Boost Buck Converter for Thermoelectric Generators

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Abstract – This paper presents a digital cascade controller for a boost buck converter to charge a vehicle battery and supply to the load. The recover of waste heat of the exhaust gas and convert into electric energy in automotive applications. The Thermoelectric generators (TEGs) are used. The temperature of the waste heat result the voltage and internal resistor of a TEG. A DC-DC converter used for the electric linking of TEGs to the on board power supply. Track the maximum power point of the TEG. The control of the DC-DC converter must be robust against dynamic changes and additionally. To track the MPP, a hill Ascend (HA) algorithm is implemented, which is also used for photovoltaic. The conversion time of the HA is minimized with an adaptive step size. Width variations of electric parameters of TEG effect the dynamic and stability of the controllers. With closed loop identification, the parameter variation is estimated, and the control parameters can be change. An experimental result shows the efficiency of the adaptive control.

Index Terms – Boost Converter, Buck Converter, Hill Ascend, PWM, Thermoelectric Generator.

1. INTRODUCTION

In contrast, the amount of fossil fuel is limited. The growing mobility increases the world-wide fuel consumption. In addition, the burden of environmental is increasing dramatically. Many governments have enacted laws to regulate and reduce the fuel consumption as well as the CO2 production of combustion engines. Conventional combustion of engines basically converts chemical energy stored in fossil fuel into mechanical energy. Unfortunately, during that process energy is the high potential to save fuel and to reduce the environment burden main part (about 50%) is disappearing as heat. A create high potential to save fuel and to reduce the environment burden. Recovery of this wasted thermal energy. Thermoelectric generator through this unused exhaust gas wasted heat can be converted into electric power. A TEG consists of several thermoelectric elements (TEs) with n- and p-type semiconductor materials. The thermoelectric power can be linked to the on-board power supply via DC-DC converters used to charge the vehicle battery and supply the load. Consequently the efficiency of the combustion engine increases, because of the alternator is relieved. To support different power classes of TEGs and on-board power supplies, for boost-buck converter is selected, with an input voltage range up to 60 V and a current range up to 20A.

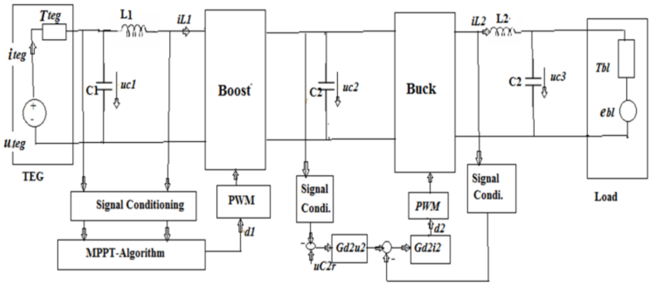

Fig.1. Overview of control structure

A boost buck converter has a high efficiency, for an extensive range of input power. Further, the input voltage of the converter is less than the output voltage. The converter has different requirements. The first requirement is that the TEG has to be operated on the maximum power point (MPP). The normal power of the TEG is 300 watt. A maximum power point tracking (MPPT) algorithm in general is based on a gradient descent and is used in particular for photovoltaic. This method can be applied to on TEG. An overview of different MPPT techniques and their presented are advantages and disadvantages. The second requirement is that the power of the TEG is used to charge the battery and to provision the vehicle for power supply. Which regulates the voltage of a storage capacity between boost and buck converter and charges the battery with a current control. The stable charging using a cascade control. Generally, the design of the control is based on the assumption that the internal resistor of a TEG is nearly constant and the voltage depends on the temperature of the waste heat. However, the electric conductivity is different, depending on the materials. The temperature at the TEG affects the internal resistor. The internal resistor of a TEG limits the maximum current and influences the closed loop dynamic of the inside current loop of the cascade control. With a detailed knowledge of the characteristic of the TEG and especially the materials, it is possible to design control parameters, which are strong against parameter variations. However, for each type of TEG or each control of the boost buck converter must be stable.

To charge the battery and supply the voltage of the load, a cascade control structure is used. By the control of the capacitor voltage between boost and buck converter it can be make sure that fluctuations or changes of the TEG are compensated. A secondary control regulates the current, which charge the vehicle battery. The advantages of a cascade control are the compensation of the disturbance by the fast current control and the higher settling time of the voltage controller to regulate the steady reference voltage. A feature of this control structure is, that the reference voltage can be changed. This allows the use of the control structure for different battery voltage levels.

2. RELATED WORK

In 1821, Thomas Johann Seebeck discovered that a thermal gradient formed between two different conductors can create electricity. At the nature of the thermoelectric effect is the fact that a temperature gradient in a conducting material results in heat flow, this results in the diffusion of charge carriers. The creates a voltage difference the flow of charge carriers between the hot and cold regions in turn. In 1834, Jean Charles Athanase Peltier invented the reverse effect, that running an electric current through the junction of two different conductors depend on the direction of the current is act like as a heater or cooler.

3. PORPOSED MODELLING

3.1 Modeling of Boost Buck Converter

The boost buck converter is a DC to DC converter. The input voltage of the boost buck converter is less or more than the output voltage. The duty cycle is depends on the magnitude of the output voltage .The step up and step down transformers are also known as the boost buck converters and these names are coming from the corresponding step up and step down transformer. The input voltages are step up or down to some level of greater than or less than the input voltage. The input power is equal to the output power by using the low renovation energy.

The working operation of the DC to DC converter is depend upon the inductor in the input resistance has the fast variation in the input current. If the switch is ON then the inductor supplied the energy from the input side and it stores the energy in the form of magnetic energy. If the switch is closed then it discharge the energy. The output circuit of the capacitor is assumed as adequate than the time constant of an RC circuit is high on the output stage. The huge time constant is compared with the switching period and result into the steady state is a constant output voltage and present at the load terminal. The constant output voltage is represented by $V_0(t) = V_0(\text{constant})$.

There are two different types of working principles in the buck boost converter.

3.1.1 Boost Converter Working

In this converter the first transistor is switched ON always and the square wave of high frequency is applied to the gate terminal for the second transistor. When the on state and the input current flow from the inductor L through the second transistor. The second transistor is in conducting. The negative terminal charging up the magnetic field around the inductor. The anode is on the potential ground by highly leading the second transistor. Because the D_2 diode cannot conduct.

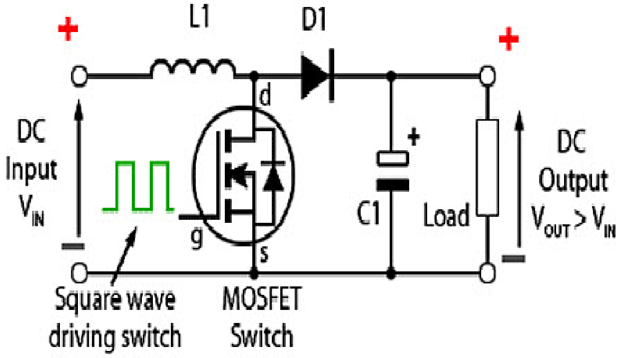

Fig.2. Boost Converter Working

For construct the oscillatory cycle the capacitor C is charging by the load applied to whole circuit in ON state. During the ON period the capacitor C can discharge often and the amount of high ripple frequency on the output voltage. The approximate potential difference is given by the equation below.

$$V_S + V_L$$

The inductor L is charged and the capacitor C is discharged through the second transistor. During the OFF period the inductor L can produce the back e.m.f and the values are depends upon the rate of change of current of the second transistor switch. The quantity of inductance coil can reserved. Hence the back e.m.f can produce any other voltage through a wide range and determined by the design of the circuit. Hence the polarity of voltage across the inductor L has reversed.

The input voltage gives the output voltage which is higher or equal to the input voltage. The diode D_2 is in forward biased and the current applied to the load boosts the capacitors to V_S + V_L and it is sufficient to supplied to the second transistor.

3.1.2 Buck Converter Working

The working operation of the buck converter. In the buck converter due to the high square wave frequency. The first transistor is turned ON and second transistor is switched OFF. If the gate current of the first transistor is more than supply current. then current is passes through the magnetic field with charging the capacitor C and then it supplies to the load. The D_1 is the Schottky diode due to the positive voltage to the cathode and it is turned OFF.

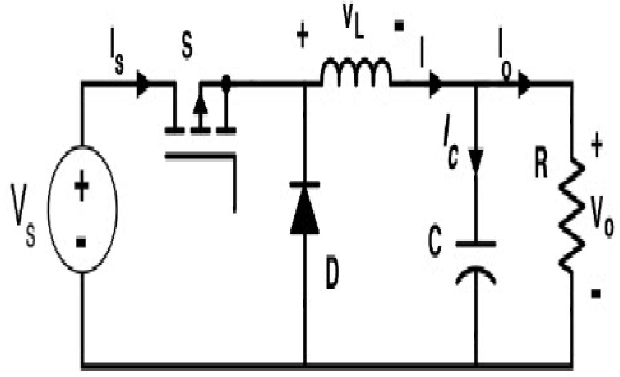

Fig.3. Buck Converter Working

The initial source of current is the inductor L. The current flow in the buck operation by using the control unit .If the first transistor is OFF. The magnetic field of the inductor is misleading and the back e.m.f is produced failing field turn around the polarity of the voltage across the inductor. The current flows in the diode D_2, the load and the D_1 diode will be turned ON.

The discharge of the inductor L decreases with the help of the current. The charge of the collector in the capacitor during the first transistor is in one state. The current flows through the load and during the off period keeping V_{out} reasonably. Hence it keeps the minimum ripple amplitude and V_{out} closes to the value of V_S.

4. CONCLUSION

A digital control of a boost buck converter for a TEG is presented. The converter can be modeled and studied with the SSA. The control of the converter includes a MPPT, whose function it is to adapt the maximum power point of the TEG. Further, a cascade controller regulates the voltage between the two converters, and a subsidiary current controller regulates the charge current of the battery. The control design is based on two degrees of freedom controller, whose parameter is well defined for a TEG, with the assumption of a steady temperature. Variations of the temperature influence the voltage and especially the resistor of the TEG, which also affects the dynamic of the control plant. A method to compensate this influence is a self-tuning controller which is uses a closed loop identification to estimate the parameter of the plant. In the experiments a RLS algorithm was used to estimate the zeros and poles of the control plant. The online re-design of the control parameters could ensure the desired closed loop dynamic of the current controller.

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