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An overview of high voltage conversion ratio DC-DC converter configurations used in DC micro-grid architectures

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ABSTRACT

This manuscript discuss about the various DC-DC converter configurations with high voltage conversion ratio utilized in DC micro-grid structures. The presented DC-DC converter topologies play a major role globally in the power generation sector including micro-grid, because of its decreased number of semiconductor devices, maximum conversion efficiency, small in size and cost of manufacturing is less. In this manuscript the DC-DC converter are categorized in to isolated and Non-isolated topologies. The first group topography works with the presence of transformer and the second group works without the transformer. These converters are capable to provide the various stages of output range. Researchers utilize these converters in the area of renewable energy generation, electric vehicle, micro sources, charge pumping applications etc. Hence they also work to improve the efficiency and reliability with reduction in components numbers and economical aspect. In this manuscript, the various topography of DC-DC converter topologies utilized in micro-grid are reviewed and comparison is made based on voltage conversion ratio, duty ratio, efficiency along with the basic operating principle. This review also reveals the research gaps, current trends, and challenges in the last part.

1. Introduction

The renewable energy source such as PV, wind are used in increased level due to environmental condition and improvement in technology and also works on decreasing the manufacturing cost. In India, the energy generation is largely dependent on coal, which is decreasing in nature. Henceforth, India has put various efforts to improve the power generation capacity by transferring from coal material to renewable energy sources. The sources such as PV, wind, tidal energy, Bio fuel, and ocean thermal energy are considered as the best alternative for the Fossil fuel [1].

By knowing the necessity of generating power from the renewable energy sources and the capacity available in nature, the literature survey is made to identify the suitable DC-DC converter topologies which will help to improve the efficiency of the system. To increases the consistency, power quality, and to attain the flexibility of the power system the micro grid technology is required, so that the distributed generation system effectiveness can be improved. Due to this consequence, the micro-grid technique has been recommended to transmit the common interconnection problems of the separate distributed renewable energy production units in several power utility systems [2,3].

Power electronic converters act as intermittent between power generation and conversion as shown in Fig. 1. A DC-DC converter was proposed in 1920s. These converters are used in wide application for the past six eras and it plays an important role in power electronics and drives. They are largely used in many industrial applications, computer hardware circuits and especially renewable energy power generation [4]. First boost converters was utilized and then to improve the efficiency and high conversion rate different techniques are derived. The various types of DC-DC converters such as buck, boost, buck boost, CUK, SEPIC, fly back, fly forward are mainly classified in to isolated and non-isolated type. If there exist an electrical contact between the input and output through transformer then it is known as isolated and at the same time the converter with absence of transformer is non-isolated.

The interleaving technique was designed by Zhang et al, and also the performance comparison for one choke and two choke interleaving approach is done. These converters are designed for the wide operating power range [5]. The integrated technique is modelled by Hanington et al. in 1999. And many researchers developed this integration technique for high voltage conversion purpose. This converter is used in the application of hybrid battery and ultra-capacitor energy storage system [6]. To improve the efficiency and conversion ratio further push-pull converters came in to existence. Ruiz-Caballero et al. designed the push-pull converter by decreasing the output diodes and to

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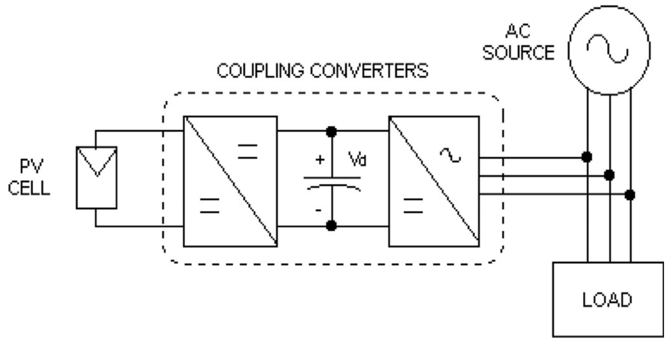

Fig. 1. Power conversion with DC-DC converter.

operate in continuous conduction mode. T.C Lim has used this push-pull technique for energy recovery in the snubber circuit. Where the recovery circuit is maintain functional along the duty cycle range. These converters are used in micro source applications [7]. The combination of LCL with Push-pull converter is designed by Michael J. Ryan in 1998. This converter structure is complex.

Since the structures are complex and operation is hard, bridge model converters are designed. The bridge model includes full bridge, half bridge and dual active bridge. Maria C. Mira designed the full bridge converter for renewable energy system applications. Dual active bridge is developed to provide an efficient way to converters in large and small signal systems. This converter is used in the application of hybrid-renewable energy scheme [8]. Active clamp technique is also designed to improve the working efficiency of the converter which is used to control the current flow [9]. To overcome the transformer losses coupled inductive and switched capacitor techniques have aroused. The Bidirectional converters are designed to step up and step down the voltage. The step down process is utilized in energy storage application and step up process is utilized in utility grid and micro grid applications. Bidirectional converters are used for flywheel energy storage application by Salinamakki et al. Hossein Ardi uses the bidirectional converter for high voltage conversion ratio for grid applications [10].

SEPIC converters are developing converters which have the feature of less losses and high conversion ratio. SEPIC technique has been proposed in 1989 and now it's in trend and well developed technique. El Khateb et al. has utilized SEPIC converter for maximum power point technique based on fuzzy logic controller [11]. Modified SEPIC converter has been proposed by Roger Gules to achieve high static gain from renewable sources [12]. Cuk converters are proposed in 1983. This converter is also derived basically from boost converter. These CUK converters are designed by eliminating the bridge circuit. Vashist Bist utilizes the CUK converter for unity power factor bridge-less circuit. This drive is implemented to achieve UPF at ac mains of wide range of speed control [13].

Overall the disadvantages in those converts are no stable efficiency, stable voltage gain, switching loss and conduction. This review work will give a clear about the suitable converter and to identify the converter topology with better efficiency and high voltage transmission ratio. This paper provides the information about the isolated and non-isolated DC-DC converter. Also analysing their efficiency, switching loss, conduction loss, and conversion ratio. The classifications are made depending on their topology. The paper is structures as follows Section 2 analyses the operation and other characteristics of isolated converter. Section 3 presents the features of the non-isolated converter and their topology. Section 4 provides a comprehensive comparison of these converters. Section 5 Details about recent trends and challenges. Section 6 is followed by conclusion.

2. Isolated converters

2.1. Integrated converters

An integrated converter is a mixture of two sections, which includes with boost topology at first section and voltage doubler topology paring second section. These converters have reduced components, smaller size, and lower weight or cost. The integrated converter topology varies and it is classified as below.

2.1.1. Integrated forward boost converter

A two phase dc-dc converter device was designed with the mixture of the forward converter along with the voltage doubler circuit to attain high step-up ratio and high efficiency. The first phase is boost up phase, which uses inductor and switch for the step up operation and isolated forward voltage delivering circuit with turn ratio N. The converter design is shown in Fig. 2a. This converter boost up the voltage from 24 V to 200 V. Its efficiency is 95.9%. The main characteristics of this converter are low switching, low voltage stress, lower duty ratio and high voltage transfer ratio. Integrated boost converter displays improved low-line efficiency due to its reduction in both conduction and switching losses.

Since the converter works in voltage-doubler mode in low line condition, it has reduced conduction loss. The switching losses of the boost switches and reverse-recovery-related losses of boost rectifiers are also considerably decreased because in the voltage-doubler mode the switching voltages are reduced [14]. For the secondary circuit, the converter depends on the predictable voltage-doubler circuit. This doubler circuit doubles the input voltage with reduced losses. Additional blocking capacitor is used to reduce voltage stress in first phase, also it is included to work in second phase and so the voltage strain of switch and diode D_1 is reduced [15]. The main advantage of this converter is, it attains high voltage ratio with best efficiency and reduced losses. High voltage gain is attained when duty cycle lies above 0.5 and it plays a major role in current sharing between two phases. This converter achieves lower voltage stress for the active switches used and for the diodes. The control strategy used in designing this converter is state space model.

2.1.2. Integrated boost fly-back converter

The design of the circuit is two phase. The converter is the mixture of boost converter along with the fly-back converter. In conventional converters Switched Capacitor (SC) with boost converter was in use. SC provides any voltage ratio limit depending on the number of capacitor integrated in converter design. However, its efficacy is vividly decreased when it is needed to deliver a constant output voltage. If there is no such restraint the SC converter can work with a high efficiency [16]. The switched capacitor and boost converter combination was not good based on efficiency and no constant output voltage is attained. Hence new type of converters is designed.

The converter reviewed here is the combination of boost converter and fly-back converter as shown in Fig. 2b. It provides high efficiency, high step up voltage gain and clamp mode converter. This converter adds coupled capacitors and diodes to attain high step up voltage gain. Two capacitors are charged in series and discharged in parallel through the coupled inductor. With specific duty ratio high voltage is achieved. The voltage strains are decreased with the help of the inactive clamp device. Hence conduction loss is decreased by using less resistance key switch. The voltage is boost up from 24 V to 400 V.

At the time of switch off period the inductive energy of the coupled inductor is reprocessed. And so, the voltage spike on the key switch can be neglected. Secondary end of the coupled inductor can be used as either fly back or forward type [17,18]. So that high step up voltage can be achieved. It operates under six stages. Its working conditions are little complex including structure. The number of components utilized here is high.