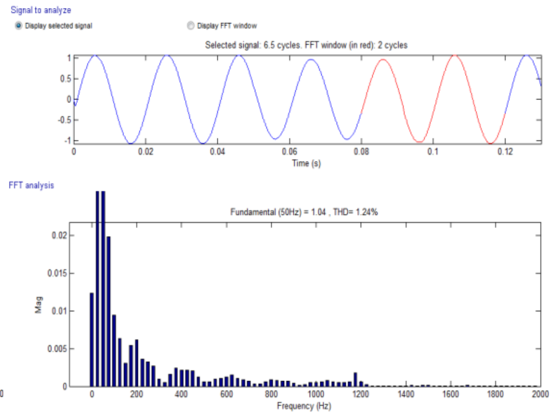


FIGURE 6(a) FIGURE 6(b)

FIGURE 6a:THD VALUE OF VOLTAGE AT SOURCE SIDE, FIGURE 6b: THD VALUE OF CURRENT AT SOURCE SIDE

Figure 6a shows the THD value of voltage at source side with UPFC. It shows the benefits possessed when using UPFC as shunt active power filter for reactive and real power compensation in renewable power generations. Figure 6b shows the THD value of current at source side with UPFC. UPFC compensates real and reactive power thus maintaining power quality.

IV. CONCLUSION

An adaptive control scheme using active power filter for renewable power generation with adaptive Neuro fuzzy inference system has been proposed to improve the power quality. The proposed system with UPFC reduces the THD from 12.4 to 3.34 which are shown in the simulated results. UPFC enables improved power quality by maintaining power factor nearer to unity. ANN which combines the advantages of fuzzy and neural network is used for getting faster dynamic response. The robust and adaptive nature of ANN leads to compensation effectiveness and improved current tracking capability and transient response. Thus Shunt active power filter with UPFC proves to be an effective solution for active power filter applications.

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