© 2018 IJSRSET | Volume 4 | Issue 4 | Print ISSN: 2395-1990 | Online ISSN : 2394-4099
Themed Section : Engineering and Technology

Converter for Sporadic Micro Power Generation Systems

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ABSTRACT

In this paper, a novel convertor for Micro power generation systems (MPGS) is proposed. These MPGS are powered by micro sources such as wind turbines, micro hydro, solar PV systems, microbial fuel cells, ground source heat pumps, and micro combined heat and power installations. High boost dc-dc converters are usually used up to step from low voltage to high voltage gain can achieve by the use of switched-capacitor and voltage-lift techniques. The proposed converter adds two capacitors and two diodes on the secondary side of the mutual inductor to achieve a high step-up voltage gain. The mutual inductor can charge the two capacitors in parallel during the switch-off period and discharge them in series during the switch-on period. However, the leakage inductor of the mutual inductor may cause high power loss and high voltage spike on the switch. Thus, a passive clamping circuit is needed to clamp the voltage level of the main switch and to recycle the energy of the leakage inductor. Simulated results are discussed on operating principle and the steady state analyses. Simulated model is developed in MATLAB/Simulink. Finally, simulated circuit with 24-V input voltage, 450-V output voltage is implemented to verify the performance of the proposed converter. The experimental results have confirmed that high efficiency and high step up voltage gain can be achieved.

Keywords: Clamp mode, Convertor, Distribution generator, MPGS.

I. INTRODUCTION

In recent years, distributed generation (DG) systems based on renewable energy sources have rapidly developed. The DG systems are composed of micro source like fuel cells, photovoltaic (PV) cells, and wind power. However, fuel cells and PV source are low-voltage sources to provide enough dc voltage for generating ac utility voltage. Although PV cells can connect in series to obtain sufficient dc voltage, it is difficult to avoid the shadow effect. Thus, high boost dc-dc converters are usually used as the front-end converters to step from low voltage to high voltage which are required to have a large conversion ratio, high efficiency, and small volume.

Theoretically, the boost converter can provide a high step-up voltage gain with an extremely high duty cycle. In practice, the step-up voltage gain is limited by the effect of the power switch, rectifier diode, and the equivalent series resistance of the inductors and capacitors. Also, the extreme duty cycle operation may result in serious reverse-recovery and electromagnetic interference problems. Some converters like the forward and fly back converters can adjust the turn ratio of the transformer to achieve a high step-up voltage gain. However, the main switch will suffer high voltage spike and high power dissipation caused by the leakage inductor of the transformer. Although the non-dissipative snubber circuits and active-clamp circuits can be employed, the cost is increased due to the extra power switch and high side driver. To improve the conversion efficiency and achieve a high step-up voltage gain, many step-up converters have been proposed.

A high step-up voltage gain can be achieved by the use of the switched-capacitor and voltage-lift techniques.

However, the switch will suffer high charged current and conduction loss. The converters use the mutual-inductor technique to achieve a high step-up gain. However, the leakage inductor leads to a voltage spike on the main switch and affect s the conversion efficiency. For this reason, the converters using a mutual inductor with an active-clamp circuit have been proposed. An integrated boost fly back converter is presented in which the secondary side of the mutual inductor is used as a fly back converter. Thus, it can increase the voltage gain. Also, the energy of the leakage inductor is recycled to the output load directly, limiting the voltage spike on the main switch. Additionally, the voltage stress of the main switch can be adjusted by the turn ratio of the mutual inductor. To achieve a high step-up gain, it has been proposed that the secondary side of the mutual inductor can be used as fly back and forward converters.

II. BLOCK DIAGRAM

Micro source/intermittent source:

The Distribution System powered by Micro Sources or Intermittent Sources such as Fuel Cell, Solar, Wind and other energy sources. These sources are low voltage sources to provide enough dc voltage for generating ac utility voltage.

Lift-DC to DC Converter:

The Lift-DC to DC converter is also called Boost converter. The high step up dc to dc converters are usually used as front end converters to step from low voltage to high voltage which are required to have a large conversion ratio, high efficiency and small volume. Theoretically the boost converter can provides high step up voltage gain with an extremely high duty cycle.

The world is now habituated with the electronics devices without which it is very difficult for the mankind to keep going. So it is very important to develop the devices error free and fast response with high efficiency. Of the research field is dc-dc converters. The dc-dc converters means the input is dc and the output is also dc. The two basic dc-dc converters are buck converter and boost converter. Based on these two converters, all other converters are derived. The semiconductor devices are used as switching devices due to which the converters can operate at high frequencies. The different arrangement of inductors and capacitors in the converters operates as a filter circuit. The resistance act as a load in the circuit which can be varied to study the behaviour during light load and heavy load.

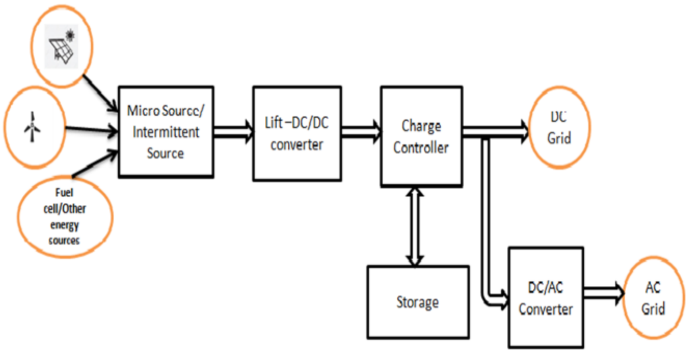

Figure 1. block diagram micro power generation systems

Charge Controller:

The charge controller, charge regulator or battery regulator limits the rate at which electric current is added to or drawn from electric batteries. It prevents overcharging and may protect against overvoltage, which can reduce battery performance or lifespan and may pose a safety risk. It may also prevent completely draining a battery, or perform controlled discharge, depending on the battery technology to protect battery life. The charge controller or charge regulator may refer to either a standalone device or to control circuitry integrated within a battery pack, battery powered device or battery charger.

Types of charge controller:

- ✓ Series charge controller.
- ✓ Shunt charge controller.
- ✓ Maximum power point tracking controller.

Battery:

Batteries operate by converting chemical energy into electrical energy through electrochemical discharge reactions. Batteries are composed of one or more cells, each containing a positive electrode, negative electrode, separator, and electrolyte Cells can be divided into two major classes: primary and secondary. Primary cells are not rechargeable and must be replaced once the reactants are depleted. Secondary cells are rechargeable and require a DC charging source to restore reactants to their fully charged state. Examples of primary cells include carbon-zinc (Leclanche or dry cell), alkaline-manganese, mercury zinc, silver-zinc, and lithium cells (e.g., lithium-manganese dioxide, lithium-sulphur dioxide, and lithium thinly chloride). Examples of secondary cells include lead-lead dioxide (lead-acid), nickel-cadmium, nickel-iron, nickel-hydrogen, nickel-metal hydride, silver-zinc, silver-cadmium, and lithium-ion. For aircraft applications, secondary cells are the most prominent, but primary cells are sometimes used for powering critical avionics equipment.

Lead-acid cells are composed of alternating positive and negative plates, interleaved with single or multiple layers of separator material. Plates are made by pasting active material onto a grid structure made of lead or lead alloy. The electrolyte is a mixture of sulphuric acid and water. In flooded cells, the separator material is porous rubber, cellulose fiber, or micro porous plastic. In recombinant cells with starved electrolyte technology, a glass fiber mat separator is used, sometimes with an added layer of micro porous polypropylene. Gel cells, the other type of recombinant cell, are made by absorbing the electrolyte with silica gel that is layered between the electrodes and separators.

DC-AC Converter:

A power inverter is an electronic device or circuitry that changes direct current (DC) to alternating current (AC). A typical power inverter device requires a relatively stable basic power source capable of supplying enough current for the intended power demand of the system. The input voltage depends on design and purpose of inverter. The inverter does not produce any power; the power is provided by the DC source.

III. CONVERTER

Description of the proposed converter

Figure 2 shows the circuit topology of the proposed converter, which is composed of dc input voltage Vin, main switch S, mutual inductors Np and Ns, one diode D1, capacitor C1, two capacitors C2 and C3, two diodes D2 and D3, output diode Do, and output capacitor Co. The equivalent circuit model of the mutual inductor includes magnetizing inductor Lm, leakage inductor Lk, and an ideal transformer. The leakage inductor energy of the mutual inductor is recycled to capacitor C1, and thus, the voltage across the switch S can be clamped. The voltage stress on the switch is reduced significantly. Thus, low conducting resistance RDS (ON) of the switch can be used. The original voltage-clamp circuit was first proposed in to recycle the energy stored in the leakage inductor. Based on the topology, the proposed converter combines the concept of switched-capacitor and mutual-inductor techniques. The switched-capacitor technique in has proposed that capacitors can be parallel charged and series discharged to achieve a high step-up gain. Based on the concept, the proposed converter puts capacitors C2 and C3 on the secondary side of the mutual inductor. Thus, capacitors C2 and C3 are charged in parallel and are discharged in series by the secondary side of the mutual inductor when the switch is turned o and turned on. Because the voltage across the capacitors can be adjusted by the turn ratio, the high step-up gain can be achieved significantly. Also, the voltage stress of the switch can be reduced. Compared to earlier studies, the parallel-charged current is not in rush. Thus, the proposed converter has low conduction loss. Moreover, the secondary-side leakage inductor of the mutual inductor can alleviate the reverse-recovery problem of diodes, and the loss can be reduced. In addition, the proposed converter adds capacitors C2 and C3 to achieve a high step-up gain without an additional winding stage of the mutual inductor. The coil is less than that of other mutual inductor converters. The main operating principle is that, when the switch is turned on, the coupled-inductor-induced voltage on the secondary side and magnetic inductor Lm is charged by Vin. The induced voltage makes Vin, VC1, VC2, and VC3 release energy to the output in series. The mutual inductor is used as a transformer in the forward converter. When the switch is turned off, the energy of magnetic inductor Lm is released via the secondary side of the mutual inductor to charge capacitors C2 and C3 in parallel. The mutual inductor is used as a transformer in the fly back converter.

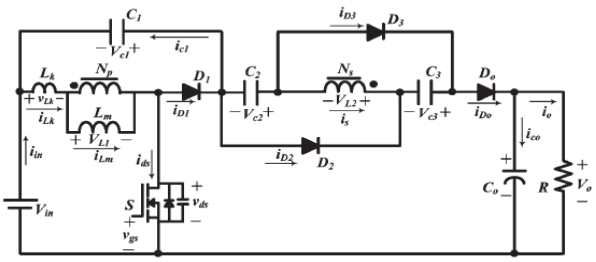

Figure 2. Circuit Configuration of Proposed Converter

To simplify the circuit analysis, the following conditions are assumed.

1. Capacitors C1, C2, C3, and Co are large enough. Thus, VC1, VC2, VC3, and Vo are considered as constants in one switching period.
2. The power devices are ideal, but the parasitic capacitor of the power switch is considered.
3. The coupling coefficient of the mutual inductor k is equal to Lm/(Lm + Lk), and the turn ratio of the mutual inductor n is equal to Ns/Np.

system specification:

Table 1. Design Parameters Of Proposed System

Sr. No	Parameters	Values
1	Input Voltage	24 V
2	Switching frequency	50kHz
3	Turns Ratio	1:4
4	Inductor	Lk:0.25µH, Lm:48µH
5	Capacitors	C1:56 µF/100V C2/C3:22µF/200V C0:180 µF/450V
6	Load Resistance	5Kω

Voltage Gain in CCM mode:

$$M_{CCM}=\frac{V_o}{V_{in}}=\frac{1+nk}{1-D}+\frac{D\,(K-1)+n(1+k)}{1-D\qquad 2}$$

Voltage Gain in DCM mode:

$$M_{DCM}=\frac{V_o}{V_{in}}=\frac{1+n}{2}+\sqrt{\frac{(1+n)^2}{4}+\frac{D^2}{2\tau L_M}}$$

The normalized magnetizing-inductor time constant is defined as

$$\tau L_M=\frac{L_M}{RT_S}=\frac{L_M f_S}{R}$$

In the boundary operation between CCM and DCM, the voltage gain of CCM is equal to the voltage gain of DCM operation. Where fs is the switching frequency In The boundary normalized magnetizing inductor time constant

$$\tau L_{MB}=\frac{D(1-D)^2}{2(1+2n)(1+n+nD)}$$

IV. SOFTWARE SIMULATION MODEL

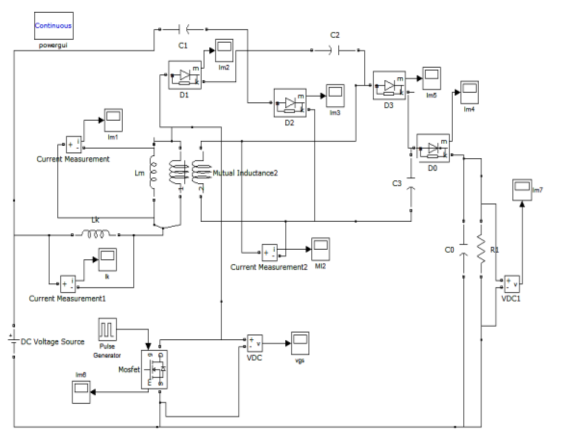

Figure 3. Matlab/simulink circuit of the converter

Matlab /Simulink Modelling And Simulation Results:

The Converter Proposed in Section II is Modelled and Simulated as shown in figure 9. Here the simulation is carried out in two cases

1. Proposed high step-up DC/DC converter.
2. Proposed high step-up DC/DC converter applied to AC load.

Case 1: Proposed high step-up DC/DC converter:

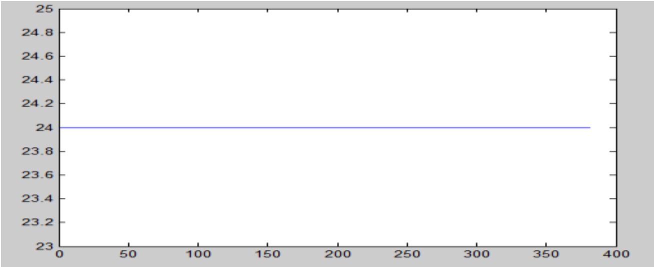

Figure 4. output waveforms of proposed converter Vds

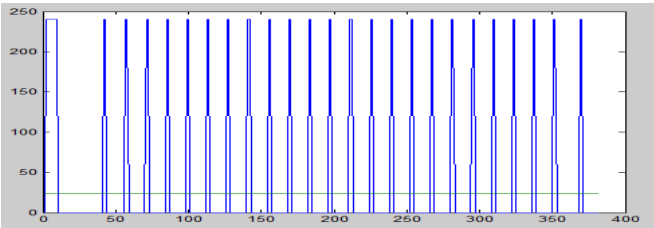

Figure 5. output waveforms of proposed converterVgs

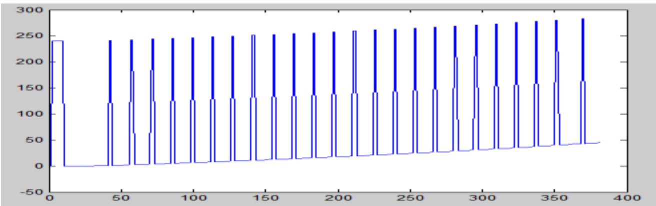

Figure 6. output waveforms of proposed converter Ilk

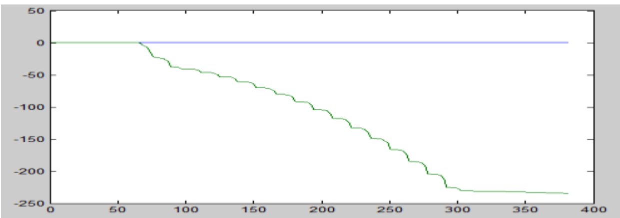

Figure 7. output waveforms of proposed converter ILm

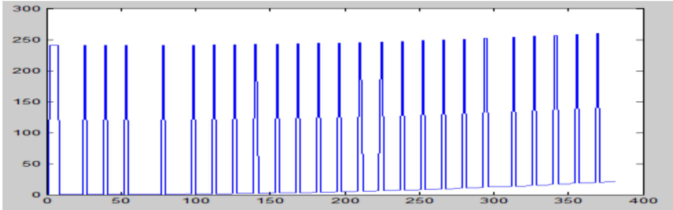

Figure 8. Waveforms of Id0

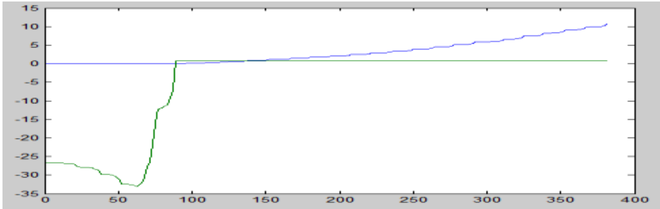

Figure 9. Waveforms of Id1

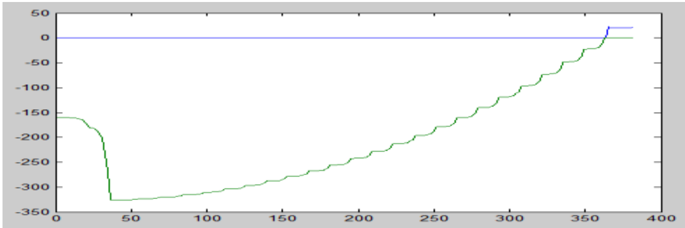

Figure 10. Waveforms of Id2

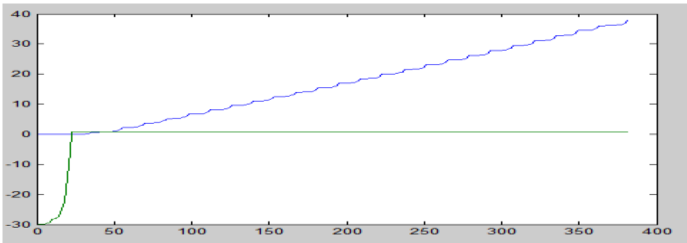

Figure 11. Waveforms of Id3

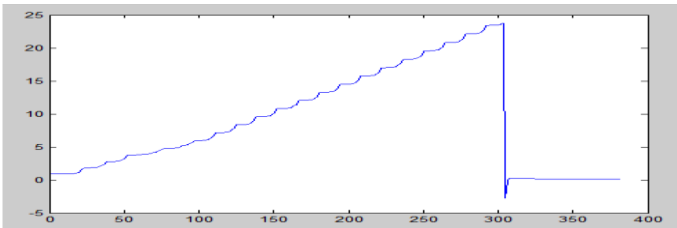

Figure 12. waveforms of Is

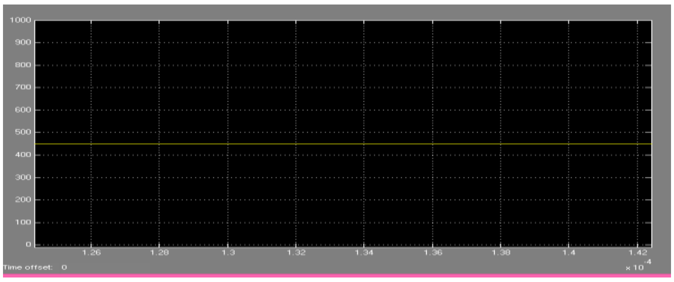

Figure 13. waveforms of Vco

Case 2: Proposed high step-up DC/DC converter applied to AC load.

The above Figure 4.1, Figure 4.2, Figure 4.3 shows the waveforms of current through leakage inductor ILK, current Through secondary IS, current through diode D2 ID2, current through diode D3 ID3, voltage across diode D1 VD1, Voltage across diode D2 VD2, voltage across output diode D0 VD0 Figure 13 shows the MATLAB/SIMULINK circuit of the proposed high step-up DC/DC converter applied to AC load with given input.

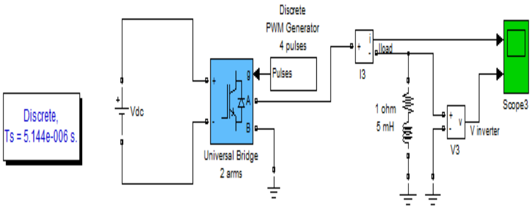

Figure 14. simulation of DC/AC converter

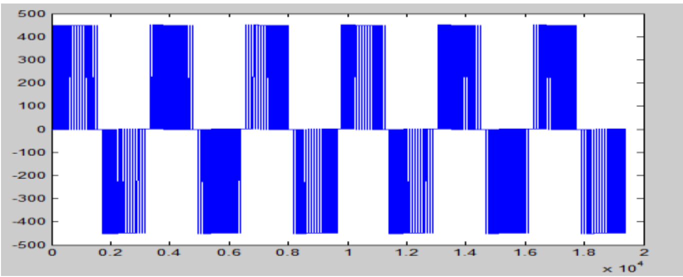

Figure 15. Inverter Output Voltage Without Filter

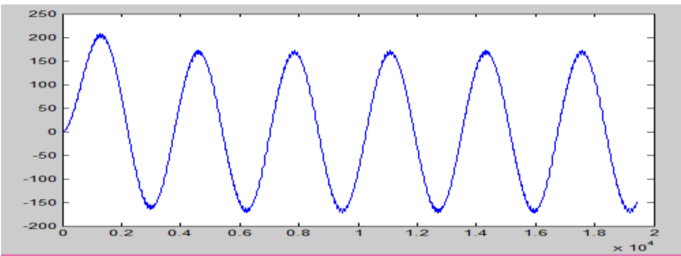

Figure 16. Inverter Output voltage with filter

Advantages:

1. By using DC-DC converter high step up voltage gain and high efficiency are achieved
2. It does not require high hilly area.
3. The material require for the system is easily available in the market.

Applications:

1. Domestic purpose as well as small scale industries
2. Rural area were the load sharing is high
3. Where the area is far away from national grid system.

V. RESULT AND DISCUSSION

The paper has proposed a converter for sporadic microwave power generation systems. By using the charging and discharging property of capacitor in series by the mutual inductor high step up voltage gain and high efficiency are achieved. Finally 24v to 450v, experimental results has confirmed that high efficiency and high step up voltage gain can be achieved.

VI. ACKNOWLEDGEMENT

We are grateful to the management of AMGOI Vathar, Diretor Dr.D.N.Mudagal For their constant encouragement to take up research oriented work.

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