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Hexagram-Converter Based Statcom for Integrating Twelve Bus Sytem with Wind Farm

KEYWORDS

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ABSTRACT *This paper presents the effectiveness of reactive power compensation using a multi-level hexagram-converter based static synchronouscompensator(STATCOM) with one cycle control(OCC)for a wind farm in to weaken loop power system. In this the static synchronous Compensator (statcom) is considered for this application Because it provides many advantages in fast response time and superior voltage support capability with its nature of voltage source the Hex-mc based statcom with proposed controlled scheme demonstrates an excellent performance, eliminating the voltage instability problems at the point of its connection to the grid.*

Index Terms-wind farm(WF), Impact study, static synchronous compensator(STATCOM),one cycle control(OCC),SCIG(sqirral cage induction generator,MSC(mechanical switched cap).

I. INTRODUCTION

To have sub-stainable growth and social progress it is necessary to meet the energy need by utilizing the renewable energy resources like wind, biomass, hydro, co-generation etc. In sustainable energy system, energy conservation and the use of renewable source are the key paradigm. The need to integrate the renewable energy like wind energy into power system is to make it possible to minimize the environmental impact on conventional plant. The integration of wind energy into existing power system presents a technical challenges and that requires consideration of voltage regulation, stability, power quality problems. However, with wind being a geographically and climatically uncontrollable resource and the nature of distributed wind induction generators, the stability and power quality issues of integrating large wind farm (WF) in grid may become pronounced, particularly into a weak power system.

Conventionally, the low-cost mechanical switched cap (MSC) banks a and transformer tap changers (TCs) are used to address these issues related to stability and power quality. However, although these devices help improve the power factor of WF and steady-state voltage regulation, the power quality issues, such as power fluctuations, voltage fluctuations, and harmonics, cannot be solved satisfactorily by them because these devices are not fast enough . Moreover, the frequent switching of MSC and TC to deal with power quality issues may even cause resonance and transient overvoltage, add additional stress on wind turbine gearbox and shaft, make themselves and turbines wear out quickly and, hence, increase the maintenance and replacement cost. Therefore, a fast shunt VAR compensator is needed to address these issues more effectively, as has been pointed out in many literatures.

II. TWELVE BUS SYSTEM AND WIND FARM DESCRIPTION

The two WFs, WF1 and WF2, are connected to the existing69-kV loop system at bus 3 and 5. The system is supplied by the two main substations, which are represented by three remote boundary equivalent sources at bus 1, 2, and 12. Among them, bus 1 is a strong bus with a short-circuit capacity of about4000 MVA. The WF2 at bus 3 is a large WF with a total rating of 100 MVA. It is a type C WF with variable-speed double fed induction generators (DFIGs) and partial back-to-back converters. The WF1 at bus 5 is located at the middle of the weak69-kV sub transmission system, and the short-circuit capacity at the bus 5 is about 152 MVA. The WF1, with a total rating of 50MVA, is a type AWF using fix-speed squirrel-cage induction generators (SCIGs). The six loads tapped on the 69-kV weak loop system are mostly rural radial loads. The loop network is normally kept closed to improve the reliability of power supply.

III. SYSTEM MODELING AND CONTROL

In this section, the system modeling, MATLAB implementation and validation of the studied 12-bus power system, WF, and STATCOM are presented.

A. Twelve-Bus System Model

In the twelve-bus system model is modeled using MATLAB. Since only balanced operation is considered for this study, the positive-sequence dynamic model is developed. Boundary equivalent source is modeled as ideal voltage sources with series equivalent impedances.

B. WF Model

The implemented model of the WFs does not include mechanic dynamics and the detailed electrical model of induction machine and it is an ideal voltage source with equivalent series and shunt impedance. In WF model All wind turbines are identical. Wind speed is uniform, so that all wind turbines share the same power generation. Each turbine runs at the same operating modes at all times, and the voltages, current, and power factor of each turbine are the same.

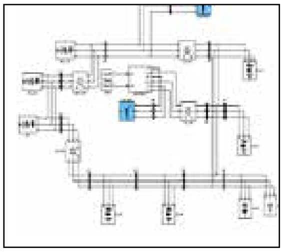

Fig .1.one line diagram of Twelve-bus studied system.

the real power of WF is controlled by the source phase angle, the reactive power of WF is controlled by a shunt cap bank at 35 kV bus of WFs, and the bus voltage of WF is controlled by the source voltage.

IV. HEXAGRAM CONVERTER FOR STATCOM APPLICATION

Multilevel VSC technologies are utilized in various types of applications, such as ac power supplies, renewable power generation, adjustable-speed drive systems, etc. Multilevel VSC-based STATCOMs can also be used with step-up transformers for higher voltage levels. In this case, since multilevel converters generate output voltage waveforms with many steps, losses in the transformers are decreased.

Several well-known multilevel topologies are used to implement high-voltage STATCOM such as:

1) Diode-Clamped Multilevel Converter (DCMC)
2) Flying-Capacitor Multilevel Converter (FCMC)
3) Generalized-Converter Topology (P2)
4) Cascade-Multilevel Converter (CMC)
5) Mixed Level Hybrid Multilevel Converter (MLHMC).

Each of these topologies differs in the number of semiconductor switches, reactive elements, current, and voltage stresses for semiconductor switches. Recently, the Power Electronics Laboratory at the University of California in Irvine (UCI PEL) has proposed a new topology for a multilevel power conversion (MC).

The HEX-MC is composed of six three-phase, two-level voltage source inverter modules, with separated capacitive dc buses CDC1–CDC6. The modules are interconnected through the coupling inductors LC12–LC61 wound on one common magnetic core.

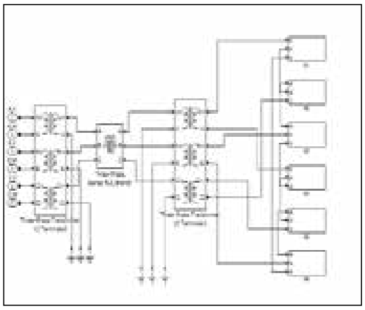

Fig.2. (a) Hexagram converter connected to three phase transformer.

According to the phase diagram in Fig. 3, the HEX-MC output voltages VAA, VBB , and VCC form a symmetrical nine-level, three-phase voltage system, defined as follows:

$VAA = Va1b1 + Vb2a2 + Va3c3 + Vc4a4$
$VBB = Vb3c3 + Vc4b4 + Vb5a5 + Va6b6$
$VCC = Vc5a5 + Va6c6 + Vc1b1 + Vb2c2$

PHASOR DIAGRAM

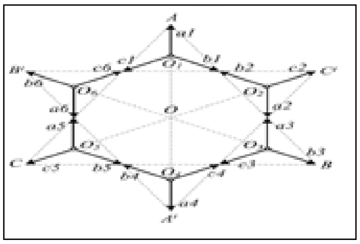

Fig.3.voltage Phasor diagram

According to the HEX-MC phase-to-phase voltages are composed of eight equal steps presenting the nine-level waveforms, and each step is formed by the corresponding phase-to phase voltage of a three-phase VSC module.

The HEX-MC and CMC require the least number of total components. The cost of an MC monotonically increases with the number of components. Moreover, the reliability of a system is inversely proportional to the number of its components. Among the presented topologies, the HEX-MC has a maximum number of voltage levels. The switch voltage stress (SVS) value equals to the same as that of DCMC and FCMC..

The OCC control principle for two-level STATCOM is applied to HEX-MC-based STATCOM. depicts the average switching model for a two-level converter. Assume that a three-phase system of grid voltages is symmetrical and balanced; then, VA + VB + VC = 0, and also assume that the voltages across the inductors are small compared with the phase grid voltages and can be neglected.

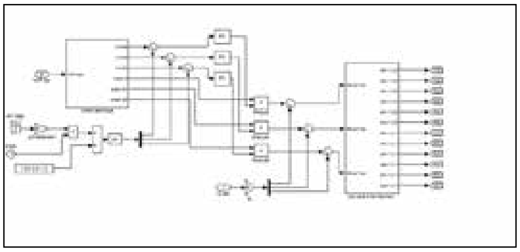

Fig.4.Control system of HEX-MC STATCOM

the difference between actual iCa and reference ι∗ca STATCOM currents reflects the active current component corresponding to the STATCOM active power which is necessary to cover the active power losses and stabilize dc-bus voltage. In other words, to keep VDC at a constant level, the equivalent STATCOM resistance RE will be adjusted by duty

ratios during each switching cycle. The control system must have two control loops. The outer one is a reactive power controller, which contains the proportional-integral (PI) controller to define a reference reactive current component, based on the voltage deviation value. Where I*mCa, I*mCb and I*mCc are the amplitude values of reference reactive currents. VmA, VmB, and Vmc are the amplitude values of phase voltages at the point of STATCOM connection. and KoP and KoI are the proportional and integral coefficients of the outer control loop, respectively. The inner control loop consists of an active power loss compensator which contains another PI controller to stabilize dc voltage, changing the value of the parameter Vm.The parameters KoP and KoI in are defined by the wind farm and grid impedances. An example of the design of the PI controller for the outer loop is presented in the next section. The principles of the inner control loop design for OCC.

such that each of them will control the dc voltages of two modules in the same output phase ofthe HEX-MC (for example, of modules I and IV formed phase A) using their averaged dc voltages.

V. SIMULATION RESULTS AND ANALYSIS

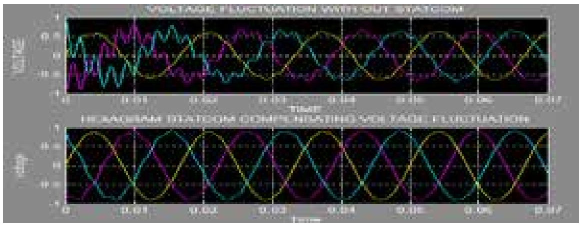

Fig.5 Comparison of simulation results

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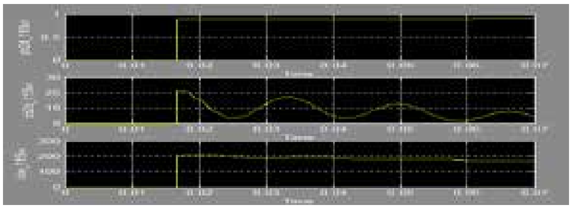

Fig.6.Bus 2 voltage and power flow from bus 2 to 3

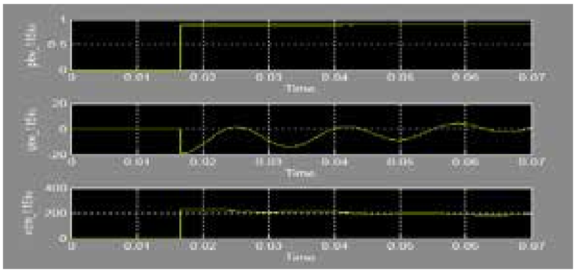

Fig.7.Bus 3 voltage and power flow from WF2

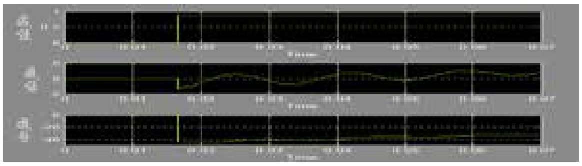

Fig.8.Bus4 voltage and power flow from bus4 to 5.

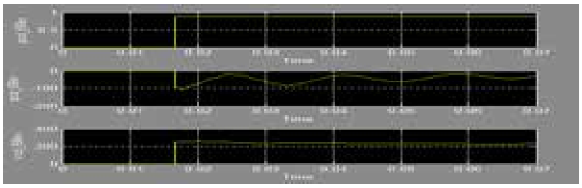

Fig.9. Bus5 voltage and WF1 power output at bus5

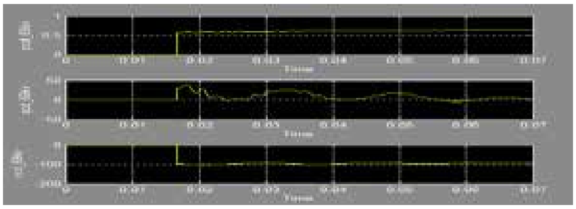

Fig.10 Bus6 voltage and WF1 power output at bus6

VI.CONCLUSIONS

This paper describes the methodology to conduct an impact study of a Hexagram-STATCOM on the integration of a large WF into a weak loop power system. The specific issues and solutions of the studied WF system are illustrated. For the system study, the models for the system, WF and STATCOM are developed. The simulation results showed that fluctuations and over current of a wind farm under randomly varying wind speed can be effectively reduced. Reactive power support the operation of a wind farm leads to voltage stabilization at the PCC and maintenance of the wind farm grid current at the rated value.

Moreover, with the proposed control technique, the HEX-MC STATCOM demonstrated satisfactory dynamic performance in stabilizing both increased and decreased grid voltage. The size and location of Hexagram-STATCOM and the system stability are assessed. It indicates that while low-cost MSCs and TCs boost the steady-state voltage locally but are ineffective to suppress the voltage fluctuations (seconds to minutes) but also inherently reduce the operation times of MSCs and TCs in the system so that the maintenance and replacement cost of MSCs, TCs, and wind turbines can be reduced, and the power quality issues related to the switching of MSCs and TCs can also be lessened.

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