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Design and Development of a Novel Multi-Axis Automatic Controller for Improving Accuracy in CNC Applications

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ABSTRACT

A ubiquitous device-widely used in many industrial applications is Computer Numerical Control (CNC) machinery. CNC controller constitutes the main part of a CNC machine, which performs the task of controlling and navigating the tool and implementation of industrial processes. Although there have been many controllers, designed and used, in CNC applications in recent years, most of them experience some limitations and disadvantages towing to the design techniques. This project aims to design and fabricate an innovative Multi Axis Automatic Controller (MAAC) to be used in CNC machinery, which has much superiority over the existing controllers and provides an ideal performance. The MAAC has a closed-loop control system, which can control and drive stepper motors, servo motors, DC motors, and hydraulic and pneumatic movement systems. An Improved accuracy and repeatability within rapid implementation of industrial process could be achieved by using the MAAC in different CNC applications.

1. INTRODUCTION

In traditional methods for the production of a new product, all the production steps are conducted by human operators with machinery operated manually; however, with the advancement and creation of Computer Numerical Control (CNC) technology, automation has taken place in a variety of industrial processes. CNC prepares an automatic control of the machine tool employing the computer which represents an advanced control system directing different types of machine tools, robots, and transmission lines in industries [1]. In a CNC machine, the data is processed by a computer, allowing the processors to turn data to electrical pulses and send them to the axis driving motors [2]. A CNC machine control system uses one of the following two methods: open-loop or closed-loop. In an open-loop control system, in case of any mechanical problems occurring in the motor shaft or axes motion system, the controller continues to send pulses to the motor driver without any knowledge of the existing error that reduces the accuracy and repeatability of the CNC machine, sometimes causing the entire industrial process to halt. Backlash has some destructive effects on the implementation of industrial processes in an open-loop system and in the presence of overload; the controller cannot detect and correct the movement errors. In the case of a closed-loop control system, the encoder sends the rotational feedback of the servomotor’s shaft to the controller. Therefore, in case any mechanical movement errors occur, the controller is aware of the error and has the ability to rectify it. In the open-loop control strategy, regardless of whether the feedback is transmitted from the motor shaft or not, the controller is unaware of the occurred defect and continues to run the process whenever defects occur in the axis movement systems. This tends to reduce the precision and repeatability of the industrial process and sometimes halts the process. The prime role of a controller in the CNC machine is to receive the position signals from the computer and convert them into mechanical motion along a definite axis using the motor of the machine, thereby reaching the desired position. The controller is made of various parts; each part causes it to move a certain amount along the defined axis [3]. After receiving and interpreting the data from the CNC software, the movement command is transmitted to the motor drivers of each motor, which causes the definite parts to move along the designed routes. Either a USB or a printer port provides the necessary connection [4]. The CNC controller parts with the synchronization and integration function receive the transmitted signal and interpret it as a controlled movement of the machine’s motors in the correct direction by the determined amount [5]. Recently, there have been several studies in the area of design and manufacturing for CNC machines, particularly, in designing the controller part. In 2009, a theoretical controller model with the capability to control and drive the servomotor was designed and the accuracy of the system was confirmed using simulated experimental data. The mean position error (MPE) of the system decreased, by using the theoretical model, from 2.99% to 1.22% [6]. In another study, to restore the old CNC machines, an open architecture CNC controller was designed and developed. This motion control system could retrofit the old CNC machines [7], also a reconfigurable hardware controller based on FPGA was designed to be used in the CNC machines. The experimental results show the feasibility of the proposed controller [8]. Whilst all the electronic parts of a CNC machine are already built and fully functional, the CNC machine is still designed to modify the results of the machine; in 2010, a small typed prototype CNC machine using a stepper motor was designed and built with the capability of communication via a USB port [9]. In 2012, an embedded numerical control system based on heterogeneous processor was designed and developed.

A 3-axis CNC machine model based on a programmable logic controller was designed and fabricated and the CNC model movement was provided by the use of stepper motors. The simulated model of the device was then designed. This research describes the laboratory tasks focusing on the circuit board holes being drilled using the fabricated CNC [11]. During this year, a mini CNC machine was designed and used to decrease the axial tracking error, contour error and the computational time required for online optimization with adaptive feed rate and predictive control methods [12]. A laboratory study is conducted to reduce the positioning error of a small to medium size CNC machine tool. The results show that the tuning process decreases the MPE of the CNC machine tool from 4.51% to 2.85% [13]. One of the functions of the CNC controller is to use a CNC laser cutting machine in modern industry, widely encountered in the manufacturing workshops. The best positioning accuracy of a regular laser cutting machine is about 0.025 mm; so, the minimum position error of these devices is about 2.5%, which makes it widely applicable for the metal industry [14].

2. MATERIAL AND METHODS: DESIGN AND FABRICATION OF MULTI-AXIS AUTOMATIC CONTROLLER

MAAC performs as a decision-making and controller unit in a CNC machine. The number of controllable axes and tool parts can increase to 9 as needed in the design and manufacturing of MAAC. The first prototype of the MAAC has a four channel controller to control a 3-axis CNC machine.

1. Data input Unit (DIU): DIU is a middleware between the computer and integrated circuits unit. The transmitted data packages from the device’s computer are transferred to DIU via input ports and after buffering, these packages are sent to the main processer unit (MPU) and the system’s circuit export movement command towards the requested point. 2. MPU: MPU forms the center of data processing and system control and all units in the system are connected via the MPU, ensuring robust two-way communication. The transmitted data packages from the computer are transferred from DIU to MPU for processing and the designated point from the NC software is diagnosed. 3. Input pulse counter unit (IPCU): Processed data packages transferred from MPU to IPCU as pulses. Following this, the pulse counting reaches a desired point. IPCU also has a display panel which shows the software requested point in real-time mode. 4. Axis position pulse counter unit (APPCU): For each requested movement step, a pulse is transmitted from the NC software to the DIU. In a similar fashion, for each movement step in each axis, a pulse is also transmitted from the movement maintenance and security unit (MMASU) placed on each axis to the APPCU. The number of transmitted pulses from the movement of MMASU declares the current position of tool in each axis. 5. Compare and Control unit (CACU): Two different data packages are entered into CACU: data packages transmitted from IPCU that determine the requested position from the NC software in each axis, and data packages transmitted from APPCU that determine the current position of the tool in each axis. CACU compares the requested point with the current position of the tool in each axis and determines the number of movement steps to a desired position in each axis and sends that to the power and command unit (PACU). CACU controls each axis movement and determines the number of movement steps to the requested position in a real-time mode. 6. Setting unit (SU): This basic configuration allows the operator to change or set all the features of the controller so as to optimize the operation performance in a specific operation. Speed, movement steps, accuracy and the other values could be set without changing the NC software values. 7. Manual control unit (MCU): An operator can control the device and move the tool in all available directions, in each axis, to the desired position without taking part in the NC software and modify or change the operation during the process in a real time mode. 8. PACU: Incoming transmitted commands from the CACU are executed in PACU and the rotor’s rotational direction and motor performance are decided via command circuits.

The fabricated MAAC connected to a built mechanical part of the CNC machine. After the design and fabrication of MAAC, it should be compared with the other similar controllers and evaluated. For this purpose, the MAAC is connected to a built mechanical part of a 3-axis CNC machine and the drilling points of the designed CAD model are operated for 20 cycles. The positioning error on each interval is measured on the manufactured part using a CMM machine. These results will be evaluated in comparison with the results of the three similar controllers for the same operational conditions. The designed CAD model that operates in the test is shown in figure 3. As shown, there are 4 drilling points in the corners of a 20 centimeter square area and the drilling point is located at the center of the square with the hole diameter being 1 millimeter.

The Mach3 Motion Card AKZ250 controller, smooth Stepper WRAP9 tech controller and the MC3660 Lead Shine 3-axis driver controller, which finds wide usage in CNC machinery manufacturing, are used in this test. The two types of motors used in this test for evaluating MAAC, LEAD SHINEST-LS-13 stepper motor, along with the specifications are listed in Table 1 and ZHENG Gearbox DC motor with the specifications are listed down in Table 2. In the first phase of the experiment, all the controllers are connected to the mechanical part of a 3-axis CNC machine with Lead Shine ST-LS-13 stepper motors and a similar test is carried out for 20 cycles. In the second phase of the experiment, the MAAC alone is connected to the mechanical part of the CNC machine with the ZHENG Gearbox DC motor and a similar test is executed for 20 times. Statistical analysis was performed with descriptive tests and graphs using MATLAB R2013a (version 8.1.0.604, license number: 724504).

3. THEORY

Some of the limitations and technical issues existing in CNC machines are - the design of the controller which is mostly used for driving two main motors, the stepper and the servomotor has limitations in terms of output power and motor torque output because of their internal design and magnetic flux induction techniques. Therefore, the burden on the output motor axis has limitations that cause the mechanical part of the machine to have a limited range of movement. This makes mass production of these CNC motor types infeasible. The precision of CNC machines with the stepper and servomotor is based on the motor's precision. This means that the motor is the key determinant of the precision for the CNC. In open-loop systems, the operator circuit of the machine is working with the initiator driver pulse within the motor compartment (motors) and there is therefore no feedback; the operator circuit continues to send pulses even if there is a disturbance and this makes the system less functional with lower precision, which may in turn result in system-level failure. Regarding the design type and the technology for producing the CNC machines, there are limitations in terms of output power in the movement axis. Therefore, carrying out vast industrial constructions with a high overload is practically impossible. It is worth noting that the design method and the technology for making CNC machines has a significant influence on the price of these machines and the price is usually high. This study is conducted to design a modern controller used in CNC machines.

This controller is designed optimally to reach a reduction in the limitations of previous controllers and has the following features: Counter system and power controller circuit are used to enable the CNC machine to connect to most kinds of motors and also hydraulic and pneumatic movement systems. Using the position detector systems and comparators for all axes, the error percentage in movement is reduced. This controller ensures a good construction of the fully automatic machines with variable sizes possible with multi-axis automatic controller (MAAC), increasing the industrial production rates via reduction in the operation time, reduced price for the CNC machines and reduced power consumption by using novel design.

4. RESULTS

In Table 3, the mean measured position error (MMPE) of three different tested positions for each controller by using the stepper motor in the X-axis and in Table 4, the MMPE, calculated for the three tested positions for each controller using the stepper motor in the Y axis, are summarized.

5. DISCUSSION

We evaluated and compared the results of the 20 tests on the designed controller with the other three controllers. It can be deduced from Table 3 that the MX3660 controller has the lowest position error amongst the three points in the X-axis with a value of MPE = 0.80% and according to the results in table 4, the MX3660 controller again has the minimum position error of all the three points with a value of 3.69%. The MPE values for the MAAC using the stepper motor along the X and Y axis are 0.40% and 0.22%, respectively.

Also, the MAAC's MPE values calculated using the DC motor for X and Y-axis are 0.54% and 0.13%, respectively. Therefore, we may confidently infer that the MAAC with stepper motor has the lowest position error when compared to the other controllers and the MAAC with the DC motor has the minimum MPE in testing. The measured errors of each controller along the X and Y axis We observe that the MAAC with a stepper motor has the minimal measured error of all the controllers with the stepper motor. However, the MAAC with the DC motor has the minimal error along both axes in the tested complex.

6. CONCLUSION

For the past few years, there have been many studies concerning the fields of design, modification and optimization of CNC machines. Pre-determined type of motors can be generally controlled and driven by the designed and fabricated controllers. An important advantage of MAAC is its capability to control and drive all types of motors which are used in CNC machinery such as stepper, servo and DC motors. In addition, the hydraulic and pneumatic linear movement systems can be driven and employed in the manufacturing of the CNC machinery, by using APPCU and CACU in the MAAC. A designed CACU, MPDU and EBU in MAAC, helps to a decrease in the percentage of positional error for the same operation comparing with the other designed controllers. The MPE for MAAC using the stepper motor during the test reduced to 3.1% and the MPE using the DC motor for the test was very low at 0.91%, so it was less than that of the other three controllers used in similar tests. Therefore, the results indicate the DC motor offers a much better performance in positioning, in comparison to the stepper motors in similar machines with similar specifications. By using MAAC, the possibility of using different motor types enables us to manufacture CNC machines on a large scale and retrofit the old ones by using MAAC.

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A Review of Various Topologies and Control Schemes of DSTATCOM Implemented on Distribution Systems

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ABSTRACT

Nowadays the demand for receiving the high quality electrical energy is being increasing as consumer wants not only reliable but also quality power .The usage of automated equipment are increasing and far more susceptible to disturbances compare to the prior generation equipment and information systems. With the deregulation of the electric power energy market, the awareness concerning the quality of power has been increased day by day among diverse categories of customers. Power quality has become an important topic to electricity consumers at all levels of usage. Power quality can be improved in distributed system by using shunt compensation device known as Distribution Static Compensator (DSTATCOM). This paper covers the different topologies of Distribution Static Compensators (DSTATCOMs) and the various control methodologies, and its selection for specific applications.

1. INTRODUCTION

Power Quality (PQ) is a term which generally refers to sustaining nearby sinusoidal waveform of power dispensation bus voltages at allowed voltage and frequency. Power Quality (PQ) linked issues are of most concern nowadays. The power quality is badly disturbed because of the using nonlinear and dynamic loads and various faults in power system broadly. Besides, the controlling equipment and electronic devices based on computer technology insist higher levels of power quality. This type of devices are sensitive to small changes of power quality, a short time change on PQ can cause great economical losses. Because of these reasons, no matter for the power business, equipment manufacturers or for electric power customers, power quality problems had become an issue of increasing interest. Under the situation of the deregulation of power industry and competitive market, as the main character of goods, power quality will affect the price of power directly in near future. The main power quality terminologies defined by IEEE Standard 1159-1995 [5], are as follows: Voltage dip, Voltage sag, Under voltage, Voltage swell, Over voltage, Voltage 'spikes', 'impulses' or 'surges', Harmonics and Flickers. Custom power devices play a major role to overcome the power quality related problems occurring in the transmission and distribution network system. Custom power devices is a strategy which is normally targeted to sensitive equipped customers, and is introduced recently and designed primarily to meet the requirements of industrial and commercial customer [12]. One of the main advantages of custom power devices is to ensure a greater reliability and a better quality of power flow to the load centers in the distribution system by successfully compensating for voltage sags, dips, surges, swell, harmonic distortions, interruptions and flicker, which are the frequent problems associated with distribution lines [13]. Custom power devices overcome the major power quality problems by the way of injecting active and/or reactive power(s) into the system. The concept of custom power devices is to use solid state power electronic components or static controllers in the medium voltage distribution system aiming to supply reliable and high-quality power to sensitive users.

Among Custom power devices, the shunt controllers have shown feasibility in term of cost-effectiveness in a wide range of problem-solving from transmission to distribution levels. In this regard, Static Synchronous Compensator (STATCOM) is an effective solution of power quality problems [10]. STATCOM systems are used in distribution and transmission systems for different purposes. The STATCOM installed in distribution systems or near the loads to improve power factor and voltage regulation is called D-STATCOM. D-STATCOMs have faster response when compared with transmission STATCOMs [11].

Distribution Static Compensator (DSTATCOM) has the ability to overcome the problem of limited bandwidth, higher passive element count which causes increased size and losses, and slower response of Static Var Compensators (SVC) and it is done by precise control and fast response during transient and steady state, with lower foot print and weight. The DSTATCOM has emerged as a promising device to provide solution for voltage related issues and also serving a host of other current related power quality problem's solutions such as voltage regulation, load balancing, reactive power compensation, power factor correction & improvement and current harmonic control [2]. In this paper, various topologies and different control techniques of DSTATCOM is demonstrated for voltage regulation or power factor correction by reactive power compensation along with harmonics elimination and load balancing. The paper is organized as follows: Section II describes the structure of DSTATCOM. Section III and IV provides the classifications and control techniques of DSTATCOM respectively and Section V gives conclusion and future work.

2. DISTRIBUTION STATIC COMPENSATOR

This is a shunt connected device that has the same structure as that of a STATCOM and connected to the point of common coupling (PCC) in distribution system having unbalanced and nonlinear loads and is shown in Fig. 1. This can perform load compensation, i.e., power factor correction, harmonic filtering, load balancing etc. when connected at the load terminals. The main function of DSTATCOM is to supply reactive power (as per requirement) to the system in order to regulate the voltage at the PCC. Active power can also be supplied if a storage battery or fly wheel is available on dc-side of the DSTATCOM [2], [3] The various component of DSTATCOM is voltage source converter, dc bus capacitor, transformer and ripple factor. The VSC converts a dc voltage into a three-phase AC voltage and synchronized with PCC through a tie reactor and capacitor. The transformer is used to match the inverter output to the line voltage [6], [7].

3. CLASSIFICATION OF DSTATCOM

The DSTATCOM can be classified on the bases of different topologies, number of switching devices and on the bases of neutral current compensation etc. These DSTATCOMs are developed to meet the requirements of different applications in distribution system. Two types of classification is discussed in this paper.

3.1. Converter Based Classification [15-18]

DSTATCOM utilizes either a voltage-source inverter (VSI) or a current-source inverter (CSI). Voltage source inverter use capacitive energy storage, while Current source inverter use inductive energy storage in their respective dc links for voltage and current [3]. However, the voltage source inverters are broadly used because of the less heat dissipated, smaller size, and the less cost of the capacitor compared to the inductor, used in the CSI, for the same power rating [4]. The VSI connected in shunt with the AC system provides multifunctional topology which can be used for different aims such as voltage regulation and compensation of reactive power, correction of power factor, and elimination of current harmonics [36]. Voltage source inverter (VSI) topology is popular because it can be expandable to multilevel, multistep & multichain topology to enhance the performance with lower switching frequency and increased power handling capacity. Various multilevel topologies are Diode clamp multilevel inverter, Cascaded H-bridge & Flying capacitor multilevel inverter are as shown in Figs-2 a, 2b, 2c.

3.1.1. Diode-Clamped Multilevel Inverter:

The most commonly used multilevel topology is the diode clamped inverter, in this topology the diode is used as the clamping device to clamp the dc bus voltage so as to achieve steps in the output voltage [37]. Thus, the main concept of this inverter is to use diodes to limit the power devices voltage stress. The voltage over each capacitor and each switch is Vdc. An n level inverter needs (n-1) voltage sources, 2(n-1) switching devices and (n-1) (n-2) diodes. The quality of the output voltage can be improved and the voltage waveform becomes closer to sinusoidal waveform by increasing the number of voltage levels. Fig. 2(a) shows a five-level diode-clamped converter in which the dc bus consists of four capacitors, C1, C2, C3, and C4. For dc-bus voltage Vdc, the voltage across each capacitor is Vdc/4 and each device voltage stress will be limited to one capacitor voltage level Vdc/4 through clamping diodes. The order of numbering of the switches for phase a is S1, S2, S3, S4, S1 ' , S2 ' , S3' and S4'.

3.1.2. Flying capacitor multilevel inverter

A quite well-known topology of multilevel inverter is Flying Capacitor Multilevel Inverter. It is quite similar to diode clamped multilevel inverter. The capacitor has to be pre-charged in this type of multilevel inverter. The topology consists of diodes, capacitors and switching devices as shown in fig. 2(c). This has been designed only up to six levels of voltage because of the practical restrictions. Each leg consists of switching devices which are in general transistors. Every inverter limb consists of cells connected in inward nested series. Every cell has two power switches and a single capacitor. Power switch is a combination of a transistor connected with an anti-parallel diode. Unlike diode clamped inverter, this topology uses capacitors for clamping [34]. An inverter with N cell will have 2N switches and N+1 different voltage levels including zero. We can also have negative voltage levels, and so all in all we can say that N cell multilevel inverter can give 2N+1 voltage levels. The voltage level is decreased as we move towards the load. The number of level depends upon the number of conducting switches in each limb. It is also known as Imprecated Cell Inverter. Since the capacitors floats with respect to earth's potential, they are called Flying Capacitor.

3.2.1. Three-Phase Three-Wire DSTATCOM [29]

The three phase three wire DSTATCOMs are used for compensation of consumer load by improving the power quality improvement in three-phase three-wire distribution system. Three phase Full bridge topology is shown in figure 3(a). For this topology the sum of current through its three legs must be zero [29]. The compensation for zero sequence current that might be folowing in the load will not be possible, nor can it eliminate any DC current flowing into the source from the load. This will result in distrortion in the source current.

3.2.2. Neutral-Clamped Three-Phase VSI topology [5]

This topology consist of a chopper circuit which is represented by the switches Schl and Sch2 , a diode Dch1 and Dch2 in parallel and inductance and resistance which are denoted by Lp and Rp. The purpose of this chopper circuit is to balance the voltages in the two capacitors as shown in figure3(c). Let the voltage across Cdc1 be Vdc1 and voltage across Cdc2 is Vdc2. Normally the two switches are left open and thus two voltages Vdc1 and Vdc2 are equal. Now suppose there is a voltage drop in Vdcl due to this there is rise of voltage in V dc2. Current is built up in the inductor Lp due to closing of switch Sch2 and once the current reaches a definite level, the switch Sch2 is opened, hence the inductor current get discharged through the diode Dchl to bring up the voltage Vdcl to the desired level.

3.2.3. Three phase four leg VSI topology [16]

VSI with four legs that are used and requires only one dc storage unit. Three of its legs are used for phase connection while the fourth leg is connected to the load neutral and the supply neutral, if available, through a reactance [6-8]. The reference current for the fourth leg is the negative sum of three phase load currents. This nullifies the effect of dc component of load current. To maintain the adequate charge on dc-side capacitor a PI regulator is used to control the flow of real power from ac side towards dc side of the converter. When the compensator is working, zero sequence current is routed to path n-n' containing switching frequency harmonics. Using fourth leg of inverter, the negative of zero sequence current **-** iois is tracked. Certainly it needs a higher bandwidth VSI to track negative of neutral current (-io) as io contains harmonics due to non-linear loads. This increases the switching losses. If this current is not tracked properly, it will leave high switching frequency current components in the N-n path, which is not desirable. The advantage of the topology is that it requires one less capacitor.

3.2.4. Star connected three phase four wire topology [43]

The main problem in compensator topologies is voltage imbalance in capacitors when using two or more capacitor and this problem become critical when load contains a dc part. The compensator uses a current source, comprising of a voltage source inverter (VSI) with six switches (S1-S6)

3.2.5. Isolated two-leg VSC [41]

Two-leg VSC have a split capacitor with a transformer in the three-phase four-wire DSTATCOM. Transformer provides isolation from the system [15]. Two-leg three-phase four-wire DSTATCOM topologies using star-delta and, T-connected are shown in Fig 7; three-phase three-wire with two phase windings connected to the two legs of VSC and third phase winding connected to middle point of the split capacitor in VSC side winding of transformer. Three phases of the system side windings are connected to the three phases of the supply and neutral of the winding is connected with the neutral of the 3 phase 4wire supply system. Ripple filter is separately connected to the supply system [26].

3.2.6. No isolated VSC without transformer [11] Non-isolated VSC-based

DSTATCOM topologies using no transformer are classified as four-leg and three-leg VSC-based topology. The four-leg VSCbased 3P4W DSTATCOM topology is shown in Figure-8 and reported in [11]. An implementation of a four-leg VSC using an adaptive neural network-based control algorithm for compensation of linear/non-linear loads is presented in [12]. The application with PV for improvement of penetration level with low voltage distribution system is reported in [13] and PQ improvement is reported in [14].

4. CONTROL TECHNIQUES OF DSTATCOM

The reactive power needed by the load is provided by the DSTATCOM and only real power is supplied by the source such that source current remains at unity PF. Load balancing is achieved by making reference source current balanced. It has real fundamental frequency component of the load current and used to decide switching of the VSC and being extracted by control techniques [40]. Different control strategies are reported in the literature such as IRP theory, SRF theory, Adaline-based control algorithm, PI controller for maintaining dc bus voltage. Some important and widely used techniques are detailed below in the subsections as follows.

4.1. Synchronous reference frame (SRF) based control strategy [35]

SRF control technique is based on transformation of current in synchronously rotating d-q frame [21-22]. The voltage signal is sensed and processed by phased lock loop (PLL) to generate sine and cosine signals as shown in figure 9. The sensed current signal then are transformed to d-q frame and filtered. After filtering the filtered currents are back transformed to abc frame and fed to hysteresis current controller for switching plus generation [23]. The mathematical transformation equations are described in [24]. The currents generated in α–β coordinates are transformed tod-q frame with the help of park's transformation using θ as transformation angle as

4.2. Instantaneous p–q Theory [21]

The control of DSTATCOM is implemented on the basis of instantaneous reactive power theory (IRPT) or p-q theory to calculate the desired compensation current. The block diagram for the control using IRPT is shown in Figure-10. In this method, the sensed threephase PCC voltages and load currents are transformed into α-β-o axis using Clark's transformation. In addition, the source must deliver no zero-sequence active power (so that the zero-sequence component of the voltage at the PCC does not contribute to the source power). The reference source currents in the reference α-β-o frame are converted to the abc frame using the reverse Clark's transformation.

The value of n (convergence coefficient) decides the rate of convergence and accuracy of estimation. For proper estimation of reference signals, the weights are averaged to compute the equivalent weight for positive sequence and negative sequence current component in the decomposed form. Fig.11 shows the basic control scheme for ac voltage regulation mode of operation. The output signal given by PI controller is multiplied by the unit templates quadrature with phase voltage and added to the real reference current component calculated using neural network. The technique is demonstrated to selectively compensate the current harmonics, load unbalance, and reactive power based on priority [28].

4. 3 Comparative study of control techniques

Based on critical reviews of publications a comparative study of control techniques is carried out. Table-1 shows a comparative study of different control schemes on the basis of performance and PQ improvement capability of DSTATCOM.

5. CONCLUSIONS AND FUTURE WORK

The DSTATCOM is very effective for improvement of power quality (PQ) problems related to both current and voltage such as load balancing, Harmonics elimination, power factor correction, voltage regulation and neutral current compensation in distribution system. This paper presents a detailed survey on various topologies and control strategies of DSTATCOM used in both 3phase 3 wire and 3phase 4 wire distribution systems. The control techniques such as IRP, SRF, SMC, NN, and AUPF are analyzed. Comparative studies of various control schemes are also presented and from the Table-1 we analyzed that IRP, AUFC and SMC are much complex then the other schemes but excellent in harmonics mitigation. For the load balancing, IRP and NN control schemes are preferred and for reactive power compensation, SMC control scheme can be implemented. This comparative study will helps the users in selecting the particular topology and control technique of DSTATCOM that suits for specific application. Currently research is going on to reduce the cost of DSTATCOM without affecting the efficiency and effectiveness in PQ improvement capability. Renewable energy (RE) penetration into the electrical utility grid is increasing day by day and affects the quality of supplied power. The weather conditions such as variable solar insolation and wind speed variations affect the power output of RE sources. The implementation of DSTATCOM in RE based power system is required to be explored as the DSTATCOM may be an effective solution for these problems.

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