A Study to Design and Implementation of an 11 Level Inverter with FACTS Capability for Distributed Renewable Energy systems

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Abstract

This paper presents, a single phase wind energy inverter (WEI) system having multilevel features with flexible AC transmission capability. The goal of this paper is to design a type of inverter with distribution static synchronous compensator (D-STATCOM) option to provide utilities with more control the power factor (PF) of distribution lines. The proposed inverter is placed between the wind turbine and grid, as regular WEI in order to regulate active and reactive power transferred to the grid, regardless of wind speed. With the help of this proposed inverter for small to medium size wind applications will eliminate the use of condenser banks as well as FACT devices to control the power factor (PF) of grid at target value, by regulating active and reactive power required by the distribution lines. The purpose of this paper is to present an idea to extend the penetration of renewable energy systems into distribution systems. In this D-STATCOM inverter modular multilevel converter topology is used, and in order to control active and reactive power by regulating the power angle and modulation index as per the requirement of distribution lines. our motive is to reduce the overall cost of system and total harmonic distortion (THD) and significantly trying to increase the efficiency of system by reducing the number of switches during designing of system .The simulation for this multilevel inverter proposed to be done by using MATLAB /SIMULINK .

Keywords: **Distribution static synchronous compensator (D-STATCOM), Power Factor (PF), Power Quality (PQ), Modular multilevel converter (MMC), multilevel inverter (MLI), wind energy inverter (WEI) ,Distributed Generator(DG).**

I INTRODUCTION

Power quality and efficiency issues arising from unmanaged power flow have been the major problem in power systems. Which include harmonics, low power factor, voltage collapse, and oscillations. Recently the role of power electronics in distribution systems has greatly increased. The Power electronic devices are usually used to convert the nonconventional energy to the suitable energy for power distribution lines (grid) by manipulating voltage, current, and frequency at a desired level. The back-to-back converter is normally used to connect the generator to the grid. In the permanent magnet (PM) wind applications, and are rectifier is used along with a maximum power point tracker (MPPT), in order to 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. With recent developments in wind energy, utilizing smarter wind energy inverters (WEIs) has become an important issue. In many countries (like USA) increasing the number of Small-to-medium (10-20k) wind turbines will make several trouble for local utilities such as harmonics or power factor (PF).To decrease power losses and improve voltage regulation at the load a high PF is generally desirable in a power system. In power system the value of PF should be near to 1.0. Which is obtain by supply or absorb the reactive power near to the load, the apparent power is reduced or we can say the current drown by the load is reduced, which decreases the power losses. Therefore the voltage regulation is improved.Traditionaly this reactive power compensation or PF improvement is done by using capacitor banks that increases the total cost of the system. 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. The proposed inverter in this paper is equipped with a D-STATCOM option to regulate the reactive power of the local distribution lines and can be placed between the wind turbine and the grid, same as a regular WEI without any additional cost. The function of the proposed inverter is not only to convert dc power coming from dc link to a suitable ac power for the main grid, but also to fix the PF of the local grid at a target PF by injecting enough reactive power to the grid. In the proposed control strategy, the concepts of the inverter and the D-STATCOM have been combined to make a new inverter, which possesses FACTS capability with no additional cost. The proposed control strategy allows the inverter to act as an inverter with D-STATCOM option when there is enough wind to produce active power, and to act as a D-STATCOM when there is no wind.

II LITERATURE SERVEY

There are many of publications on integration of renewable energy systems into power systems. An idea to design and implement 11 level inverter with FACT capability using MMC topology is well described in [1] .The concept to design a system having FACTs capability comes from [2] but in this paper there is no detailed information regarding the efficiency or topology used for the converter. Publication on FACTS applications for grid integration of wind and solar energy was presented in [3]. In [4], a complete list of the most important multilevel inverters was reviewed. Also, different modulation methods such as sinusoidal pulse width modulation (PWM), selective harmonic elimination, optimized harmonic stepped waveform technique, and space vector modulation were discussed and compared. Among all multilevel topologies [5]–[6], In [7] a recent multilevel inverter application and converter are well elaborated. And an inverter with D-STATCOM designing is introduced in [8] but without multilevel feature in the inverter. The cascaded H-bridge multilevel converter is very well known for STATCOM applications for several reasons [9-11] The main reason is that it is simple to obtain a high number of levels, which can help to connect STATCOM directly to medium voltage grids. The modular multilevel converter (MMC) was introduced in the early 2000s [12], [13]. Reference [8] and [14], a new single-phase inverter using hybrid clamped topology for renewable energy systems are presented. The proposed inverter is placed between the renewable energy source and the main grid. The main drawback of the proposed inverter is that the output current has significant fluctuations that are not compatible with IEEE standards, may be the problem is related to the snubber circuit design. Several other applications of custom power electronics in renewable energy systems exist, including [15] an application of a custom power interface where two modes of operation, including an active power filter and a renewable energy STATCOM. In this paper, the proposed WEI utilizes MMC topology, which has been introduced recently for HVDC applications. Replacing conventional inverters with this inverter will eliminate the need to use a separate capacitor bank or a STATCOM device to fix the PF of the local distribution grids.

III EXISTING SYSTEM

A high PF is generally desirable in a power system to decrease the power losses and improve voltage regulation at the load. For this purpose the power factor correction/Improvement is done

Through supply or absorb reactive power near to the current drawn by the load is reduced, which decreases the power losses. Hence the reactive power compensation is performed near large loads .In the existing system the voltage is regulated by capacitor banks and power factor improvements in done by shunt and series connection of capacitor which makes the system bulky and costly that is undesired. If we are going to use regular STATCOMs for small to medium size single phase wind application to avoid these capacitor banks that also does not make economic sense and increase the total cost of the system significantly. Fig (1) shows the block diagram of the existing system in which all the basic structure shown.

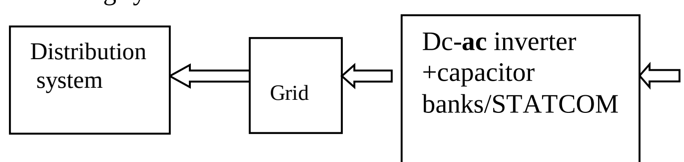
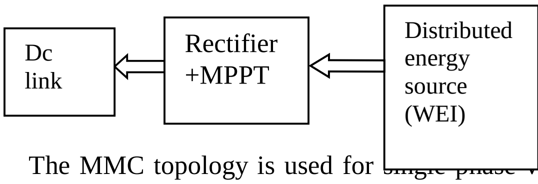


FIG:1 Block Diagram of Existing System.

Disadvantages of existing system:

1) Output current and voltage having significant fluctuation.
2) Does not provide good solutions for end users.
3) Subjected to unwanted PQ disturbances.
4) Total cost of the system is more for small to medium wind application
5) Less efficient.

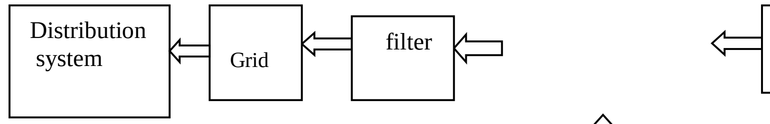
IV PROPOSED SYSTEM: The proposed inverter in this paper is equipped with D-STATCOM in order to regulate the reactive power of the local distribution lines and place between turbine and grid same as wind energy inverter (WEI) without any additional cost .The D-STATCOM used in the proposed system is not only converts the dc form of voltage coming from the dc link into desired ac form but also regulate PF of local load at a grid target PF by injecting enough reactive power to the grid. This concept of the inverter and D-STATCOM have been combined with no additional cost. In this strategy inverter act as an inverter with D-STATCOM option when there is enough wind to produce active power and it will act as just D-STATCOM when there is no wind. The active power controlled by adjusting angle $\boldsymbol{\delta}$,which is angle between the voltage of grid and the inverter, reactive power is regulated by controlling the modulation index m . The MMC topology is used for single phase voltage source inverter that meets the IEEE standards and capable to control PF of the grid regardless of the wind speed Fig. (2) Shows the complete grid-connected mode configuration of the proposed inverter



The MMC topology is used for single phase voltage source inverter that meets the IEEE standards and capable to control PF of the grid regardless of the wind speed Fig. (2) Shows the complete grid-connected mode configuration of the proposed inverter. The dc link of the inverter is connected to the wind turbine through a rectifier using MPPT and its output terminal is connected to the utility grid through a series-connected Second-order filter and a distribution transformer.

And the Fig (3) shows a model the proposed system in which configuration of the component used in the proposed system shows in which the wind turbine generator or we can say that wind energy source system is used which is nothing but a DG system that generate power for middle to small scale utilization of power, and the output of this system is in AC form or we say fluctuated AC form that is further fed to rectifier with MPPT circuitry and output is now converted into DC form which fed to the dc link system that reduces the complexity of the overall system and provide proper input to the D-STATCOM block for further distribution of the power to the transmission line.

And after passing through dc link this energy is fed to the D-STATCOM system having FACT capability which the key of configured proposed the system, where we are going to use MMC topology.



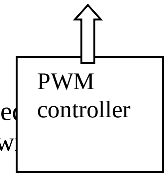
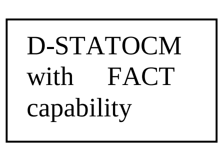


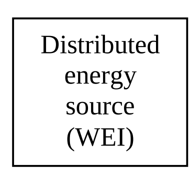
Fig.(2) block diagram of the proposed System

This D-STATCOM inverter system in controlle controller system that CPWM controller show Fig(5)

Which control the two mode operation of the proposed system .Now the output of the D-STATCOM inverter output is feed to the filter where noise regulation the voltage is done, then this regulated voltage is fed to the transformer that manage the voltage as per the requirement of the load or demand the users. The overall the poer distribution is done by the grid system followed by the transformer. In this proposed system our motive is to regulate power factor which is occur in the output of distributive generator or we can say wind energy conversion system. And also we wants reduce the harmonic components of voltage, trying to eliminate sag ,swell and increase the efficiency the of this system by reducing number of switch in the proposed system that will be completed on our further simulation of this model using MATLAB/simulink that is now in process in now days.

In MMC topology consists of several half-bridge (HB) sub modules (SMs) per each phase, which are connected in series. An n-level single phase MMC consists of a series connection of $2(n-1)$ basic SMs and two buffer inductors. Each SM having two semiconductor switches, which operate in complementary mode, . MMC requires large capacitors which may increase the cost of the systems; however, this problem is offset by the lack of need for any snubber circuit. The main benefits of the MMC topology are modular design based on identical converter cells; Fig. 4 shows the circuit configuration of a single-phase MMC and the structure of its SMs consisting of two power switches and a floating capacitor. This MMC topology is shows in Fig (4).





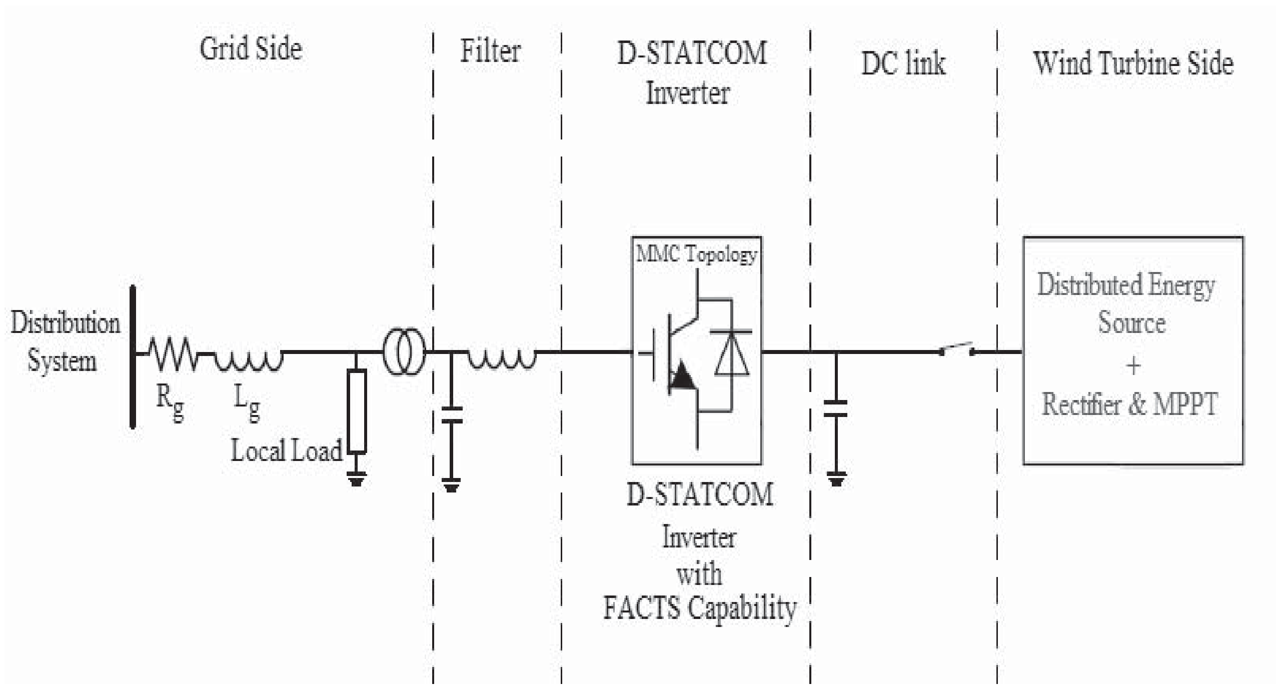


Fig (3) complete configuration of the proposed 11 level inverter with FACTS capability

1) When the wind is blowing and active power is coming from the wind turbine: the inverter + D-STATCOM mode. In this mode, the device is working as a regular inverter to transfer active power from the renewable energy source to the grid as well as working as a normal D-STATCOM to regulate the reactive power of the grid in order to control the PF of the grid.

2) When wind speed is zero or too low to generate active power: the D-STATCOM mode. In this case, the inverter is acting only as a source of reactive power to control the PF of the grid, as a D-STATCOM. This option eliminates the use of additional capacitor banks or external STATCOMs to regulate the PF of the distribution feeder lines.

This two mode operation is very good for the utilization of the proposed system. Because of this strategy the system is very efficient and the proposed system is very reliable. In the system that has to be design(11 level inverter) has also the option for the condition when there is no wind available that concept is unique for the wind energy conversion system. This concept is already used in the Photo voltaic power generation but now we are going to implement this theory also for the wind energy conversion system.

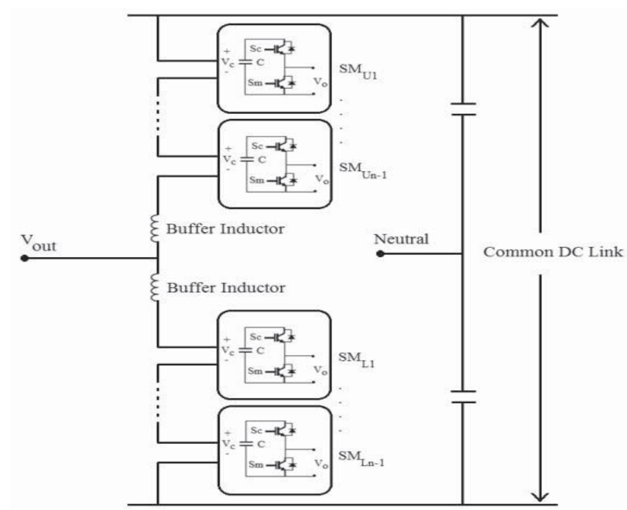


Fig.(4) shows the proposed MMC topology.

The relation between the target reactive power and the target PF is,

$$P_G = \left(\sqrt{P_G^2 + Q_T^2}\right) \times PF_T \tag{1}$$

The target reactive power for the grid is,

$$Q_T = \sqrt{\left(\frac{P_G}{\mathrm{PF}_T}\right)^2 - P_G^2}. \quad (2)$$

Using the above formula (1) active power is controlled and using (2) reactive power is controlled.

The second function of the controller systems is to keep the capacitors 'voltages balanced. In order to do this, a carrier based pulse width modulation (CPWM) method is used. The third function of the controller system is the PWM generation block. In this block, based on the desired modulation index, power angle, voltages of the capacitors, direction of the current flowing through the switches and the controller generates the PWM signals in order to meet all condition of the system requirements.

This PWM controllers system shows in Fig (5) in which the basic control strategy is performed and with help of the operation we can manage the two mode operation also, means this controller handle like a D-STATCOM +Inverter when there is wind available and the system just behave as D-STATCOM when there is no wind available for wind energy conversion system. In the proposed control strategy, active and reactive power transferred between the inverter and the distribution grid is controlled by selecting both the voltage level of the inverter and the angle δ between the voltages of inverter and grid, respectively. The amplitude of the inverter voltage is regulated by changing the modulation index *m* and the angle δ by adding a delay to the firing signals which concludes, Following active power and reactive power equations as (3) and (4) respectively.

$PS = -mEsEL \sin \delta/X$

*(3-)*active power.

$QS = -mEsEL \cos \delta - E2/X$

(4)-reactive power.

These equations to improve the power factor of the grid system/distributive lines, And also reduces the harmonic of the output voltage as well as out power. means ultimately using above concept power factor improvement is obtain by using proposed system.

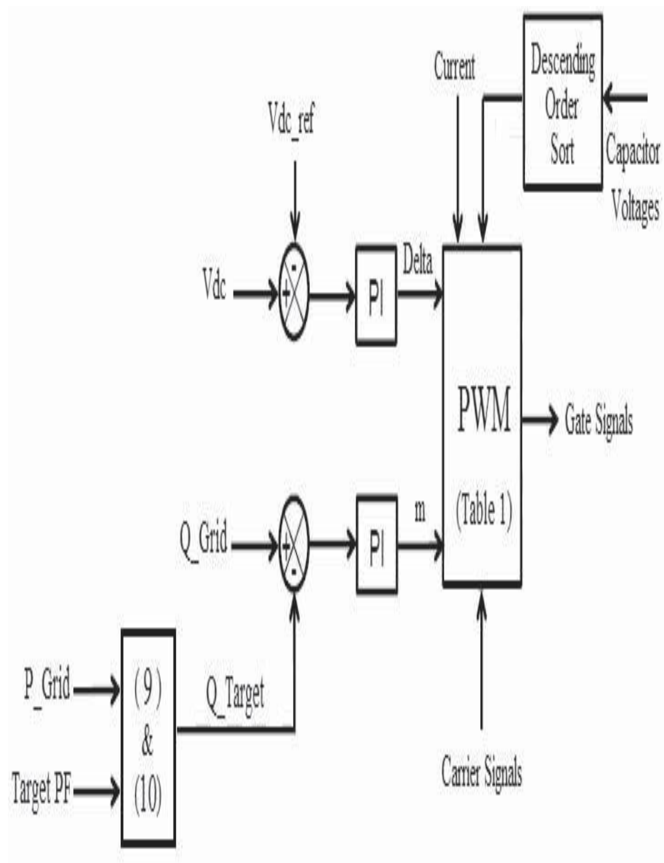


Fig.(5) shows the proposed controller system. Proposed system having two modes of operation

V EXPECTED RESULT

The result of this proposed model of multilevel inverter power factor of out voltage should be near 1,or approximately equals to 1 .And harmonic gets reduced and the efficiency get increased by using less number of switches in the designing of MMC based topology .In expected output all the power quality issues should be eliminated using above strategy .The main purpose above operation in active power controlling and the reactive power which proposed to be obtain and the efficiency of the system is increased in the because in simulation design we are going to decrease number of switch and the work is on progress.

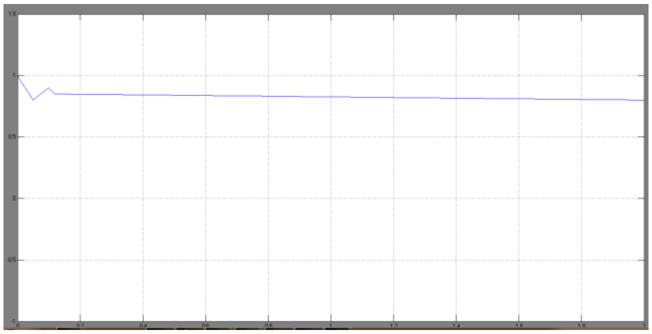


Fig (6) power factor waveform tends to 1.

VI CONCLUSION AND FUTURE SCOPE

In this paper the Multilevel inverter with FACTS capability for small to med-size wind installations is proposed to design the proposed system the of an inverter with FACTS capability in a single unit without any additional cost. Because this design will eliminate the requirement of external STATCOM devices to regulate the PF of grid .The presented topology is very suitable for small to medium power applications .The active and reactive power is regulated for the improvement of power quality and also reduces the power quality problems.

The MPPT algorithm is used to converts the output power of the wind turbine. The proposed controller system adjusts the active power by adjusting the power angle and reactive power is controllable by modulation index. Finally it should be noted that the power quality problems are reduced. A strategy needs to be developed for further investigation to make the inverter level increases Future scope of this project to improve the power quality issues of the distribution system using multilevel inverter level increases and reduces the harmonics.

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