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Power Quality Step up Using Modular Multilevel Converter for Renewable Energy Source

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Abstract: Multilevel inverters have received more attention in industrial application, such as motor drives, FACTS devices and renewable energy systems, etc.Primarily multilevel inverters are known to have output voltages with more than two levels. A modular multilevel converter (MMC) is one of the next-generation multilevel converters intended for high or medium-voltage power conversion without transformers. Compared with the existing multilevel converters, one of the most desirable advantages offered by MMC may be its ability to process both active power and reactive power with its terminals directly connected to high-voltage networks. D-STATCOM (Distribution Static Compensator) is a shunt device which is generally used to solve power quality problems in distribution systems. D-STATCOM is used in correcting power factor, maintaining constant distribution voltage and mitigating harmonics in a distribution network. In this paper MMC D-STATCOM inverter controls the DC link voltage as well as the active and reactive power transferred between the renewable energy source, specifically wind turbine, and the grid in order to regulate the power factor (PF) of the grid regardless of the input active power from wind turbine. In this concept in future by increasing the levels of Multilevel Inverter we improve the power quality.

Key Words: Bidirectional switch, Total Harmonic Distortion (THD), D-STATCOM, Modular Multi-level Converter, Renewable Energy Source.

I. INTRODUCTION

Traditionally, large power plants use fossil fuels to generate electricity. The electric utility industry has begun to update more and more in recent years. Relevant issues such as global warming, toxic missions, energy cost, power market, and increasing energy demand have affected power industry growth. Over the past decade, utilities have shown decreased willingness to invest in large-scale power plants and, consequently, have shifted to smaller distributed energy sources closer to loads [2].In addition, power facility upgrades are essential in order to make a profit in the competitive power market. Thus, renewable energy sources such as wind, solar, biomass, and geothermal are attractive alternatives for power utilities. Renewable energy systems offer several advantages over conventional energy sources such as natural gas or coal. First, renewable energy systems are clean sources of energy found in most regions, and they emit no greenhouse gases. Renewable energy sources are also abundant, free, and generally not affected by political instability. Although the initial capital cost for most renewable energy sources is greater than conventional natural gas or coal power plants, renewable may be more cost-effective long term as compared to conventional sources because of lower operating and maintenance costs. Wind energy generation began in the 1980s when wind turbines with only a few tens of kW rating were connected to power grids without much control. Due to variations of wind speed, generated power was associated with pulsations applied directly to the grid. Furthermore, this system had no control on active and reactive power transfer. Today, great improvements in wind energy generation necessitate the use of power electronics in order to control active and reactive power transfer between wind turbines and main grids. The rapid development of power electronics as well as increasing energy demand has increased power electronics usage in renewable energy systems. In addition, DG application in power systems has led to increased use of power electronics to regulate renewable energy sources tied to main

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grids. Figure 1 shows the configuration of power electronics for wind energy sources

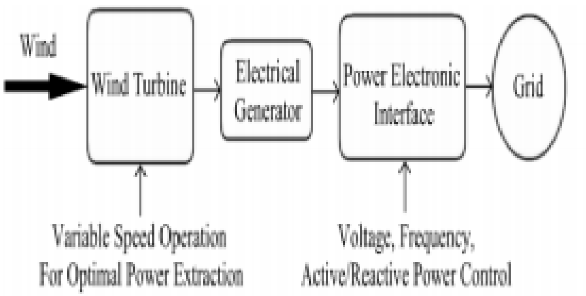

Fig.1 Application of power electronics in wind energy systems

II. CONCEPT OF THE MMCTOPOLOGY

Modular Multilevel Converter (MMC) is the most advanced topology for large scale commercial deployment. MMC is the topology used by SIEMENS for HVDC Plus technology [9-10]. The structure of this topology is based on several modules in which each module consists of a floating capacitor and two switches. This topology is an ideal choice for FACTS applications if the capacitor voltages maintain balanced. MMC is able to transfer active and reactive power regardless of the load characteristics. The main drawback of this topology is that it requires large capacitors in comparison with similar topologies which may affect the total cost of the inverter. However, this problem can be alleviated by the lack of need for any snubber circuits.

The main benefits of the MMC topology are: modular design based on identical converter cells, simple voltage scaling by a series connection of cells, simple realization of redundancy, and possibility of a common DC bus [11-13]. Figure 2(a) shows the circuit configuration of a single-phase MMC. The converter is composed of an arbitrary number of identical sub-modules (SMs). An nlevel single-phase MMC consists of a series connection of basic SMs and two buffer inductors. Fig. 2(b) shows the structure of each SM consisting of two power switches and a floating capacitor. The output voltage of each SM is equal to zero if the main switch (Sm) is On and the auxiliary switch (Sc) is Off or is equal to the SM's capacitor voltage (Vc) if Sm is Off and Sm is On. A complicated control strategy is required in order to keep the capacitors voltages balanced. In other words, each SM has two distinct states in normal operation. The first state is when the capacitor is On (Sc is On and Sm is Off). Depending on the polarity at the SM terminals, current either flows through or its freewheel diode.

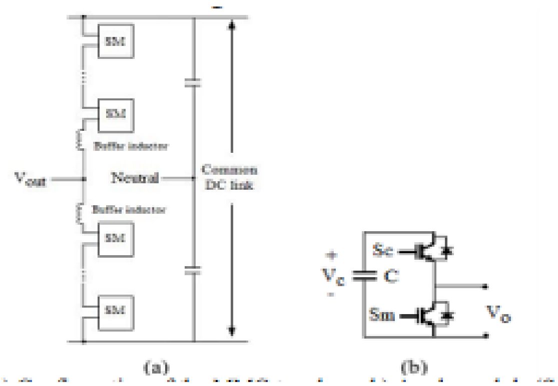

Fig.2 a) Configuration of the MMC topology, b) A sub-module (SM)

By properly switching between these two states, proper voltage can be maintained for each SM. Therefore, the total DC side is the sum of all capacitors voltages in one leg. In this topology, the high number of levels reduces the average switching frequency without compromising of power quality. This topology has found practical applications with up to 200 SMs per phase and up to 400 MW. The DC link of the MMC is connected to the distributed energy source (i.e., a wind turbine) through a rectifier using maximum power point tracker (MPPT).The output terminal of the MMC is connected to the utility grid through a series-connected second-order filter and a distribution transformer balanced.

III. CONTROLLER DESIGN

The aim of the designed D-STATCOM inverter is to provide utilities with distributive control of VAR compensation and power factor (PF) on feeder lines. This inverter is able to control the active and reactive power regardless of the input active power required by the DC link. Generally, there are two modes of operation for DSTATCOM inverter when it is connected to the grid: 1) when active power is gained from the wind turbine and it powers the DC link, which is called inverter mode, 2) when no active power is gained from the wind turbine, which is called DSTATCOM mode. The proposed DSTATCOM

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inverter is able to maintain the PF of the grid at a certain target value whether the DC link capacitors are charged by the current comes from the rectifier or the DC link is open circuited and DC link capacitors are charged by the grid. The power flow between a STATCOM and a line is governed by the same equations that describe the power flow between two active sources separated by an inductive reactance. For normal transmission lines this inductive reactance, modeled by jX in Fig. 3, is the inductance of a transmission line. For a STATCOM the modeled inductance is the inductance ofthe transformer that connects the STATCOM to the line.In Figure 3 the RMS voltage of the STATCOM is given as Es and is considered to be out of phase by an angle of δ to the RMS line voltage: El . The active power transferred from the STATCOM to the line is given by (6) and the reactive power transferred from the STATCOM to the line is given by (7).

$$P_S = \frac{E_S E_L}{X} \sin\delta \quad (6)$$

$$Q_s = \frac{E_s E_L \cos\delta - E_L^2}{X} \quad (7)$$

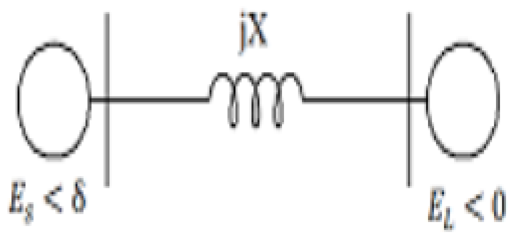

Fig.3 Simple system diagram describing the power flow between two sources

IV. SIMULATION RESULTS

Here the simulation is carried out by two different cases they are five and seven level DSTATCOM models

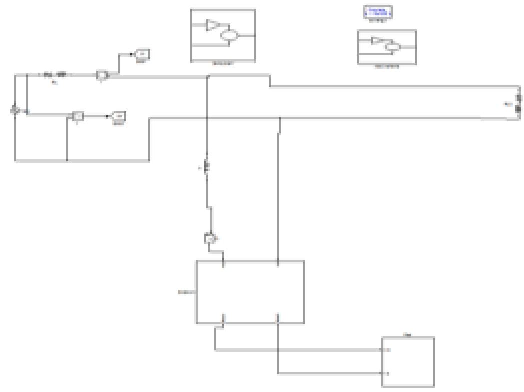

Fig.4 shows the Matlab/simulink model of proposed converter

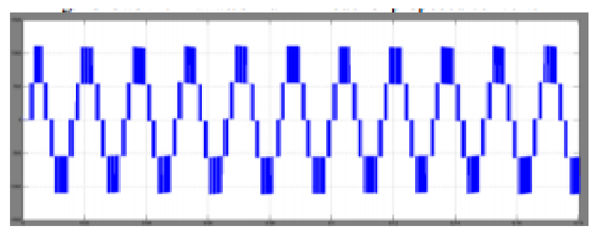

Fig.5 Output voltage of the D-STATCOM for five level inverter

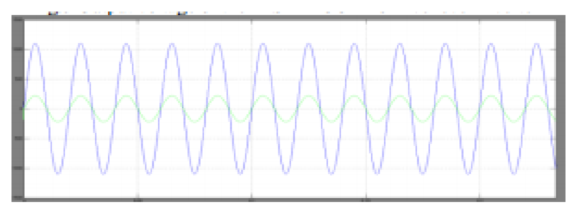

Fig.6 Power factor of the grid

V. CONCLUSIONS

A novel symmetrical multilevel inverter topology has been proposed in this paper. The most important feature of the system is being convenient for expanding and increasing the number of output levels simply with less number of bidirectional switches. This method results in the reduction of the number of switches, the multilevel inverter generates near-sinusoidal output voltage and as a result, has very low harmonic content. In five level THD value is 53.38% without filter and seven level inverter THD is 17.68% so we observe both THD for different levels to increase level to reduce the THD means power quality is improved. The proposed single-phase DSTATCOM inverter using MMC topology can actively regulate the reactive power on individual feeder lines while providing the variable output power of the renewable energy source. The aim is to provide utilities with distributive control of VAR compensation and power factor correction on feeder lines. The proposed DSTATCOM inverter performs in two modes: 1) inverter mode, in which there is a variable active power from the wind turbine, 2) D-STATCOM mode, in which the DC link is open circuit and no active power is gained from the renewable energy source. Finally by increasing the levels, power quality is also improved so in the next generation this concept can be implemented at the higher levels to improve the Power Quality.

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