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Power Quality Improvement Features for Distributed Energy System by Using 11- Level Inverter

Angala Anil Kumar
Master of Technology-Power Electronics & Electric Drive, PostGraduate Student,
Vignan Institute of Technology and Sciences,
Nalgonda

K.Venkateswarlu
Master of Technology,
Assistant Professor,
Vignan Institute of Technology and Sciences,
Nalgonda

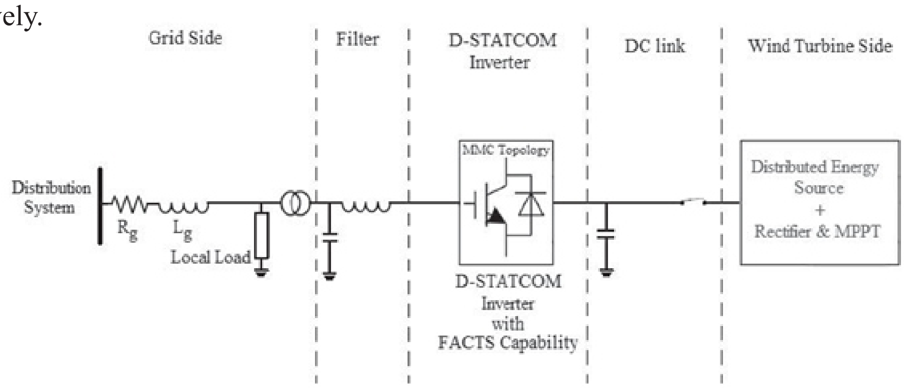
Abstract:

In this paper, a new single-phase wind energy inverter (WEI) with flexible AC transmission system (FACTS) capability is presented. The proposed inverter is placed between the wind turbine and the grid, same as a regular WEI, and is able to regulate active and reactive power transferred to the grid. This inverter is equipped with distribution static synchronous compensators option in order to control the power factor (PF) of the local feeder lines. Using the proposed inverter for small-to medium-size wind applications will eliminate the use of capacitor banks as well as FACTS devices to control the PF of the distribution lines.

The goal of this paper is to introduce new ways to increase the penetration of renewable energy systems into the distribution systems. This will encourage the utilities and customers to act not only as a consumer, but also as a supplier of energy. Moreover, using the new types of converters with FACTS capabilities will significantly reduce the total cost of the renewable energy application. In this paper, modular multilevel converter is used as the desired topology to meet all the requirements of a single-phase system such as compatibility with IEEE standards, total harmonic distortion (THD), efficiency, and total cost of the system. The proposed control strategy regulates the active and reactive power using power angle and modulation index, respectively.

The function of the proposed inverter is to transfer active power to the grid as well as keeping the PF of the local power lines constant at a target PF regardless of the incoming active power from the wind turbine. The simulations for an 11-level inverter have been done in MATLAB/Simulink. To validate the simulation results, a scaled prototype model of the proposed inverter has been built and tested. The role of power electronics in distribution systems has greatly increased recently. The power electronic devices are usually used to convert the nonconventional forms of energy to the suitable energy for power grids, in terms of voltage and frequency.In permanent magnet (PM) wind applications, a back-to-back converter is normally utilized to connect the generator to the grid.

A rectifier equipped with a maximum power point tracker (MPPT), converts the output power of the wind turbine to a dc power. The dc power is then converted to the desired ac power for power lines using an inverter and a transformer. recent developments in wind energy, utilizing smarter wind energy inverters (WEIs) has become an important issue. There are a lot of single-phase lines in the United States, which power small farms or remote houses [1], [2]. Such customers have the potential to produce their required energy using a small-to-medium-size wind turbine. Increasing the number of small-to-medium wind turbines will make several troubles for local utilities such as harmonics or power factor (PF) issues.



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The uniquework in this paper is the use of MMC topology for a singlephasevoltage-source inverter, which meets the IEEE standard519 requirements, and is able to control the PF of the gridregardless of the wind speed Fig. 1 shows the completegrid-connected mode configuration of the proposed inverter.The dc link of the inverter is connected to the wind turbinethrough a rectifier using MPPT and its output terminal isconnected to the utility grid through a series-connectedsecond-order filter and a distribution transformer.

1.A high PF is generally desirable in a power system to decrease power losses and improve voltage regulation at the load. It is often desirable to adjust the PF of a system to near 1.0. When reactive elements supply or absorb reactive power near the load, the apparent power is reduced. In other words, the current drawn by the load is reduced, which decreases the power losses. Therefore, the voltage regulation is improved if the reactive power compensation is performed near large loads. Traditionally, utilities have to use capacitor banks to compensate the PF issues, which will increase the total cost of the system.

2.The modern ways of controlling the PF of these power lines is to use small distribution static synchronous compensators (D-STATCOMs). The D-STATCOMs are normally placed in parallel with the distributed generation systems as well as the power systems to operate as a source or sink of reactive power to increase the power quality issues of the power lines. Using regular STATCOMs for small-to-medium size single-phase wind applications does not make economic sense and increase the cost of the system significantly. This is where the idea of using smarter WEIs with FACTS capabilities shows itself as a new idea to meet the targets of being cost-effective as well as compatible with IEEE standards.

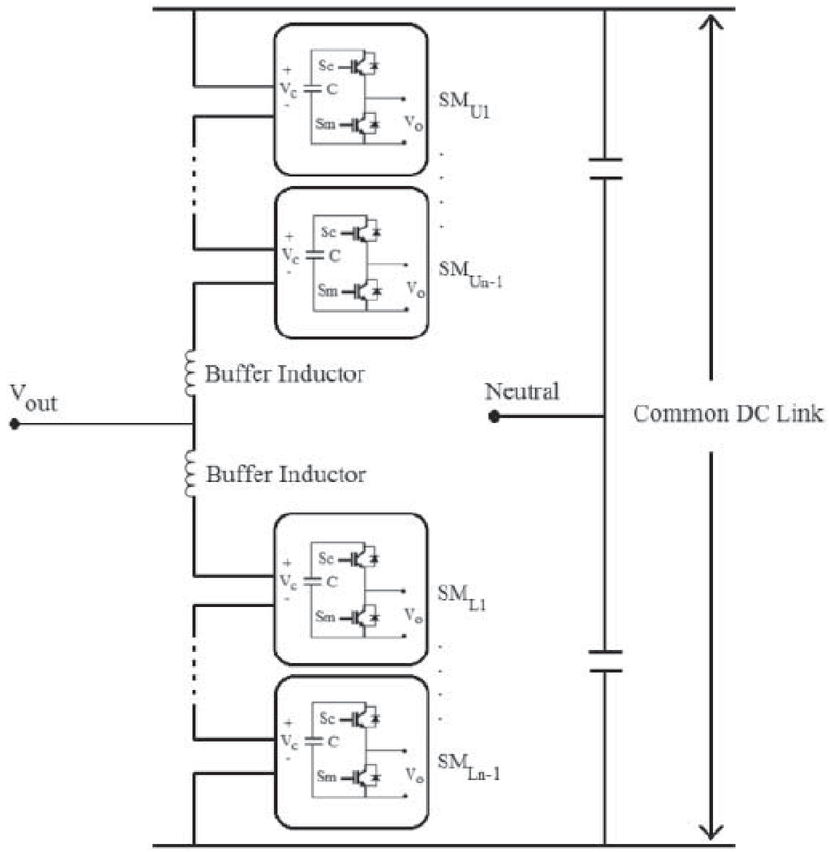

Fig. 2. Structure of a single-phase MMC inverter structure.

The main benefits of the MMC topology are: modulardesign based on identical converter cells, simple voltagescaling by a series connection of cells, simple realizationof redundancy, and possibility of a common dc bus. Fig. 2shows the circuit configuration of a single-phase MMC andthe structure of its SMs consisting of two power switches anda floating capacitor.

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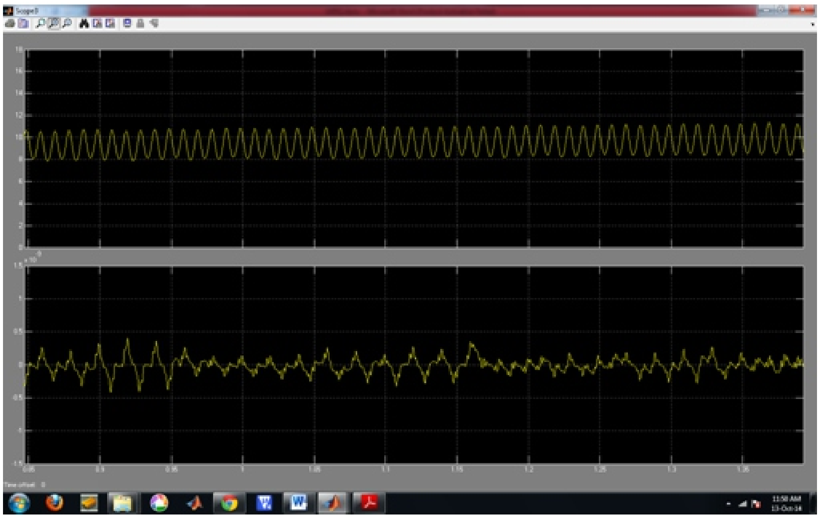
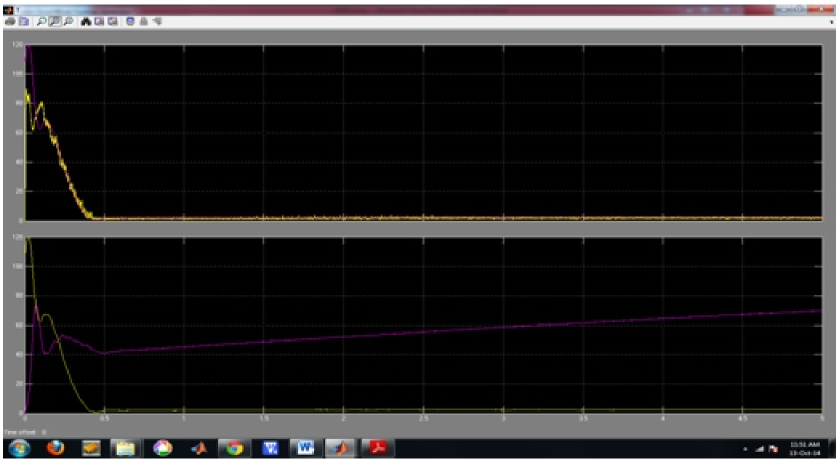
Output :
Screen shots:

Simulated output voltage of an 11-level inverter.



Simulated active and reactive power of the inverter



Torque of the wind turbine generator

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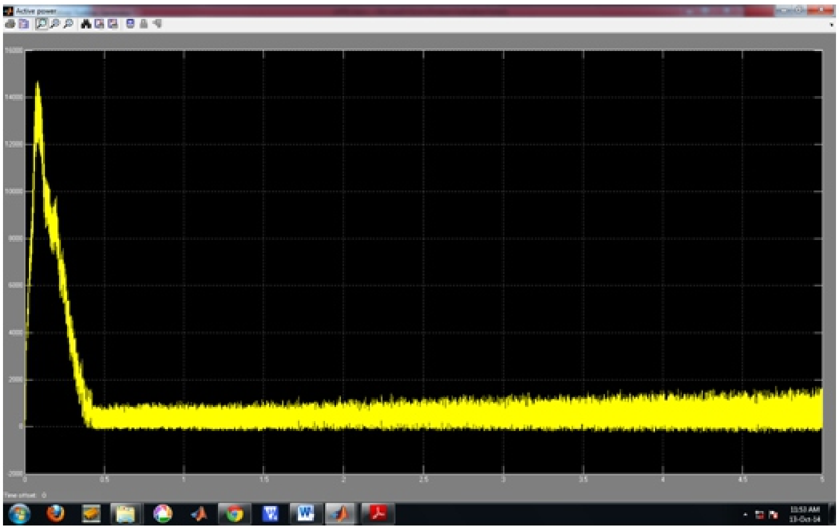

Active power of the wind generator turbine

Conclusion:

In this project, the concept of a new multilevel inverter with FACTS capability for small-to-mid-size wind installations is presented. The proposed system demonstrates the application of a new inverter with FACTS capability in a single unit without any additional cost. Replacing the traditional renewable energy inverters with the proposed inverter will eliminate the need of any external STATCOM devices to regulate the PF of the grid. Clearly, depending on the size of the compensation, multiple inverters may be needed to reach the desired PF. This shows a new way in which distributed renewable sources can be used to provide control and support in distribution systems.

The proposed controller system adjusts the active power by changing the power angle (delta) and the reactive power is controllable by the modulation index m. The simulation results for an 11-level inverter are presented in MATLAB/Simulink. To validate the simulation results, a scaled prototype of the proposed 11-level inverter with D-STATCOM capability is built and tested. Practical results show good performance of the proposed control strategy even in severe conditions.

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