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Review of Isolated DC-DC Converter for photovoltaic applications

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Abstract - In this paper, the recent development in DC-DC converter are identified and examined. The search is to ease the difficulties associated with new converter topologies employed in renewable energy in various photovoltaic applications. New converter topologies have lower parts, easy to control, cheaper and are suitable alternatives to the various circuit combination in series or parallel connection. The converters are classified by number of divisions that bother on the isolation between the ports, the DC link connects the ports. Electromagnetic connected converters uses a DC-link to connect input ports, both input and output port are isolated. Converters are magnetically connected where input ports and output ports are seperate multiple winding and isolated from the winding. The structure, characteristics, operation, formation, merits and demerits of the converters are presented. In few papers compared converters based on the distinct features of the converters. The review identifies that converter properties depend on specific application requirement and thus meets all the demands in the industry. Predicted future research work aim is to update research done during the time gap from last reviews.

Key Words: DC-DC Converter, Isolated converters,Photovoltaic applications.

1.INTRODUCTION

Recently, more usage of fossil fuels causes pollution issues, which has adverse effect on the planet. Uncertainity in climate changes impact economic and social development activities globally. Due to excessive combustion of fossil fuels causes excessive carbon emissions. Moreover, due to sudden increase in the oil prices in 2020 and 2021 because of pandemic added a force behind the switching to renweable resources from fossil fuels.

Below have listed out the problems faced by fossil fuels

1) Monster measures of carbon dioxide are delivered into the climate.

2) Carbon dioxide causes global warming

3) Combustion of coal discharge sulphur dioxide gas lead to acid rain.

4) Supply of fossil fuel are restricted and are not sustainable.

Therefore, renewable energy sources such as wind, solar, fuel cells, are chosen to generate power. But generation of output voltage is low, therefore there is a need to connect DC- DC converter to amplify the value of voltage. The output of the converted voltage is given to the input of inverter.

Conventionally, PV cells are connecting in series, due to mismatch of model shadow effect on PV cells, decreases efficiency. In order to solve the conventional problem high step-up DC-DC converter to step up or boost the outcome of solar panels.

Traditional isolated converters have low efficiency due to high turn ratio of transformers such as flyback and full bridge converters. Non-isolated converters efficiency decreases in a large number in high voltage gain, output diode reverse recovery problem, cascade boost converter with coupled inductor results cost, high stress voltage and instability problems.

Advanced ultra-lift and Super-lift converters are used to achieve high voltage gain, in such converters duty cycles of PWM voltage should be close to unity, results in increasing efficiency.

Studied various DC - DC converters and presented in this paper.

2. Detailed Explaination of Various Converter

1) High step-up Z-source DC-DC converter with flyback and voltage multiplier.

Z-source converter which has a high voltage gain, right usage of ZCS solve the reverse recovery problem. Proposed topology consists of two identical capacitors and inductors in the z-source network. To increase the voltage gain coupled inductors and voltage multipliers are employed. Two operating modes during one switching period in the steady state. Assumed ideal condition to all the semiconductor devices.Circuit analysis and design guidelines explained in detail with equations.Performance comparision between different single switch converters is represented.

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Converter	Voltage Gain	Switch Voltage Stress	Input current	Reverse-recovery problem
conventional boost	$\frac{1}{1-D}$	$\frac{V_{in}}{1-D}$	continuous	large
flyback	$n.\frac{D}{1-D}$	$V_{in}(\frac{D}{1-D}+n)$	discontinuous	large
conventional Z-source	$\frac{1-D}{1-2D}$	$\frac{V_{in}}{1-2D}$	discontinuous	large
Z-source based in [7]	$n.\frac{1+D}{1-2D}$	$\frac{V_{in}}{1-2D}$	continuous	small
proposed converter	$\frac{(2n+1)-D}{1-2D}$	$\frac{V_{in}}{1-2D}$	discontinuous	small

Chart:1 Comparision table

Novel high step-up Z-source DC-DC converter with flyback and voltage multiplier is presented. Proposed converter eliminates the complexity problem and duty cycle in existed high step-up converter.

Working on stress on the diode, efficiency, output voltage of panel has kept for future scope.

2) A Three-Phase Step-Up DC–DC Converter With a Three-Phase High-Frequency Transformer for DC Renewable Power Source Applications.

Proposed a converter which developed for industrial applications. The purpose of this converter to reduced output voltage ripple due to three-phase output converter. Two operating regions for switch modulation. To regulate input current and output voltage regulation, current-mode control strategy.

Development in three-phase DC-DC converter to increase the electronic power density ratings. Advantages of three-phase DC-DC isolated converter is 1) reduction in input and output filters volume, reduction of weight and size of the isolation transformer. 2) low rms current levels.

Few drawbacks from conventional converter have overcome in the three-phase step-up DC-DC isolated converter characteristics. It presents a low input ripple current, output-voltage ripple due to the three-phase output current. It requires small capacitance value. Reduces the voltage level across the switches because of transformer. Assuming all semiconductor components are ideal i.e, they present zero impedance when the circuit is on and the infinite impedance when the switch is off. Duty ratio of the switches controls power flux transfer and output and input voltage ratio.

A detailed circuit description and analysis of the circuit operation. This converter contains three controlled switches and high frequency transformer. Reduces the converter volume dur to input and ouput filters are fed by three times the switching frequency. This converter meet the requirement of reduced input ripple current in industrial applications. Leakage inductance is reduced which helps in choosing switching frequency. Converter achieves 87% efficiency with rated 3.4kW output power and 27V input and output voltage.

3) Design and Development of Single Switch High Step-Up DC–DC Converter

A new single switch high step-up DC-DC converter is proposed by consisting boost and single ended primary inductor converter along with diode-capacitor circuit which helps in reduce the stress across the semiconductor devices. Converter produces low switching voltage so that efficiency of the converter increased. Converter are classified as isolated and non-isolated. With non-isolated converter faces the issue such as low DC voltage, stress on the switches. Weight volume, efficiency, requires high duty cycle, large conduction loss and reverse recovery issues. In order to overcome the drawbacks of non-isolated converters, isolated converters are proposed to step-up the voltage and for high voltage gain.Numerous converters are proposed with different combination of circuit . Proposed converter tried to improve efficiency in non-isolated converter by design the circuit.

4) Isolated Modular Multilevel DC-DC converter with DC fault current control capability based on current fed dual active bridge for MVDC application.

Proposed converter is dual-active bridge (DAB) circuits including soft switching and small passive components hence high efficiency and high power density can be achieved. dv/dt in the converter is mitigated with the quasi-three-level modulation. Integrated the battery energy storage to a multivoltage DC grid. Operating principle explained for both normal and DC fault conditions.

In dual-active bridge (DAB) DC-DC converter. Employed two H-bridge connected through an AC transformer, which has the advantages of bdirectional power flow, inherent-zero-voltage switching (ZVS), low total device rating (TDR), high efficiency achieved in the circuit, Wide research has been conducted to meet the requirement of dual active bridge at medium-voltage level. The cell based structure reduces the di/dt, which avoides excessive capacitor discharge.

Detailed analysis have done and formed table. Proposed converter combines the advantages of both dual active bridge and modular multilevel converter based DC-DC converter. Dynamics of dual active bridge based converters are simple, modular multilevel converter has the superior current control capability.

Mode	Throughout Power	Transformer rms current
I	$\frac{V_{arm}^2}{\omega L_s} d\phi \left(2D^T - \frac{\lvert\phi\rvert}{2\pi}\right)$	$\frac{V_{arm}}{\omega L_s}\sqrt{(1-\frac{4}{3}D^T)[(1-d)D^T\pi]^2 + \frac{d(6D^T\pi-\lvert\phi\rvert)\phi^2}{3\pi}}$
II	$\frac{V_{arm}^2}{\omega L_s} d\phi \left[1 - \frac{\lvert\phi\rvert}{\pi} - \frac{\pi(1-2D^T)^2}{2\lvert\phi\rvert}\right]$	$\frac{V_{arm}}{\omega L_s}\sqrt{(1-\frac{4}{3}D^T)[(1-d)D^T\pi]^2 + \frac{d\{(6D^T\pi-\lvert\phi\rvert)\phi^2-[\lvert\phi\rvert-(1-2D^T)\pi]^3\}}{3\pi}}$
III	$\frac{V_{arm}^2}{\omega L_s} d\phi(\pi-\lvert\phi\rvert)\left(\frac{1}{2\pi}-\frac{1-4D^T}{2\lvert\phi\rvert}\right)$	$\frac{V_{arm}}{\omega L_s}\sqrt{(1-\frac{4}{3}D^T)[(1-d)D^T\pi]^2 + \frac{d\{(3\lvert\phi\rvert-2D^T\pi)(2D^T\pi)^2-[\lvert\phi\rvert-(1-2D^T)\pi]^3\}}{3\pi}}$
IV	$\frac{2V_{arm}^2}{\omega L_s}\frac{\phi}{\lvert\phi\rvert} d\pi(D^T)^2$	$\frac{V_{arm}}{\omega L_s}\sqrt{(1-\frac{4}{3}D^T)[(1-d)D^T\pi]^2 + \frac{d(3\lvert\phi\rvert-2D^T\pi)(2D^T\pi)^2}{3\pi}}$

Chart:2 Power and Transformer current in DC-DC Converter

5) Stability analysis of isolated bidirectional dual active full-bridge DC-DC converter with triple phase-shift control.

Research work presents bidirectional dual full bridge DC-DC converter with triple phase-shift control under arbitrary parameter changes. Specifically worked on the stabilkty determination of power converter in a systematic way. Presence of nonlinearity in the converter output when we used practically therefore lyapunov functions is applied to determine the stability of the converter in each and every stage.

Generally paper works on the efficiency, stress on the switches and diodes, compactness, but stability also one of the important factor, this paper gave importance on the stability in the design.

Novel method indentified the problem of size and nature of the circuit parameters changes frequently. Stability is determined by observing the simulation output in power electronic circuits because, generally power converter exhibits non-linearity and theoretically analysing stability is very difficult. But simulation is not a correct method of analyzing the circuit because with components when we experimented the state of the circuit is different compared to simulation output. Its not possible to simulate to get results like hardware experiment. There will be a huge difference in hardware results and software results.

In this reseach work, they have developed a mathematical model for the bidirectional converter which is a non linear system. Several stages of the circuit has been developed.

Concept of time varying state equation model developed by replacing the nonlinear circuit components by linear. Because of the linear time-varying state equation, stability analysis of the bidirectional converter is possible in the entire operating period. Stability is analysed in every stage, hence no abrupt change in the converter during its operating period.

By applying the concept of eigen values of the matrix A, asymptotically stable is determined if the real parts of the eigen values of the matrix are negative. Stability is analysed by lyapunov function method. For the current converter lyapunov function is sufficient to find the stability analysed lyapunov function topology theoretically depends on the converter and its working condition stability methodology can be changed.

6) Design and Analysis of an Interleaved Flyback–Forward Boost Converter With the Current Autobalance Characteristic

Without an additional current sharing module, switched capacitors are used effectively to control the voltage source fuction and balancing of currents of interleaved two phases. Turns ratio is reduced by the voltage lift function of the switched capacitors. Alternate operation of flyback and forward modes. Problem faced by stresses of the output diodes and reverse-recovery problem is reduced.

Interleaved boost converter plays role of cancelling the input and output ripples, which also reduces the size of the electromagnetic interference filters and energy storage inductors.

In power electronic systems, general problems are maintenance, repair, fault tolerance, low heat dissipation. Passive components generally occupy the size and weight of the circuit. Turns ratio effects the magnetizing current of the transformer, reduced turns ratio suppresses the core loss and volume of the magnetic core.

Proposed paper designed an equation where magnetizing current ration reduced to less than 1. They have explained about how magnetizing current effects the volume of the magnetic core.

Due to ZVT soft switching, switching losses are reduced and power density can be improved. The research work experimented based on 48-380 V DC-DC prototype and verified.

7) Analysis and implementation of a ZVS/ZCS DC-DC switching converter with voltage step-up.

Explained in detail regarding ZVS/ZCS based DC-DC converter with comparision table.

	Proposed converter	Boost converter	Coupled-inductor [6]	Cascade boost converter [8]	Isolated transformer [13]
Switch ZVS	O	X	O	O	O
Diode ZCS	O	X	X	X	O
V_o/V_{in}	$\frac{n(1+n)}{1-\delta}$	$\frac{1}{1-\delta}$	$\frac{1+n\delta}{1-\delta}$	$\frac{1}{(1-\delta)^2}$	$\frac{n}{1-\delta}$
Voltage stress of switches	$\frac{V_{in}}{1-\delta}$	$\frac{V_{in}}{1-\delta}$	$\frac{V_{in}}{1-\delta}$	$\frac{V_{in}}{(1-\delta)^2}$	$\frac{V_{in}}{1-\delta}$
Voltage stress of diodes	V_o	V_o	$\frac{nV_{in}L_m}{L_m+L_{lk}}+V_o$	V_o	V_o

Chart:3 Parameters comparision in various converter

Coupled inductors and isolated transformer are helped to achieve high voltage gain without extremly high duty ratio of power switches.

8) A rectification topology for high-current isolated DC-DC converter.

Secondary side of the transformer is subjected to current triple rectification. In conventional method center-tapped, current doubler rectifier, converter can carry high current and withstand thermal capability.

Proper justification has given why conventional converter with center-tapped, current doubler rectifier is not suitable for high-current converters.

Elaboratly done the comparision of current triple rectifier with conventional center-tapped and current doubler rectifier.

Rectifier Topology	Center-tapped Rectifier	Current Doubler Rectifier		Current Tripler Rectifier		
DC Voltage Gain	$\frac{2}{N}\cdot D$	$\frac{2}{N}\cdot D$		$\frac{2}{N}\cdot D$		
Transformer Secondary Winding RMS Current	$\sqrt{\frac{1}{4}+\frac{D}{2}}\cdot I_o$	$\sqrt{\frac{D}{2}}\cdot I_o$		$\sqrt{\frac{1}{36}+\frac{D}{2}}\cdot I_o$		
SR Voltage Stress	$\frac{V_{in}}{N}\cdot 2$	$\frac{V_{in}}{N}\cdot 2$		$\frac{V_{in}}{N}\cdot 2$		
SR RMS Current	$\sqrt{\frac{1}{4}+\frac{D}{2}}\cdot I_o$	$\sqrt{\frac{1}{4}+\frac{D}{2}}\cdot I_o$		$\sqrt{\frac{1}{4}+\frac{D}{2}}\cdot I_o$		
Inductor DC Current	L	L_1	L_2	L_1	L_2	L_3
	I_o	$\frac{I_o}{2}$	$\frac{I_o}{2}$	$\frac{I_o}{3}$	$\frac{I_o}{3}$	$\frac{I_o}{3}$
Inductance Values For Identical output current ripples	$L_{Cent-tapped}=L$	$L_{CDR}=2L$	$L_{CDR}=2L$	$L_{CTR}=3L^{**}$	$L_{CTR}=3L^{**}$	$L_{CTR}=3L^{**}$
Total Inductor Copper Loss*	$I_o^2\cdot R_L$	$\frac{1}{2}\cdot I_o^2\cdot R_L$		$\frac{1}{3}\cdot I_o^2\cdot R_L$		
Total Output Current Ripple	$\frac{V_o\cdot T\cdot(1-2\cdot D)}{2}\cdot\frac{1}{L}$	$\frac{V_o\cdot T\cdot(1-2\cdot D)}{2}\cdot(\frac{1}{L_1}+\frac{1}{L_2})$ $(\frac{V_o\cdot T\cdot(1-2\cdot D)}{2}\cdot\frac{1}{L},\ for\ L_1=L_2=2L)$		$\frac{V_o\cdot T\cdot(1-2\cdot D)}{2}\cdot(\frac{1}{L_1}+\frac{1}{L_2}+\frac{1}{L_3})$ $(\frac{V_o\cdot T\cdot(1-2\cdot D)}{2}\cdot\frac{1}{L},\ for\ L_1=L_2=L_3=3L)$		
Individual Inductor Current Ripple	L	L_1	L_2	L_1	L_2	L_3
	$\frac{V_o}{2\cdot L}\cdot(1-2\cdot D)\cdot T$	$\frac{V_o}{L_1}\cdot(1-D)\cdot T$	$\frac{V_o}{L_2}\cdot(1-D)\cdot T$	$\frac{V_o}{L_1}\cdot(1-D)\cdot T$	$\frac{V_o}{L_2}\cdot(1-D)\cdot T$	$\frac{V_o}{2\cdot L_3}\cdot(1-2\cdot D)\cdot T$

*Given the DCR value of each inductor is R_L.
**Various sets of inductance values can be selected for identical output current ripples.

Chart:4 Current tripler comparision with current triple and doubler circuit.

Research work even proposed N-trupler rectifier but it becomes impractical for higher current ouput because of complicated structure of the transformer.

3. CONCLUSIONS

The main objective of the paper in this review, is to update the research status in the application of DC - DC converter in the photovoltaic applications. The multi input and isolated converter play a good role in photovoltaic systems. Basically, various types of converter encouraged in research work. These converters reduce cost and handle various control issues which arise from connecting to several converters to common DC bus. Various Isolated converters are explained in detail.several proposed topologies are cascaded inputs, three level inputs and current-fed inputs. Some desired features in these converters are high voltage gain, low losses, and multiple output voltage.

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