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A High Efficiency Step-Up DC-DC Converter Combining KY and Multilevel Modular Converter with Low Switching Voltage and Current Stress

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Abstract: *A novel step up converter is presented, which combines the KY converter and the Multilevel Modular Converter (MMC). The proposed system combines KY and MMC. MMC is integrated to reduce the voltage and current stresses of switching device, improve efficiency, and fault-tolerant capability. The KY converter contains SR boost converter and coupled inductor with the turn's ratio it is used to improve the voltage gain. Therefore, the voltage gain is higher in the converter output, and can be determined by adjusting both the duty cycle and the turn's ratio. The proposed step-up converter has no floating output current, and reducing the output voltage ripple. By combining achieves the features of KY and MMC.*

1. Introduction

Now a days the demand of green power is increased gradually. Solar, wind, fuel, geothermal, biomass are some sources of green power. Lot of applications, converters have much importance, such as boosting the small output voltage to high voltage. The voltage gains of buck-boost converter and traditional boost converter are not high for the loads need. Till now, a lot of voltage-boosting techniques presented, such as inductors and charge pump, coupled inductors, here the output voltage become floating, this will result to increase the complexity of the application, and also these converters are made up of so many components therefore the converters relatively complicated. In many situations the output current are non-pulsating, the voltage gain is inadequate. In HVDC use of DC/DC power converters increase output voltage to the high voltage (HV) level, and it results to efficient transmission for long distances. HVDC results to reduce the power losses, cabling cost, step up grid bulky transformer etc. A new Voltage boosting converter is described here, and combines KY converter with Multilevel Modular Converter. Here KY converter having one SR buck-boost converter connection, and also one coupled inductor having turn`s ratio, it is used to increase the voltage gain. The MMC containing SC or CC. SC or CC based DC-DC converters are used in high power applications and they are having advantages like high power density, high efficiency and control simplicity. For offshore system the exponential voltage gain was implemented using SC DC-DC with the help of Marx concept. Combination of top and bottom cells provide high degree of modularity in each cells. The main important thing of modularity method is, when a single module fails, the converter can function at a reduced power level. It is also practicable to localize any fault in the system, hence system reliability can improve. It's having less maintenance, since it takes small interval of time to clear the fault. In modular structure the usage of cheaper components which is having low voltage / current stress in a system helps to distribute the power handling in multiple modules. MMC is integrated to reduce the voltage and current stresses of switching device, improve efficiency, and fault-tolerant capability.

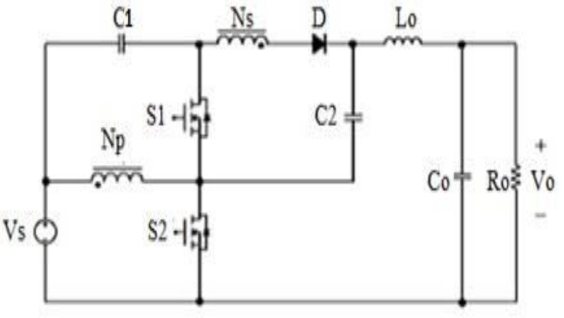
2. SYSTEM CONFIGURATIONS

There are two system to be explain, they are,

1. KY converter
2. Multilevel Modular Converter
3. Combination of KY converter and MMC

2.1 KY converter

The KY converter is shown in Fig 1, which consists of MOSFETs switches namely S_1 and S_2, For voltage gain enhancement there uses a coupled inductor with turns ratio, its primary is known as N_p and the secondary is N_s. C_1 is known as energy transferring capacitor, C_2 is charge pump capacitor, A diode D_1 is used, the output side containing Output capacitor C_o, resistor R_o, The input voltage is V_i, output voltage is V_o.



3. Fig. 1 KY converter

MODE 1:

An input voltage V_i is induced in the primary turns N_p which causes the L_m to be magnetized, since the S_1 is turned off and S_2 is turned on, it also causes a voltage which is equivalent to V_i*Ns/Np to be induced across the secondary turns $N_{p.}$ In addition, D_1 becomes forward biased; C_2 is charged to $V_i+V_{C1}+Vi*Ns/Np$ and the voltage across L_o ie,V_{lo} is a negative value, equal to $V_{C2}-V_o$, thus making L_o demagnetised. As a consequence, input voltage V_i together with the voltage across C_1 (V_{C1}), plus the induced voltage on Ns (V_{Ns}), plus the voltage across L_o, provides the energy to the load. When D_1 become forward biased, $C_2= V_i+V_{C1}+Vi*Ns/Np$, Voltage across L_o = $V_{C2}-V_o$, This voltage will makes the L_o demagnetised. So in this condition in order to provide the energy to the load, the input voltage together with voltage across C_1, induced voltage on N_s and voltage across L_o add together. Fig. 2 shows the mode 1 operation of KY converter with coupled inductor.

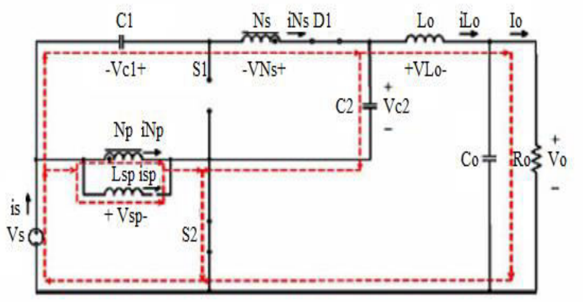


Fig. 2 Mode 1 Operation of KY Converter with Coupled Inductor

MODE 2:

S_1 is turned on but S_2 is turned off. Therefore, the V_{C1} voltage is imposed on Np, thereby causing the magnetizing inductor L_m to be demagnetized and the voltage across Ns to be induced ,equal to-V_{C1}*Ns/Np. When switch S_1 is on and S_2 is off, L_m is demagnetised which is caused due to the imposing of voltage V_{C1} on N_p. It also causes a voltage to be induced across N_s which is equal to V_{C1}*Ns/Np. Fig. 3 shows the mode 2 operation of KY converter with coupled inductor

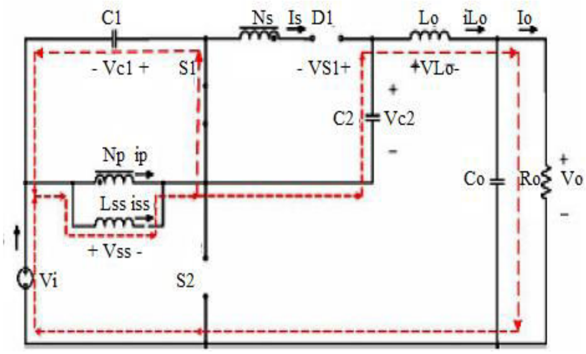


Fig. 3 Mode 2 Operation of KY Converter with Coupled Inductor

When the D_1 become reverse biased. L_o become magnetised since the voltage on L_o is equal to $V_i+V_{c1}+V_{c2}-V_o$ which is a positive value, So energy to the lo and load is provided by the addition of input voltage, voltage across lm and voltage across c2. In addition, D_1 becomes reverse biased, the voltage on L_o is a positive value, equal to $V_i+V_{c1}+V_{c2}-V_o$, thus causing L_o to be magnetized. As a result, the input voltage V_i, together with the voltage across Lm (V_{Np}), plus the voltage across C_2 provides the energy to L_o and the load. Fig. 3 shows the Mode 2 operation of KY converter with coupled inductor.

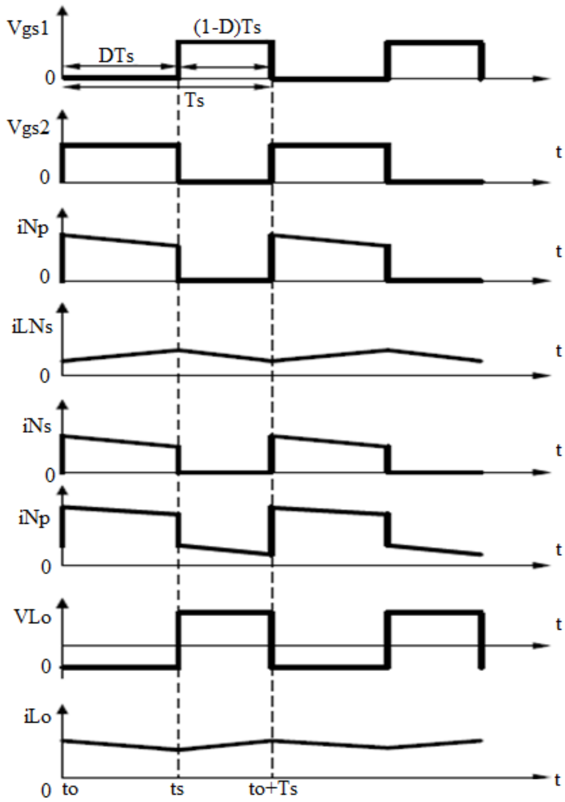


Fig.4 Waveforms of KY Converter

Fig. 4 shows the waveforms of a KY converter with a coupled inductor. Here, the output current is continuous and it is not pulsating. And the output voltage waveform does not contain any ripple.

2.2 Multilevel Modular Converter

A five port system is present in SL- based module. This five port system consists of two top and bottom cells, where each one contains 2 capacitors, one inductor and two diodes. The six port DS based module comprised of two cells in the top and bottom of its module and also it has a single active switch one diode, one inductor and one capacitor. The figure is shown below. The input module of the cascaded SL based circuit is integrated to the module #1 which is shown in the figure 5(a), the ports 5 and 6 of module #n of cascaded DS based topology are connected to an output module which has two capacitors and two diodes which is shown in figure 5(b). The below figure shows the above described 2n+1 level cascaded configurations of the SL and DS based modules.

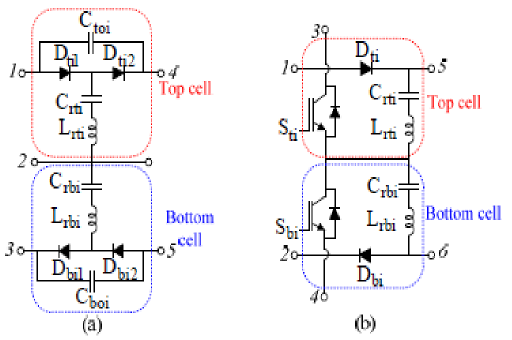


Fig. 5 Structure of SL-Based Module and DS Based Module

2.3 Operating Principles of the 2n+1 Level Cascaded SL-and DS-based Configurations

Figures 6 and 7 show the 2n+1 level cascaded SL- and DS-based topologies, respectively. Note that n is an even number in figure 7.

2.3.1 Cascaded SL-based Configuration

➢ **State I**

When t_0 to t_1, S_b is ON ie, the bottom switch, Then S_t is OFF. The diodes D_{ti1}`s (i=1, 2, …, n) in each top cell are forward-biased by $V_s$ and $C_{toi}$`s. As a result, C_{rti}`s are charged by $V_s$ and $C_{toi}$`s (i=1, 2, …, n-1), as shown in below Figure 3.6(a).

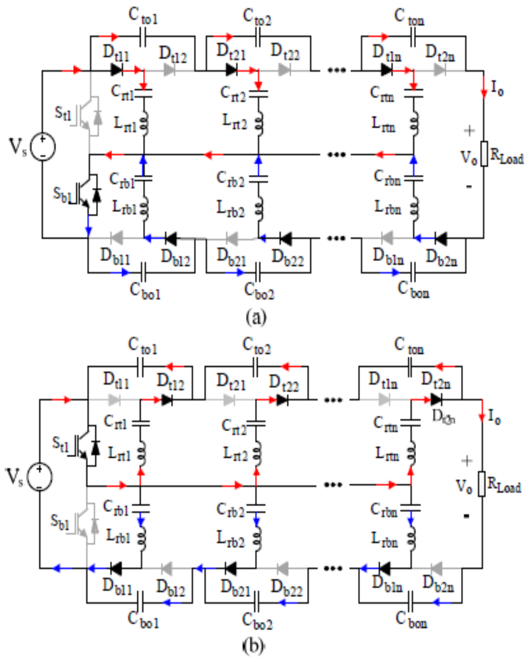


Fig. 6 State I and State III Operation of the 2n+1 Level Cascaded SL-Based Topology.

Here C_{ton} is discharged to the load. In contrast, in the bottom cells, C_{rbi}`s are discharged to the output capacitors, $C_{boi}$`s. For the general 2n+1 level cascaded SL-based topology, the currents through the top and bottom capacitors are

$$i_{Crti}(t) = \frac{\pi Po}{Vo}\sin(\omega_r t),\ i= 1,2,\ldots,n$$

$$i_{Crbi}(t) = -\frac{\pi Po}{Vo}\sin(\omega_r t),\ i = 1,2,\ldots,n$$

The voltages of the top and bottom resonant capacitors can be obtained as follows:

$$v_{Crti}(t) = iVs - \frac{\pi Po}{Vo C_{Crti} \omega r}\cos(\omega_r t) i = 1,2,\ldots,n$$

$$v_{Crbi}(t) = iVs + \frac{\pi Po}{Vo C_{Crti} \omega r}\cos(\omega_r t)\ i =1,2..n$$

➢ **State II**

In this state, all the switches are turned OFF. The diodes are reversed-biased and the resonances stop, Therefore, the inductor currents become zero.

➢ **State III**

State III begins when S_t in ON-state and S_b in OFF-state at t_0. The diodes D_{ti2}s and diodes D_{bi1}s are forward-biased, it is shown figure 3.6(b). In the bottom cells, C_{rb}i`s are charged by Vs and $C_{boi}$`s(i=1, 2, …, n-1), whereas C_{rti}`s are discharged to $C_{toi}$`s. As a result, the voltages of C_{rbi}`s are equal to i times the input voltage level.

➢ **State IV**

The operation of this state is similar to that of State II

2.3.2 Cascaded DS-based Configuration

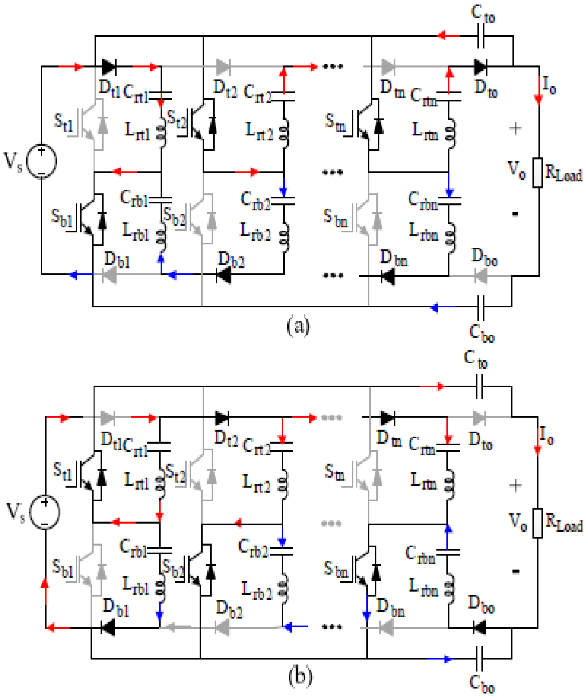


Fig. 7 State I and State III Operation of the 2n+1 Level Cascaded DS-Based Topology

- **State I**

At t = t_0, S_{bi} (i=1, 3, …, n-1) and S_{ti} (i=2, 4, …, n) are turned ON, whereas S_{bi} (i=even) and S_{ti} (i=odd) are OFF in the top and bottom cells. Therefore, in the top and bottom cells, the odd numbered C_{rti}`s and even numbered $C_{rbi}$`s are charged by V_s, C_{rti}`s (i=2, 4, …, n), and $C_{rbi}$`s (i=1, 3, …, n-1).In this state, the output capacitor C_{to} is charged by C_{rtn}, whereas C_{bo} is discharged to the load, as shown in figure 3.7(a).

- **State III**

During this time interval, S_{bi}`s (i=1, 3, …,n-1) and $S_{ti}$`s (i=2, 4, …, n) are OFF, whereas S_{bi}`s (for i even) and $S_{ti}$`s (for i odd) are ON. Therefore, in the top cells, C_{rti}`s (i=1, 3, …, n-1) are discharged to $C_{rti}$`s (i=2, 4, …, n). The odd numbered C_{rbi}`s are charged by $V_s$and the even numbered $C_{rbi}$`s. Figure 8 shows the key voltage and current waveform of MMC.

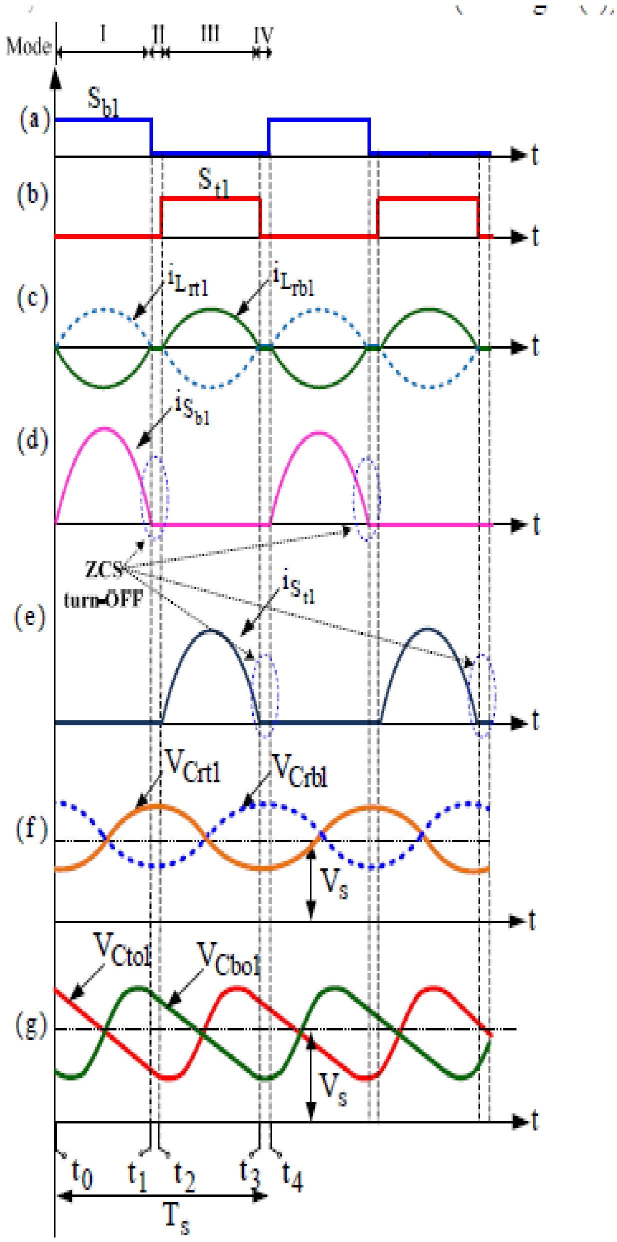


Fig. 8 Key Current and Voltage Waveforms of the MMC

3. COMBINATION OF KY CONVERTER AND MMC

Here combining KY converter and Multilevel Modular Converter. The KY converter contains SR boost converter and coupled inductor with the turn's ratio it is used to improve the voltage gain. Therefore, the voltage gain is higher in the converter output, and can be determined by adjusting both the duty cycle and the turn's ratio. The proposed step-up converter has no floating output current, and reducing the output voltage ripple.

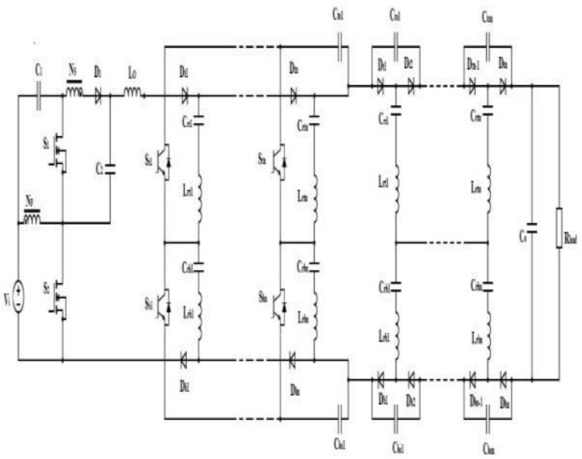


Fig. 9 KY- MMC Converter

The operation of combined configuration is similar individual operation of KY and MMC

3.1 Simulation

The simulation is done by using Matlab R2016a Simulink, the specifications and parameters are listed in the table I and II given below.

3.2 Simulation Diagram

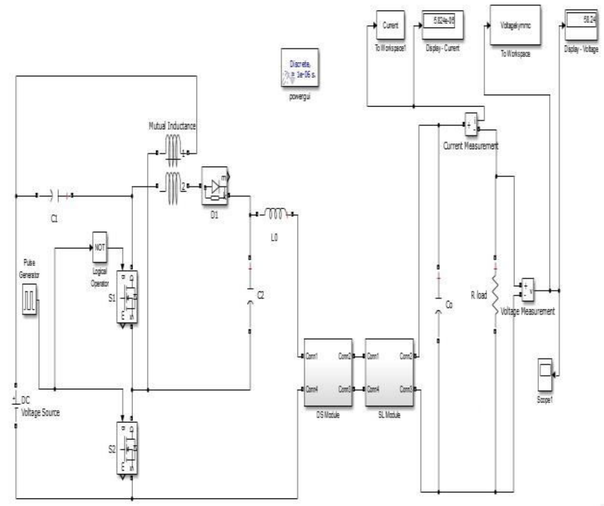


Fig. 10 Simulation Diagram

3.2 Simulation Result

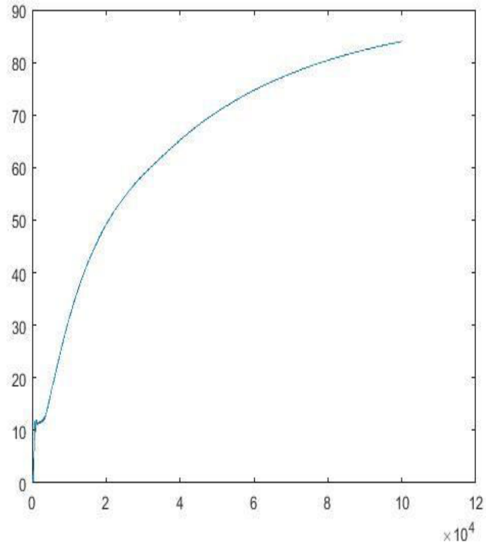


Fig. 11 Simulation Result – Voltage Waveform

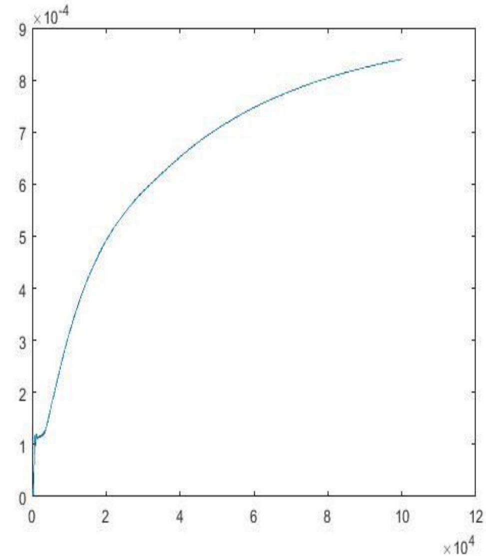


Fig. 11 Simulation Result – Current Waveform

Table I Five-Level System Specification

Specifications	Value
Output power	0.07056 W
Input voltage	12 V
Output voltage	84 V
Switching frequency for MMC	4.5 kHz
Switching frequency for	100kHz

Parameter	Value
KY MOSFET switches $S1$,$S2$	STP120NF, VDS=100V, ID=120A, Ron=10.5mΩ
KY Diode $D1$	V20120C, VR=120V, $IF(AV)$=20A, VF=0.54V @ IF=5A
KY Energy-transferring capacitor $C1$	Two 470μF/50V Rubycon capacitors with positive terminals connected in series
KY Charge pump capacitor $C2$	Two 47μF/100V MIEC capacitors connected in parallel
KY Output capacitor Co	Two 220μF/100V MIEC capacitors connected in parallel
KY Coupled inductor Core	PTS40/27/I 3C92, Np:Ns=1:3, Lm=148.7μH, $Ll1$=0.3μH, k≒0.997
KY Output inductor Lo Core	ER40/20/13, N=20, air-gap of 0.35mm, Lo=188μH
MMC Resonant inductor	2.4 μH with powder core
MMC Resonant capacitor	6 μF/450 V – Film capacitor
MMC Output capacitor	30 μF/450 V – Film capacitor
MMC IGBT module	600 V-SKM200GB063D from SEMIKRON
MMC Diode	DSEP2X91-06A

Table II Prototype Components

3. CONCLUSION

A multilevel converter is build up with KY converter. In order to improve the voltage gain of the multilevel converter, the KY converter has one coupled inductor which has turns ratio and also it contains a buck boost converter which is rectified synchronously. In order to reduce the output voltage ripple, the step p converter has no floating output current. The voltage gain is higher in the converter output. And this voltage gain can be find by adjusting its turn's ratio and duty cycle. The MMC consist of SL and DS based modules to achieve the voltage gain and high efficiency. The cascaded DS based topology has many modules and equal power sharing is achieved among its modules. Due to this, the switching devices experiences low losses and low cost than other approaches. By looking the power device count, efficiency and fault tolerant capability, the cascaded hybrid topology is really advantage than other DC to DC approaches. When external fault is added to the circuit, the circuit remains stable. Hence the system remains highly fault tolerant.

4. ACKNOWLEDGEMENT

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5. REFERENCES

[1] K. I. Hwu, Y. T. Yau "KY Converter and Its Derivatives" IEEE Power Electron, 2009
[2] K. I. Hwu, W. Z. Jiang "Voltage Gain Enhancement for Step-Up Converter Constructed by KY and Buck-Boost Converters" IEEE Power Electron, 2014
[3] A. Parastar, Yong Cheol Kang, Jul-Ki Seok "Multilevel Modular DC/DC Power Converter for High Voltage DC-Connected Offshore Wind Energy Applications" IEEE Transactions on Industrial Electronics, 2014
[4] G.Rajkumar, Sowmya K. P "A high efficiency high step up dc-dc convertor combining ky and cuk converters with low switch voltage stress" Journal of CPRI, 2015