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A Single Phase Inverter with D-Statcom Capability for Small Wind Turbine

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Abstract—*This paper presents the design of a novel multi-level D-STATCOM inverter for renewable energy systems using modular multi-level converter (MMC) topology. The aim of the work is to design a new type of inverter with FACTS capabilities to provide utilities with more knowledge about the distribution systems, specifically on end points. The inverter is placed between the renewable energy source, specifically a wind turbine, and the distribution grid in order to regulate the active and reactive power required by the grid. This inverter is capable of controlling active and reactive power by controllingits phase angle and modulation index, respectively. The unique contribution of the proposed work is to combine the two concepts of inverter and D-STATCOM using a novel voltage source converter (VSC) multi-level topology in a single unit without any additional cost. Simulations of the proposed inverter, with threelevels, have been completed in Matlab/Simulink. The simulation resultsvalidate the performance of the proposed control strategy.*

1. INTRODUCTION

The electric utility industry has begun to update more and more in recent years. New issues such as global warming, toxic emissions, energy cost, a broadening power market, and increasing demand have affected the growth ofthe power industry. Over the past decade, the willingness of utilities to invest in large-scale power plants has decreased and utilities have started shifting to smaller distributed energy sources closer to loads. Renewable energy systems offer several advantages over conventional energy sources such as natural gas or coal. They are clean sources of energy that can be found in most regions without emitting any greenhouse gases. Renewable energy is abundant andfree, and generally not affected by political instability. The main disadvantage of renewable energysources is that they are mostly located in remote areas and far away fromlarge loads. In addition, the use of renewable energy sources is limited by the fact that they are not always available.Nowadays, with recent developments in semiconductor technologies, power electronic devices have been enormously deployed in power systems to control the active and reactive power flow. A power electronic device is one that consists of a number of semiconductor components that is used to perform a specific function in a system. There are a number of advantages to use power electronic devices, but the most important is the capability to control and manage the flow of electrical power. Using power electronics has made it possible to connect AC or DC sources with different voltage or frequency levels to each other. Among all power quality concerns, controlling the active and reactive power transferring to or from the grid requires major attention. Power electronic-based flexible AC transmission System (FACTS) devices have been developed in order to provide more knowledge and control on power systems.

Traditionally, capacitor banks have been used to control the reactive power on a power grid, but with deployment of power electronics in power systems, STATCOMs were born and received more and more attention during recent years. The aim of this work is to combine the two concepts of inverters and D-STATCOMs into a so-called D-STATCOM inverter in order to enjoy the benefits of an inverter with DSTATCOM capability without any additional cost. A multilevel D-STATCOM inverter is a power electronic device that is placed between a renewable energy source and a distribution grid not only to provide active power, but to control reactive power on the system. Multi-level converters have several advantages compared to the conventional two level converter. They have the capability to perform at a lower switching frequency, they have lower total harmonic distortion (THD), and they have less dv/dt across switches and therefore less voltage stress on the devices [2-6]. The proposed D-STATCOM inverter in this paper could replace existing inverters used for renewable energy systems, specifically for small- to mid-sized wind applications. The D-STATCOM inverter is a cost-effective inverter with a DSTATCOM's capability to regulate active and reactive power on distribution systems. Deployment of DSTATCOM inverters can provide utilities with more information and control, specifically at end points that utilities do not monitor adequately. The unique contribution of this work is to combine the two concepts of inverter and D-STATCOM using modular multi-level converter (MMC) topology in a single unit, which is in series with the renewable energy source, without any additional cost. Fig. shows a

complete configuration of the proposed MMC inverter with FACTS capabilities.

2. METHODOLOGY

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 are kept balanced. It requires only one DC source which is proper for renewable energy inverters, it is easy to design for higher levels, and it can deliver active and reactive power regardless of the load characteristics. MMC has a modular design based on identical converter cells which make it a suitable choice for high-level applications. 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. Each leg of an n-level MMC inverter consists of several basic sub-modules (SMs) and two inductors which are in series. Thislowers di/dv and therefore the voltage stress across the switches.

3. BLOCK DIAGRAM

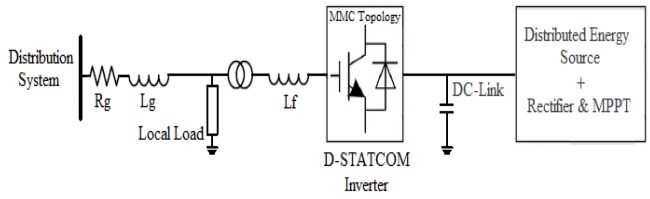

Fig. 1: D-STATCOM inverter system

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 noactive power is gained from the wind turbine, which is called D-STATCOM mode.

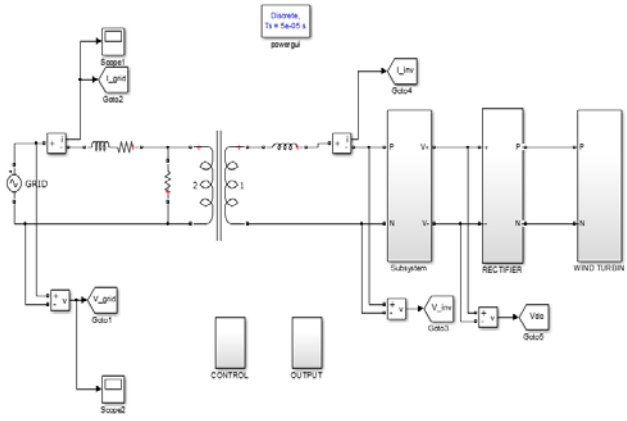

Fig. 2: D-STATCOM inverter system simulation

4. PROPOSED D-STATCOM INVERTER

At this time, the modular multilevel converter (MMC) isthe newest topology for large scale commercial applications. FIG. shows the configuration of the MMC topology.The structure of this topology is based on several modules inwhich each module consists of a floating capacitor and twoswitches. This topology is an ideal choice for FACTSapplications if the capacitor voltages are kept balanced. Itrequires only one DC source which is proper for renewableenergy inverters, it is easy to design for higher levels, and itcan deliver active and reactive power regardless of the loadcharacteristics. MMC has a modular design based onidentical converter cells which make it a suitablechoice for high-level applications. The main drawback ofthis topology is that it requires large capacitors incomparison with similar topologies which may affect thetotal cost of the inverter. However, this problem can bealleviated by the lack of need for any snubbed circuits. Eachleg of an n-level MMC inverter consists of several basic sub modules (SMs) and two inductors which are in series. Thislowers dv/dt and therefore the voltage stress across theswitches.

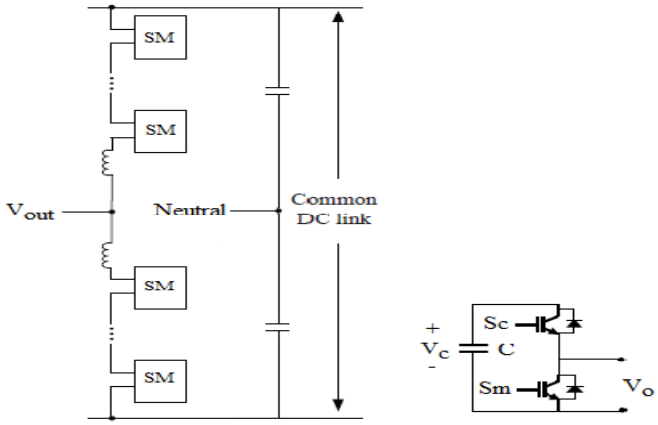

Fig. 3: Configuration of the MMC topology and its sub-module

5. CONTROL SYSTEM

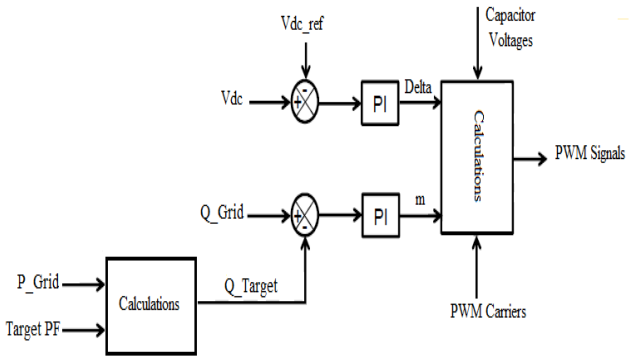

Fig. 4: The proposed controller system

The control system consists of three separate parts. Thefirst part is to define the modulation index which is done bycomparing the actual reactive power on the grid with therequired reactive power considering the target power factor(PF). The second part is to define the power angle which isdone by comparing the DC link voltage with a referencevoltage defined by the specifications of the inverter. Thedefined values of modulation index and power angle areapplied to the reference sinusoidal signal which is required togenerate the PWM signals. The third part of the controlsystem is to select the required SMs to generate the propergate signals. Generally, the controller measures the SMs'capacitor voltages and sorts them in descending order. Thesuitable switching pattern will be chosen based on thedirection of the current flowing through the switches.

6. OUTPUT RESULT

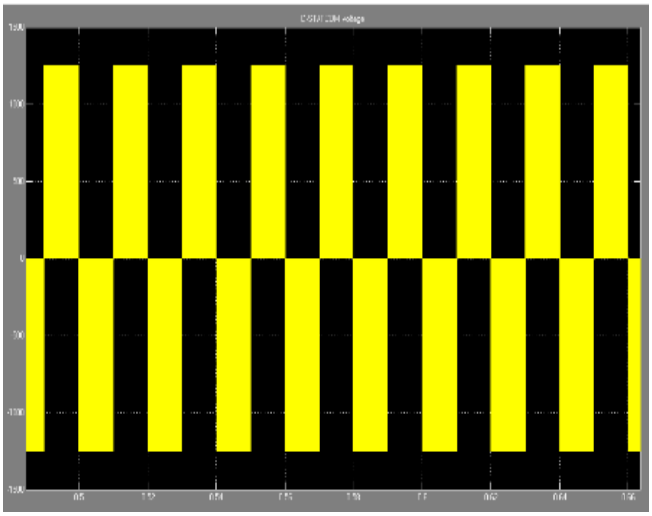

Fig. 5: Output voltage of the D-STATCOM inverter

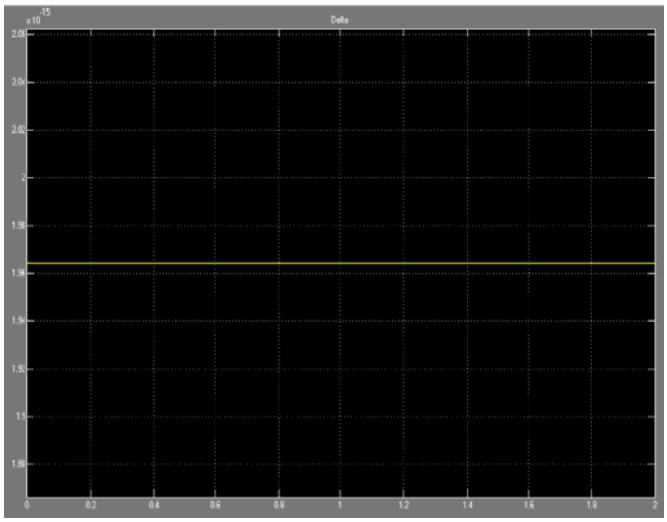

Fig. 6: Power angle

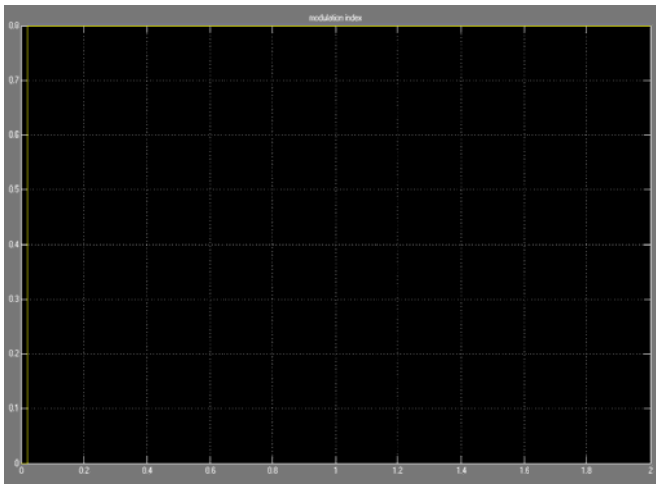

Fig. 7: modulation index

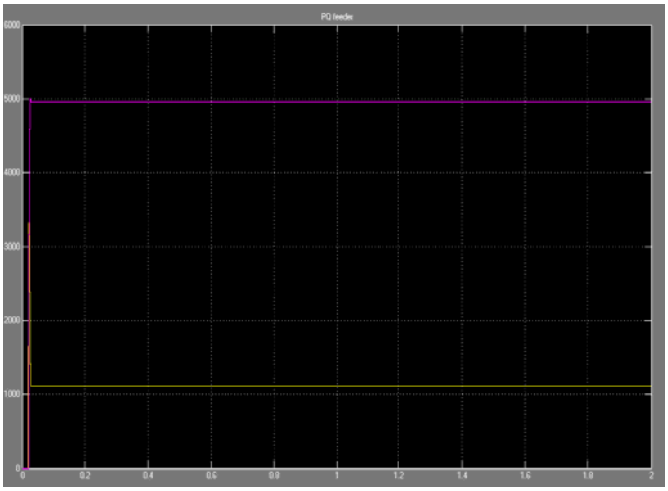

Fig. 8: PQ FEEDER

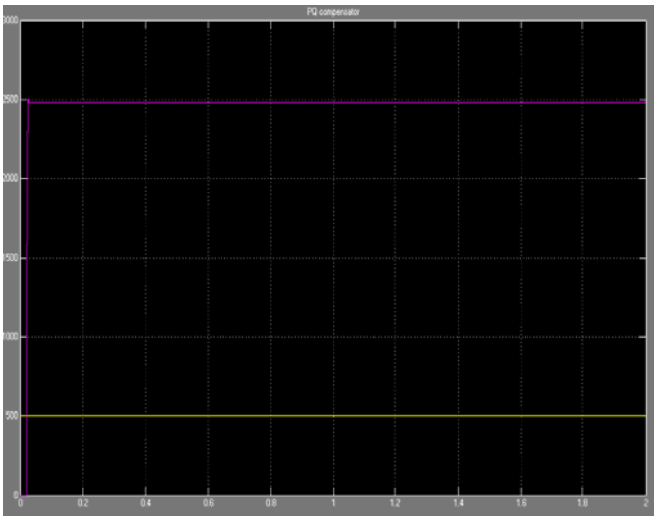

Fig. 9: PQ COMPENSATOR

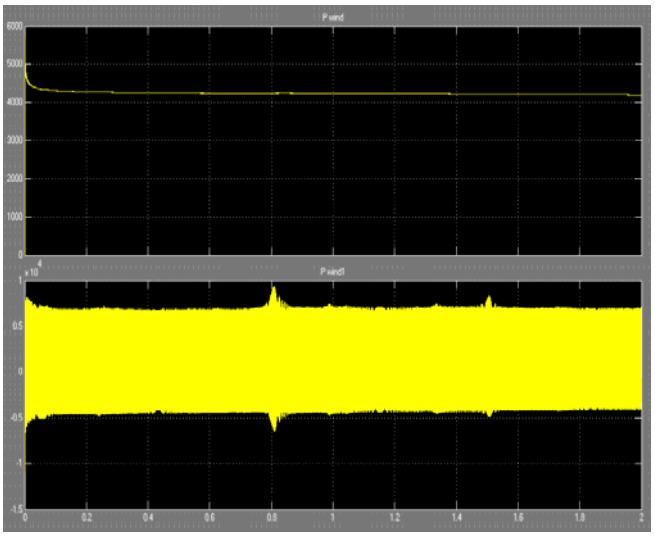

Fig. 10: PQ wind

7. CONCLUSIONS

In this proposal the concept of a D-STATCOM inverter is presented. The proposed inverter suggests a new way in which small renewable sources can be used to provide control and support in distribution systems. The MMC DSTATCOM inverter has the ability to provide utilities with capacitive VAR compensation. The unique work of this research is to combine the two concepts of D-STATCOM and inverter using the most advanced multi-level topology to make a single unit called D-STATCOM inverter. In the current research a new D-STATCOM inverter using the most advanced multi-level topology called MMC is presented. In this project, MMC is used as the voltage source converter (VSC) topology to make a D-STATCOM that is not only able to regulate reactive power, but is able to link to a wind turbine and regulate the active power transferred to the grid. 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.

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