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A Single-Phase D-Statcom Five Level Inverter for Wind Applications

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***Abstract*-Application of renewable energy systems has become very popular, increasing application of renewable energies in utilities can result in problems for the whole system dynamics. This dissertation presents the design of a novel multi-level inverter with FACTS capability for small to mid-size (10–20kW) permanent-magnet wind installations using modular multi-level converter (MMC) topology. The aim of the work is to design a new type of inverter with D-STATCOM 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 concepts of inverter and D-STATCOM using multi-level topology in a single unit without additional cost. Simulations of the proposed inverter, with 5 levels, have been conducted in MATLAB/Simulink. 5 level inverter is able to fix PF of the grid. Furthermore, total cost of the prototype models, which is one of the major objectives of this research, is comparable with market price**

Keywords- MMC- modular multi-level converter, PF-power factor.

I. INTRODUCTION

The electric utility industry has begun to update more and more in recent years, Relevant issues such as global warming, toxic emissions, 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. 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 With the exception of hydro, wind energy currently has the greatest share in renewable energy sources. The capacity of wind has more than doubled during the last two decades and the cost has decreased by one-sixth . Rapid progress in wind technology has reduced wind energy cost to such an extent that it is competitive with conventional energy. Most commercial wind systems include a horizontal-axis wind turbine, and a generator connected to the grid using power electronic converters. Generally, wind generation systems utilizing permanent magnet (PM) generators possess a rectifier associated with a maximum power point tracker (MPPT) and an inverter. Figure provides the configuration of a PM-based wind system [1]. Power electronic-based flexible AC transmission systems (FACTS) have been developed in order to enhance Control of active and reactive power transfer on feeder lines. FACTS components have been found to be the most efficient and economical method to control power transfer in interconnected AC transmission systems. FACTS systems include a wide range of power electronic devices used in power systems to ensure secure power transmission in AC systems . One of the most well-known FACTS devices is the static synchronous compensator (STATCOM), a STATCOM is a power electronic device based on a voltage source converter (VSC) [2]. The STATCOM is able to connect in parallel with a power system and act as a source, or sink, of reactive power in order to enhance power quality of the systems. It can also provide active power if connected to a source of power such as a renewable energy source If the STATCOM is applied on a distribution system, it is called distribution STATCOM (D-STATCOM). The application of D-STATCOM is very similar to a regular STATCOM. STATCOMs are typically utilized on the high-voltage side of the distribution systems because of their high cost. Deploying STATCOMs at the consumer level is not economically feasible. The aim of this work is to combine the two concepts of inverter and D-STATCOM in a single unit in order to enjoy the benefits of an inverter with D-STATCOM capability with no additional cost. The inverter with FACTS (D-STATCOM) capability is a power electronic device that is placed between the renewable energy source and the distribution grid has capability to provide power factor control by regulating active and reactive power control on the system[3][4][5].

II. LITERATURE SURVEY

This paper presents a new D-STATCOM Inverter is presented for small to mid-sized wind turbine applications. The proposed 5-level inverter is regulating the power factor of the capable of Line using hybrid-clamped multi-level topology. It is also able to eliminate a great number of harmonics using OHSW Technique. Simulations are carried out in MATLAB/Simulink The results show that the OHSW technique is a feasible Modulation scheme for the D-STATCOM Inverter and that the Hybrid-clamped topology is capable of operating under the Dynamic conditions presented by a wind turbine. Also, simulation results show that the THD is actually lower than the predicted THD because some of the harmonics are suppressed by the inductances and capacitances in the circuit [1].

This paper proposes a digital control system for a voltage-controlled D-STATCOM applied to single-phase low-voltage distribution networks. With this control system, the D-STATCOM maintains the PCC voltage regulated even under severe load and/or grid disturbances. Results included in the paper demonstrate that the proposed system has good steady-state and transient performances with large load variations, as well as with parametric variations. Therefore, this voltage regulation system can be used as an immediate and temporary solution to minimize problems caused by inadequate voltage levels, until a permanent solution is implemented [2].

This paper presents the concept of a D-STATCOM electrical converter is bestowed. The projected electrical converter suggests a brand new approach during which tiny renewable sources may be wont to offer management and support in distribution systems. The cascaded 9 level DSTATCOM electrical converter has the flexibility to supply utilities with electrical phenomenon volt-ampere compensation and decreases the total harmonic distortion. The distinctive work of this analysis is to mix the 2 ideas of D-STATCOM and electrical converter victimisation the foremost advanced multi-level topology to form one unit known as D-STATCOM electrical converter. Within the current analysis a brand new D-STATCOM electrical converter victimization the foremost advanced multi-level topology known as cascaded is bestowed. During this project, cascaded multilevel topology is employed because the voltage supply device (VSC) topology to form a D-STATCOM that's not solely able to regulate reactive power however is ready to link to a turbine and regulate the active power transferred to the grid [3].

This paper presents the concept of the inverter of D-STATCOM for 5-level and 7-level are simulated and compared. The renewable energy source like wind energy source system is used to provide the continuous and pure power supply at the distribution side of the system. As the output power of the wind turbine is not vary with the different levels of inverter the total cost of the system is reduced. But the Total Harmonic Distortion (THD) of the system is reduced to a maximum extent. Thus FACTS devices like D-STATCOM can be used in small and mid-size wind application with less distortion in the system. The proposed device provides an inverter and D-STATCOM in a single unit without any additional cost. The proposed DSTATCOM inverter can provide utilities with more knowledge at end points of the distribution lines. The goal is to increase the penetration of renewable energy systems, specifically wind, to the distribution systems [4].

This paper proposes DSTATCOM system is an efficient mean for mitigation of PQ disturbances introduced to the grid by DERs. DSTATCOM compensator is a flexible device which can operate in current control mode for compensating voltage variation, unbalance and reactive power and in voltage control mode as a voltage stabilizer. The latter feature enables its application for compensation of dips coming from the Performance of DSTATCOM system has been supplying network. The simulation results show that the found to be satisfactory for improving the power quality at the consumer premises. DSTATCOM control algorithm is flexible and it has been observed to be capable of correcting power factor to unity, eliminate harmonics in supply currents and provide load balancing. It is also able to regulate voltage at PCC. The control algorithm of DSTATCOM has an inherent property to provide a self-supporting DC bus of DSTATCOM. It has been found that the DSTATCOM system reduces THD in the supply currents for non-linear loads. Rectifier-based non-linear loads generated harmonics are eliminated by DSTATCOM When single-phase rectifier loads are connected, DSTATCOM currents balance these unbalanced load currents [5].

III. PRPOSED DESIGN AND STRUCTURE OF THE D-STATCOM

The proposed inverter is able to correct the power factor of the line, especially at the end points of the distribution lines where there is not enough attention to the line behavior. Multiple D-STATCOM inverters on the feeder lines would help utilities increase their knowledge of the distribution system leading to greater efficiency, reliability, and control. The unique work in this paper is the bringing together and combination of several relatively new concepts. The design objectives of the project include: minimize the overall switching frequency of the inverter; minimize the total harmonic distortion in order to maintain compliance with IEEE standards and maximize energy conversion efficiency; and finally, keep the cost of the inverter as low as possible. The D-STATCOM Inverter falls under the category of devices known as custom power electronics. Most of the research on custom power electronics has stemmed from the research done on STATCOM devices that integrate battery energy storage. Generally, the purpose of the D-STATCOM Inverter is to increase the value to the utility of a small wind turbine located on a single-phase feeder line by providing extra control and information. The D-STATCOM Inverter represents one stage of a three-stage power electronics block that makes up the entire converter structure. The first of these first of these stage is wind turbine maximum point tracker (MPPT) This stage transfers the maximum power from wind turbine while transferring Quasi Dc output of permanent magnet generator into uniform dc voltage .The second stage, the DC-DC boost, boost provided by the MPPT to the desired DC link voltage required by the D-STATCOM Inverter The final stage of D-SATCOM inverter focus of this research is the voltage source converter source converter that can provide the grid with VAR control and power factor correction independents of wind turbine production Fig1-shows system structure.

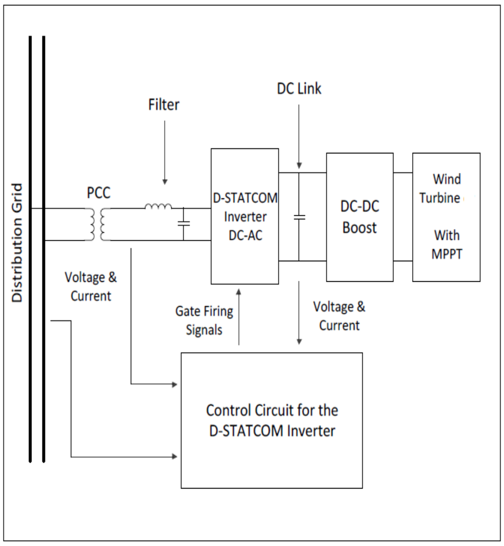

Fig1-System structure

II. PROPOSED CONTROL STRATEGY

This inverter is designed to control the flow of active and reactive power between the wind turbine and the grid. It is able to provide utilities with distributive control of VAR compensation and power factor (PF) on feeder lines. To enhance the reactive power control of the proposed inverter, it is equipped with the additional D-STATCOM option. This option permits the inverter to deliver reactive power fully independent from the wind speed. When the wind speed is too low to generate active power, the inverter acts as a source of reactive power to control the PF of the grid, like a D-STATCOM. The 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 D-STATCOM inverter when it is connected to the grid: 1) when active power is gained from the wind turbine, which is called inverter mode, 2) when no active power is gained from the wind turbine, which is called D-STATCOM mode. The active and reactive power flow of the D-STATCOM is governed by,

$$P = \frac{E_S E_L Sin\delta}{X}$$

$$Q = \frac{mE_S E_L Cos\delta - E_L^2}{X}$$

WhereEs, EL, δ and m are the voltage of the STATCOM, voltage of the line, power angle, modulation index, and inductance between the inverter and the grid, respectively. The steady state operation of the D-STATCOM inverter is controlled by adjusting δ and m, so that it provides the desired amount of active power and reactive compensation. The modulation index is used to control the active power while the power angle is used to control the reactive power transferring between the wind turbine and the grid.

V. MULTI-LEVEL TOPOLOGY

Numerous industrial applications require medium to high power capability. Some medium voltage For a medium- to high-voltage power application, rating limitations of power electronic components do not allow to connect only a single power semiconductor switch. Therefore, a multi-level converter can be a suitable alternative for these applications. Multi-level converters can also be a suitable choice for renewable energy systems. During the past three decades, several multi-level topologies have been developed Modular multilevel converter (MMC) topology is a new multi-level topology that recently has gained much attention, specifically for mid- to high-voltage applications. Primary benefits of MMC topology include: modular design based on identical converter cells, simple voltage scaling by a series connection of cells, simple realization of redundancy, and the possibility of a common DC bus. The diode-clamped (DC) Topology, also called neutral-point clamped (NPC), topology is based on the utilization of a number of diodes in order to block small DC sources. The configuration of a single-phase 5-level diode-clamped inverter is shown in Figure 2.

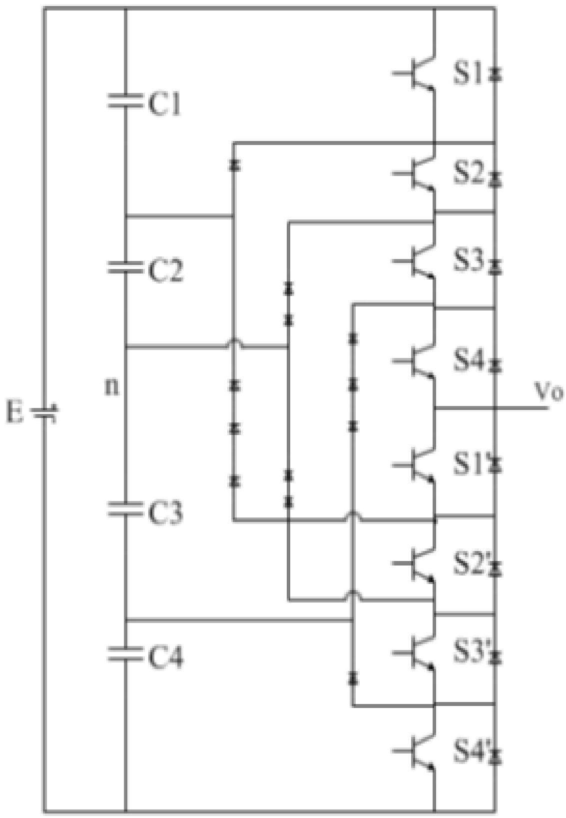

Figure 2. Single-phase 5-level DC topology

The DC topology can easily be extended to a generic n-level configuration in a 5-level diode-clamped inverter; the DC bus voltage is split into four equal voltage steps. In this case, the number of diodes required to clamp the voltage changes point by point. Each diode is sized to provide voltage blocking for the voltage across one capacitor. For instance is represented only by one diode, while D1'is represented by three diodes equal to D1,which are in series because it must block voltage across capacitors C2,C3andC4 , meaning that it is allowed to use one diode with higher blocking capability or three diodes in series with equal blocking capability to D1. Considering the diode reverse voltage for an n-level inverter, calculated by

Vr=E/n-1, the diode reverse voltage for a 5-level inverter is equal to E/4 , thus demonstrating that increasing the number of levels results in decreased voltage stress on the components. Operation of 5-level NPC topology is shown in Table I.

Table I: Switching table for the 5-level DC topology

Switches								Output Voltage
S1	S2	S3	S4	S1’	S2’	S3’	S4’	Vo
1	1	1	1	0	0	0	0	+E/2
0	1	1	1	1	0	0	0	+E/4
0	0	1	1	1	1	0	0	0
0	0	0	1	1	1	1	0	-E/4
0	0	0	0	1	1	1	1	-E/2

In Table I, the on-state and off-state of the switches is shown by 0 and1, respectively. Any shortcut should be avoided in each of the switching states, meaning that all switches cannot be turned on simultaneously.

In addition, Si and Si’, where i is the number of the switches, should be switched in a complementary way. For instance, when is S1 is on, S1’should be off and vice versa. This has to happen for all the other switches.

VI. CONCLUSION

The concept of a D-STATCOM Inverter is presented and shows a new way in which distributed renewable sources can be used to provide control and support in distribution systems. The D-STATCOM Inverter is able to provide utilities with capacitive VAR compensation and demonstrates how distributed renewable sources can strengthen the existing grid, not weaken it. In this paper, a multilevel topologies and modulation schemes are discussed. The design of a 5-level D-STATCOM Inverter using the hybrid-clamped topology is presented. The hybrid-clamped topology is able to operate under the dynamic conditions presented to it by a wind turbine. The design objectives of the inverter were to minimize: the overall switching frequency, the total harmonic distortion, and the overall cost of the inverter, the overall total harmonic distortion at the output of the inverter is reduced. However, the current 5-level inverter would be unable to meet grid requirements without implementation of a large and bulky filter thus more levels would be required for practical implementation of the OHSW scheme. Finally, the cost of the inverter if built would be rather high due to both the number of components used in the hybrid-clamped topology as well as the need for a customized transformer to boost the output voltage to grid level.

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