ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Power Quality Improvement by 13-Level Inverter with FACTS Capability for Distributed Energy Systems

Mrs. Suneetha
PG Scholar,
Department of EEE,
E.V.M College of Engineering and Technology.

Mrs.Raghavarani
Assistant Professor,
Department of EEE,
E.V.M College of Engineering and Technology.

Abstract:

In this paper, a new single-phase wind energyinverter (WEI) with flexible AC transmission system (FACTS) capability is presented. The proposed inverter is placed betweenthe wind turbine and the grid, same as a regular WEI, and isable to regulate active and reactive power transferred to the grid.This inverter is equipped with distribution static synchronouscompensators option in order to control the power factor (PF) ofthe local feeder lines. Using the proposed inverter for small-tomedium-size wind applications will eliminate the use of capacitorbanks as well as FACTS devices to control the PF of thedistribution lines. The goal of this paper is to introduce newways to increase the penetration of renewable energy systemsinto the distribution systems. This will encourage the utilities andcustomers to act not only as a consumer, but also as a supplier ofenergy. Moreover, using the new types of converters with FACTScapabilities will significantly reduce the total cost of the renewableenergy application.

In this paper, modular multilevel converteris used as the desired topology to meet all the requirements of asingle-phase system such as compatibility with IEEE standards,total harmonic distortion (THD), efficiency, and total cost ofthe system. The proposed control strategy regulates the activeand reactive power using power angle and modulation index,respectively. The function of the proposed inverter is to transferactive power to the grid as well as keeping the PF of the local power lines constant at a target PF regardless of the incomingactive power from the windturbine. The simulations for an13-level inverter have been done in MATLAB/Simulink. Tovalidate the simulation results, a scaled prototype model of thepro-posed inverter has been built and tested.

I. INTRODUCTION:

THE ROLE of power electronics in distribution systemshas greatly increased recently. The power electronicdevices are usually used to convert the nonconventionalforms 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 are normallyutilized to connect the generator to the grid. A rectifierequipped 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 powerfor power lines using an inverter and a transformer. Withrecent developments in wind energy, utilizing smarter windenergy inverters (WEIs) has become an important issue. Thereare a lot of single-phase lines in the United States, whichpower small farms or remote houses [1], [2]. Such customers Have the potential to produce their required energy using asmall-to-medium-size wind turbine. Increasing the number ofsmall-to-medium wind turbines will make several troublesfor local utilities such as harmonics or power factor (PF)issues.

A high PF is generally desirable in a power system todecrease power losses and improve voltage regulation at theload. It is often desirable to adjust the PF of a system to near 1.0. When reactive elements supply or absorb reactive powernear the load, the apparent power is reduced. In other words,the current drawn by the load is reduced, which decreases thepower losses. Therefore, the voltage regulation is improvedif the reactive power compensation is performed near largeloads. Traditionally, utilities have to use capacitor banks tocompensate the PF issues, which will increase the total costof the system. The modern ways of controlling the PF of thesepower lines is to use small distribution static synchronous compensators(D-STATCOMs).

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

The D-STATCOMs are normallyplaced in parallel with the distributed generation systems aswell as the power systems to operate as a source or sink ofreactive power to increase the power quality issues of thepower lines. Using regular STATCOMs for small-to-mediumsizesingle-phase wind applications does not make economicsense and increase the cost of the system significantly. This iswhere the idea of using smarter WEIs with FACTS capabilitiesshows itself as a new idea to meet the targets of beingcost-effective as well as compatible with IEEE standards.The proposed inverter in this paper is equipped with aD-STATCOM option to regulate the reactive power of the localdistribution lines and can be placed between the wind turbineand the grid, same as a regular WEI without any additionalcost. The function of the proposed inverter is not only toconvert dc power coming from dc link to a suitable ac powerfor the main grid, but also to fix the PF of the local grid at atarget PF by injecting enough reactive power to the grid. In theproposed control strategy, the concepts of the inverter and theD-STATCOM have been combined to make a new inverter,which possesses F

ACTS 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 whenthere is no wind. The active power is controlled by adjusting.

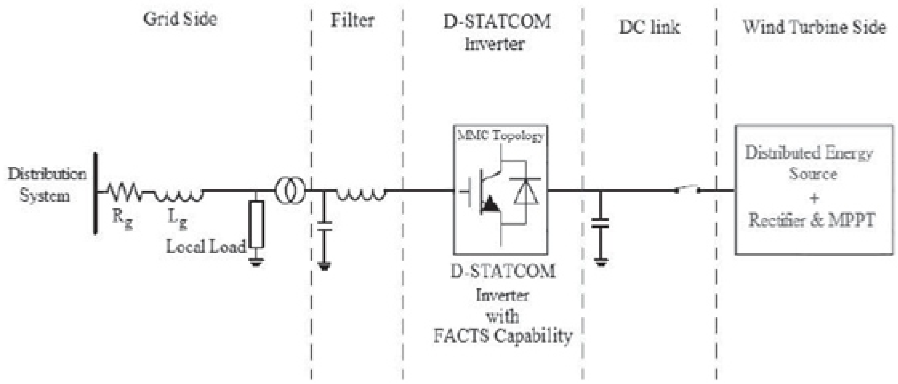

Fig. 1.Complete configuration of the proposed inverter with FACTS capability

The power angle δ, which is the angle between the voltagesof the inverter and the grid, and reactive power, is regulatedby the modulation index m. There are a large number of publications on integration ofrenewable energy systems into power systems. A list of completepublications on FACTS applications for grid integrationof wind and solar energy was presented in [3]. In [4], newcommercial wind energy converters with FACTS capabilitiesare introduced without any detailed information regarding theefficiency or the topology used for the converters. In [5], a complete list of the most important multilevel inverterswas reviewed. Also, different modulation methods such assinusoidal pulsewidth modulation (PWM), selective harmonic Elimination, optimized harmonic stepped waveform technique,and space vector modulation were discussed and compared.Among all multilevel topologies [6]–[9], the cascadedH-bridge multilevel converter is very well known forSTATCOM applications for several reasons [10]–[12]. Themain reason is that it is simple to obtain a high numberof levels, which can help to connect STATCOM directlyto medium voltage grids.

in the early 2000s [13], [14]. Reference[15] describes a MMC converter for high voltage DC (HVDC) applications. This paper mostly looks at the maincircuit components. Also, it compares two different typesof MMC, including H-bridge and full-bridge submodules. In [9] and [16], a new single-phase inverter using hybridclamped-topology for renewable energy systems is presented.The proposed inverter is placed between the renewable energy Source and the main grid. The main drawback of the proposedinverter is that the output current has significant fluctuationsthat are not compatible with IEEE standards. The authors Believe that the problem is related to the snubber circuit design. Several other applications of custom power electronics inrenewable energy systems exist, including [17] an applicationof a custom power interface where two modes of operation,including an active power filter and a renewable energySTATCOM. application [18] looks at the currentsourceinverter, which controls reactive power and regulatesvoltage at the point of common coupling (PCC). Varma et al. [19], [20] propose an application of photovoltaic (PV) solarinverter as STATCOM in order to regulate voltage on threephasepower systems,

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

for improving transient stability andpower transfer limit in transmission systems. The authorscalled their proposed system PV-STATCOM. Similar to windfarms (when there is no wind), solar farms are idle duringnights. We proposed a control strategy that makes the solarfarms to act as STATCOMs during night when they arenot able to produce active power. The main purpose of thePV-STATCOM system is to improve the voltage control andthe PF correction on three-phase transmission systems.In this paper, the proposed WEI utilizes MMC topology,which has been introduced recently for HVDC applications. Replacing conventional inverters with this inverter will eliminatethe need to use a separate capacitor bank or a STATCOMdevice to fix the PF of the local distribution grids.

Obviously,depending on the size of the power system, multiple invertersmight be used in order to reach the desired PF. 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.

II. MODULAR MULTILEVEL CONVERTER:

MMC has gained increasing attention recently. A number ofpapers were published on the structure, control, and applicationof this topology, but none has suggested the useof that for inverter + D-STATCOM application. This topologyconsists of several half-bridge (HB) submodules (SMs) pereach phase, which are connected in series. An n-level singlephaseMMC consists of a series connection of 2(n − 1) Basic SMs and two buffer inductors. Each SM possessestwo semiconductor switches, which operate in complementarymode, and one capacitor. The exclusive structure of MMCbecomes it an ideal candidate for medium-to-high-voltage

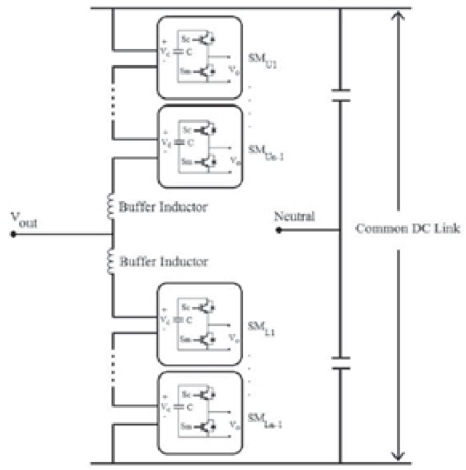

Fig. 2.Structure of a single-phase MMC inverter structure.

Applications such as wind energy applications. Moreover, thistopology needs only one dc source, which is a key point forwind applications. MMC requires large capacitors which mayincrease the cost of the systems; however, this problem is offsetby the lack of need for any snubber circuit.Applications such as wind energy applications. Moreover, thistopology needs only one dc source, which is a key point forwind applications. MMC requires large capacitors which mayincrease the cost of the systems; however, this problem is offsetby the lack of need for any snubber circuit.

The output voltage of each SM (vo) is either equal to its capacitor voltage (vc) or zero, depending on the switching states. The buffer inductors must provide current control in each phase arm and limit the fault currents. To describe the operation of MMC, each SM can be considered as a two pole switch. If Sui, which is defined as the status of the ithsubmodule in the upper arm, is equal to unity, then the output of the ith SM is equal to the corresponding capacitor voltage; otherwise it is zero.

Likewise, if Sli which is defined as the status of the ithsubmodule in the lower arm, is equal to unity, then the output of the ith lower SM is equal to the corresponding capacitor voltage; otherwise it is zero. Generally, when Sui or Sli is equal to unity, the i th upper or lower SM is ON; otherwise it is OFF. Therefore, the upper and Lower arm voltages of the MMC are as follows:

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

$$v_{upperArm} = \sum_{i=1}^{n-1}(S_{ui}v_{ci}) + v_{l1} \quad (1)$$

$$v_{lowerArm} = \sum_{i=1}^{n-1}(S_{li}v_{ci}) + v_{l2} \quad (2)$$

Where v13 and v12 are the voltages of the upper and lower buffer inductors, n is the number of voltage levels, and vci is the voltage of the ith SMs capacitor in upper arm or lower arm. A single-phase 13-levelMMC inverter consists of 20 SMswhich translates to 40 power switches, 20 capacitors, and2 buffer inductors. The dc and ac voltages of the 13-levelMMC are described by

$$\begin{aligned} v_{DC} &= v_{upperArm} + v_{lowerArm} \\ &= \sum_{i=1}^{10}(S_{ui}v_{ci}) + \sum_{i=1}^{10}(S_{ui}v_{ci}) + (v_{l1} + v_{l2}) \quad (3) \end{aligned}$$

$$v_{out} = \frac{v_{DC}}{2} - v_{upperArm} = -\frac{v_{DC}}{2} + v_{lowerArm}. \quad (4)$$

III. PROPOSED CONTROL STRATEGY:

The proposed controller consists of three major functions. The first function is to control theactive and reactive power

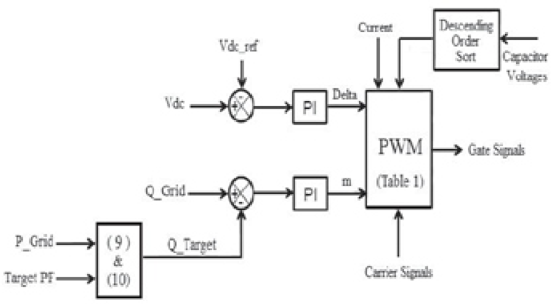

Fig.3. Schematic of the proposed controller system.

Transferred to the power lines, the second function is to keep the voltages of the SMs' capacitors balanced, and the third function is to generate desired PWM signals. Fig. 3 shows the complete proposed controller system. The aim of the designed inverter is to transfer active power coming from the wind turbine as well as to provide utilities with distributive control of volt-ampere reactive (VAR) compensation and PF correction of feeder lines. The application of the proposed inverter requires active and reactive power to be controlled fully independent, so that if wind is blowing, the device should be working as a normal inverter plus being able to fix the PF of the local grid at a target PF (D-STATCOM option), and if there is no wind, the device should be only operating as a D-STATCOM (or capacitor bank) to regulate PF of the local grid. This translates to two modes of operation: 1) when wind is blowing and active power is coming from the wind turbine: the inverter plus 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 and 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. Obviously, the device is capable of outputting up to its rated maximum real power and/or reactive power, and will always output all real power generated by the wind turbine to the grid. The amount of reactive power, up to the design maximum, is dependent only on what the utility asks the device to produce.Generally, (5) and (6) dictate the power flow between aSTATCOM device and power lines

$$P_S = -\frac{E_S E_L}{X}\sin\delta \quad (5)$$

$$Q_S = -\frac{E_S E_L \cos\delta - E_L^2}{X} \quad (6)$$

where X is the inductance between the STATCOM (here asinverter) and the grid which is normally considered as output filter inductance added to the transmission line inductance. The root mean square (RMS) voltage of the STATCOM (= inverter) is given as Es and is considered to be out of phase by an angle of δ to the RMS line voltage E1.

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 inverterand 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

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

$$P_S = -\frac{mE_SE_L}{X}\sin\delta \quad (7)$$

$$Q_S = -\frac{mE_SE_L\cos\delta - E_L^2}{X}. \quad (8)$$

In this paper, m is the key factor to control the reactive power compensation and its main task is to make the PF of the grid equal to the target PF. δ is the control parameter to Adjust the active power control between the inverter and the grid.Several assumptions should be considered for the proposed controller which is as: 1) the load on the feeder line should be considered fixed for a small window of time and there is no change in the load during a cycle of the grid frequency; 2) the feeder line can be accurately modeled as a constant P, Q load. This means that the power produced by a wind turbine will displace other power on the feeder line and not add toit; and 3) although making a change in m or δ has effect on both (7) and (8), it is assumed that a change in the modulation index will predominantly affect Q, while a change in delta will predominantly affect P. Any effect on Q from a small change in delta is thus ignored. This results in controlling P and Q independently. Equation (9) shows the relation between the target reactive power and the target PF

$$P_G = \left(\sqrt{P_G^2 + Q_T^2}\right) \times \mathrm{PF}_T \quad (9)$$

Where PG is the amount of active power on the grid, QT is

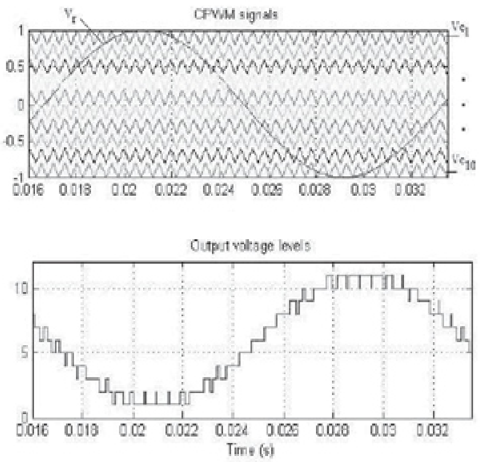

Fig.4. CPWM waveforms for an13-level MMC inverter, and the generated output voltage levels.

The target amount of reactive power, and PFT is the target PF desired by the utility. So, QT can be calculated as

$$Q_T = \sqrt{\left(\frac{P_G}{\mathrm{PF}_T}\right)^2 - P_G^2}. \quad (10)$$

Using (9) and (10), the target reactive power for the grid is determined and is compared with the actual value of the reactive power of the grid. Using a PI compensator will determine the desired value for the modulation index. The power angle is also determined by comparing the actual dc voltage of the inverter with a reference value. A PI compensator determines the desired value for the power angle.The second function of the controller systems is to keep the capacitors' voltages balanced. In order to do this, a carrier basedPulse width modulation (CPWM) method isUsed.

The top graph in Fig. 4 shows the reference signal and the carrier waveforms for an13-level MMC inverter using CPWM technique. The bottom graph of Fig. 4 shows the output voltage levels generated based on Table I.In an13-level CPWM technique, ten carrier signals are compared with a reference sinusoidal signal. In Fig 4, based on the phase of the reference signal (vr), there are 13 operating regions where each region defines a voltage level in the output

$$n_{\mathrm{upperArm}} + n_{\mathrm{lowerArm}} = 10 \quad (11)$$

Where nupperArm and nlowerArm are the numbers of SMs which are ON (Sc is ON and Sm is OFF in Fig. 1) in the upper arm or lower arm, respectively. In an13-level MMC inverter, there are ten upper andten lower SMs where each SM has a capacitor. For instance,in voltage level 1 of Table I, all the upper SMs should beOFF and all the lower SMs should be ON, which translates to the fact that the main switches Sm of all upper SMs and theauxiliary switches (Sc) of all lower SMs have to be ON andall the other switches have to be OFF. In this case, the inputdc voltage is applied only to the ten lower capacitors, so that

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

TABLE I
OPERATING REGIONS FOR AN 11-LEVEL MMC INVERTER

Voltage level	Status	$n_{UpperArm}$	$n_{lowerArm}$	V_{out}
1	$v_r \geq v_{C1}, v_{C2}, v_{C3}, v_{C4}, v_{C5}, v_{C6}, v_{C7}, v_{C8}, v_{C9}, v_{C10}$	0	10	$5v_{dc}/10$
2	$v_r < v_{C1}$ $v_r \geq v_{C2}, v_{C3}, v_{C4}, v_{C5}, v_{C6}, v_{C7}, v_{C8}, v_{C9}, v_{C10}$	1	9	$4v_{dc}/10$
3	$v_r < v_{C1}, v_{C2}$ $v_r \geq v_{C3}, v_{C4}, v_{C5}, v_{C6}, v_{C7}, v_{C8}, v_{C9}, v_{C10}$	2	8	$3v_{dc}/10$
4	$v_r < v_{C1}, v_{C2}, v_{C3}$ $v_r \geq v_{C4}, v_{C5}, v_{C6}, v_{C7}, v_{C8}, v_{C9}, v_{C10}$	3	7	$2v_{dc}/10$
5	$v_r < v_{C1}, v_{C2}, v_{C3}, v_{C4}$ $v_r \geq v_{C5}, v_{C6}, v_{C7}, v_{C8}, v_{C9}, v_{C10}$	4	6	$v_{dc}/10$
6	$v_r < v_{C1}, v_{C2}, v_{C3}, v_{C4}, v_{C5}$ $v_r \geq v_{C6}, v_{C7}, v_{C8}, v_{C9}, v_{C10}$	5	5	0
7	$v_r < v_{C1}, v_{C2}, v_{C3}, v_{C4}, v_{C5}, v_{C6}$ $v_r \geq v_{C7}, v_{C8}, v_{C9}, v_{C10}$	6	4	$-v_{dc}/10$
8	$v_r < v_{C1}, v_{C2}, v_{C3}, v_{C4}, v_{C5}, v_{C6}, v_{C7}$ $v_r \geq v_{C8}, v_{C9}, v_{C10}$	7	3	$-2v_{dc}/10$
9	$v_r < v_{C1}, v_{C2}, v_{C3}, v_{C4}, v_{C5}, v_{C6}, v_{C7}, v_{C8}$ $v_r \geq v_{C9}, v_{C10}$	8	2	$-3v_{dc}/10$
10	$v_r < v_{C1}, v_{C2}, v_{C3}, v_{C4}, v_{C5}, v_{C6}, v_{C7}, v_{C8}, v_{C9}$ $v_r \geq v_{C10}$	9	1	$-4v_{dc}/10$
11	$v_r < v_{C1}, v_{C2}, v_{C3}, v_{C4}, v_{C5}, v_{C6}, v_{C7}, v_{C8}, v_{C9}, v_{C10}$	10	0	$-5v_{dc}/10$

the output voltage is vDC/2. Fig. 5 illustrates the selection of capacitors for different voltage levels shown in Table I. The most critical issue to control MMC is to maintain the voltage balance across all the capacitors. Therefore, the SMs' voltages are measured and sorted in descending order during each cycle. If the current flowing through the switches is positive, so that capacitors are being charged, nupperArm and nupperArm and of the SMs in upper arm and lower arm with the lowest voltages are selected, respectively.

As a result, ten capacitors with lowest voltages are chosen to be charged.Likewise, if the current flowing through the switches is negative, so that capacitors are being discharged, nupperArmand nupper Arm of the SMs in upper arm and lower armwith highest voltages are selected, respectively. As a result,ten capacitors with highest voltages are chosen to be discharged.Consequently, the voltages of the SMs' capacitorsare balanced. Considering Table I and based on thedirection of the current flowing through the switches, theproper algorithm will be selected to maintain capacitorbalance.

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 using Table I, the controller generates the PWM signals in order to meet all the system requirements.

IV. SIMULATION AND PRACTICAL RESULTS:

The design of an13-level MMC inverter was carried out in MATLAB/Simulink. The simulation is 20 s long and contains

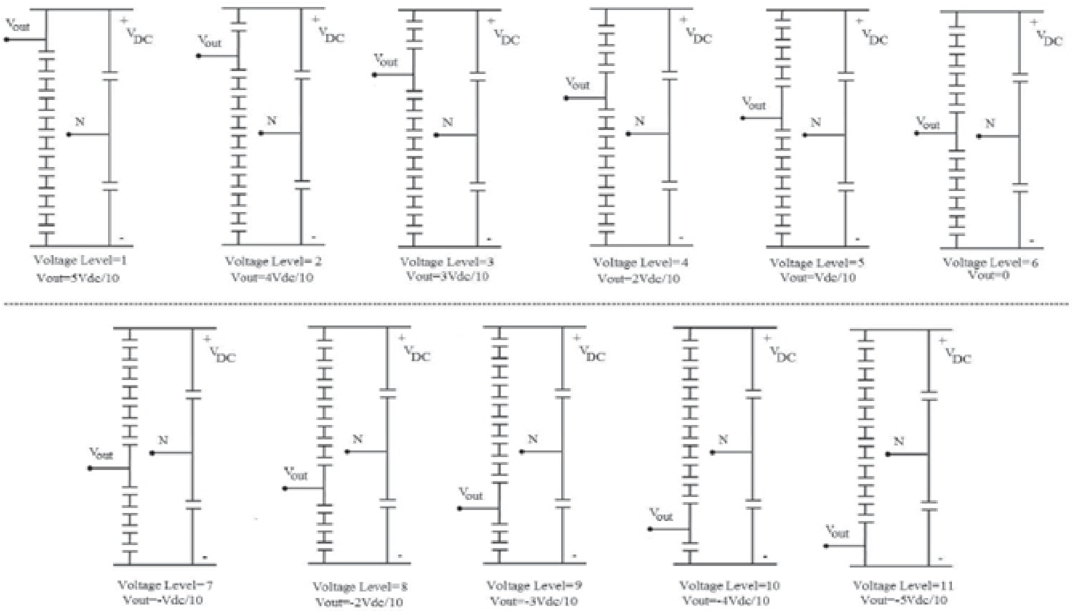

Fig.5.SelectionofSMs'capacitorsfordifferentvoltagelevels.

TABLE II
PARAMETERS USED FOR THE SIMULATION

Parameter	Value
L_{line}	15 mH
R_{line}	1 Ohm
L_{Filter}	5 mH
Transformer primary voltage	12000 V
Transformer secondary voltage	600 V
Switching frequency	2 kHz
Load active power	50 kW
Load reactive power	34.8 kVAR
Target PF	0.90
DC link Voltage	2000 V

severe ramping and de-ramping of the wind turbine. The goal is to assess the behavior of the control system in the worst conditions. Table II shows the values of the parameters used for the simulation.Before t = 6 s, there is no wind to power the wind turbine; therefore, the dc link is open-circuited. At t = 6 s, the input

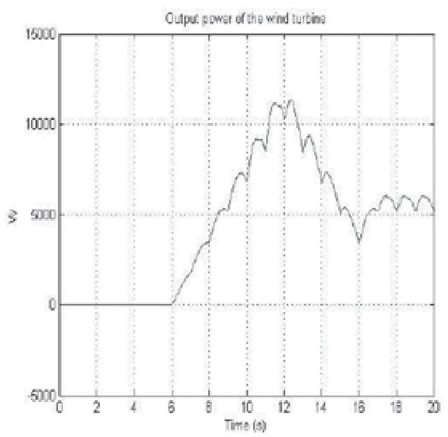

Fig. 6.Simulated output active power from the wind turbine.

Power of the inverter is ramped up to 12 kW in 5 s, and then ramped down to 3.5 kW 4 s later. Fig. 6 shows the output active power from the wind turbine. In the simulation, thelocal load makes the PF 0.82. When the simulation starts, the inverter provides enough compensation to reach the target PF 0.90. Fig. 7 shows the output active and reactive power

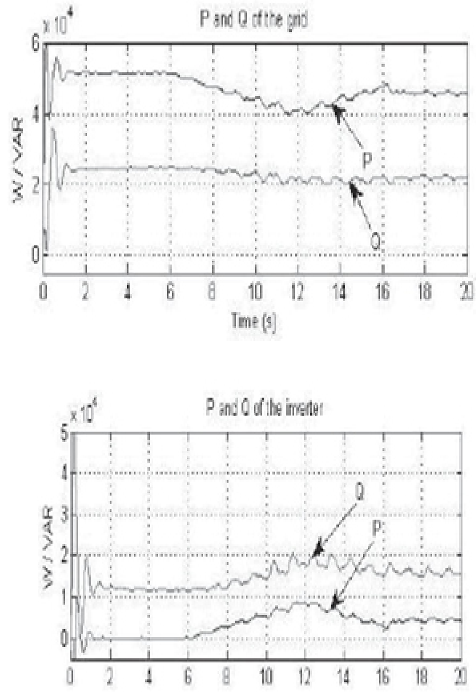

Fig. 7.Simulated active and reactive power of the inverter (top graph), active and reactive power of the power lines (bottom graph).

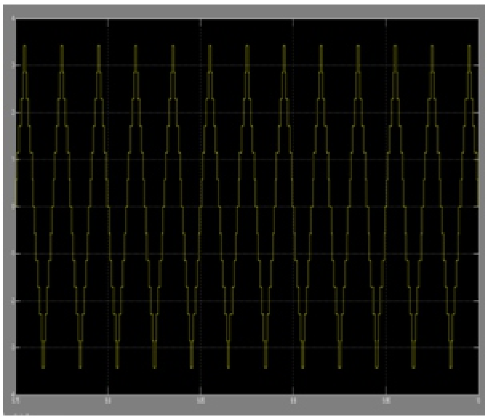

Fig.8. Simulated output voltage of an 13-level inverter.

From the wind turbine and the grid. After t = 6 s, the output power of the wind turbine is increased, and as a result the level of active power provided by the feeder line is decreased by the same amount. The simulated output voltage of the inverter before the filter is shown in Fig. 8. Fig. 9 shows the PF of the grid.

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

The PF of the grid is constant at 0.90 regardless of the active power from the wind turbine, showing that the main goal of the inverter is achieved. The set-point for dc link voltage of the inverter is 2000 V and the RMS value of the output ac voltage is 600 V. The delta and modulation index graphs are shown in Fig. 10. As soon as the active power comes from the wind turbine, the controller system increases the value of the power angle in order to output more active power to the grid. Therefore, the active power provided from the feeder lines to the load is decreased, and as a result the reactive power from the feeder lines is decreased. Consequently, the modulation index is increased by the controller system to inject more reactive power needed by the load.

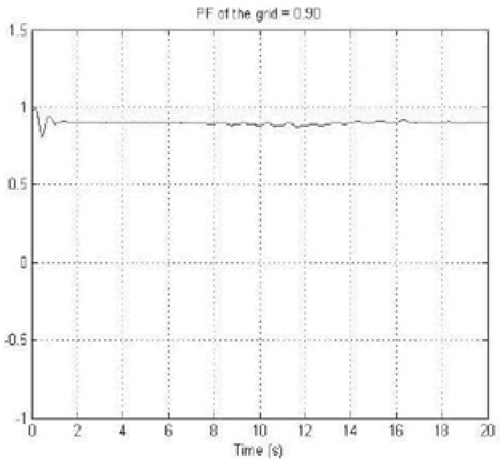

Fig.9. Simulated PF of the grid.

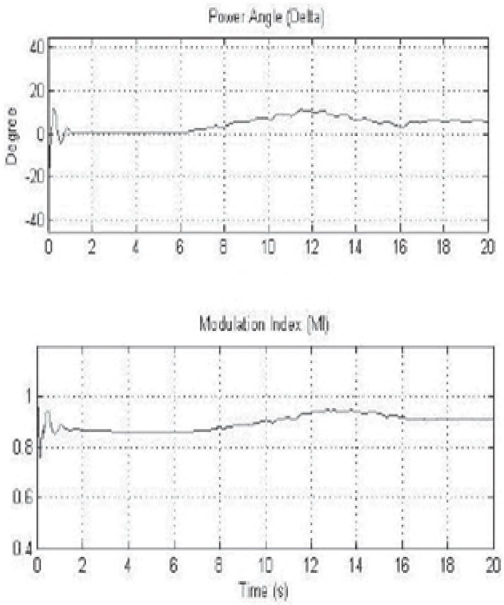

Fig.10. Simulated delta and modulation index of the 13-level inverter.

To validate the simulation results, a scaled version of the proposed inverter has been built and tested. The power rating of the scaled prototype model is 250 W and/or VAR, whichis limited by the rating of the semiconductor devices. The experimental results serve only as a proof-of-concept. In order to implement the control strategy and to handle the feedback signals, two CLP 1304 ds PACE systems have been synchronized. A three-phase PM generator driven by a variable speed dc motor is used to emulate the wind speed change. Fig. 13 shows the test bench setup and the 13-level prototype inverter.Fig. 12 shows the output voltage of the inverter where theswitching frequency and the values of the LC filter is 2 kHz,5 mH, and 10 μF, respectively. The efficiency of the inverteris close to 0.95. The experimental output voltage THD andcurrent TDD is 2.7 and 2.12%, respectively.

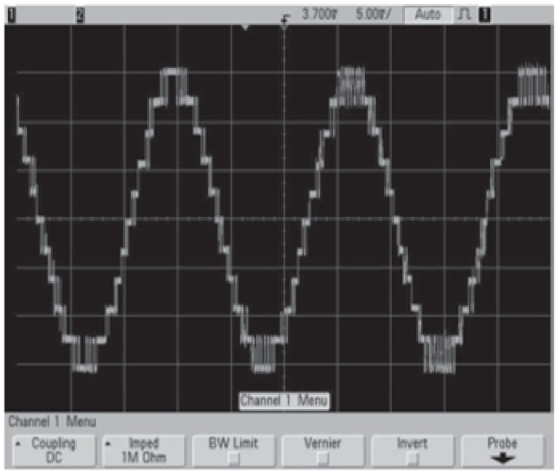

Fig.12. Output voltage of the proposed 13-level inverter.

V. CONCLUSION:

In this paper, 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 unitwithout 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.

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

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 an13-level inverter are presented in MATLAB/Simulink. To validate the simulation results, a scaled prototype of the proposed13-level inverter with D-STATCOM capability is built and tested. Practical results show good performance of the proposed control strategy even in severe conditions.

REFERENCES:

1] U.S. Solar Market Insight, 2010 Year End Review Executive Summary, SEIA, Washington, DC, USA, 2013.

[2] AWEA U.S. Wind Industry Annual Market Report Year Ending 2010, AWEA, Washington, DC, USA, 2013.

[3] S. A. Rahman, R. K. Varma, and W. H. Litzenberger, "Bibliography of FACTS applications for grid integration of wind and PV solar power systems: 1995–2010 IEEE working group report," in Proc. IEEE Power Energy Soc. General Meeting, Jul. 2013, pp. 1–17.

[4] A. Beekmann, J. Marques, E. Quitmann, and S. Wachtel, "Wind energy converters with FACTS capabilities for optimized integration of wind power into transmission and distribution systems," in Proc. CIGRE/IEEE PES Joint Symp. Integr. Wide, Scale Renew. Resour. Power Del. Syst., Jul. 2009, pp. 1–9.

[5] J. Rodriguez, J. S. Lai, and F. Z. Peng, "Multilevel inverters: Survey oftopologies, controls, and applications," IEEE Trans. Ind. Appl., vol. 49,no. 4, pp. 724–738, Aug. 2002.

[6] F. Z. Peng, J. S. Lai, J. W. McKeever, and J. VanCoevering, "A multilevelvoltage-source inverter with separate DC sources for static VArgeneration," IEEE Trans. Ind. Appl., vol. 32, no. 5, pp. 1330–1338,Oct. 1996.

[7] L. M. Tolbert and F. Z. Peng, "Multilevel converters as a utility interfacefor renewable energy systems," in Proc.IEEE Power Eng. Soc. SummerMeeting, vol. 2. Jul. 2000, pp. 1271–1274.

[8] S. Kouro, M. Malinowski, K. Gopakumar, J. Pou, L. G. Franquelo,B. Wu, et al., "Recent advances and industrial applications of multilevelconverters," IEEE Trans. Ind. Electron., vol. 57, no. 8, pp. 2553–2580,Aug. 2010.

[9] C. Tareila, P. Sotoodeh, and R. D. Miller, "Design and control ofa single-phase D-STATCOM inverter for wind application," in Proc.PEMWA, Jul. 2012, pp. 1–5.

[10] B. Gultekin and M. Ermis, "Cascaded multilevel converter-based transmissionSTATCOM: System design methodology and development of a12 kV ±12 MVAr power stage," IEEE Trans. Power Electron., vol. 28,no. 13, pp. 4930–4950, Nov. 2013.

[13] K. Sano and M. Takasaki, "A transformerless D-STATCOM basedon a multivoltage cascade converter requiring no DC sources,"IEEE Trans. Power Electron., vol. 27, no. 6, pp. 2783–2795,Jun. 2012.

[12] X. Liang, Y. Xu, X. Chen, and C. Guo, "The simulation research ofSTATCOM based on cascaded multi-level converter," in Proc. 4th Int.Conf. Electr. Util. DRPT, Jul. 2013, pp. 494–498.

[13] M. Davies, M. Dommaschk, J. Dorn, J. Lang, D. Retzmann, andD. Soerangr,HVDC PLUS Basic and Principle of Operation.Erlandgen,Germany: Siemens AG Energy Sector, 2009.

[14] B. Gemmell, J. Dorn, D. Retzmann, and D. Soerangr, "Prospects ofmultilevel VSC technologies for power transmission," in Proc. IEEETransmiss.Distrib. Conf. Exposit., Apr. 2008, pp. 1–16.

[15] C. D. Barker and N. M. Kirby,"Reactive power loading of componentswithin a modular multi-level HVDC VSC converter," in Proc. IEEEEPEC, Oct. 2013, pp. 86–90.

[16] C. P. Tareila, "A single-phase D-STATCOM Inverter for distributedenergy sources," M.S. thesis, Dept. Electr. Comput. Eng., Kansas StateUniv., Manhattan, KS, USA, Aug. 2013.

17] Z. Yang, C. Shen, L. Zhang, M. L. Crow, and S. Atcitty, "Integration of a STATCOM and battery energy storage," IEEE Trans. Power Syst., vol. 16, no. 2, pp. 254–260, May 2001.

[18] S. Chakraborty, B. Kroposki, and W. Kramer, "Evaluation of control and voltage regulation functionalities in a single-phase utility-connected inverter for distributed energy applications," in Proc. IEEE ECCE, Sep. 2009, pp. 1753–1759.

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

[19] R. K. Varma, S. A. Rahman, A. C. Mahendra, R. Seethapathy, and T. Vanderheide, "Novel nighttime application of PV solar farms as STATCOM (PV-STATCOM)," in Proc. IEEE Power EnergySoc. General Meeting, Jul. 2012, pp. 1–8.

[20] R. K. Varma, E. M. Siavashi, B. Das, and V. Sharma, "Real-time digital simulation of a PV solar system as STATCOM (PV-STATCOM) for voltage regulation and power factor correction," in Proc. EPEC, Oct. 2012, pp. 157–163.

[21] R. K. Varma, S. A. Rahman, V. Sharma, and T. Vanderheide, "Novel control of a PV solar system as STATCOM (PV-STATCOM) for preventing instability of induction motor load," in Proc. 25th IEEE CCECE, May 2012, pp. 1–5.

[22] R. Marquardt and A. Lesnicar, "New concept for high voltage—Modular multilevel converter," in Proc. PESC, Jun. 2004, pp. 1–5.

[23] A. Lesnicar and R. Marquardt, "An innovative modular multilevelconverter topology suitable for a wide power range," in Proc. IEEEPower Tech. Conf., vol. 3. Jun. 2003, pp. 1–6.

[24] M. Saeedifard and R. Iravani, "Dynamic performance of a modular multilevelback-to-back HVDC system," IEEE Trans. Power Del., vol. 25,no. 4, pp. 2093–2912, Oct. 2010.

[25] J. Kim, S. Sul, and P. Enjeti, "A carrier-based PWM method with optimal switching sequence for a multilevel four-leg voltage-source inverter," IEEE Trans. Ind. Appl., vol. 44, no. 4, pp. 1239–1248,Aug. 2008.

[26] J. Pou, J. Zaragoza, S. Ceballos, M. Saeedifard, and D. Boroyevich,"A carrier-based PWM strategy with zero-sequence voltage injectionfor a three-level neutral-point-clamped converter," IEEE Trans. PowerElectron., vol. 27, no. 2, pp. 642–651, Feb. 2012.

Author's Details :

Mrs.NALLAMOTHU SUNEETHA was born in India.He pursuing M.Tech degree in Power and industrial drives in EEE Department in EVM COLLEGE OF ENGINEERING (SAI TIRUMALA NVR engineering college) narasaraopet, Guntur ,Andhrapradesh ,India.

Mrs. RAGHAVARANI.P was born in India in the year of 1988.She received B.Tech degree in Electrical and Electronics Engineering in the year of 2008&M.Tech degree in power electronics in the year of 2013 from JNTUK, Kakinada. She is currently pursuing Ph.D. degree in electrical engineering. Her research interests are in the area of power systems especially generation, transnsmission, distribution and utilization of electrical energy. He is a professional member of IEEE and a member of Power and Energy Society(PES) since 2011.He is acting as counselor for LITS -IEEE student branch.