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SIMULATION OF D-STATCOM BASED INVERTER TOPOLOGY FOR DG SYSTEMS USING FUZZY LOGIC

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Abstract— This dissertation presents the implementation and simulation of a novel multilevel inverter with FACTS capability for small to medium size (10–20kW)permanent-magnet wind installations using Modular Multilevel Converter (MMC)topology.The aim of the project is to implement a new type of inverter with DSTATCOM option to provide utilities with more control on active and reactive power transfer of distribution lines. The inverter is placed between the renewable energy source, specifically a wind turbine, and the distribution grid in order to fix the power factor of the grid at a target value, regardless of wind speed, by regulating active and reactive power required by the grid. The inverter is capable of controlling active and reactive power by controlling the phase angle and modulation index, respectively. The unique contribution of the proposed work is to combine the two concept's of inverter and DSTATCOM using a novel voltage source converter multilevel topology in a single unit. Simulations of the proposed inverter,11-levels have been conducted in MATLAB/Simulink for two systems including 20kW/kVAR and 250 kW/VAR.

I. INTRODUCTION

Recently, renewable energy systems have become more prominent in electricity production. Renewable energy sources, such as wind or solar energy, have been playing an important role in energy production. Figure 1.1 illustrates a modern power grid in which electricity is made by conventional power plants and renewable energy power sources.The theory can be applied to shunt applications. A shunt-type full-bridge reactive power compensator with line-frequency switching and condensed capacitance has been projected in [9]. It has advantages of line-frequency switching and small-sized capacitor; nevertheless, large-harmonic current generated and large-grid-connected inductors wanted are challenges. Disadvantages of the line-frequency switching have an important impact in shunt-type compensator; consequently, this project applies the theory to the shunt-type reactive power compensator. The resultant shunt reactive power compensator has little capacitance compared to the normal voltage-source-type single-phase STATCOM, and accomplishes low-harmonic current and compacted inductor as equal as for the typical STATCOM.

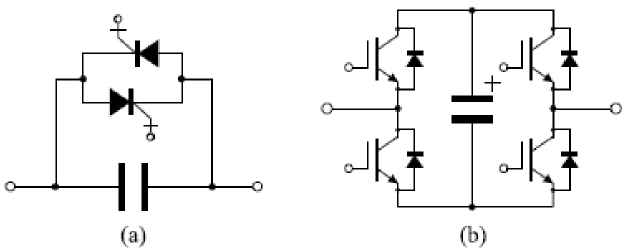

Fig. 1.1 Circuit configurations of two types of series compensators (a) GCSC (b) Voltage-source-type full-bridge compensator including SSSC and MERS

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II.CONTROL STRATEGIES AND APPROACHES

The control system is the heart of state-of-the-art STATCOM controller for dynamic control of reactive power in electrical system. Based on the operational requirements, type of applications, system configuration and loss optimization, essential control parameters are controlled to obtain desired performance and many control methodologies in STATCOM power circuits have been presented in [3]. In a square-wave mode of operation, phase angle control (a) across the leakage reactance (L) is the main controlling parameter. This control is employed in a two-level converter structure, where DC voltage (Vdc) is dynamically adjusted to above or equal to or below the system voltage for reactive power control. In a three-level configuration, the dead-angle or zero-swell period (b) is controlled to vary the converter AC output voltage by maintaining Vdc constant. The control system for STATCOM operated with PWM mode employs control of a and m (modulation index) to change the converter AC voltages keeping Vdc. For voltage regulation, two control-loop circuits namely inner current control loop and external/outer voltage control loop are employed in STATCOM power circuit. The current control loop produces the desired phase angle difference of the converter voltage relative to the system voltage and in turn, generates the gating pulses, whereas the voltage control loop generates the reference reactive current for the current controller of the inner control loop. This control philosophy is implemented with proportional and integral control (PI control) algorithm or with a combination of proportional (P), integral (I) and derivative (D) control algorithm in d–q synchronous rotating frame. Figs. 3.16 and 3.17 illustrate the PI methodology for two-level and three level GTO-VSC based STATCOM power circuits. The general mathematical approach, modeling and design of control systems for compensator circuits are proposed.

In the process of designing and implementation of control system, acquisition of many signals is involved. Initially, the essential AC and DC voltages and current signals (instantaneous values/vectors) are sensed using sensors. In the next step, these signals are synthesized by techniques such as d–q synchronous rotating axis transformation, alpha–beta stationery reference frame of transformation and so on. Phase locked loop circuit is normally employed to calculate phase and frequency information of the fundamental positive sequence component of system voltage which synchronizes AC converter output voltage. Third step involves generation of compensating command signals based on three kinds of state of-the-art control methodologies, linear, nonlinear and special control techniques. Fourth step is to generate required gating signals for the solid-state devices.

III.STATIC SYNCHRONOUS COMPENSATORS (STATCOM)

Line commutating thyristor device-based solid-state reactive power compensators were developed in the 1970s. These are used either as thyristor switched capacitors or thyristor controlled reactor (TCRs) or a combination thereof with passive filters eliminating dominant harmonics generated from electronic switching phenomenon. These are basically VAR impedance-type controllers, commonly known as static VAR compensator (SVC), where susceptance of the TCR is controlled by varying the firing angle. The technology is well matured, but its operational flexibility and versatile applications are limited.With the advent of voltage-source converter (VSC) technology built upon self-commutating controllable solidstate switches viz. gate turn-off thyristor (GTO), insulated gate bipolar transistor (IGBT), injection-enhanced gate transistor (IEGT), integrated gate commutated thyristor (IGCT) or gate commutated thyristor (GCT) and so on, it has ushered a new family of FACTS controllers such as static synchronous compensators (STATCOM) and unified power flow controller (UPFC) have been developed. The self-commutating VSC, called as DC-to-AC converter, is the backbone of these controllers being employed to regulate reactive current by generation and absorption of controllable reactive power with various solid-state switching techniques. The major attributes of STATCOM are quick response time, less space requirement, optimum voltage platform, higher operational flexibility and excellent dynamic characteristics under various operating conditions.These controllers are also known as STATic COMpensator (STATCOM), advanced static VAR compensator (ASVC), advanced static VAR generator (ASVG), STATic CONdenser (STATCON), static var generator (SVG), synchronous solid-state VAR compensator (SSVC), VSC-based SVC or self-commutated SVC or static synchronous compensator (SSC or S2C). EPRI in USA is a pioneer to conduct research in this area and has been instrumental to develop a number of existing STATCOM projects in collaboration with power utilities/industries. Power industries such as GE, Siemens, ABB, Alsthom, Mitsubishi, Toshiba and so on, with their in-house R&D facilities have given birth to many versatile STATCOM projects presently in operation in high-voltage transmission system to control system dynamics under stressed conditions. The VSC-based STATCOM has emerged as a qualitatively superior technology relative to that of the line commutating thyristor-based SVC being used as dynamic shunt compensator.GTO-based VSCs (GTO-VSC), commercially available with high power capacity, are employed in high power rating controllers with triggering once per cycle [fundamental frequency switching (FFS)]. Although IGBT and IGCT devices are available with reasonably good power ratings, these are being mainly used in low- to medium rating compensators operated under pulse-width modulation (PWM) switching, that is, multiple switching (1–3 kHz) in a cycle of operation. Use of these switching devices in high power rating controllers is yet to be fully commercialized and therefore its use is limited. In the state-of-the-art STATCOM equipments, two major topologies of VSC-bridges viz. multi-pulse and multi-level are the most common for operation under FFS or PWM mode or selective harmonic elimination modulation. For high power rating STATCOMs, GTO-VSC is still the choice for operation under square-wave mode of switching, that is, once per cycle. A concept of multi-level voltage reinjection in DC circuit of VSC topology, as an alternative to high-frequency device switching adopted under PWM control or instead of adopting higher multi-level topology under FFS principle, has been reported to multiply the pulse-order several times without employing additional VSCs. With commercialization of this approach, there would be a major saving of solid-state devices and magnetic components.A comprehensive review on the STATCOM technology and its development are carried out in this project. The project includes ten sections viz. (i) working principle of STATCOM, (ii) solid-state switching devices and technology, (iii) STATCOM topologies and configurations, (iv) control methodologies and approaches, (v) component selection, (vi) specific applications, (vii) simulation tools, (viii) latest trends and perspective research potentials (ix) concluding remarks and (x) references.

CONCLUSION AND FUTURE WORK

The concept of a new multi-level inverter with FACTS capability was presented in this dissertation. The proposed inverter represents a new way in which small renewable sources can provide control and support in distribution systems. The MMC inverter with D-STATCOM capability supplies utilities with capacitive VAR compensation. The unique contribution of this work is to combine the two concepts of D-STATCOM and inverter using the most advanced multi-level topology to create a single-phase wind inverter with FACTS capability. The proposed power electronics device acts as a renewable energy inverter with D-STATCOM option.

Future Work

However, one future project is to implement fuzzy logic. In order to provide the faster action on the controlling system. Thus by using fuzzy logic controller obtain a smooth control on power factor, Active and Reactive power. In recent years,the number and variety of applications of fuzzy logic have increased significantly.The applications range from consumer products such as cameras, camcorders,washing machines, and microwave ovens to industrial process control, medical instrumentation, decision-support systems, and portfolio selection.

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