Reactive power management and improve Power factor of RES sources using Multi level inverter based STATCOM

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ABSTRACT:

In this paper discussed, wind power generation with flexible AC transmission system (FACTS). To get better power quality results employed Shunt voltage controller based FACT device i.e. distribution static synchronous compensators (DSTATCOM). In proposed technique, inverter is located between the wind turbine and the grid, identical as a normal Wind Energy Inverter (WEI), and is able to modify energetic and reactive power transferred to the grid. This inverter is geared up with distribution STATCOM option so as to manipulate the energy aspect power factor (PF) of the neighbourhood feeder lines. Using the proposed inverter for small-to medium-length wind packages will cast off using capacitor banks in addition to FACTS gadgets to manipulate the PF of the distribution strains. In this paper compensated the lively and reactive electricity within the multi level inverter. In the multi level inverter higher compensated the active power and the reactive. Designed 17 level multi level inverter. Total harmonic distortion also calculated in the17 –Level multi stage inverter. The goal of this article is to introduce new methods to boom the penetration of renewable energy structures into the distribution systems. This will inspire the utilities and customers to behave now not best as a patron, however additionally as a dealer of power. Moreover, the usage of the brand new types of converters with FACTS abilities will drastically lessen the whole value of the renewable strength utility. In this paper, modular multilevel converter is used because the favoured topology to fulfil all the requirements of a single-segment machine including compatibility with IEEE standards, overall harmonic distortion (THD), performance, and overall fee of the gadget. The proposed manage strategy regulates the active and reactive energy the use of energy angle and modulation index, respectively. The characteristic of the proposed inverter is to switch lively energy to the grid in addition to keeping the PF of the neighbourhood electricity traces constant at a goal PF no matter the incoming energetic strength from the wind turbine. The simulations for an 11-stage inverter had been executed in MATLAB/Simulink.

Keywords: DSTATCOM, Multilevel Inverter (MLI), Wind Energy Inverter (WEI).

I. INTRODUCTION:

The Role of wind energy in distribution structures has significantly increased currently. Present Renewable energy power generations increasing very rapidly to reach the power demand. Renewable energy system converts the energy found in sunlight, wind, falling-water, sea wave, geothermal heat, or biomass into a form, we can use such as heat or electricity. Most of the renewable energy comes either directly or indirectly from sun and wind and can never be exhausted, and therefore they are called renewable. In India, Energy sources like solar and wind power are readily available and much sought after. They produce clean energy power which does not affect the Ozone layer. As India is a tropical country with no distinctive seasons, photovoltaic are preferred. Growing concern over the diminishing fossil fuel supplies, as well as the impact of fossil fuel based energy generation on global warming and climate change, has led to intense research into renewable energy generation. Also the need for large scale low carbon solar electricity production has become increasingly urgent for reasons of energy security and climate change mitigation.

In Present Century electrical engineers have mainly two problems

1.Produce more power generation by adopting renewable energy like solar, wind, fuel cell *etc*...,.

2. Managing those power generations based on power demand and maintain power quality.

In everlasting magnet wind programs, a lower back-to-lower back converter is usually utilized to connect the generator to the grid. A rectifier prepared with a most power factor tracker (MPPT), converts the output electricity of the wind turbine to a dc power. The dc strength is then converted to the favored ac power for energy traces the usage of an inverter and a transformer. With latest developments in wind strength, utilizing smarter wind energy inverters (WEIs) has end up an critical difficulty. Increasing the range of small-to-medium wind turbines will make numerous issues for local utilities which includes harmonics or power factor (PF) issues. A high PF is normally acceptable in a strength device to decrease strength losses and enhance voltage law on the load. It is regularly proper to modify the PF of a system to near1.0. When reactive elements supply or absorb reactive strength close to the burden, the plain energy is reduced. In other phrases, the modern-day drawn via the burden is decreased, which decreases the power losses. Therefore, the voltage law is progressed if the reactive electricity compensation is accomplished close to massive masses. Traditionally, utilities ought to use capacitor banks to compensate the PF troubles, to be able to boom the overall fee of the machine. The contemporary ways of controlling the PF of these electricity strains is to apply small distribution static synchronous compensators (D-STATCOMs). The D-STATCOMs are typically located in parallel with the distributed era structures as well as the power structures to operate as a source or sink of reactive energy to boom the power first-rate troubles of the strength traces. Using ordinary STATCOMs for small-to-medium length single-segment wind programs does no longer make financial feel and increase the price of the system extensively. This is in which the idea of the usage of smarter WEIs with FACTS abilties suggests itself as a brand new concept to satisfy the targets of being price-powerful as well as compatible with IEEE standards. The proposed inverter on this paper is geared up with a D-STATCOM choice to regulate the reactive strength of the local distribution strains and may be positioned between the wind turbine and the grid, equal as a normal WEI with none extra value. The feature of the proposed inverter is not best to transform dc strength coming from dc hyperlink to a appropriate ac energy for the main grid, but additionally to restore the PF of the nearby grid at a goal PF by using injecting sufficient reactive strength to the grid. In the proposed manipulate method, the principles of the inverter and the D-STATCOM. The proposed control approach allows the inverter to behave as an inverter with D-STATCOM option while there is enough wind to produce active power, and to act as a D-STATCOM while there's no wind. The active electricity is managed by using adjusting of the inverter and the grid, and reactive electricity is regulated through the modulation index m. There are a massive variety of courses on integration of renewable electricity systems into energy structures. A list of whole courses on FACTS applications for grid integration of wind and solar strength changed into provided in [3]. In [4], new business wind electricity converters with FACTS talents are delivered with none targeted data regarding the performance or the topology used for the converters. In [5], a whole list of the most essential multilevel inverters changed into reviewed. Also, distinct modulation strategies which include sinusoidal pulse width modulation(PWM) selective harmonic removal, optimized harmonic stepped waveform approach, and area vector modulation had been discussed and in comparison. Among all multilevel topologies [6]–[9], the cascaded H-bridge multilevel converter is very widely recognized for STATCOM packages for several motives [10]–[12]. The important motive is that it is easy to achieve a excessive number of levels, that may assist to attach STATCOM without delay to medium voltage grids.

The modular multilevel converter (MMC) turned into delivered excessive D.C voltage for HVDC power transmission. This paper typically seems at the primary circuit components. Also, it compares two exclusive styles of MMC, which include H-bridge and full-bridge sub modules. In [9] and [16], a new single-phase inverter using hybrid clamped topology for renewable strength systems is provided. The proposed inverter is positioned between the renewable strength source and the principle grid. The important disadvantage of the proposed inverter is that the output present day has sizable fluctuations that aren't well suited with IEEE requirements. The authors accept as true with that the problem is associated with the snubber circuit layout.

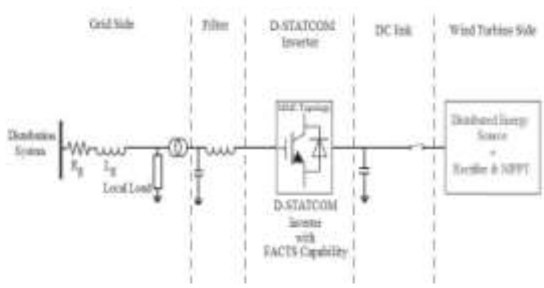

Fig.1. Structure of Proposed inverter topology

II. MODULAR MULTILEVEL CONVERTER

MMC has received growing interest currently. A wide variety of papers were posted on the structure, control, and alertness of this topology [21], [22],. This topology includes numerous half of-bridge (HB) sub modules (SMs) in keeping with every segment, which might be connected in collection. An n-stage segment MMC consists of a series connection of 2(n − 1) primary SMs and two buffer inductors. Each SM possesses two semiconductor switches, which function in complementary mode, and one capacitor. The distinct shape of MMC will become it a really perfect candidate for medium-to-high-voltage packages consisting of wind strength packages. Moreover, this topology desires most effective one dc supply, which is a key point for wind applications. MMC calls for large capacitors which may additionally boom the price of the systems; however, this problem is offset by means of the dearth of need for any snubber circuit. The principal features of the MMC topology are: modular layout primarily based on equal converter cells, easy voltage scaling by a chain connection of cells, easy cognizance of redundancy and opportunity of a not unusual dc bus as shows the circuit configuration figure.2.In this MMC and the shape of its SMs including two strength switches and a floating capacitor. The output voltage of every SM (vo) is either identical 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 poles witch. If Sui, which is defined as the status of the i^{th} sub module in the upper arm, is equal to unity, then the output of the i^{th} SM is equal to the corresponding capacitor voltage; otherwise it is zero. Likewise, if S_{li} which is defined as the status of the i^{th} sub module in the lower arm, is equal to unity, then the output of the i^{th} lower SM is equal to the corresponding capacitor voltage; otherwise it is zero. Generally, when Sui or S_{li} 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:

$$V_{\text{upper Arm}}=\sum_{i=1}^{n-1} s_{ui} v_{ci} + v_{11}$$

$$V_{\text{lower Arm}}=\sum_{i=1}^{n-1} s_{ui} v_{ci} + v_{11}$$

Where v_{11} and v_{12} are the voltages of the upper and lower buffer inductors, n is the number of voltage levels, and v_{ci} is the voltage of the i^{th} SMs capacitor in upper arm or lower arm. A single-phase 11-levelMMC inverter consists of 20 SMs which translates to 40 power switches, 20 capacitors, and2 buffer inductors. The dc and ac voltages of the 11-levelMMC are described by

$$V_{DC}=V_{\text{upper Arm}}+V_{\text{lower arm}}$$

$$=\sum_{i=1}^{10}(s_{ui} v_{ci})+\sum_{i=1}^{10}(s_{ui} v_{ci})+(V_{11}+V12)$$

$$V_{out}=\frac{V_{DC}}{2}-V_{upperarm}=\frac{V_{DC}}{2}-V_{lowerarm}$$

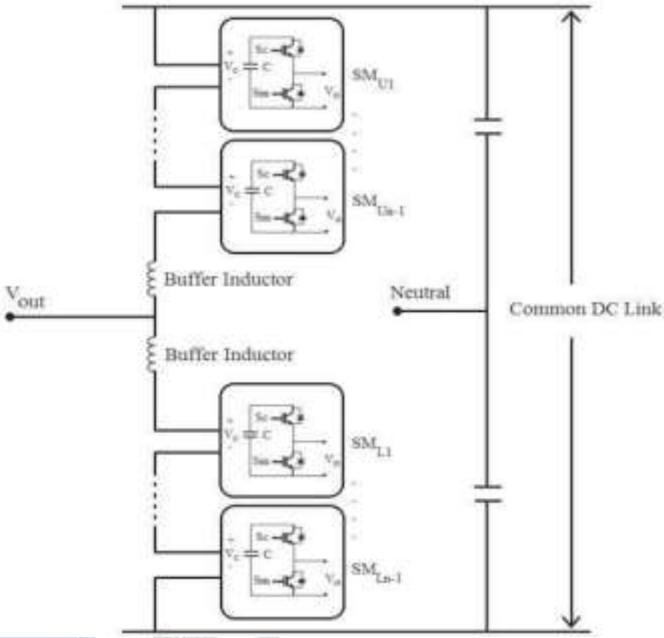

Fig.2. Configuration of Single phase MMC Converter

III. PROPOSED CONTROL STRATEGY

The proposed control Strategy contains mainly three features, Control the active and reactive power of transferred to the power lines, balances voltages of the SMs' capacitors and generates desire PWM pulse signals. The aim of the designed inverter is to transfer lively power coming from the wind turbine in addition to to provide utilities with distributive manage of volt-ampere reactive (VAR) reimbursement and PF correction of feeder strains. The software of the proposed inverter requires active and reactive energy to be managed absolutely impartial, so that if wind is blowing, the tool have to be operating as a ordinary inverter plus (1) being capable of restore the PF of the local grid at a goal PF (D-STATCOM), and if there is no wind, the device ought to be most effective operating as a D-STATCOM to adjust PF of the local grid. This interprets to two modes of operation: 1) when wind is blowing and active strength is coming from the wind turbine: the inverter plus D-STATCOM mode. In this mode, the tool is working as a regular inverter to transfer active energy from the renewable strength supply to the grid as well as working as a everyday D-STATCOM to adjust the reactive electricity of the grid if you want to manage the PF of the grid and wind velocity is 0 or too low to generate active power. The schematic diagram of proposed control scheme is shown in fig.3.

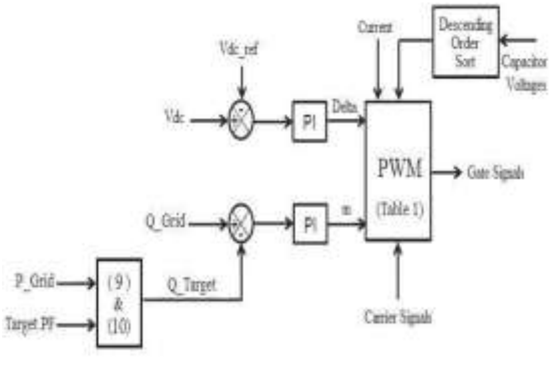

Fig. 3. Schematic diagram of proposed controller scheme.

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 are 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 to it; 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 where PG is the amount of active power on the grid, QT is the target amount of reactive power, and PFT is the target PF desired by the utility. So, QT can be calculated as Using 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.

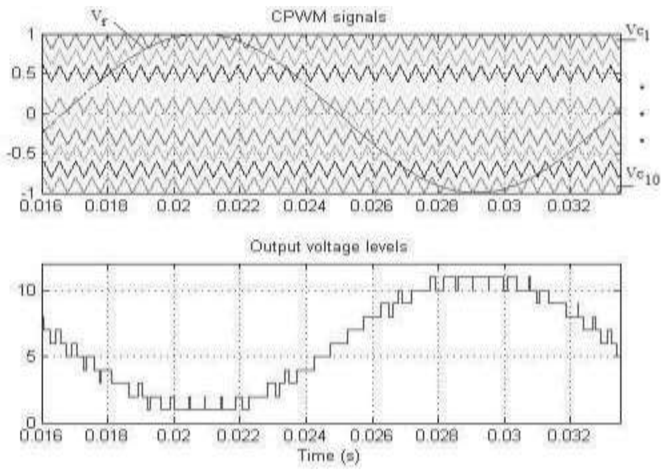

Fig. 4. CPWM waveforms for an 11-level MMC inverter, and the generated output voltage levels.

Voltage level	Status	$n_{UpperArm}$	$n_{lowerArm}$	V_{out}
1	$V_r \ge V_{c1}, V_{c2}, V_{c3}, V_{c4}, V_{c5}, V_{c6}, V_{c7}, V_{c8}, V_{c9}, V_{c10}$	0	10	$5v_{dc}/10$
2	$V_r < V_{c1}$ $V_r \ge V_{c2}, V_{c3}, V_{c4}, V_{c5}, V_{c6}, V_{c7}, V_{c8}, V_{c9}, V_{c10}$	1	9	$4v_{dc}/10$
3	$V_r < V_{c1}, V_{c2}$ $V_r \ge V_{c3}, V_{c4}, V_{c5}, V_{c6}, V_{c7}, V_{c8}, V_{c9}, V_{c10}$	2	8	$3v_{dc}/10$
4	$V_r < V_{c1}, V_{c2}, V_{c3}$ $V_r \ge V_{c4}, V_{c5}, V_{c6}, V_{c7}, V_{c8}, V_{c9}, V_{c10}$	3	7	$2v_{dc}/10$
5	$V_r < V_{c1}, V_{c2}, V_{c3}, V_{c4}$ $V_r \ge V_{c5}, V_{c6}, V_{c7}, V_{c8}, V_{c9}, V_{c10}$	4	6	$v_{dc}/10$
6	$V_r < V_{c1}, V_{c2}, V_{c3}, V_{c4}, V_{c5}$ $V_r \ge V_{c6}, V_{c7}, V_{c8}, V_{c9}, V_{c10}$	5	5	0
7	$V_r < V_{c1}, V_{c2}, V_{c3}, V_{c4}, V_{c5}, V_{c6}$ $V_r \ge V_{c7}, V_{c8}, V_{c9}, V_{c10}$	6	4	$-v_{dc}/10$
8	$V_r < V_{c1}, V_{c2}, V_{c3}, V_{c4}, V_{c5}, V_{c6}, V_{c7}$ $V_r \ge V_{c8}, V_{c9}, V_{c10}$	7	3	$-2v_{dc}/10$
9	$V_r < V_{c1}, V_{c2}, V_{c3}, V_{c4}, V_{c5}, V_{c6}, V_{c7}, V_{c8}$ $V_r \ge V_{c9}, V_{c10}$	8	2	$-3v_{dc}/10$
10	$V_r < V_{c1}, V_{c2}, V_{c3}, V_{c4}, V_{c5}, V_{c6}, V_{c7}, V_{c8}, V_{c9}$ $V_r \ge V_{c10}$	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	$-5v_{dc}/10$

TABLE I: Operating Regions for An 11-Level MMC Inverter

IV. SIMULATION RESULTS:

The design of an 11-level MMC inverter was carried out in MATLAB/ Simulink. The simulation is 20 s long and contains 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 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.

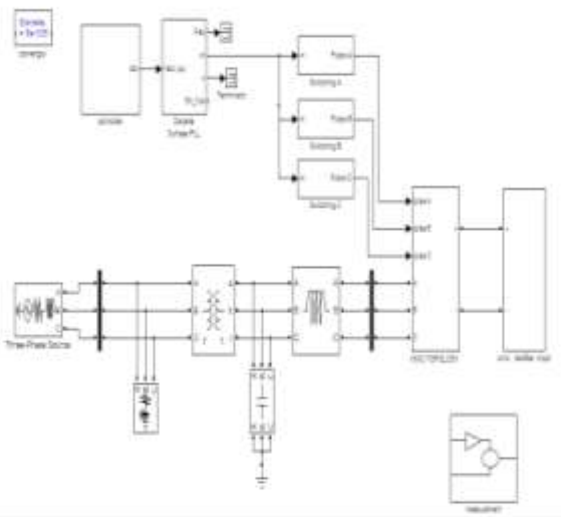

Fig. 5.Matlab/simulink model of the proposed method

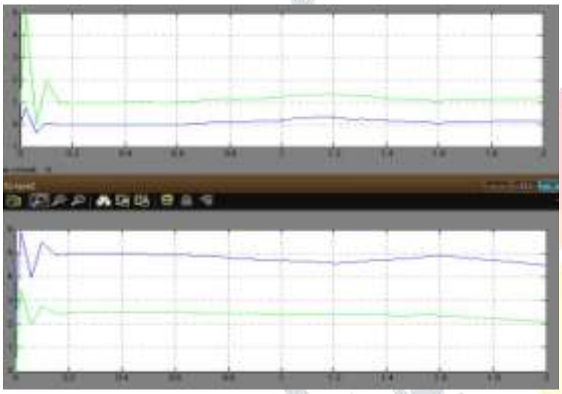

Fig. 6. Simulated active and reactive power of the inverter (top graph), active and reactive power of the power lines (bottom graph).

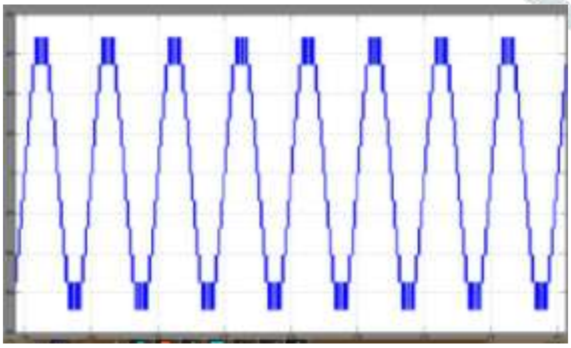

Fig. 7. Output voltage waveform of an 17-level inverter.

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. 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.

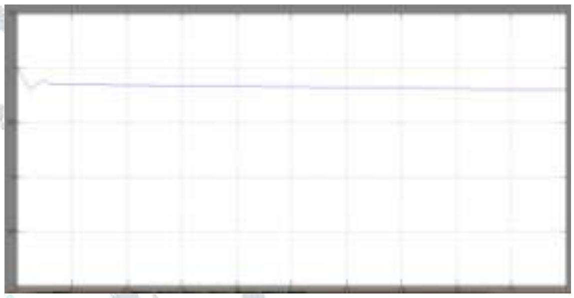

Fig. 8.Simulation result PF of the grid wave form.

V. CONCLUSION

In this paper, the idea of a brand new multilevel inverter with FACTS functionality for small-to-mid-size wind installations is provided. The proposed system demonstrates the software of a brand new inverter with FACTS capability MMC converter unit with the aid of without any extra cost. By using proposed control strategy compensated both active and reactive power problems effectively. Multi level inverter 17 – level itself additionally compensated the active power and reactive power. Replacing the conventional renewable power inverters with the proposed inverter will dispose of the need of any outside STATCOM gadgets to adjust the PF of the grid. Clearly, relying on the scale of the compensation, more than one inverters can be needed to attain the preferred PF. The simulation effects for an 17-degree inverter are offered in MATLAB/Simulink. To validate the simulation outcomes proposed 17-degree inverter with D-STATCOM capability is worked very well.

VI. REFERENCES

[1] U.S. Solar Market Insight, 2010 Year End Review Executive Summary,SEIA, Washington, DC, USA, 2011.

[2] AWEA U.S. Wind Industry Annual Market Report Year Ending 2010,AWEA, Washington, DC, USA, 2011.

[3] S. A. Rahman, R. K. Varma, and W. H. Litzenberger, "Bibliography of FACTS applications for grid integration of wind and PV solar powersystems: 1995–2010 IEEE working group report," in Proc. IEEE PowerEnergy Soc. General Meeting, Jul. 2011, pp. 1–17.

[4] A. Beekmann, J. Marques, E. Quitmann, and S. Wachtel, "Wind energyconverters with FACTS capabilities for optimized integration of windpower into transmission and distribution systems," in Proc. CIGRE/IEEEPES 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. 1130–1138,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.

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