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High Gain Step up Converter Using Multilevel Inverter for HVDC Application

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Abstract: The large-scale renewable energy sources and HVDC grid is connected by a pure DC system where high-power high-voltage step-up DC–DC converters are the solution tools to transmit the electrical energy. The converter can achieve high efficiency and low-cost with the help of an LC parallel resonant tank where soft switches are employed. If transformer is used large amount of harmonic distortion is observed. Hence an attempt is made in this project to reduce harmonic distortion, overcome power demand and to produce high step up voltage by using multilevel inverter topology. The proposed method is extensively simulated in simulated in MATLAB/SIMULINK.

Key words: Renewable energy · Voltage step-up converter · Multilevel Inverter · Soft switching · DC Motor

INTRODUCTION

The improvement of renewable energy sources is essential to mitigate the pressures of exhaustion of the fossil fuel and environmental pollution. At present, most of the renewable energy sources are utilized with the shape of AC power. The generation equipments of the renewable energy sources and energy storage devices usually enclose DC conversion stages and the produced electrical energy is delivered to the power grid during DC/AC stages, ensuing in additional energy loss. Moreover, the common problem of the renewable energy sources such as wind and solar, is the large variations of output power and the connection of large scale of the renewable sources to the power grid is a enormous challenge for the conventional electrical equipment, grid structure and function. DC grid, as one of the solutions to the over mentioned issues, is an rising and promising approach which has been drawn much interest recently [1-4].

At present, the voltages over the DC stages in the generation equipments of the renewable energy sources are moderately low, in the variety of several hundred volts to several thousand volts, hence, high-power high-voltage step-up DC-DC converters are required to deliver the produced electrical energy to HVDC grid. Moreover, as the connectors involving the renewable energy sources and HVDC grid, the step-up DC-DC converters not only broadcast electrical energy, but also segregate or rub kinds of fault situation, they are one of the solution equipments in the DC grid [5]. Newly, the high-power high-voltage step-up DC-DC.High power high voltage step up DC-DC converter are recently used [5-29]. If we need high voltage means by using step up transformer. The applications of offshore wind form is compared with the recital of Full Bridge (FB) Converter,Single Active Bridge, LCC resonant Converter [7-10]. The 3 topologies such as 3-phase SAB converter, series resonant converter and dual active bridge (DAB) converter, which are more relevant for high-power applications due to low current stress of each bridge, are also studied and intended for high-power high voltage step-up applications [11-13].

Medium frequency transformer can be connected between two DC-DC converter which is called Modular Multilevel Converter (MMC) these are very much suitable for HVDC grid applications [14-16]. For these isolated topologies the main interruption is the invention of the high-power HV medium frequency transformer. The transformer archetype not yet to be describe. Compare to single large capacity transformer, Multiple small capacity isolated converter connected in series/parallel is more valuable [17-20].

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Galvanic isolation is not compulsory for the applications.The uses of transformer would increase the cost, lossess and volume, particularly for HV applications [21]. Non-isolated topologies for HPHV applications have been recently proposed [21-29]. Boost converter is used to transmit energy from±50kV to ±200kV [22]. To achieve HV gain by using BOOST converter and BUCK/BOOST converter [23]. The output power and voltage are shared by the two converter, so voltage and current ratings of switches and diodes are reduced. Efficiency low due to hard switching and large recovery loss of the diode. Soft switching technology is critical to improve the conversion efficiency which is suitable for HPHV applications [31]. The novel type of resonant step up converter with soft switching to be designed which have the advantages of low switch stress and low reverse recovery problem, large voltage gain is also easy [26-28]. Resonant transformer less modular DC-DC converter is proposed, in this type unequal voltage stress on the thyristor to be avoided with the help of a active switching network (i.e) 1 AC capacitor, 4 identical active switches.Thyristor having high voltage and current rating.The advantages of while using the thyristor is limit switching frequency of converter and slow dynamic response [30]. A novel resonant step-up DC-DC converter is projected, which not only can realize soft switching for main switches and diodes and large voltage-gain, but also has relatively lower correspondent voltage stress of the semiconductor devices and bidirectional magnetized significant inductor.Fullbrigde inverter to be used to convert DC-AC.

The converter can achieve high voltage-gain using LC corresponding resonant tank. It is characterized by zero-voltage-switching (ZVS) turn-on and nearly ZVS turn-off of major switches as well as zero-current-switching (ZCS) turn-off of rectifier diodes, moreover, the consequent voltage stress of the semiconductor devices is poorer than other resonant stepupconverters. To achieve double voltage gain by using voltage doubler to be connected from the output, if the input is 100V means finally we get 200V as the output with the help of voltage doubler which is convert low AC to high DC [31].

In this paper, a multilevel inverter is used to attain high voltage, which having increase power rating,reduced EMI, improving harmonic performance and minimize the sign current. This multilevel inverter can be more fit for high power applications.. Hybrid cascade multilevel inverter to be used and the topology used in this method reduces the number of power switches when compared to the conventional cascaded H-bridge multilevel inverter. The operation principle of the system has been successfully verified by simulation and experiment results.

Proposed Modulation

Inverter and Topologies: Multilevel voltage source inverter is recognized as an important option to the regular two- level voltage source inverter especially in high voltage application. The model of a multilevel converter to attain high power is to use a series of power semiconductor switches with several lower voltage dc sources to act upon the power change by synthesizing a set of steps voltage waveform. Using multilevel presentation, the amplitude of the voltage is enlarged, stress in the switching devices is reduced and the overall harmonics profile is improved.

Basic Concept of Multilevel Inverter: These environmentally-friendly energy sources can then be renewed into AC currents. However, as multilevel inverters are able of producing large amounts of energy, the sum of energy produced is dependent upon how much DC power is used. Higher sources of DC power will offer more powerful AC power.

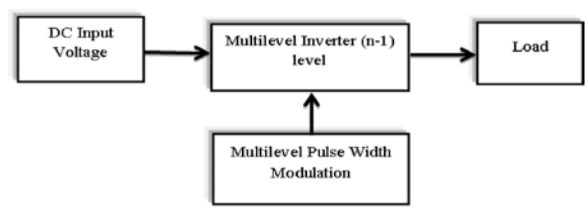

Fig. 1: Multilevel inverter system

Multilevel inverters are significantly different from usual inverter where basically two levels are generated. In which each assembly of devices contribute to a step in the output voltage waveform. The steps are enlarged to attain an nearly sinusoidal waveform. The number of switches involved is increased for every level increment. Multilevel inverter is a power electronic arrangement that synthesizes a desired voltage from numerous levels of direct current voltage as inputs.

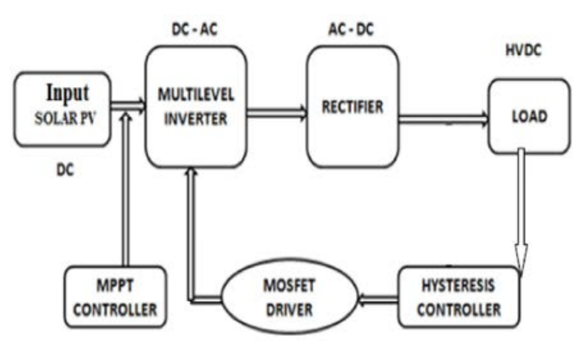

Fig. 2: Block Diagram for Step up Converter with Multilevel Inverter

Hybrid Cascade MLI: The cascaded multilevel inverter as shown in Fig consists of a full-bridge inverter, capacitor voltage separator, an supplementary circuit comprising four Sic diodes and a Si IGBT switch. The inverter produces output power in five levels: 0, 0.5Vdc, Vdc, 0, -0.5Vdc and -Vdc. The reward of the inverter topology are:

- Improved output voltage quality.
- Smaller filter size.
- Lower EMI.
- Lesser THD compared with usual three- level PWM.
- Reduced number of switches compared to the usual 5-level inverter

An MOSFET H-Bridge inverter and an MOSFET H-Bridge inverter are used as a hybrid multilevel inverter. The MOSFET inverter can be used at higher volt-ampere rating than the IGBT inverter; however, the MOSFET inverter can be operated at higher switching frequency than the IGBT inverter. This illustrates that the hybrid inverter can function at higher volt-ampere evaluation with lower switching losses than a conventional cascaded multilevel inverter.

The MOSFET inverter can operate at primary switching frequency (square wave) and the IGBT inverter can operate at PWM switching mode. The hybrid inverter has the equal number of power switches compared to a conventional cascaded multilevel inverter.

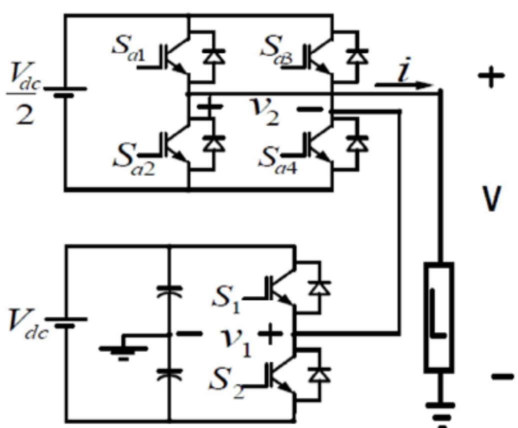

Fig. 3: Hybrid Cascaded Multilevel Inverter.

$$f(t) = m.\sin(\omega t) \rightarrow (3.1)$$

$$\frac{T_p}{T_c} = \begin{cases} 2\left(f(t) - \frac{1}{2}\right); \frac{1}{2} \le f(t) \le 1 \\ 2\left(\frac{1}{2} - f(t)\right); 0 \le f(t) \le \frac{1}{2} \end{cases} \longrightarrow 1$$

$$A1 = \begin{cases} 1; f(t) \ge 0 \\ 0; f(t) < 0 \end{cases} \longrightarrow 2 \quad ; \quad A2 = \begin{cases} 1; |f(t)| \ge \frac{1}{2} \\ 0; |f(t)| < \frac{1}{2} \end{cases} \longrightarrow 3$$

where f(t) is a reference signal

m is modulation index (0.0/1.0 – 1.0/1.0)

A1 is a multiplexing signal #1.

A2 is a multiplexing signal #2

◎◎ ◎◎ ◎◎ ◎◎ is pulse width of PWM (0.0-1.0)

Modes of Operation: By means of H-Bridge Cascaded multilevel inverters, we preserve inverter up to three energy levels. Different positions of switches settle on unusual voltage levels.

Table 1: Operational Modes of HCMLI

Vo	S1	S2	S3	S3'	S4	S4'
+Vdc	ON	OFF	ON	ON	OFF	OFF
+Vdc/2	ON	OFF	OFF	ON	OFF	ON
0	OFF	OFF	OFF	OFF	OFF	OFF
-Vdc/2	OFF	ON	OFF	ON	OFF	ON
-Vdc	OFF	ON	OFF	OFF	ON	ON

Each inverter level can create three different voltage outputs i.e +Vdc, 0 and –Vdc by connecting the dc source to the ac output in different combinations of the four switches which are S1, S2, S3 and S4. To gain +Vdc switches S1 and S4 are turned ON, but –Vdc can be obtained by turning ON switches S2 and S3. By spinning ON S1, S2, S3 and S4 the output voltage is zero. The ac outputs of each of the dissimilar full-bridge inverter levels are coupled in sequence such that the synthesized voltage waveform is the addition of the inverter outputs. The amount of output phase voltage levels m in a cascade inverter is illustrate by m = 2s+1, where s is the amount of part dc sources. The phase voltage is

$$Van = Va1 + Va2 + Va3 + Va4 + Va5. \qquad (4)$$

MOSFET: MOSFETs are small compared to BJTs so it fabricated easily and space saving scheme on the integrated circuits. Input impedance are very soaring so they do not load the circuits, loading cause does not arise. Operating occurrence is very high, so may be used at high frequency. Used in digital circuits for its reliability. Effect of resonance is less than BJT. So high signal to noise ratio. The characteristics and concert of many analog circuits can be considered by changing the sizes of the MOSFET used. There for MOSFETs are widely used in analog circuits. In the communication, networking and computer board design MOSFETs are widely used.The gate signal is specified to the MOSFET is from the PWM techniques. It is more appropriate for high power appliance circuites evaluate to other switches.

Hysteresis Controller with Constant Switching Frequency:

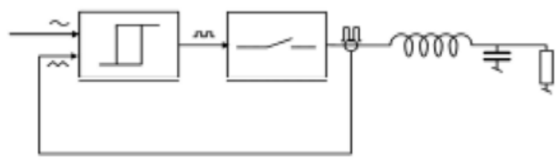

Fig. 4: Current Mode Hysteresis Controller

The hysteresis controller can be prepared with either a current- or a voltage loop. The profit of hysteresis controllers are mainly the linear modulation caused by the saw tooth-shaped wave with ideally straight slopes and by the vast power supply elimination ratio, PSRR, if the supply distinction can be considered very slow compared to the switching frequency.The basic process of the current form hysteresis controller is: The output inductor integrates the discrepancy voltage between the output voltage of the power phase and the output voltage of the amplifier. If the output power of the amplifier can be calculated constant within one switching time, the integration results in a saw tooth shaped inductor current, which is subtracted from the position current programming voltage and fed into a hysteresis transom to control the switching frequency by manipulative the time-delay trough the controller loop.

Switching Loss: Consider a MOSFET switch connected across a dc voltage of rate Vdc. During on Time, the current through switch is Idc. The figure shows the waveforms of the voltage and current during switch when it is operated at a switching frequency ofFs=1/Ts, whereTs is the switching period. In the figure,Vm,Im are the voltage across and the current through the MOSFET.Switching losses can be measured from the turn on and turn off character of the switch. Instantaneous voltage and current during on time t_C(ON))are:

$$V(t)=V_{dc}-(V_{dc}-V_{on})*t/t_{c(on)} \quad (5)$$

$$I(t)=I_{dc*\,t}/t_{c(on)\,6} \quad (6)$$

where,

V(t),I(t) – Instantaneous Voltage and current
V_{dc} – Voltage across the switch when turned off
V_{on} – Voltage across the switch when turned on
T - Time in sec
T_c– turn on across over period.
I_{dc} – current through switch when turn on
T_s – sampling time in sec.

Although the turn-on loss is avoided due to zero power turn-on condition, since the tail currentcharacteristic, the turn-off loss of the IGBTs can only be alleviated gratitude to the slow increasing of the voltage across the active switch.The high-voltage large-current Silicon Carbide (SiC) MOSFET is available in the turn-off loss the converter could be reduced significantly.

Simulation and Results
Converter Circuit:

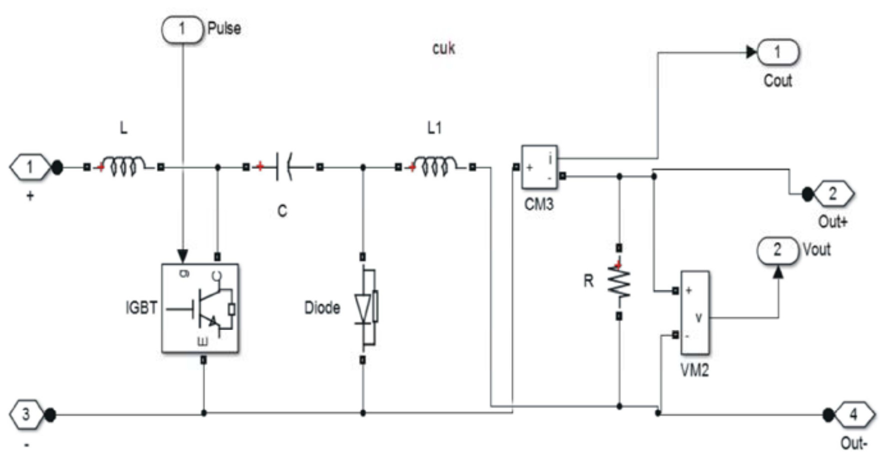

Fig. 5: Circuit Diagram for Converter

Power conversion is converting electric energy from one type to another, converting among AC and DC, or just varying the voltage or frequency, or some arrangement of these.

Hysteresis Controller:

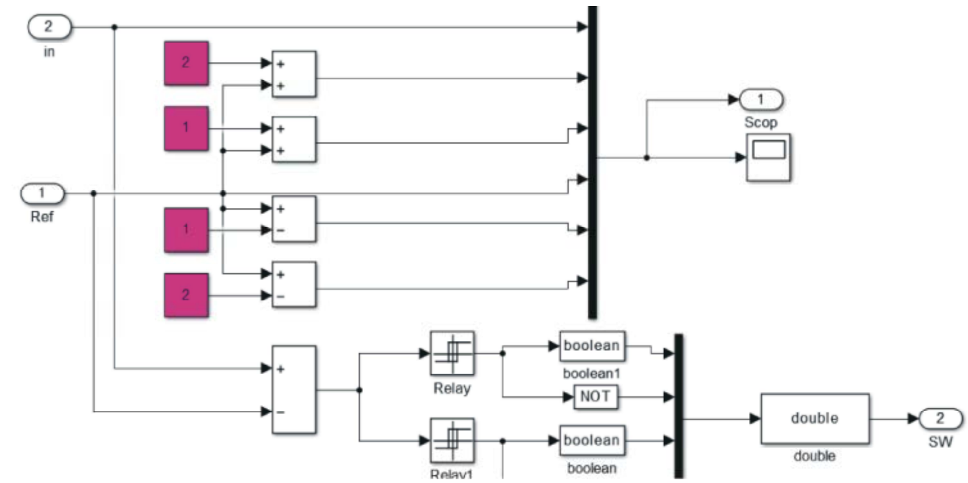

Fig. 6: Circuit for Hysteresis Controller

Hysteresis controller used to generate pulses to switches. Comparator compare the actual and reference currents and it generate error signal to controller. Hysteresis band current control is used to control load current and verify switching signal for inverter switches.

There are bands above and under the position voltage. If the difference between the reference and inverter current reaches to the upper (lower) limit, the current is strained to decrease. The HB that has inverse comparative relation with switching frequency is defined as the difference between Ih and Il (Hb=Ih-Il).

Multilevel Inverter:

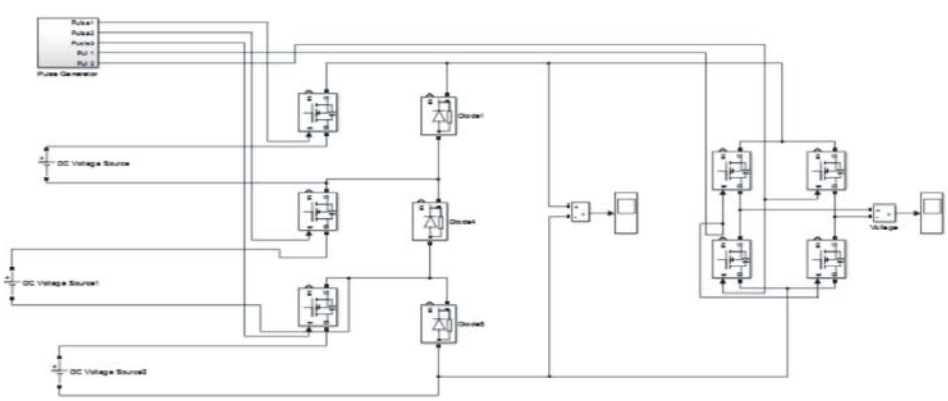

Fig. 7: Circuit for Multilevel Inverter

It will increase the voltage of 0 to 300V which is increased by step by step. Using H-Bridge Cascaded multilevel inverters, we can inverter up to three voltage levels. Different level of switches determine different voltage levels.

PV Module: Photovoltaics are finest known as a technique for produce electric power by using solar cells to convert energy opening the sun into a flow of electrons. The photovoltaic consequence refers to photons of light stimulating electrons into a upper state of energy, allowing them to act as charge carriers for an electric current.Solar cells construct express current electricity from sun light which can be used to power apparatus or to recharge a battery. The first sensible application of photovoltaics was to power orbiting satellites and other s paceship, but today the majority of photovoltaic modules are used for grid coupled power generation.

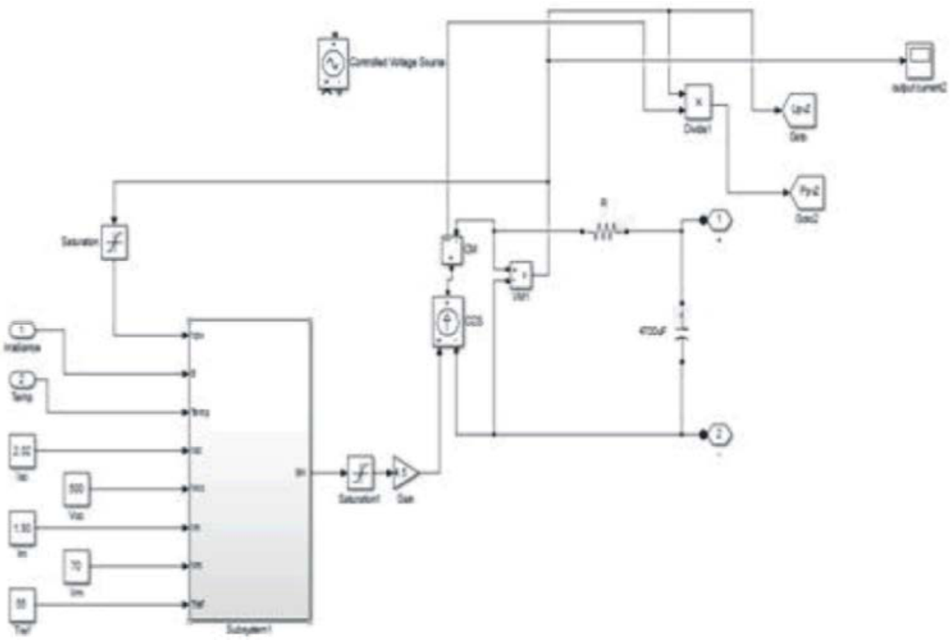

Fig. 8: Circuit for PV Cell

To achieve this characteristic, the DC/DC power converter connected to the single-phase voltage source inverter must create a V voltage, while the DC/DC power converter coupled to the four wire inverter must produce a 2V voltage. In this way, a seven level shaped output voltage signal is calculated. The multilevel inverter generates two 90º shifted output voltages.

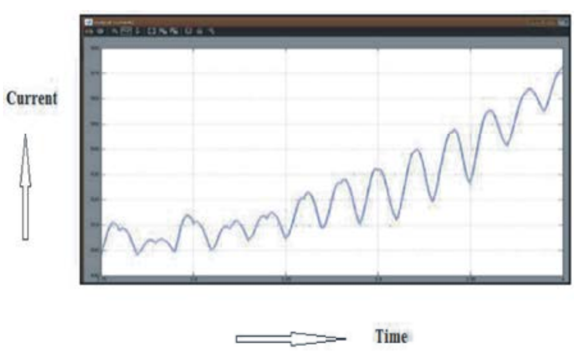

Fig. 9: Output of Current

The above output represents between the time verses current and it is experiential that current increases but not linearly and it finally looks like a sinusoidal waveform.There are bands above and under the reference voltage. If the difference among the reference and inverter current reaches to the upper (lower) limit, the current is compulsory to decrease. The HB that has inverse proportional relative with switching frequency is defined as the difference between Ih and Il (Hb=Ih-Il).

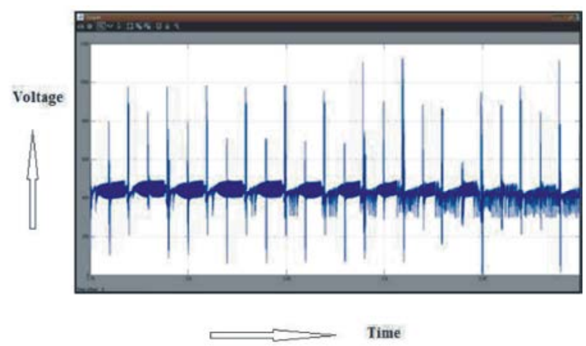

Fig. 10: Output of Converter

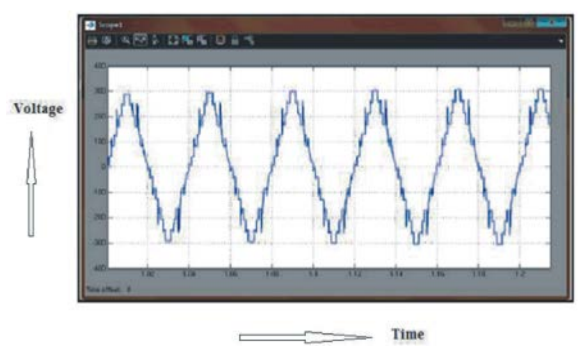

Fig. 11: Output of Multilevel Inverter

The sum of output phase voltage levels m in a cascade inverter is define by m = 2s+1, where s is the number of detach dc sources. The phase voltage Van = Va1 + Va2 + Va3 + Va4 + Va5

Fig. 12: Output of Gain Voltage

The above diagram fig represents the final output voltage. Here we achieve 350V which is used for HVDC applications. For the constant output power, the average input current decreases with the increase of the input voltage,hence, the conduction loss will decrease with the increase of the input voltage. But, the switching frequency increases with the increase of the input voltage hence, the switching loss (turn-off loss) resolve increase with the increase of the input voltage. So there is a finest efficiency working point in the input voltage range.

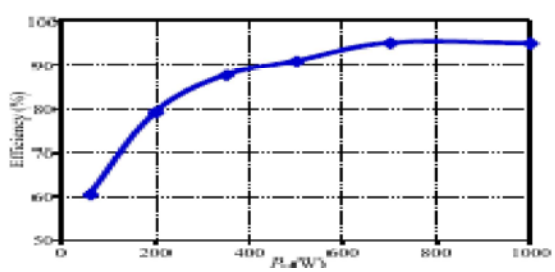

Fig. 13a: Conversion Efficiency at different output power less than normal input voltage

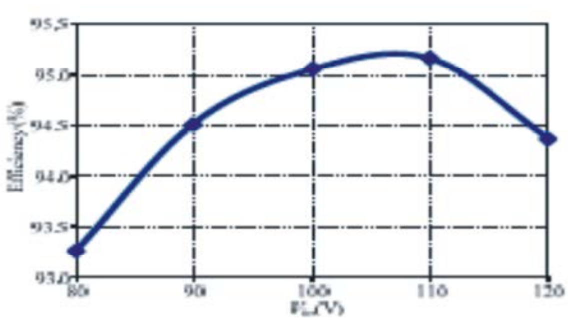

Fig. 13b: Conversion Efficiency for different input voltages at full load

The advantages of this systems are given:Reduced voltage stress,Current ripple could be minimize, High voltage conversion is possible without using additional converters and Overall cost of the system reduced. The applications are

- Power conditioning,
- Power grid
- Industrial motor drives and
- Electrical transport

CONCLUSION

Thus the multilevel inverter and dc-dc converter is achieve very high step-up voltage gain which is suitable for high-power high-voltage applications. The converter uses the resonant inductor to distribute power by charging beginning the input and discharging at the output. The resonant capacitor is employed to achieve zero-voltage turn-on and turn-off for the dynamic switches and Zero Current Switching for the rectifier diodes.Conversely the parameters of the resonant tank find out the maximum switching frequency, range of switching frequency and current ratings of dynamic switches and diodes. The converter is restricted by the variable switching frequency. Through simulation result 350V is obtained as an output with the use of multilevel inverter. The simulation result will be compared and verified experimentally.

REFERENCES

1. Abdel-Khalik, A.S., A.M. Massoud, A.A. Elserougi and S. Ahmed, 2013. Optimum power transmission-based droopcontrol design for multi-terminal HVDC of offshore wind farms, IEEE Trans. Power Syst., 28(3): 3401-3409.
2. CIGRE B4-52 Working Group, HVDC grid feasibilitystudy, Melbourne: International Council on Large Electric Systems, 2011.
3. Meyer, C., 2007. Key components for future offshore DC grids, PhD Thesis, RWTH Aachen University.
4. Deng, F. and Z. Chen, 2013. Design of protective inductors for HVDC transmission line within DC grid offshore wind farms, IEEE Trans. Power Del., 28(1): 75-83.
5. Deng, F. and Zhe Chen, 2013. Operation and control of a DCgrid offshore wind farm under DC transmission system faults, IEEE Trans. Power Del., 28(1): 1356-1363.
6. Meyer, C., 2007. Key components for future offshore DC grids, PhD Thesis, RWTH Aachen University.
7. Max, L., 2009. Design and control of a DC collection grid for a wind farm, PhD Thesis, Chalmers University of Technology.

8. Chen, W., A. Huang, S. Lukic, *et al*, 2011. A comparison of medium voltage high power DC/DC converters with high step-up conversion ratio for offshore wind energy systems, in Proc. IEEE ECCE, pp: 584-589.
9. Zhou, Y., D. Macpherson, W. Blewitt and D. Jovcic, 2012. Comparison of DC-DC converter topologies for offshore wind-farm application, in Proc. Conf. PEMD, pp: 1-6.
10. Fan, S., W. Ma, T.C. Lim, *et al*, 2013. Design and control of a wind energy conversion system based on a resonant dc/dc converter, IET Renew. Power Gener., 7(3): 265-274.
11. Deng, F. and Z. Chen, 2013. Control of improved full-bridge three-level DC/DC converter for wind turbines in a DC grid, IEEE Trans. Power Electron., 28(1): 314-324.
12. Meyer, C., M. Höing, A. Peterson and R.W. De Doncker, 2007. Control and design of DC grids for offshore wind farms, IEEE Trans. Ind. Appl., 43(6): 1475-1482.
13. Engel, S.P., N. Soltau, H. Stagge and R.W. De Doncker, 2013. Dynamic and balanced control of three-phase highpower dual-active bridge DC–DC converters in DC-grid applications, IEEE Trans. Power Electron., 28(4): 1880-1889.
14. Meyer, C. and R.W. De Doncker, XXXX. Design of a threephase series resonant converter for offshore DC grids.
15. Luth, T., M. Merlin, T. Green, F. Hassan and C. Barker, 2014. High frequency operation of a DC/AC/DC system for HVDC applications, IEEE Trans. Power Electron., 29(8): 4107-4115.
16. Stephan, K., 2012. Modular DC/DC converter for DCdistribution and collection networks, PhD thesis, EPFL, Switzerland.
17. Chen, W., X. Ruan, H. Yan and C.K. Tse, 2009. DC/DCconversion systems consisting of multiple converter modules: stability, control and experimental verifications, IEEE Trans. on Power Electron., 24(6): 1463-1474.
18. Zhou, Y., D. Jiang, P. Hu, *et al*., 2014. A prototype of modular multilevel converters, IEEE Trans. Power Electron., 29(7): 3267-3278.
19. Park, K. and Z. Chen, 2013. Analysis and design of a parallelconnected single active bridge DC-DC converter for highpower wind farm applications," IEEE Power electronics and Applications (EPE), pp: 1-10.
20. Zhan, C., A. Bullock, C. Smith and A. Crane, 2011. Power collection and transmission systems, European PatentApplication, EP2341594A1, 2011.
21. Hagar, A.A., 2011. A new family of transformerless modular DC-DC converters for high power applications, Ph.D.dissertation, Dept. Elect. Eng., Univ. of Toronto, Toronto,ON, Canada.
22. Monjean, P., J. Delanoe, J. Auguste, C. Saudemont, J. Sprooten, A. Mirzaian and B. Robyns, 2010. Topologiescomparison of multi-cell medium frequency transformer for offshore farms," in Proc. IET AC and DC Power Transmission, pp: 1-5.
23. Zhan, C., C. Smith, A. Crane, *et al*, 2010. DC transmission and distribution system for a large offshore wind farm, in Proc. IET AC and DC Power Transmission, pp: 1-5.
24. Denniston, N., A. Massoud, S. Ahmed, *et al*, 1986. Multiple module high gain high voltage DC-DC transformers for offshore wind energy systems, IEEE Trans. Ind.Electron., 58(5): 1877-1886.
25. Chen, W., A. Huang, C. Li, *et al*, 2013. Analysis and comparison of medium voltage high power DC/DC converters for offshore wind energy systems, IEEE Trans. Power Electron., 28(4): 2014-2023.
26. Jovcic, D., 2009. Step-up dc-dc converter for megawatt size applications, IET Power Electron., 2(6) 675-685.
27. Parastar, A., A. Gandomkar, M. Jin and J. Seok, 2013. High power solid-state step-up resonant Marx modulator with continuous output current for offshore wind energysystems, in Proc. IEEE ECCE, pp: 1709-1716.
28. Jovcic, D., 2009. Bidirectional, high-power DC transformer, IEEE Trans. Power Del., 24(4): 2276-2283.
29. Robinson, J., D. Jovcic and G. Joós, 2010. Analysis and design of an offshore wind farm using a MV DC grid, IEEE Trans. Power Del., 25(4): 2164-2173.
30. Hagar, A.A. and P.W. Lehn, 2014. Comparative evaluation of a new family of transformerless modular DC-DC converters for high-power applications, IEEE Trans.Power Delivery, 29(1): 444-452.
31. Ortiz, G., J. Biela, D. Bortis and J.W. Kolar, 2010. Megawatt, 20 kHz, isolated, bidirectional 12kV to 1.2kV DC-DCconverter for renewable energy applications, in Proc. Int. Power Electron. Conf., pp: 3212-3219.
32. Wu Chen, Xiaogang Wu, Liangzhong Yao, Wei Jiang and Renjie Hu, 2015. A Step-up Resonant Converter for Grid-Connected Renewable Energy Sources IEEE Tans. Power ele., 30(6): 3017-3029.