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ANALYSIS AND MODELING OF HIGH GAIN BUCK-BOOST DC-DC CONVERTER FOR SOLAR PV APPLICATION WITH FEEDBACK USING PI CONTROLLER

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ABSTRACT

Previously, we have used the different types traditional buck boost converter which has less voltage output gain. In this paper had introduced a new proposed buck-boost converter which will help us to get voltage gain is square time when compared to traditional buck-boost converter with positive output voltage. The input of the buck-boost converter is dc supply which is fed from solar panel for solar PV application The two switches which are used in our buck-boost converter switch operation is made simultaneously which will help us to make this into continuous conduction (CCM), in which two inverters are magnetized and two capacitors are discharged in the above switching operation for a switch-on-period. Where as in switched-off period is vice-versa. In further, we have used the PI controller technique to remove ripples in the output voltage. Finally, we have simulated our circuit in the MATLAB/Simulink and observed the outputs for different inputs.

INTRODUCTION

The use of electrical devices and energy has expanded dramatically in recent years. Renewable energy sources have gotten a lot of attention as an innovative alternative technique of directly generating electricity, as the need for power is significantly increasing day by day. Using various renewable energy sources can reduce harmful emissions from harming the environment while also providing endless primary energy resources. Solar energy, wind turbines, and fuel cells are just a few examples of renewable energy sources. Fuel cells and solar cells, on the other hand, have a low output voltage. To boost the voltage delivered to the grid or be compatible with other applications, a high efficiency and step-up DC-DC converter is desired in power conversion systems.

DC-DC CONVERTER

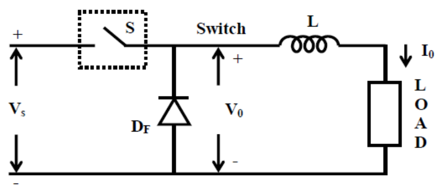
DC-DC power converters are used to convert an unregulated DC voltage input (i.e., a voltage that may contain noise) into a regulated output voltage. DC-DC converters are electronic devices that are employed when we need to efficiently convert DC electrical power from one voltage level to another. They're required since, unlike AC, DC cannot be easily ramped up or down with a transformer. A DC-DC converter is the DC equivalent of a transformer in many aspects. There are several methods for converting DC to DC voltage. Depending on a variety of operating conditions and specifications, each of these methods has its own set of advantages and disadvantages. The voltage conversion ratio range, maximum output power, power conversion efficiency, power density, galvanic separation of input and output, and number of components are examples of such requirements.

Types of DC-DC converters

Buck, boost, and buck-boost are the three primary types of dc-dc converter circuits. A power device is employed as a switch in each of these circuits. A thyristor, which is turned on by a pulse fed at its gate, was previously used. The thyristor is linked in series with the load to a dc supply in all of these circuits, or a positive (forward) voltage is provided between the anode and cathode terminals. When the current falls below the holding current or a reverse (negative) voltage is placed between the anode and cathode terminals, the thyristor switches off. So, a thyristor is to be force-commutated, which necessitates the use of an additional circuit, which frequently involves the use of another thyristor. Later, GTOs came into the market, which can also be turned off by a negative current fed at its gate, unlike thyristors, requiring proper control circuit. The turn-on and turn-off times of GTOs are lower than those of thyristors. So, the frequency used in GTO-based choppers can be increased, thus reducing the size of filters. Earlier, dc-dc converters were called 'choppers', where thyristors or GTOs are used. It may be noted here that buck converter (dc-dc) is called as 'step-down chopper', whereas boost converter (dc-dc).

Buck Converters (dc-dc)

Fig .1.1 illustrates a Buck converter (dc-dc). Only a switch is shown, for which a device from the transistor family, as described previously, is used. When the switch (i.e., a device) is switched off, a diode (also known as a freewheeling diode) is employed to allow the load current to pass through it. It's an inductive (R-L) load. A battery (or back emf) is sometimes connected in series with the load (inductive). The load current must be permitted a channel due to the load inductance, which is provided by the diode; otherwise, in the absence of the aforementioned diode, the high induced emf of the inductance, as the load current decreases, may harm the switching device.



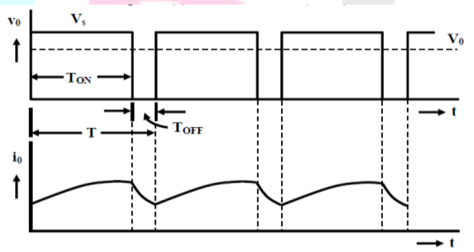


Fig 1: circuit diagram of Buck converter

Fig 2: Waveform of Buck converter

Boost Converters (dc-dc)

Fig.3 depicts a boost converter (dc-dc). Only a switch is illustrated, for which a transistor family device is typically employed. A diode is also connected in series with the load. The load is of the same sort as the one described previously. The load has a very low inductance. The input supply is considered to have an inductance, L. It's worth noting where the switch and diode are in this circuit versus where they are in the buck converter (Fig2).

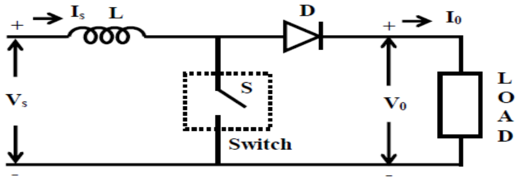


Fig 3: circuit diagram of Boost converter

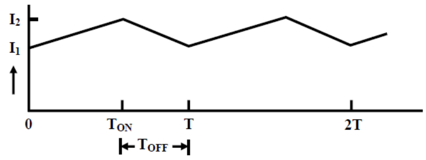


Fig 4: Waveform of Boost converter

BUCK-BOOST CONVERTERS (DC-DC)

Figure 5 depicts a buck-boost converter (dc-dc). Only a switch is illustrated, for which a transistor family device is typically employed. A diode is also connected in series with the load. It's worth noting how the diode is connected, as opposed to how it's connected in a boost converter (Fig4.). After the switch and before the diode, the inductor L is connected in parallel. The load is of the same sort as the one described previously. In parallel with the load, a capacitor, C, is connected. In this case, the polarity of the output voltage is the polarity of the input voltage. The supply current (is) flows through the path, Vs, S, and L, during the time interval, TON, while the switch, S, is turned on.

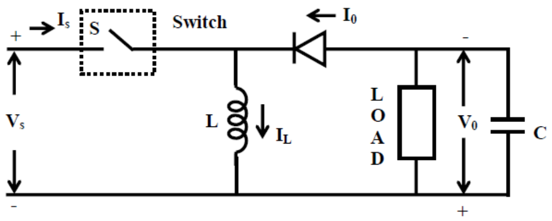


Fig 5: circuit diagram of Buck-Boost converter

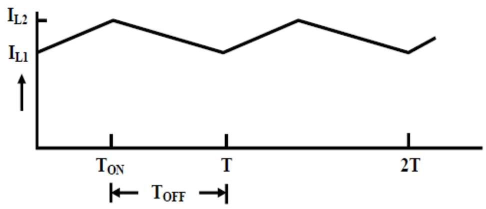


Fig 6: Waveform of Buck-Boost Converter

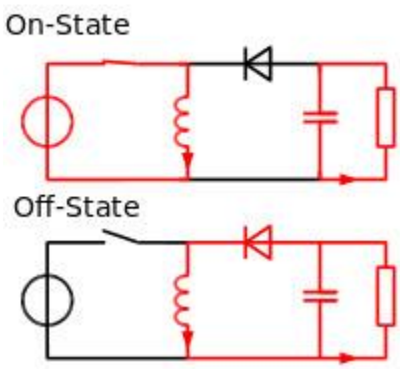


Fig 7: Switching modes of Buck-Boost Converter

2.1 Modes of Buck Boost Converters

There are two different types of modes in the buck boost converter. The following are the two different types of buck boost converters.

2.1.1 Continuous Conduction Mode

The current from end to end of the inductor never goes to zero in continuous conduction mode. As a result, the inductor partially drains before the switching cycle completes. The current and voltage waveforms of a buck–boost converter running in continuous mode are represented in the figure below.

case-1: When switch S is ON

During this state the inductor charges and the inductor current increases. The current through the inductor is given as

$$I_L = (1/L) * \int V * dt$$

case-2: When switch S is OFF

The diode will be forward biased when the switch is turned off because it permits current to flow from the output to the input (p to n terminal), and the Buck Boost converter circuit can be redesigned as follows.

The inductor is now discharged via the RC and diode combo. Assume that the inductor current is I"L, off, before the switch is closed. The current flowing through the inductor is calculated as follows:

$$I'''_{L,off} = -(1/L) * \int V_{out} * dt + I''_{L,off}$$

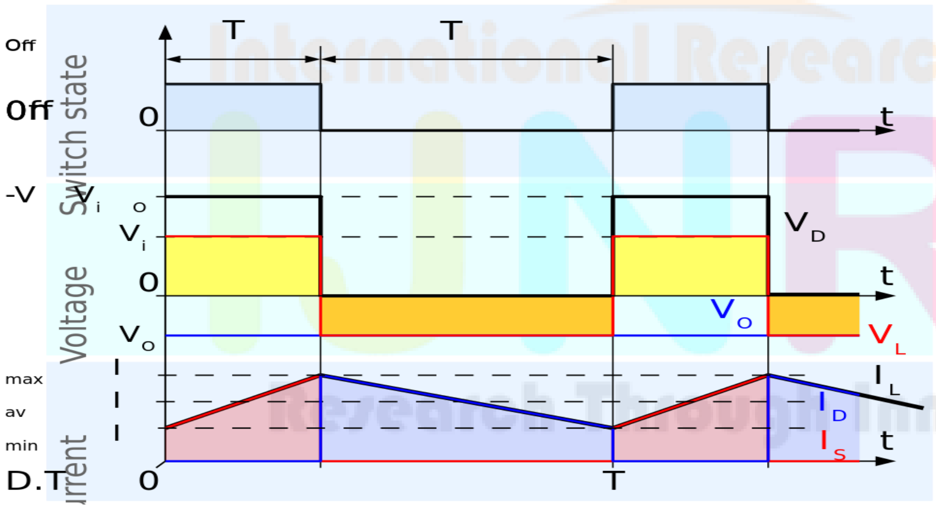


Fig 8: CCM of Buck-Boost Converter

2.1.2 Discontinues conduction mode

In this mode the current through the inductor goes to zero. Hence the inductor will totally discharge at the end of switching cycles. The waveforms of current and voltage in a buck–boost converter operating in discontinuous mode is shown in below figure.

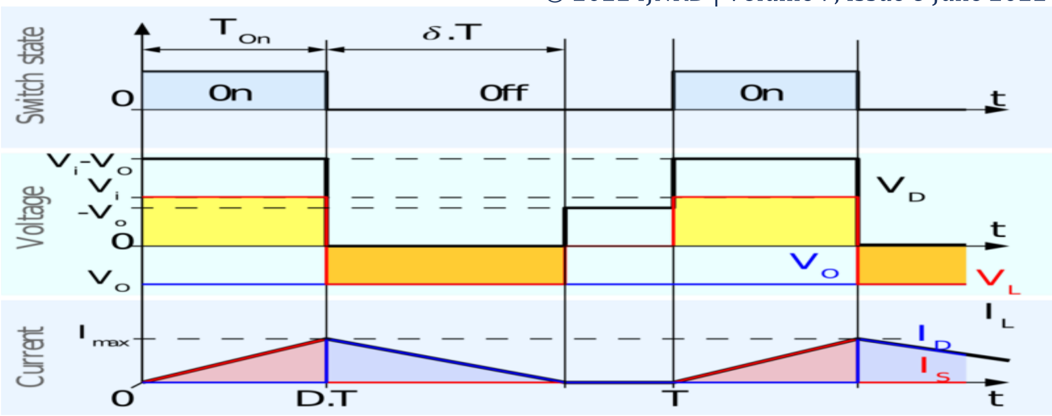


Fig 9: DCM of Buck-Boost Converter

PROPOSED BUCK-BOOST CONVETER

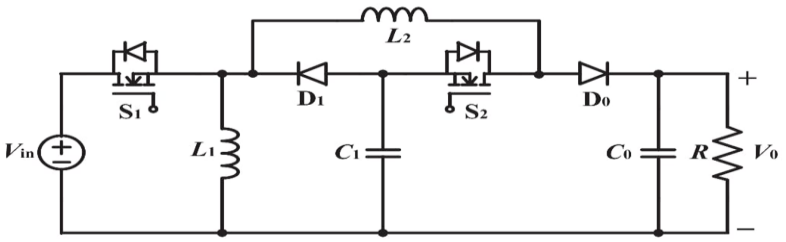


Fig 10: circuit diagram of Proposed Buck-Boost converter

An additional switching network is placed into the typical buck-boost converter in this suggested system, and a novel transformer less buck-boost converter is proposed. The proposed buck-boost converter's main feature is that its voltage gain is quadratic of that of a traditional buck-boost converter, allowing it to operate over a wide range of output voltages, i.e., the proposed buck-boost converter can achieve high or low voltage gain without requiring an extreme duty cycle. Furthermore, the polarity of this novel transformer less buck-boost converter is positive, and the output voltage is common-ground with the input voltage.

3.1 OPERATING PRINCIPLES

When the new transformer less buck-boost converter works in CCM, it has two states of operation: state 1 and state 2.

STATE 1 (NT < t < (N+D))

VL1 = Vin

VL2 = (VC1+ Vin)

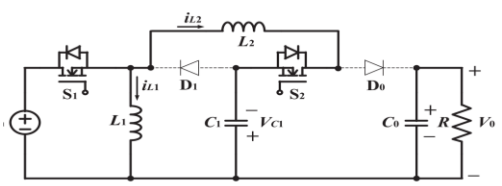


Fig 11: Switch ON state of Proposed Buck-Boost converter

STATE 2 ((N+D)T < t < (N+1))

$V_{L1} = -V_{in}$

$V_{L2} = -(V_{C1} + V_O)$

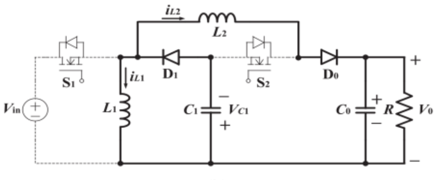


Fig 12: Switch OFF modes of Proposed Buck-Boost converter

If losses V_{in} I_{in} s are ignored Pin = Po i.e., = $V_O I_O$

Based on voltage gain input current and output current relation can be obtained

$I_{im}/I_O = (1\text{-}D/D)^2$

The Ohm's law for the resistive load R is

$$V_O = I_O R$$

By using the ampere-second balance principle on the output capacitor Co

$I_{in} = D\,(I_{L1} + I_{L2})$

$I_O = (1 - D)\,IL_2.$

$I_{L1} = D^2(2D - 1)\,V_{in}/\,(1 - D)^4R$

$I_{L2} = D^2V_{in}/\,(1 - D)^3R.$

The current stress of the two power switches (S1 and S2) and two diodes (D1 and D0) is

$I_{S1} = D\,(I_{L1} + I_{L2}) = D^4V_{in}/\,(1 - D)^4R$

$I_{S2} = DI_{L2} = D^3V_{in}/\,(1 - D)^3R$

$I_{D1} = (1 - D)\,(I_{L1} + I_{L2}) = D^3V_{in}/\,(1 - D)^2R$

$I_{D0} = (1 - D)\,I_{L2} = D^2V_{in}/\,(1 - D)^2R.$

2.2 CURRENT RIPPLES OF INDUCTOR AND VOLTAGE RIPPLES OF CAPACITOR

The ripples of the inductor current iL1 and iL2 can be given as

$\Delta i_{L1} = (V_{L1}/L_1)\,DT_S = DV_{in}/L_1f_s$

$\Delta iL2 = (V_{L2}/L_2)\,DT_S = DV_{in}/\,(1 - D)\,L_2f_S$

(Where fs is the switching frequency).

The ripples of the voltage across the capacitors C1 and C0,

i.e., Δv_{C1} and Δv_{C0} are

$\Delta v_{C1} = \Delta Q/C = DV_O/\,(1 - D)\,RC_1f_S$

$\Delta v_{C0} = \Delta Q/C = DV_O/RC_Of_S$

For a converter operating in the boundary condition mode (BCM), the current of inductor just reduces to zero at the end of each switching cycle. Note that, here, we assume that the inductor current iL1 is continuous and only take the inductor L2 as an example. The dc current of the inductor L2 is

$I_{L2} = (Vin + V_{C1}/2L_2)\ DT_S.$

In addition, defining the normalized inductor time constant on the inductor L2 as

$\tau_{L2} = L_2f_S/R.$

then, the boundary condition about the inductor L2 can be derived as

$\tau_{L2B} = (1 - D)^{2/}2D$

It is clear at when $\tau_{L2} > \tau_{L2B}$, the proposed buck–boost converter operates in CCM. Otherwise, it operates in DCM.

SOLAR PV APPLICATIONS

Solar energy is used to generate electricity, which is dependent on the photovoltaic effect in certain materials. When certain materials are exposed to direct sunlight, they produce an electric current. This effect can be noticed when two thin layers of semiconductor materials are combined. This combination will have a depleted quantity of electrons in one layer. When sunlight touches this layer, it absorbs photons from the sun's rays, causing electrons to be energised and jump to the next layer. This effect causes a charge difference between the layers, resulting in a very small potential difference. Solar cells are the smallest unit of such a combination of two layers of semiconductor materials for producing an electric potential difference in sunlight.

PI CONTROLLER

PI CONTOLLER MODE PI control is suitable more popular because of its capability to maintain accurate set point. This chapter aim at establish plan & achievement of common PI controllers at different operating points of transformer less buck boost converter.

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Kp and KI values are designed utilizing the trial-and-error process. The PI controller receives the error, and the PI's output is sent to the PWM generator. PWM generates duty cycles based on PI output.

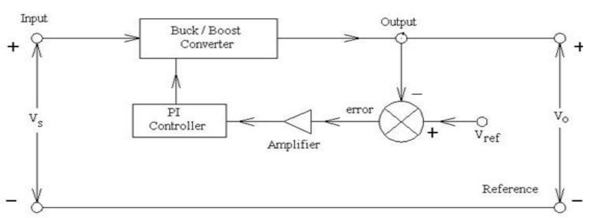

Fig 13: Block diagram of Proposed Buck-Boost converter with PI Controller

The proportional-integral controller mode is the outcome of combining the proportional and integral controller modes. This mode gives you some of the benefits of both control actions. The proportional plus reset action controller is another name for this mode. The proportional and integral modes' equations are combined to yield the following analytic formula for this mode:

$$P = Kp\ ep + Kp\ Kt\ p\ dt + pt\ (0)$$

where pt (0) = Integral term value at t = 0 (initial value)

SIMULATION DIAGRAM

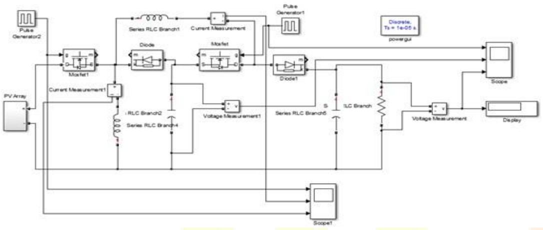

Fig 14: Simulated circuit diagram of Proposed Buck-Boost converter

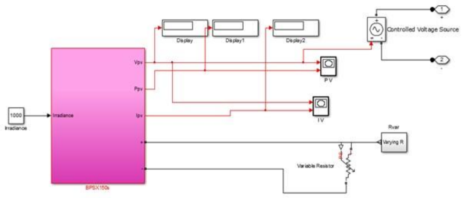

Fig 15: circuit diagram of PV Array

Kop and KI values are designed utilizing the trial-and-error process. The PI controller receives the error, and the PI's output is sent to the PWM generator. PWM generates duty cycles based on PI output.

When the load value of R changes from 130ohm to 180ohm, the proposed converter with PI controller operates in step-up mode and maintains constant output voltage V0=40.5V.

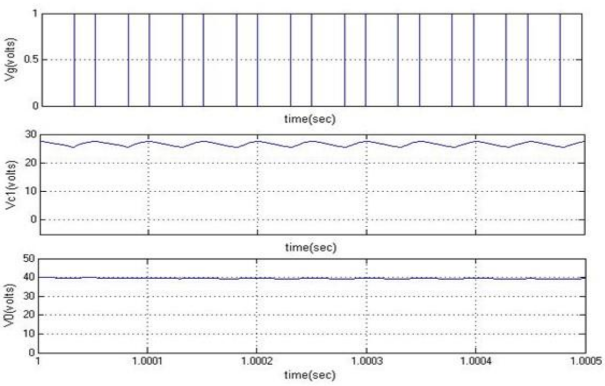

Fig 16(a): proposed converter with PI controller in step-up mode (v_g, v_{c1} and Vo)

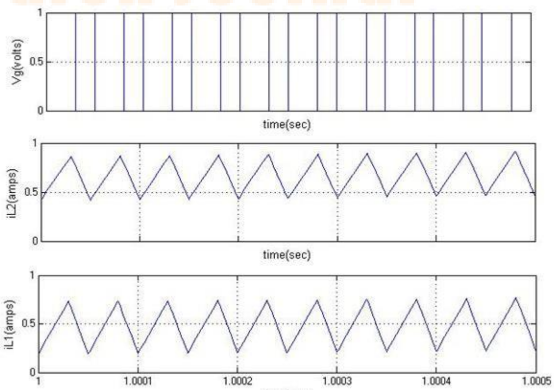

Fig 16(b): proposed converter with PI controller in step-up mode (v_g, i_{L1} and i_{L1})

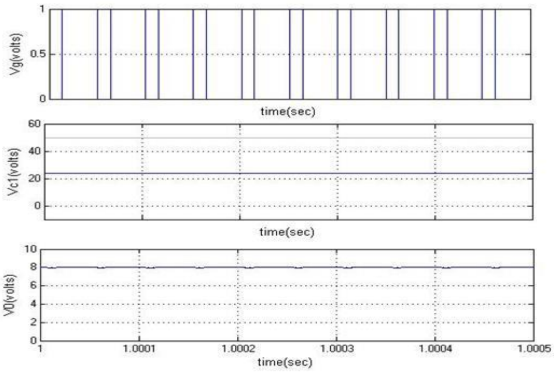

Fig 16(a): proposed converter with PI controller in step-down mode (v_g, v_{c1} and Vo)

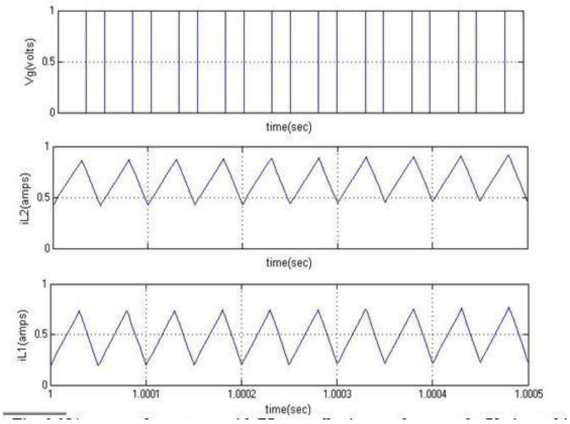

Fig 16(a): proposed converter with PI controller in step-down mode (v_g, i_{L1} and i_{L1})

Table 1: Comparison of two proposed converters: one without feedback and one with feedback

	Transformer less buck-boost converter without feedback	Transformer less buck-boost converter with feedback
No. of switches	2	2
No. of diodes	2	2
No. of inductors	2	2
No. of capacitors	2	2
Output voltage (buck mode)	6.89	8
Output voltage (boost mode)	38.27	40.5

Kp and KI values are designed utilizing the trial-and-error process. The PI controller receives the error, and the PI's output is sent to the PWM generator. PWM generates duty cycles based on PI output.

CONCLUSION

A new transformer less suggested buck/boost converter with feedback has been modelled and studied using MATLAB. This converter is projected to overcome the drawbacks of normal (conventional) buck/boost converters by injecting an additional switch network into the regular (conventional) buck/boost converter. Stepped up/down potential gain, positive polarity output voltage-gain, transparent control method, and simple architecture are all features of the TLBC (transformer less buck/boost converter). As a result, TLBC proposed a suitable solar energy appliance to manage with low or lower voltage PV arrays, which is suitable for industrialized activities requiring massive step-down volt aged gain. Without employing any severe duty cycles, the converter may function in a wide range of output voltages. Within a duty (percentage) ratio of 0.4-0.6, it delivers sufficient gain. Not only would a scheduled converter provide high voltage gain, but it will also reduce extreme steep duty cycles from powered switches and increase the efficiency of the proposed one. To maintain a consistent output voltage regardless of load situation, a PI controller and a PWM generator can be used to send driving signals to power switches.

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