A review on different control techniques using DSTATCOM for distribution system studies

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Article Info	ABSTRACT
	This paper focus on distribution system by applying different control techniques in order to improve the performance of the system. In the distribution system mainly concentrate on power quality issues like reactive power control, harmonic elimination, power factor correction, etc. Because of power quality problems voltage, current, frequency are continuously changing in power systems. These changes will effects the performance of power systems. Power quality problems can be compensated by placing DSTATCOM which is connected at PCC in parallel. It is shunt connected VSI along with the filters, with the help of DSTATCOM voltage sag, swell and THD can be controlled. This paper presents detailed explanation about performance and configuration of latest control techniques to control the DSTATCOM.

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1. INTRODUCTION

Generally, Power system is combination of Generation, Transmission and Distribution of power. The main consideration is quality of power delivered to consumers [1]. In recent years usage of Power Electronic equipment and reactive power consuming loads are increased these are the main causes for the rise of power quality problems. To reduce power quality problems shunt active power filters are used, it is similar to voltage source inverter to produce reverse harmonic currents using Clark's transformation technique. This control strategy used to instantaneous reactive power theory to develop shunt active power filter for non linear loads [2]. There are many power quality problems, out of them compensation of reactive power and elimination of harmonic currents are the major problems, these are caused by non linear loads, these problems can overcome by active power filters and to control the active power filters, Phase Locked Loop (PLL) are placed major role.All equipment related to Electrical and Electronics are suffers from power quality problems when they are connected to distribution system [3]. This may leads to sudden change in current, voltage profiles which results in poor performance of equipment and power losses by using fundamental frequency based modified I_d-I_q control scheme to develop reference current to control DSTATCOM, out of all the custom power devices distribution compensator is one of the most effective power device to explain the issues related to power quality [4].

A Distribution Static Compensator (*DSTATCOM*) is a Voltage Source Inverter (VSI)-based Power Electronic device [5]. Usually, this device is supported by short-term energy stored in a DC capacitor. Alternatively, it can also clean up the voltage of a utility bus from any unbalance and harmonic distortion.

In power Electronics controller circuits different controll techniques used are PWM techniques, Resonant Converters, DC-DC converter circuits, Multilevel Inverter, etc. Bi-Directional Theee Phase Parallel Resonant High Frequecny AC link converter is given [6]. Two Phase Interleaved high gain DC converter using MPPT Algorithm is explain [7]. Enhancemet of Active Power Filter using SRF Theroy is given [8] Interleaved DC-DC converter technique is explained [9] Half Birdge Resonant Converter technique is explaind [10]. PI controler and Fuzzy logic controller circuits are proposed in all the above Power Electronics controller circuit for getting the desired output voltage and gain. The design is shown in Figure 1.

Advantages of DSTATCOM:
a. It compensates negative sequence currents.
b. For various types of load compensates reactive power.
c. Eliminates harmonics effectively which are caused by the non linear loads.
d. It will perform harmonic compensation and load balancing also.
e. Improves the current harmonic distortion.
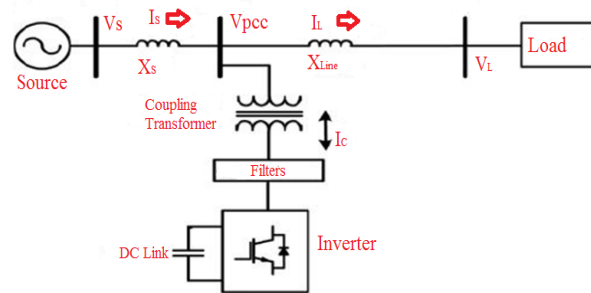f. It improves the quality of power by reducing voltage sags and fluctuations.

Figure 1. Power flow diagram

Consider a system having source and load after giving supply because of different types of load some unwanted quantities like Harmonics, Reactive power, voltage sage & swells are fed back to supply side [11]-[14]. To control these unwanted parameters, a device is connected at a point of common coupling by changing the control techniques. For example consider a PI controller, this compare the given source parameters with reference parameters and generate pulses. These pulses are used to operate VSI-IGBT circuit. The control techniques compensates output parameters [15]. Thus by changing the device control technique, the unwanted parameters are controlled and the performance of the distribution system are improved, P-Q reference theory is used to develop reference currents to control DSTATCOM to improve power quality.

A Distribution static compensator is a power device which is connected in shunt configuration to decrease the problems related to power quality which includes harmonic elimination, load balancing like voltage and current related problems. In this review various control techniques for DSTATCOM are mentioned clearly.

2. SYSTEM CONFIGURATION

The Figure 2. shows the circuit diagram for voltage source based DSTATCOM connected to 3-phase AC mains leading to the non linear loads with source impedance Z_s ($Z_s=R+jX_L$) to control the DSTATCOM using self tuning filters based on different control techniques for the estimation of reference current generation [16]-[18]. Here input variables are connected at PCC voltages of (V_a,V_b,V_c) supply current (I_{sa}, I_{sb}, I_{sc}) load current (I_{La}, I_{Lb}, I_{Lc}). In that interfacing inductances are connected at distribution side of voltage source V_s for reduction of ripple current. Three phase DSTATCOM topology with interfacing LCL filters DSTATCOM gives sufficient reactive power demand to the load side so that only active power is generated by the source and it will delivered to the loads therefore sources remains balanced and sinusoidal, dc link capacitors are placed for neutral current compensation and also acting as power exchangers to the converters.
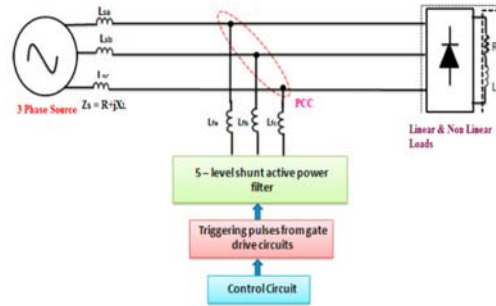
Figure 2. Voltage source based DSTATCOM

3. DIFFERENT CONTROL TECHNIQUES
3.1. PSWM technique

In 2018 A.Awalludin, C.Ltohin proposed this technique [19] for Cascaded Multilevel Converters, when the recuperating converter system produced high harmonic current, this can compensated with PSPWM. PS-PWM offered extremely low distortion *in* phase current. In 2017 R.Shibarani, Dr.C.Srinivasa rao, Dr.M.Vijaya kumara [20] offered PSPWM based five level shunt active power filter for power quality improvement in power system network. In this paper main objectives are hormonic elimination and power factor improvement. These can be done with the help of phase shift carrier pulse width modulation techniques along with clark transformation. Due to non linear loads, power quality problems are increasing in distribution system. In power quality problems hormonics are main consideration. In this article to reduce the hormonics by using five level cascaded multi level DSTATCOM is placed, to generate gating signals to the voltage source inverter, phase shift carrier PWM technique is used. In this technique comparision between traingular carrier signals with sinusoidal refference signals is done, to generate triggering pulsess to VSI. In this control technique cascaded 5-level inverter has been implemented based on shunt active power filter, to convert three phase source voltages V_{sa}, V_{sb}, V_{sc} and load currents I_{la}, I_{lb}, I_{lc} into two phase V_α, V_β and I_α, I_β can be performed by using clark transformation. The output of clark transformation is given as a input of the p & q transformation. In this active and reactive powers are devides and passed through pass band filters therefore active and reactive powers are uptained and the reference current are determined. With the help of output of clark transformation voltage, along with the output of active and reactive powers these are given as a input to the inverce clark transformation ($\alpha\beta$ to abc).

The Figure 3 shows the PS-PWM Technique. These inverse Clark transformation outputs are given as inputs to the reference currents of PS-PWM. In the PSPWM produces firing pulses to power switching of VSI by using this technique in this article %THD at source side is maintained with in IEEE 519 standards i.e 3.27 so that source current maintained balanced way that will not effect the loads which are connected at PCC.
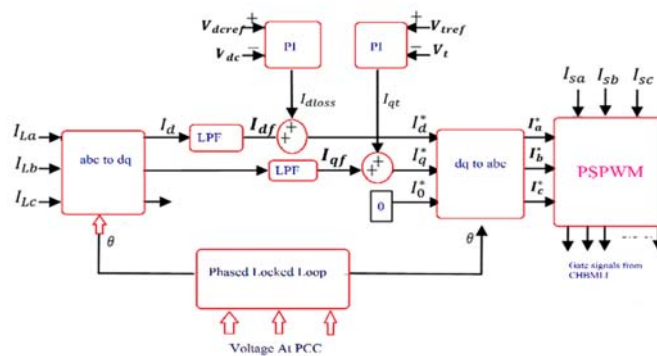

Figure 3. PS-PWM Technique

3.2. Harmonic elimination PWM technique

In 2017Ahmed Majed, Zainal Salam, Abdual Moeed Amjad [21] developed Harmonic elimination PWM based direct control for 23 level multilevel distribution STATCOM using differential evolution algorithm.

In this article authors explained about harmonic elimination PWM technique, and explains the comparisons between HEPWM & PSPWM [22]-[24]. The objective of this article is harmonic elimination [25]. By using multilevel voltage source inverter only non triplent harmonic components are considered for the elimination because, triplent harmonics are reduces the internal harmonics reduces line to line voltages to solve 11HEPWM switching angles can be performed by using DE algorithm that is synthesised to 23 level cascaded multi level VSI by using these higher levels of multilevel VSI. The output voltage will increase. So that there is no need to use step up transformers to boost output voltage. Advantages of HEPWM are

a.   Wide modulation index.
b.   Small in step size.
c.   THD values are below 5%.
d.   Improves output voltage.
e.   Superior harmonic spectra & lower switching losses so fixed switching frequency can reduce the size of coupling inductor.

The Figure 4 shows the harmonic elimination using PWM technique. To eliminate harmonics in the given system must depends on proper exchange of reactive power and efficient control of DSTATCOM [26] to achieve this two approaches are present direct & indirect control [27]. In this control technique main concentration is on phase angle of VSI (δ) & modulation Index (M), here phase angle is control variable and modulation is treated as a constant at maximum value of modulation index.

Switching angles of each H-bridge are generated based on comparison between low frequency reference signal modulations with high frequency triangular carrier signal. The Required switching angles are pre computed by solving the equations stored in the memory whenever the requirement of wave construction it fetch from memory. Mainly controller divided into three parts. They are, a) Generation of d-q current b) Inner current control and c) PWM generation [28], [29]

In this controller, mainly consists of phase locked loop along with dq park transformation. It is used to convert time varying parameters into dc quantities from the point of common coupling extract variables of voltage & current, these are giving input to the park transformation, here those quantities are converted into dc quantities in order to generate proportional integral signals [30]. One of the input is from park transformation output and other one is from extracted dc parameters at VSI with this controller generates proper V_{cd}^*, V_{cq}^* are convert into M, δ are given as input to the PWM generator. In the given system these M value are pre calculated by using DE approach where as δ value are retrieved from the tables. Depends on the values of M offered by controller. Output voltage of grid is synchronized with the help of PLL.
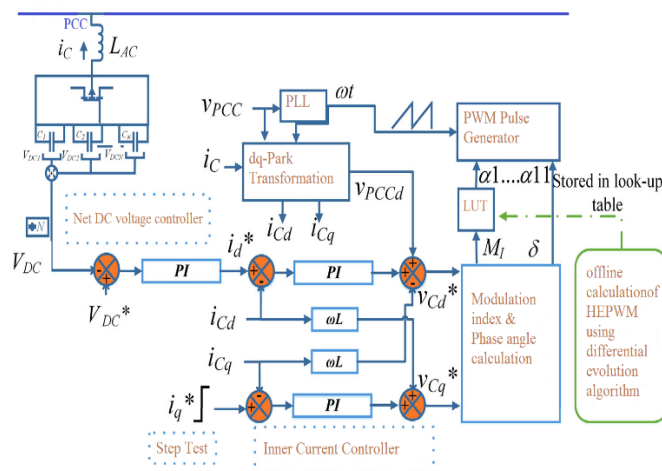

Figure 4. Harmonic elimination using PWM technique

3.3. Recursive least square (RLS) harmonic estimation technique

In 2018 Bhimsingh [31] proposed maximum power point tracking technique to a three phase system to enhance power quality and support the three phase AC grid by supplying power both to the grid and the connected loads. In 2015 Priyabrat garanayak, Gayadhar Panda, Pravat Kumar Ray [32] illustrated harmonic estimation using RLS algorithm and elimination with improved current control technique based SAPF in a distribution network [33], [34]. In this paper explained about recursive least square harmonic estimation technique, in this amplitude and phase angle of basic fundamental harmonics is performed. Advantages of RLS are,

a. With this computation is Easy.
b. Accuracy is good.
c. Good convergence.
d. Tracking time less.
e. Power factor is nearly unity.

RLS technique is used to generate pulses or commands to turn on the voltage source inverter based on two approaches like a) Frequency domain approach and b) Time domain approach.

In case of frequency domain approach signals will generate by using Fourier method or kalmon filtering method, in time domain approach [35], [36] to generate pulses may divided into

a. Instantaneous P-Q theory.
b. Synchronous d-q reference frame theory.
c. Notch filters or PI controllers.

RLS technique is used for estimator, from the AC bus noisy harmonic signals are collected and these are treated as a test signals. This algorithm is applicable for two times, one is source current without and with shunt active power filters to generate reference signals for switching operation. Shunt active power filter is designed to convert fixed abc to rotating dq frame and in this case low pass filters also used to reduce the harmonics in nonlinear current and also for better performance of shunt active power filter improved current controlled techniques also used for distribution side by using RLS technique [37], [38] estimate dominant harmonics of supply side current and also estimate fundamental phase angle and amplitude.

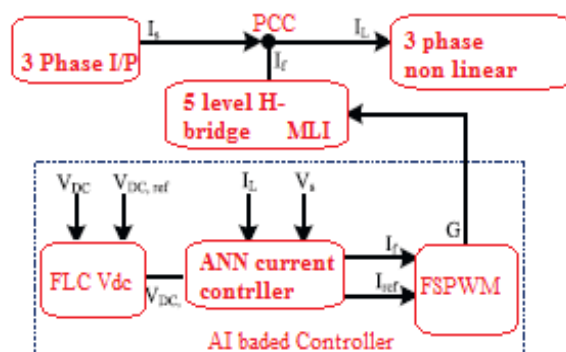### 3.4. An artificial intelligence based controller

In 2014 Vasundhara Mahajan, Pramod Agarwal, Hari Om Guptha proposed [39] An Artificial intelligence based controller for multilevel harmonics filter. In this artificial intelligence based controller is used for harmonic compensation and dc voltage regulation. This theory is used to develop and estimate the reference current by this better performance will observed [40]. Advantages are,

a. Fast responding time.
b. Easy and quick estimation of Fourier analysis.
c. Doesn't require any mathematical model.
d. Repetitive training and self adjusting capability.

In this case consider harmonic filters have five level cascaded H-bridge multilevel inverter and artificial intelligence based controller used. This controller is combination of Fuzzy logic controller [41], ANN current controller and FSPWM. In this scheme instantaneous power theory is implemented and reference component is considered by using ANN and after this approach is uses two different fuzzy logic controllers. In that one is for reducing dc voltage and second one is producing gate pulses for the IGBT inverter.

The Figure 5 shows the bock diagram for Artificial Intelligence based controller. The ANN is having capability as fast as compared with other controllers. To get the reference signals Instantaneous power theory is used for generate current reference signals, Fuzzy Logic controller is used for multilevel inverter to control voltage and currents. In Fuzzy logic controller, the main function is voltage regulation and other one is filter current errors can adjustable. These can be done by few steps as given below.

a. Initially recognisation of inputs and output parameters then formulation of control rules possibilities from association functions and control rules.
b. Possibilities from association functions and control rules then convert fuzzy sets into crisp sets then after tuning of gains for desired performance.
c. With this controller can achieved source current harmonics of 2% for increasing RL load and 2.53% for RC Loads. With can achieve fast convergence and minimization of DC voltage ripples but variation in time w.r.t loading parameters completed.
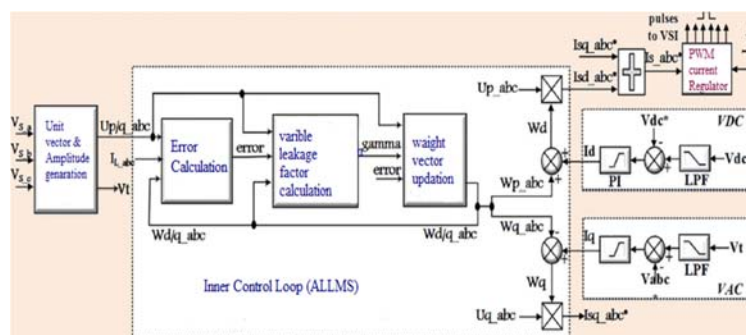
order to improve the performance of rectifier. One of the most popular and regular rectifier type is PWM based rectifier, with the help of this can achieve lower input current harmonics and high power factor. In this study three neuro fuzzy controllers are used in suggested PWM rectifier along with dq axis currents also controllable.These controllers are based on combination of execution of functions of fuzzy controllers by ANN constructively. Advantages of NFC are,

a.   These are robust in structure.
b.   It is having non linear structure.
c.   Not require mathematical model.

Here Sugeno one of the fuzzy rule is used and NFC is having two inputs, one output and six layers, and one for each input five member ship functions are changes In this control technique two units of NFCs are used one for to control of dc bus voltage and other to control dq axis current [46]. As an inputs of NFCs error and changes of reactive and active current these are used for dq axis current control, rectifier generates the change of voltage in both dq axis components are obtained from output of NFCs these are used in dq axis current controls. Figure.7 gives the block diagram of ANN.
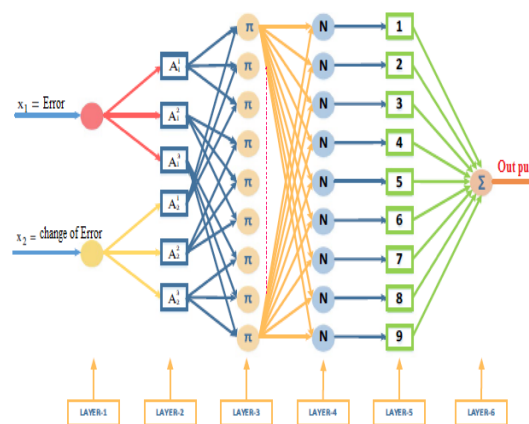

Figure 7. Block diagram of ANN

4.   CONCLUSION

This paper presents Comprehensive review on distribution system and power quality problems. In this survey mainly concentrate on different types of control techniques of DSTATCOM. The basic control techniques are Synchronous Reference Frame theory, Instantaneous Reactive power component theory, Symmetrical component theory these control strategies are reviewed with the help of basic control techniques power quality problems will be evaluated. In this paper novel control techniques are Recursive least square method, phase shift pulse width modulation method, Fuzzy Logic Controller, Neural Network method, Neuro Fuzzy controllers are reviewed. For better performance of DSTATCOM and problems in a distribution side also resolved by these techniques.

The future work of this article is higher levels of multilevel inverter can consider to obtain better results of switching devices, use of other multilevel inverter topology to improve performance of system. By using different new control strategies improve the power quality and also reduce the harmonic distortion.

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