Review of Different DC to DC Converters Based for Renewable Energy Applications

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Abstract - *Now days, a huge problem in many countries is the power storage. This problem occurs because of the high load which is cannot be covered by the conventional energy power generation. This leads to search for new sources of energy to extract electric power from it. DC to DC converters are a good solution to this problem in order to increase the power conversion efficiency. In this paper five types of non-isolated DC to DC converters are presented which are Buck boost converter, Cuk converter, SEPIC converter, Positive output super left Luo converter and Ultra life Luo converter. The performance of non-isolated converters is evaluated based on the results to determine the best converter that is match with renewable energy.*

Key Words: DC to DC converter, non-isolated converter, renewable energy, Buck boost converter, Cuk converter, Spic converter, Luo converter.

1.INTRODUCTION

Now days electric power demands are increasing. Many countries and application starts to move to renewable energy source instead of exact sources that are used. The reasons of changing to renewable energy are free pollution, does not cost and it is easy to access. The thermal power plants cause about 75 – 82% of thermal pollution which is caused undesirable changes in the environment. Within a few coming years the depletion of fossil fuel will finish because of the increasing of extraction by time. It is difficult and expensive to implant the normal distribution system on hilly region. The stand-alone renewable energy system (SARES) which is known as remote area power supply (RAP) scenario is overcoming. The Solar and wind are the most popular renewable energy that are utilized among other renewable energy sources like geothermal, biomass and tidal. These resources have future scope on grid parity [1]. Various issues of renewable energy have been investigated by many countries like China, Mexico, India, Finland and other Europe countries to deploy [2]. This research is focus on PV solar generation only, because it is easy to install and more reliable. Due to the uncertainty of irradiances, the photo voltaic system's output voltage is variable. DC to DC power electronic converters are used to provide a constant or regulated output voltage. In 1920s they establish a DC to DC converters technique. They start using it in many industrial applications such as computer hardware circuits especially in energy power generation. Power electronic based DC–DC converters are employed to resolve the use of conventional simple voltage divider circuits such as rheostat and potential divider. This method provides less output voltage than input and less efficiency.

According to the applications, there are several DC to DC converters that are used to modulate the input voltage. Generally, there are two types of DC to DC converters which are isolated DC to DC converter and non-isolated DC to DC converter. The input and output of isolated DC to DC converter are isolated also depending on the electrical barrier. This is done by using high frequency transformer. Protecting the sensitive load is the major advantage of isolated DC to DC converter. Either positive or negative polarity can be used for configuring the converter output. The problem is it has high interference noise capability. The electrical barrier is absent in case of non-isolated DC to DC converter. The non-isolated DC to DC converters are low cost and simple design compare to the isolated DC to DC converters. Five types of non-isolated DC to DC converters are presented in this paper. To concerning reliable switching strategies control, higher efficiencies and fault-tolerant configurations, different topologies of DC to DC converters are developed and they based on renewable energy applications. Figure 1 shows the typical renewable energy system with DC to DC converter [3].

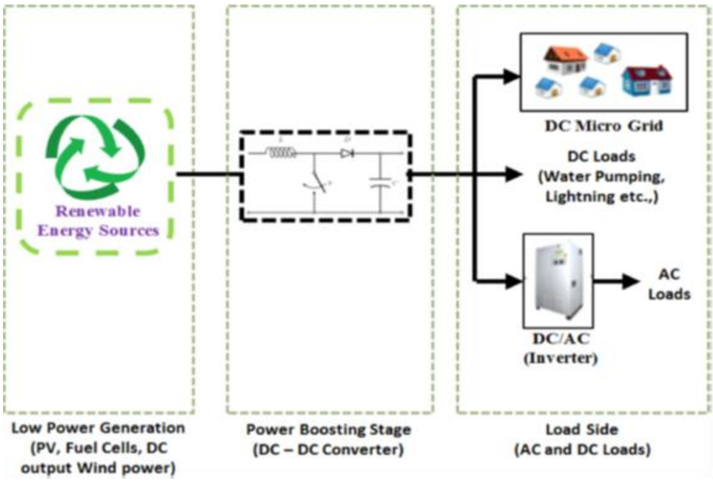

Fig -1: Typical renewable energy system with DC to DC converter

This research focuses on different non-isolated DC to DC converters performance analysis. These converters are buck boost, Cuk, SEPIC and two types of Luo converters (Positive output super lift and ultra-lift). Figure 2 shows the basic circuit for each type of the DC to DC converters that covered in this paper.

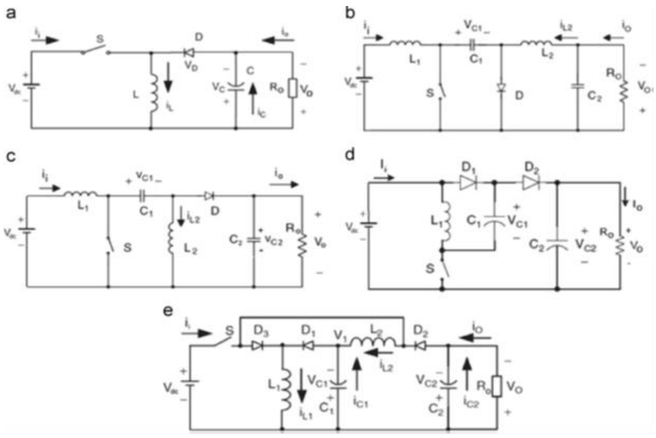

Fig -2: DC to DC converters a- Buck boost converter, b- Cuk converter, c- SEPIC converter, d- Positive output super lift Luo and e- Ultra-lift Luo

Each converter has its unique characteristics that is differ to other types [4]. These converters are used in many different applications like electric vehicles, distributed DC systems, electric traction, machine tools, fuel cell, special electrical machine drives and solar PV based applications [5, 6, 7, 8, 9].

2. DC TO DC CONVERTERS TYPES

2.1 Buck boost converter

The basic buck is combined with boost DC converter topology to introduce the buck boost converter. Different applications are based on buck boost converter implementation such as motor drives, stand alone and grid connected photo voltaic system [10]. The solar PV based applications using buck boost converter still under research to increase the efficiency [11]. Based on buck boost converter topology, different non-isolated DC to DC converters are developed by worldwide researchers such as cuk, SEPIC and Luo converters to increase the voltage gain. A group of researchers analyzed the effect of discontinuity in buck boost non inverting converter that happened by the effective duty cycle [12]. A novel compensation technique is used for rectifying to smooth transition during mode changes. Based on DC link inductors, a novel multiport converter is proposed by [13]. The advantage of proposed converter is it can step the voltage up or down between any two ports. For renewable energy applications, this converter offers an alternate solution. A novel solar cell power supply system is proposed based on buck boost topology [14]. The proposed topology works with two input DC to DC converter. A commercial AC line and solar PV array are used as power sources. To track the optimum operating voltage, an inexpensive and simple optimum operating point tracker has been developed. Many other researchers' groups are developed and implement DC to DC converters based on buck boost converter. Some of them focuses on optimization, other group presents dynamic and synchronous buck boost converter. Other research group proposed a high efficient converter depending on smooth transition control strategy [15].

2.2 Cuk converter

Cuk converter is a negative output capacitive DC to DC fly back energy converter. It is developed based on the simple buck boost converter. The only difference is that cuk converter is using capacitor for power transfer and energy storage rather than inductor [16]. The cuk converter output voltage polarity is reversed of the input voltage. This converter is produces free ripple output if it is connected is suitable way and it can be sued in many applications [17]. Depending on cuk converters there are different topologies are introduced [18]. The modified cuk converter efficiency is significantly improved. To control the current and voltage, this converter is recommended for optimal bidirectional operation [19]. Several control techniques like sliding mode control and conventional proportional integral (PI) are used within closed loop systems and fuzzy logic controller to regulate the output voltage [20]. BLDC motor drive and renewable energy like PWM contains this converter in their implementation.

2.3 SEPIC converter

SEPIC is single ended primary inductance converter. In order to obtain higher output voltage using this converter the ON switch time should be longer than OFF time. if this condition did not occur the converter will fail to provide the required output. The converter design should take in account several parameter considerations. By adding high frequency transformer to the conventional SEPIC converter, the output voltage ripple is reduced. This type of arrangement leads to obtain continuous output current, low switching stress, and minimized output ripple [21]. To obtain the DC power from available AC line, AC to DC converter is required. To correct the power factor in AC line, the SEPIC converter is proposed. SEPIC converter is widely used in solar power generation field to regulate flickering DC voltage. There are different control methodologies that are recommended to obtain the maximum power like PI control, sliding mode control, dP/dV feedback control and fuzzy logic control that can be used to increase the robustness [22]. Solar fed DC motor sensor less is performed through the SEPIC converter [23]. This proposed system can be the solar based transportation solution. The major criteria of SEPIC converter design are the switching losses and conduction. This issue can be reducing by using soft switching technique and it will minimize the current ripple output [24]. For fuel cell generation system, a hybrid topology which is the combination of fly back and SEPIC converters is proposed.

2.4 Positive-output super-lift Luo converter

Super-lift technique is more powerful than cuk and SPIC converters. What makes it powerful; it can generate arithmetic progression output voltage and has high efficiency and power density. A positive output super-lift Luo converter operates high voltage transfer gain and large voltage amplification in first quadrant. This converter is used by industrial and domestic applications but it is still under research [25]. Luo et al. introduced a new super left technique that contains series of inductors and capacitors which are implemented together to rise the output voltage in high geometric progression [26]. At same time other researcher group introduces other modification on positive output super lift Luo converter which works on increasing the voltage transfer gain [27]. By applying sliding mode control technique with positive output super lift Luo converter in parallel, the load voltage regulation and proper load current sharing will balance [28].

2.5 Ultra-lift Luo converter

Ultra-lift Luo converter performs very high voltage transfer gain conversion. The product of voltage lift Luo converter and super lift Luo converter equals to the voltage transfer gain of ultra-lift Luo converter. It has complex closed loop control design because it using small variation to generate high output voltage in duty ratio. It has higher efficiency than other non-isolated DC to DC converters.

3. PERFORMANCE ANALYSIS COMPARISON

In this section a brief comparison between the different non-isolated DC to DC converters based on theoretical performance using MATLAB. There are different characteristic properties for each converter in various aspects. With maximum power point tracking algorithm, buck boost, Cuk and SEPIC DC to DC converters are studied for photo voltaic systems. In this section, individual performance of DC to DC converters are presented for optimum operating point. The study shows that the buck boost DC to DC converter gives optimum MPPT operation in any load condition and solar irradiation.

From the experiment results. It can be concluding that only buck boost and Cuk converters have the ability to achieve the optimal operation. In order to limit the output voltage ripple, the capacitance of the filter must be larger than boundary capacitance maximum value. It can be noticed that the buck boost, Cuk and SEPIC DC to DC converters have same voltage transfer gain according to the nature configuration of them. The voltage transfer gain of positive output super lift Luo and ultra-lift Luo converters is higher compared to previous three types. For maximum permissible, the values of indicator and capacitor can be determined by using the mathematical expressions of peak to peak indicator ripple current and peak to peak capacitor ripple voltage. To determine the operating conditions of the individual elements in the circuit, the RMS current flowing is used to compute the efficiency through total power loss. The operating duty ratio of maximum voltage across the switch is provided by the voltage stress on the power semiconductors. In DC to DC converters design, this is useful to select the switch rating. For renewable applications, the switching converter efficiency is a prime factor during design DC to DC converters. Figure 3. shows the different DC to DC converters efficiency depending on output power.

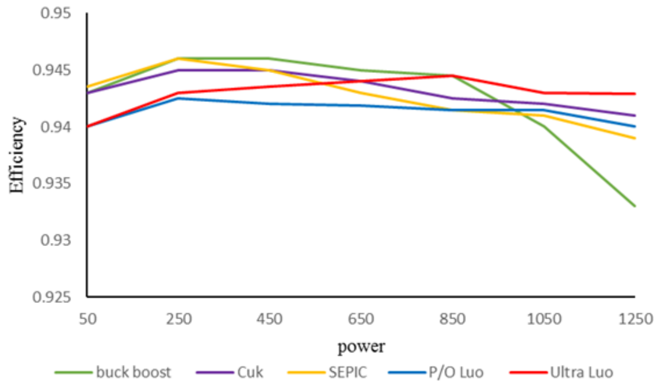

Fig -3: Efficiency vs Power

There is a small variation between different DC to DC converters when taking into account only output power. For particular input and output power rating, the Buck boost converter efficiency is reasonable because the efficiency reduces is very low with power increasing when comparing it with other non-isolated DC to DC converters. At higher power, Ultra-lift Luo converter gives higher efficiency. For medium power applications, the Cuk, SEPIC and super lift Luo are most suitable converters. For low power, the Buck boost is the best one. Ultra-lift Luo converter is the more advisable one for high power renewable energy systems because it offer higher efficiency than other types. The issues with Ultra-lift Luo converter is it produces inverted output of input voltage. When the duty ratio is increasing, the voltage stress is become larger on the switch; this will increase the semiconductor switch power ratings and the cost. Non-isolated DC to DC converters switching power loss are studied well. In the minimum loss of elements that is using switching converters, it is noticed that the efficient energy conversional is so lies. Figure 4. and figure 5. Shows the total power loss in switches and diodes.

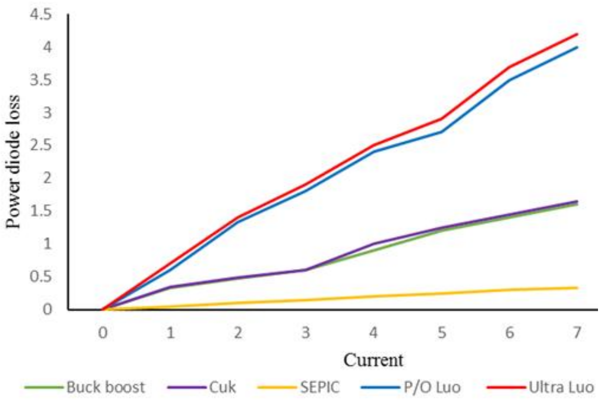

Fig -4: Total power loss in diode

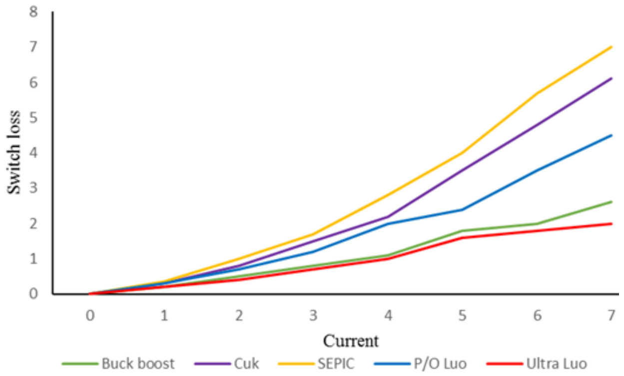

Fig -5: Total power loss in switch

From figures it can be noticed that when the input current is increasing the losses is increasing also. Because of the configuration of each converter, it is noticed that the Ultra-lift and super lift Luo converters have a higher power loss in diodes. Generally, there is a high power loss in diode at the SEPIC, super lift Luo and Ultra-lift Luo. Buck boost and Cuk have power loss also but not high as others. The durability of the converter is determined by the loss and frequency operation of switch power. The loss of ON/OFF of switches is counted with total switch losses that shown in figure 6. Using high performance soft switch will minimize the switching loss. The Buck boost and Luo converters have low switching loss, the Cuk and SEPIC have higher switching loss. The energy storage elements power loss is shown in Figure 6.

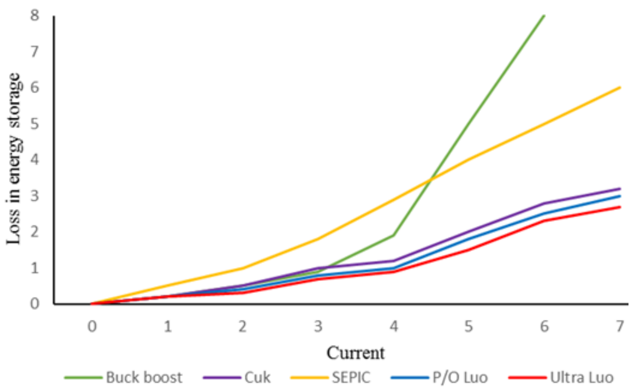

Fig -6: Total loss in energy storage elements

The total energy storage elements loss contains the capacitor power loss and indicator power loss. The energy storage loss in Buck boost converter is small because it contains one inductor only, the energy storage loss is increasing by increase the input current only. The SEPIC converter has higher energy storage power loss. The Cuk, super lift and Ultra-lift Luo have very similar loss. Generally, the capacitors have a higher failure rate at electronic circuits. Selecting of inductors and capacitors will affect the converters design because of power loss in energy storage. Figure 7. Shows the total loss of power for the non-isolated DC to DC converters that studied in this paper.

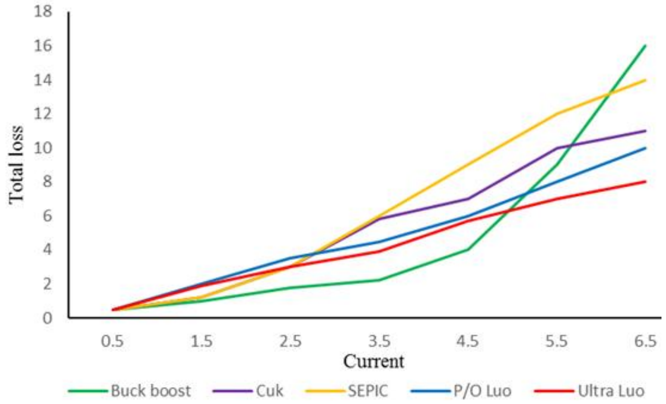

Fig -7: Total power loss

3. CONCLUSIONS

The best solution to reduce system cost and increase the efficiency is by using non-isolated DC to DC converters. Five types of non-isolated DC to DC converters are reviewed in this paper. These are Buck boost, Cuk, SEPIC, super lift Luo and Ultra-lift Luo converters. There are limitations for each kind of these converters which are well discussed in this paper. Different parameters are analyzed to determine the characteristics of each converter. From the experiment result we can conclude that Buck boost converter is best for low power applications. It is applicable for many low power applications like solar PV, portable applications, drives motor and fuel cell. Ultra-lift Luo is the best one for high power applications that they need large voltage from low voltage source. For medium range power, Cuk and SEPIC are the right choice according to their characteristics.

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