Extensive Review on Five-level Inverter based DSTATCOM Using Fuzzy Logic

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Abstract - The Flexible AC Transmission Systems (FACTS) technology is a new research area in power engineering. It introduces the modern power electronic technology into traditional AC power systems and significantly enhances power system controllability and transfer limit. FACTS devices provide a better adaptation to varying operational conditions and improve the usage of existing installations. They have basic applications such as power flow control, increasing of transmission capability, voltage control, reactive power compensation, stability improvement and power quality improvement. The DSTATCOM is technology of the FACTS and it is based on a voltage-source inverter. Fuzzy logic is used to represent qualitative knowledge, and provides interpretability to system models. N. Henini et.al [1] has summarized fuzzy logic as a body of concepts and techniques for dealing with imprecision, information granulation, approximate reasoning and computing with words rather than numbers. The research represents extract of the deep study of the DSTATCOM and survey of the literature.

keywords- DSTATCOMP, AC power, FACTS, Fuzzy logic, Fuzzy controller, Inverter.

I. INTRODUCTION

Rapid advances in more environmentally-friendly smart-grid technologies are influencing the 21st century leading economies such as the US, China, and Europe to shift from the 20th century electric grid. As these economies become flamboyant and so has the utility of electricity intensified as a catalyst for economic growth among these nations. With transmission and distribution networks still serving as critical link between electric generators and their consumers, the technological sophistication garnered so far does not match the consumer's power quality and reliability demands. Hence, it is about time to transform the current grid (often referred to as “dumb-grid”).

The distribution system is relatively perceived as an interface between the bulk and the custom powers, whose control objective is to strike a balance between the two for maintaining continuous healthy operation of the system. A good distribution control system is therefore expected to enhance the overall system efficiency through loss reduction and power quality control. Presently, distribution system equipment such as the tap changing transformers, synchronous machines, capacitor banks, static volt-ampere-reactive compensators (SVCs), and many other flexible ac transmission systems (FACTS) controllers at device level, including DSTATCOM are being applied for such control. However, there are numerous challenges facing the area at the moment in terms of the smart-grid de-centralizing functionality which include: voltage and reactive power compensation (now known as Volt-VAR optimisation); distribution system automation (DSA); power factor correction (PF); phase current balancing; integrate-able low loss transformers (to improve efficiency), distributed resources (typically, between 1kW - 50MW), and dispersed energy storage facilities (normally sited at consumer loads), which call for radical change in the type of controllers designed in these equipment for general system power quality improvement.

Power quality issues, causes, effects and analysis have become an important aspect of research work in recent days. As the power is generated in power stations which are generally far away from load centers, the huge amount of power generated from a generating station is transported to the consumer through transmission lines. The transmission of power from the generating point to the point of consumption is combined with variations of weather, variations in loads, variations in demands etc. which compromises the quality of power. Industrial and commercial consumers of electrical power are becoming increasingly sensitive to power quality problems. Reliability and quality are two important parameters in the field of power engineering. Combining today's utility power with the ever increasing quantity of electrical sensitive load yields one of the major contributors to downtime in business and industries today. Issues of deregulation, standards and customer awareness (economics and legal) have brought forth a great deal of focus and motivation in these areas.

II. THEORY AND SYSTEM MODEL

The voltage sag is a major problem that the power system network is facing now-a- days. This is a severe problem and affects the functioning of the equipment. Therefore, this problem should be mitigated in order to maintain the efficiency of the power network. The use of custom power devices solves this problem.

A. Distribution Static Compensator (DSTATCOM)

DSTATCOM is a shunt connected device designed to regulate the voltage either by generating or absorbing the reactive power. The schematic diagram of a D-STATCOM is as shown in Figure 1.1 which contains DC capacitor, Voltage Source Inverter (VSI), coupling transformer and reactor.

It is a power electronic converter based device used to protect the distribution bus from voltage unbalances.

Figure 2.1 Schematic diagram of a D- STATCOM.

As in the case of Dynamic Voltage Regulator (DVR), the VSI generates voltage by taking the input from the charged capacitor. It uses Pulse Width Modulation (PWM) switching technique for this purpose. This voltage is delivered to the system through the reactance of the coupling transformer. The voltage difference across the reactor is used to produce the active and reactive power exchange between the STATCOM and the transmission network.

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Control Strategy: The main aim of the control strategy implemented to control a D-STATCOM used for voltage mitigation is to control the amount of reactive power exchanged between the STATCOM and the supply bus. When the PCC voltage is less than the reference (rated) value then the D-ATACOM generates reactive power and when PCC voltage is more than the reference (rated) value then the D-ATACOM absorbs reactive power.

B. Space Vector Modulation (SVM)

The space vector modulation techniques differ from the carrier based in that way, there are no separate modulators used for each of the three phases. Instead of them, the reference voltages are given by space voltage vector and the output voltages of the inverter are considered as space vectors.

Figure 2.2 Space Vector Modulations Principle.

There are eight possible output voltage vectors, six active vectors U_1 - U_6, and two zero vectors U_0, U_7 (Fig. 2.2). The reference voltage vector is realized by the sequential switching of active and zero vectors. In the Fig. 2.2 there are shown reference voltage vector U_c and eight voltage vectors, which corresponds to the possible states of inverter. In the each sector the reference voltage vector Uc is obtained by switching on, for a proper time, two adjacent vectors. The reference vector Uc can be implemented by the switching vectors of U_i, U_2 and zero vectors U_0, U_7.

III. RELATED WORK

N. Henini, F. Benzerafa and A. Tlemçani,[1] Effort for improvement of power quality in distribution systems has been gradually increased. Traditionally, fixed, mechanical switched reactor/capacitor banks and Static Var Compensator have been used for improving the power quality issue in distribution systems. In recent years, applications of inverter based power quality conditioner have been growing for reactive power compensation in distribution systems, since their response is faster than that of the conventional compensators. Distribution STATCOM (D-STATCOM) is an inverter based power quality conditioner device used to improve the power quality issues in distribution systems. This research work describes the modeling and the control of a distribution static synchronous compensator (DSTATCOM), with the aim of improving the quality of electric network; we were also required to develop and implement a method of control by a fuzzy logic controller. Switching pulses for the five-level inverter are generated by Space Vector Modulation (SVM). Simulation results are provided to illustrate the performance of our controller. Validation of models and control algorithms is carried out through simulations in SimPowerSystems of MATLAB/Simulink.

Deepmala and A. Kumar,[2] This research work presents the modelling of D-STATCOM for radial distribution system. The device is used to compensate the node voltage to 1 p.u and its effect is studied on constant power (CP) and generic ZIP model. With the device placement at each node real power, reactive power, size of reactive compensation and percent rate of under voltage mitigated nodes are calculated. The best location of the device is decided on the basis of power loss reduction and percent rate of under voltage mitigated nodes (RUVMN) separately. The effect of summer load variation on the D_STATCOM placement is also presented in this research work.

A. Jain, A. R. Gupta and A. Kumar,[3] This research work presents an effective method for the identification of candidate bus for DSTATCOM placement for the minimization of power losses and improvement of voltage profile in radial distribution system with load modeling. The D-STATCOM is modeled for determination of its size by assuming the voltage magnitude as 1 p.u. at the candidate bus. The validity of the method is tested on the standard IEEE 33-bus radial distribution system by performing load flow analysis after compensating the candidate bus using MATLAB software. The results obtained are compared without and with the D-STATCOM for all load models. The voltage profile and the losses reduction is obtained for IEEE 33 bus test system with the optimal placement of D-STATCOM based on the sensitivity index.

V. M. Hrishikesan, K. Venkatraman, M. P. Selvan and S. Moorthi,[4] Wind energy conversion systems contribute a significant fraction of total electric power generation from renewable energy based systems. Since several decades, Squirrel Cage Induction Generator (SCIG) has been considered as the backbone of wind power industry. The concept of dynamic reactive power compensation of induction generator based wind farms is gaining paramount importance because of the formation of weak grids due to the increased penetration of such wind farms. The purpose of the present work is to explore the applications of Distribution STATic COMpensator (D-STATCOM) in SCIG based wind farms for the compensation of reactive power during both normal and abnormal grid conditions.

Y. Deng, Y. Wang, K. H. Teo and R. G. Harley,[5] This research work presents a generalized space vector modulation (SVM) method for any modular multilevel converter (MMC). The proposed SVM method produces the maximum level number (i.e., 2n+1, where n is the number of submodules in the upper or lower arm of each phase) of the output phase voltages and a higher equivalent switching frequency than other modulation methods, which consequently leads to reduced harmonics in the output voltages and currents. Compared with earlier modulation methods for MMCs, the proposed SVM method provides two more degrees of freedom, i.e., the redundant switching sequences and the adjustable duty cycles, thus offering significant flexibility for optimizing the circulating current suppression and capacitor voltage balancing. This SVM method is a useful tool for further studies of MMCs, as it can be conveniently extended for any control objectives. The demonstrated results validate the analysis.

T. Durán and J. Pereda,[6] DC to AC conversion technology has succeeded in obtaining high power quality (voltages and currents) using multilevel inverters. These inverters can generate several levels of voltage that reduce the harmonic distortion of the generated sine waves in the AC side. However, the output voltages always are discrete, so a non-negligible harmonic distortion remains. This distortion can be reduced by increasing the number of voltage levels generated by the multilevel inverter, but this means reduce the reliability and increase the number of semiconductors. This research work proposes a novel continuous space vector modulation (C-SVM) that generates continuous AC voltages without using filters and reduces the total harmonic distortion (THD) of the voltage under 1%. This proposed modulation requires two variable power sources (e.g. buck converters) but can be implemented in simplified three-phase cascaded multilevel converters. Moreover, this continuous modulation allows the implementation of a novel cascaded multilevel inverter with a reduced topology. Simulated results show the proposed space vector modulation and the output voltage and currents obtained in inductive loads and in an induction motor.

N. Jarutus and Y. Kumsuwan,[7] In this research work, a phase-shift space vector modulation technique is proposed to control the dual-load of the nine-switch inverter. The proposed algorithm is based on a carrier-based space vector pulse width modulation (SVPWM) under the constant frequency (CF) and the variable frequency (VF) operation modes. The modulation signals are operated by without crossover to avoid the distortion of output voltages. The switching states can prevent the short through in the inverter leg. For the CF-mode, the modulation indices are identical and less than, or equal to $2/\sqrt{3}$. Therefore, the sum of phase-shift angles is 0°. For the CF and VF modes, the displacement phase-shift angle is able to adjust from 0° to 360°, when the sum of modulation indices is less than, or equal to $2/\sqrt{3}$. The proposed phase-shift SVPWM technique is verified by simulation results, showing good steady-state performance.

IV. PROBLEM STATEMENT

The capacitor banks were used for reactive power compensation and voltage regulation, but they have great problems such as stress and sudden changes in capacitors. Also their response to transient errors is very slow, so they were replaced by Static Var Compensators which will reduce the time of response and improve the voltage stability .But the SVC transient stability is low, so DSTATCOM is suppose to be used instead of these devices because it has fast response in compensation and voltage profile correction.

V. CONCLUSION

Flexible AC Transmission Systems (FACTS) devices such as Static Synchronous Compensator (STATCOM) can be used to solve the power quality issues related to transmission lines while DSTATCOM can improve the power quality and dynamic performance in a distribution network. The Static Synchronous Compensator (STATCOM) is a shunt-connected reactive power compensation device that is capable of generating and/or absorbing reactive power at a given bus location and in which the output can be varied. It is used to inject the AC voltage to compensate the decrease in the supply voltage. The switches of the VSI are operated based on the pulse width modulation (PWM) technique to generate the voltage of required magnitude and frequency. The design of FLCs for a DSTATCOM to improve power quality and dynamic performance of a distribution power system, FLC has to be designed for the DC voltage regulator, the AC voltage regulator, and the current regulator. The effect of Harmonic compensation using PI and Fuzzy Controller can be eliminated.

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