Comparative Analysis of DC to DC converter for Electrical Vehicle Application using Renewable Energy Sources

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Abstract— *Energy research in recent decades has concentrated on optimizing the efficiency of our current electric infrastructure as well as harvesting power from renewable sources. Energy storage technologies are essential to these two fields of study. Energy storage is currently a major issue in many nations. In order to lessen the variable production of renewable resources over extended periods of time and enable these types of resources to be scheduled based on the daily fluctuations in demand, storage of energy can be used as an alternative to natural gas generators. The high load, which is beyond the capacity of conventional energy power generation, is the cause of this issue. This prompts the hunt for fresh energy sources from which to generate electricity. To solve this issue and boost power conversion efficiency, DC-to-DC converters have been a good option. This paper presents the following five kinds of non-isolated DC-DC converters: Cuk, Buck-boost, Positive output super left Luo, SEPIC, and Ultra life Luo converters. Based on the findings, the non-isolated converters effectiveness is assessed in order to identify the optimal converter for use with renewable energy sources.*

Keywords- Electric Motor Drive Control, Electrical Vehicle, Renewable Energy Sources, DC-to-DC Converter

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I. Introduction

The need for electric power is growing these days. Renewable energy sources are starting to replace more conventional sources in many nations and applications. The benefits of switching to renewable energy include zero pollution, no cost, and ease of access. About 75–82percent of thermal pollution, which results in unfavorable variations to the environment, is caused by thermal power plants. The depletion of fossil fuels will end in the next few years due to increased extraction over time. The normal distribution system is expensive and challenging to implement in hilly areas. The Remote Area Power supply (RAP) scenario, also referred to as the SARES (Stand-Alone Renewable Energy System), is being overcome. Among the other renewable energy sources which include biomass, geothermal, and tidal, the most widely used ones are solar and wind. Grid parity is a potential future use for these resources [1]. Numerous nations, including China, Mexico, India, Finland, and other European nations, have looked into various aspects of renewable energy to deploy [2]. Only PV solar generation is the subject of this research because it is more dependable as well as simple to install. The photovoltaic system output voltage varies because of the unpredictability of irradiances. Power Electronic Converters (PECs) that convert DC to DC have been utilized for supplying a regulated or constant output voltage. They develop a DC-DC converter approach in the 1920s. They began utilizing it in numerous industrial applications, including computer hardware circuits, particularly in energy power production. DC-DC converters having power electronics had been utilized to eliminate the requirement for traditional, basic voltage divider circuits like potential dividers and rheostats. This technique yields lower efficiency and less output voltage than input.

Several DC-to-DC converters have been utilized, depending on the applications, to modulate the input voltage.

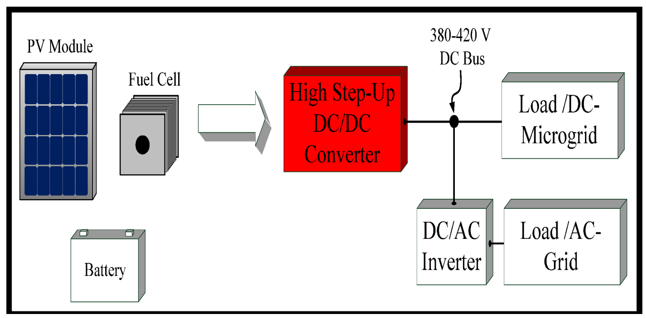

Fig. 1 Generalized System configuration of RES to DC-to-DC converter

Isolated and non-isolated DC-to-DC converters have been the 2 main categories of DC-to-DC converters. Depending on the electrical barrier, the isolated DC-to-DC converter's output & input are also isolated. The high-frequency transformer is used for this. Keeping the delicate load safe is the primary benefit of an isolated DC-to-DC converter. The converter output could be configured with polarity which either negative or positive. Its high capability for interference and noise is the issue. An electrical barrier does not exist when a DC-to-DC converter is not isolated from the rest of the system. In contrast to non-isolated & isolated converters are not only more cost-effective but also have a cleaner and more straightforward design. This research represents 5 kinds of non-isolated DC-to-DC converters. A variety of DC-to-DC converter topologies are being developed, with an emphasis on renewable energy applications, to provide fault-tolerant configurations, higher efficiencies, and dependable switching strategies control. A conventional renewable energy system that utilizes a DC-to-DC converter is depicted in Figure 1 [3].

The various non-isolated DC-to-DC converters' performance evaluation is this research's primary topic. Cuk, Buck-boost, SEPIC, and 2 varieties of Luo converters (Positive output super lift as well as ultra-lift) are among these converters. The fundamental circuit for every kind of DC-to-DC converter explained in this research is depicted in Figure 2.

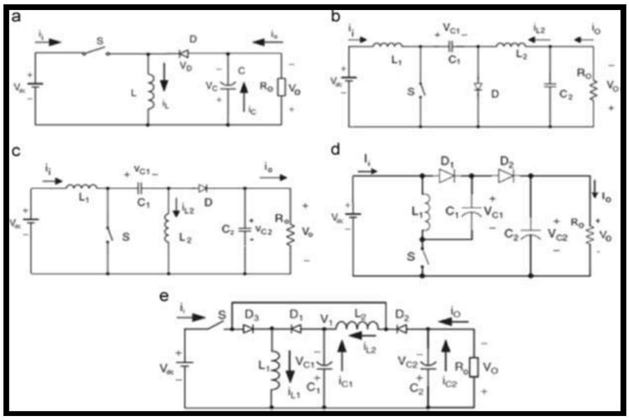

Figure 2 depicts the basic circuit for each type of the DC-to-DC converter

Every converter has distinct qualities that set it apart from the others [4]. Some of the many applications for these converters include distributed DC systems, electric vehicles, electric traction, fuel cells, special electrical machine drives, machine tools, and applications based on solar photovoltaics. These are just some of the thousands of applications. [5, 6, 7, 8, 9].

II. FUNDAMENTALS OF DC TO DC CONVERTERS

Buck Boost Converter: It is created by combining the fundamental buck with boost DC converter topology. This has been used in a range of applications, involving standalone and motor drives and grid-connected photovoltaic systems [10]. Research is ongoing to improve the efficacy of buck-boost converters used in solar photovoltaic applications [11]. Researchers from all over the world have created a variety of non-isolated DC-to-DC converters on the basis of buck-boost converter topology, including SEPIC, cuk, and Luo converters, to boost the voltage gain . Researchers examined the impact of a discontinuity caused by the effective duty cycle in a buck-boost non-inverting converter [12]. In order to rectify and smooth the transition during mode changes, a novel compensation technique is employed. A new multiport converter is presented in [13], which is based on DC link inductors. It is advantageous that the converter that has been suggested has the capability of adjusting the voltage between any two ports in either direction. This converter provides a different approach for applications involving renewable energy. Based on buck-boost topology, a novel solar cell power supply system is suggested [14]. The suggested topology makes utilization of a DC-to-DC converter which has two inputs. An array of solar photovoltaic cells and a commercial AC line are the sources of power. An optimum operating point tracker that is both inexpensive and fundamental has been developed in order to monitor the voltage that is optimal for operation. DC-to-DC converters on the basis of buck-boost converters are developed and implemented by numerous other research groups. While one group represents a dynamic as well as the synchronous buck-boost converter, another focuses on optimization. A highly efficient converter based on a smooth transition control strategy was proposed by another research group [15].

CUK Converter: One type of energy converter is known as a Cuk converter, and it is a negative output capacitive DC-to-DC flyback converter. It was constructed with the fundamental buck-boost converter serving as its basis. The only difference is that the cuk converter makes use of capacitors for the storage of energy and transfer of power, as opposed to inductors, which are used for these functions [16]. This means that the polarity of the input, as well as the output voltage of the cuk converter, are both inverted. This converter is beneficial for a broad variety of applications because it forms free ripple output when it is associated in the correct manner [17]. Depending on the cuk converters, a number of different topologies need to be implemented [18]. The modified cuk converter efficiency has increased significantly. For an ideal bidirectional operation, this converter is advised for controlling the voltage and current [19]. Variable control strategies, which include sliding mode control as well as traditional PI (Proportional Integral), are utilized by closed-loop systems as well as fuzzy logic controllers in order to make adjustments to the voltage that is output [20]. PWM and BLDC motor drives are examples of renewable energy sources that use this converter in their operations.

SEPIC Converter: The device is a SEPIC or single-ended primary inductance converter. With this converter, the ON switch time needs to be longer as compared to the OFF time to achieve a greater output voltage. The converter will not produce the necessary output if this condition is not met. Several parameter considerations should be incorporated into the converter design. The traditional SEPIC converter output voltage ripple is decreased by adding a higher-frequency transformer. Low switching stress, minimal output ripple, and continuous output current are the results of this kind of configuration [21]. An AC to DC-converter is needed in order to extract power from DC from the available AC line. The SEPIC converter is suggested as a way to adjust the power factor in an AC line. To control flickering voltage of DC, SEPIC converters have been broadly utilized in the solar power generation industry. Different control approaches, such as sliding mode, dP/dV feedback, PI, and fuzzy logic control, which could be utilized to boost robustness, are advised in order to reach maximum power [22]. The SEPIC converter is used to operate a solar-fed DC motor sensor-less [23]. This suggested system might be the answer for solar-powered mobility. The switching losses and conduction are the two main design parameters for SEPIC converters. By employing the soft switching technique, this problem can be reduced and the current ripple output can be minimized [24]. A hybrid topology for fuel cell generation systems is suggested, combining flyback and SEPIC converters.

Positive-output super-lift Luo converter: Super-lift approach outperforms SPIC and CUK converters in terms of power. Its ability to produce an output voltage with an arithmetic progression and its high efficiency and power density are what gives it its power. Larger amplification of voltage, as well as higher voltage transfer gain, are operated in the first quadrant by a positive output super-lift Luo converter. Although there are domestic and industrial uses for this converter, research is still continuing [25]. To improve the voltage of output in a higher geometric progression, Luo et al. presented a novel super-left approach that uses a series of inductors as well as capacitors [26]. Simultaneously, another research team presents an additional modification to the positive output super lift Luo converter, aimed at enhancing the voltage transfer gain [27]. The load voltage regulation and appropriate load current sharing will balance when the sliding mode control technique is used in conjunction with a positive output super lift Luo converter connected in parallel [28].

Ultra-lift Luo converter: Extremely higher voltage transfer gain conversion is accomplished by the ultra-lift Luo converter. The voltage transfer gain of an ultra-lift Luo converter is the product of a voltage-lift Luo converter and a super-lift Luo converter. Because it uses a smaller difference to generate a higher output voltage in the duty ratio, it has a complex closed-loop control design. While compared to the other non-isolated DC-to-DC converters, it is more efficient.

III. PERFORMANCE ANALYSIS OF THE CONVERTER

This section provides a quick, MATLAB-based theoretical performance comparison of various non-isolated DC to DC converters. Every converter has unique characteristics that vary in a number of ways. For solar power systems, DC-to-DC converters with SEPIC, Cuk, and buck-boost algorithms with MMPT are investigated. The individual DC-to-DC converter performance is shown in this section for the ideal operating point. According to the study, the buck-boost DC-to-DC converter provides the best MPPT operation under all loads as well as solar irradiation conditions.

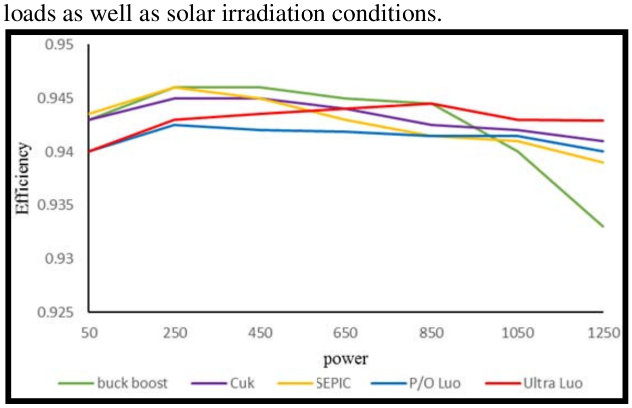

Fig. 3 Efficiency V/S Power

From the experiment results. It can be concluded that the only converters capable of achieving the best performance are Cuk & Buck-Boost converters. The capacitance of the filter requires to be higher in comparison to boundary capacitance max. value to limit the ripple in output voltage. It is evident that, in accordance with their respective nature configurations, the voltage transfer gain of the SEPIC, Cuk, and buck-boost DC-to-DC converters is the same. In comparison to the preceding three types, the voltage transfer gain of positive output super lift Luo as well as ultra-lift Luo converters is higher. The peak-to-peak ripple voltage and peak-to-peak ripple current of the capacitor and indicator can be found using the mathematical expressions for the maximum allowable values.

By computing the efficacy by overall power loss, the RMS current flowing in the circuit is used to ascertain the operating conditions of each individual element. The voltage stress on the power semiconductors provides the operating duty ratio of the max. voltage across the switch. In the design of DC-to-DC converters, this is helpful in choosing the switch rating. When designing DC-to-DC converters for the renewable energy applications, switching converter efficiency is a key consideration. Figure 3 illustrates how the effectiveness of DC-DC converters varies on the basis of output power.

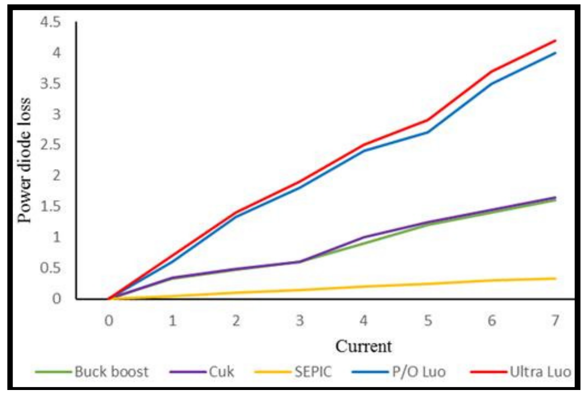

Fig. 4 Total Power Loss in Diode

When comparing DC-to-DC converters solely on the basis of output power, there is a tiny variance. While comparing with other non-isolated DC-to-DC converters, the Buck-boost converter's effectiveness is reasonable for a given input as well as output power rating because it decreases very little as power increases.

The Ultra-lift Luo converter has a greater effectiveness at higher power. The best converters for medium power applications are the SEPIC, super lift Luo and Cuk models. The Buck-boost is the most effective for low power. For higher-power renewable energy systems, the ultra-lift Luo converter is the better option due to its higher efficiency compared to other kinds. The Ultra-lift Luo converter's inverted input voltage output is one of its problems. The voltage stress on the switch increases with a duty ratio increase, which raises the cost and power ratings of semiconductor switches. Switching power loss in non-isolated DC-to-DC converters has been thoroughly studied. The efficient energy conversional is found to be so lies in the min. loss of elements when utilizing switching converters.

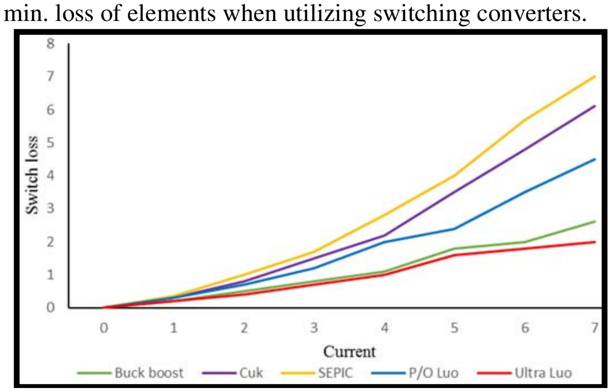

Fig. 5 Total Power Loss in Switch

The figures make it abundantly clear that the losses increase in proportion to the amount of current that is being input. Since the configuration of each converter is different, it has been observed that the Ultra-lift along with the Super-lift Luo converters have a greater power loss in the diodes than the other converters. Generally speaking, the diode that is located at the SEPIC, ultra-lift Luo, and super-lift Luo experiences a significant loss of power. Although not as much as others, Cuk and Buck-Boost also experience a power loss. The loss along with the frequency of switch power operation determines the converter's longevity. The total switch losses displayed in Figure 6 include the loss of switches turning on and off. Reducing switching loss could be achieved by utilizing higher-performance soft switches. Switching loss is lower for the Buck-boost and Luo converters and higher for the Cuk and SEPIC. Figure 6 illustrates the energy storage element's power loss.

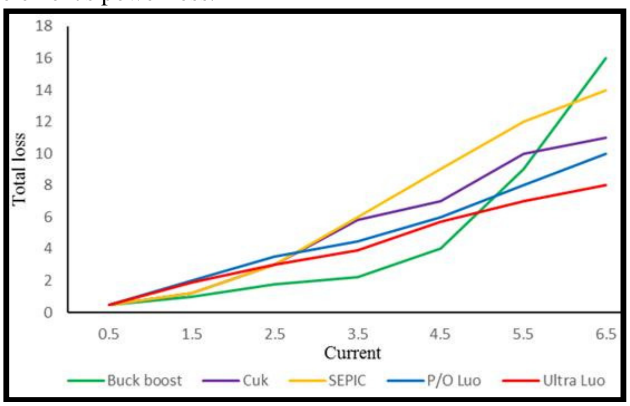

Fig. 7. Total Power Loss

The indicator power loss and capacitor power loss are included in the overall energy storage element loss. Because the Buck-boost converter only has one inductor, its energy storage loss is minimal and only increases when the input current is increased. Higher energy storage power loss is experienced by the SEPIC converter. The loss of the Cuk, Super Lift, and Ultra-lift Luo is extremely comparable. In electronic circuits, capacitor failure rates are typically higher. Because the power loss in the energy storage, the choice of inductors and capacitors will have an impact on the converter's design. The total power loss for the non-isolated DC-to-DC converters examined in this paper is displayed in Figure 7.

IV. CONCLUSION

Non-isolated DC-to-DC converters are the best way to lower system costs and boost efficiency. This paper reviews 5 kinds of non-isolated DC-to-DC converters. The converters in question are Cuk, Buck-Boost, Super Lift Luo, SEPIC, and Ultra-lift Luo. Each type of converter has certain limitations, which are covered in detail in this paper. A variety of parameters are examined in order to ascertain each converter's characteristics. We can infer from the experiment's results that low-power applications are best suited for Buck-boost converters. Numerous lower-power applications, which include fuel cells, motors, portable devices, and solar PV, can be powered by it. The best option for higher power applications that require a larger voltage from a lower voltage source is the Ultra-lift Luo. Based on their respective features, Cuk and SEPIC are the best options for medium-range power.

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