International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 2 Issue 7, July - 2013

# Reviewing Potentials Aspects Of DC-DC Controllers: A Study

Mahesh Gowda N M
*Asst. Prof*: Dept of Electronics & Communication Eng.
PES College of Engineering
Mandya, India

Dr. S. S. Parthasarathy
*Prof*.: Dept. of Electrical & Electronics Eng.
PES College of Engineering
Mandya, India

***Abstract*— A DC-to-DC converter is an electronic circuit which converts a source of direct current (DC) from one voltage level to another. With a vast range of applications like personal computers, office equipment, spacecraft power systems, laptop computers, and telecommunications equipment, as well as DC motor drives. DC-DC converters have highly attracted the area of research in power controlling system. This paper presents a brief survey of DC-DC converters and its widely used topologies structurally classified into isolating and non-isolating converters, their modes of operation, and a brief discussion on the some of the current studies conducted on the similar domain to give a compact summarization of the core topic which is still in the eye of many researcher.**

***Keywords-component; DC-DC Converter, Power Control, PI, Buck, Boost***

## I. INTRODUCTION

A DC-to-DC converter [1] is a device that accepts a DC input voltage and produces a DC output voltage. Typically the output produced is at a different voltage level than the input. In addition, DC-to-DC converters are used to provide noise isolation, power bus regulation, etc. The switched mode DC-DC converters are some of the simplest power electronic circuits which convert one level of electrical voltage into another level by switching action. These converters have received an increasing deal of interest in many areas. This is due to their wide applications like power supplies for personal computers, office equipment, appliance control, telecommunication equipments, DC motor drives, automotive, aircraft, etc. The analysis, control and stabilization of switching converters are the main factors that need to be considered. Many control methods are used for control of switch mode DC-DC converters and the simple and low cost controller structure is always in demand for most industrial and high performance applications. Every control method has some advantages and drawbacks due to which that particular control method consider as a suitable control method under specific conditions, compared to other control methods. The control method that gives the best performances under any conditions is always in demand. The commonly used control methods for DC-DC converters are pulse width modulated (PWM) [2], voltage mode control, PWM current mode control with proportional (P), proportional integral (PI), and proportional integral derivative (PID) controller [3]. These conventional control methods like P, PI, and PID are unable to perform satisfactorily under large parameter or load variation. Therefore, nonlinear controllers come into picture for controlling DC-DC converters. The advantages of these nonlinear controllers are their ability to react suddenly to a transient condition. The different types of nonlinear controllers are hysteresis controller, sliding mode controller, boundary controller, etc.

The hysteresis control methods for power converters are also gaining a lot of interest due its fast response and robust with simple design and implementation. The hysteresis controllers react immediately after the load transient takes place. Hence the advantages of hysteretic control over other control technique include simplicity, do not require feedback loop compensation, fast response to load transient. However, the main factors need to be considered in case of hysteresis control are variable switching frequency operation and stability analysis.

The DC-DC converters, which are non-linear and time variant system, and do not lend themselves to the application of linear control theory, can be controlled by means of sliding-mode (SM) control [4], Which is derived from the variable structure control system theory (VSCS) [5]. Variable structure systems are systems the physical structures of which are changed during time with respect to the structure control law. The instances at which the changing of the structure occurs are determined by the current state of the system. Due to the presence of switching action, switched-mode power supplies (SMPS) [6] are generally variable structured systems. Therefore, SM controllers are used for controlling DC-DC converters.

SM control method has several advantages over the other control methods that are stability for large line and load variations, robustness, good dynamic response, simple implementation. Ideally, SM controllers operate at infinite switching frequency and the controlled variables generally track a particular reference path to achieve the desired steady state operation. But an infinite switching frequency is not acceptable in practice, especially in power electronic circuits and therefore a control technique that can ensure a finite switching frequency must implemented. The extreme high speed switching operation results in switching losses, inductor and transformer core loss and electromagnetic-interference (EMI) generation. Variable switching frequency also complicates the design of input and output filter. Hence, for SM controllers to be applicable to DC-DC converters, their switching frequency should be constricted within a practical range.

Though SM control compiles of various advantages, SM controlled converters suffers from switching frequency variation when the input voltage and output load are varied. Hence there are many control methods which have been developed for fixed switching frequency SM control such as

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 2 Issue 7, July - 2013

fixed frequency PWM based sliding mode controllers, adaptive SM controller, digital fuzzy logic SM controller, etc. In case of adaptive control, adaptive hysteresis band is varied with parameter changes to control and fixate the switching frequency. But, these methods require more components and are unattractive for low cost voltage conversion applications.

The different types of hysteresis controller are hysteretic voltage-mode controller, $V^2$ controller, and hysteretic current-mode controllers. The current hysteresis control incorporates both the advantages of hysteresis control and current mode control. It can be implemented using two loop control method. The error between the actual output voltage and reference voltage gives the error voltage. A PI control block can use the voltage error signal to provide a reference current for hysteresis control. This is also called sliding mode control for DC-DC converter. Therefore, the current mode hysteretic controller can be considered as a sliding mode control system and the analysis of hysteretic controller can be done as per sliding mode control theory. The essential tools of this nonlinear control theory can be introduced for the study of the behavior of hysteresis controller.

The proposed study encapsulates the topologies of DC-DC converters and their mode of operation. The study also discusses most significant prior literature work in the line of study of DC-DC converters. Section 2 discusses about the classification of the DC-DC converters followed by its respective mode of operation in Section 3. Section 4 discusses about the related work and finally in section 5 we make some concluding remarks.

## II. Classification of DC-DC Converters

The simplest DC to DC converter is the voltage divider using resistors. However, there are not many voltage divider circuits in use because the non-load resistor dissipates power, lowering the overall power efficiency. Optimal DC to DC converters use switching techniques to move charge or current in such a way that creates a larger or smaller voltage or current on the output. There are many different types of DC-DC converter, each of which tends to be more suitable for some types of application than for others. For convenience they can be classified into various groups, however. For example some converters are only suitable for stepping down the voltage, while others are only suitable for stepping it up; a third group can be used for either. Another important distinction is between converters which offer full dielectric isolation between their input and output circuits, and those which don't. Needless to say this can be very important for some applications, although it may not be important in many others. In this data sheet were going to look briefly at each of the main types of DC-DC converter in current use, to give you a good overview. We'll start first with those which don't offer input-output isolation, and then progress to those which do.

### Non-isolating converters

The non-isolating type of converter is generally used where the voltage needs to be stepped up or down by a relatively small ratio (say less than 4:1), and there is no problem with the output and input having no dielectric isolation. Examples are 24V/12V voltage reducers, 5V/3V reducers and 1.5V/5V step-up converters. There are five main types of converter in this non-isolating group, usually called the buck, boost, buck-boost, Cuk, and charge pump converters.

The buck converter is used for voltage step-down/reduction, while the boost converter is used for voltage step-up. The buck-boost and Cuk converters can be used for either step-down or step-up, but are essentially voltage polarity reversers or 'inverters' as well. (The Cuk converter is named after its originator, Slobodan Cuk of Cal Tech University in California.) The charge-pump converter is used for either voltage step-up or voltage inversion, but only in relatively low power applications.

**Buck Converter**: A buck converter (DC-DC) is shown in Fig. 1. Only a switch is shown, for which a device belongs to transistor family. Also a diode (termed as freewheeling) is used to allow the load current to flow through it, when the switch (i.e., a device) is turned off. The load is inductive (R-L) one. In some cases, a battery (or back emf) is connected in series with the load (inductive). Due to the load inductance, the load current must be allowed a path, which is provided by the diode; otherwise, i.e., in the absence of the above diode, the high induced emf of the inductance, as the load current tends to decrease, may cause damage to the switching device. This circuit is also called as a step-down chopper; as the output voltage is normally lower than the input voltage.



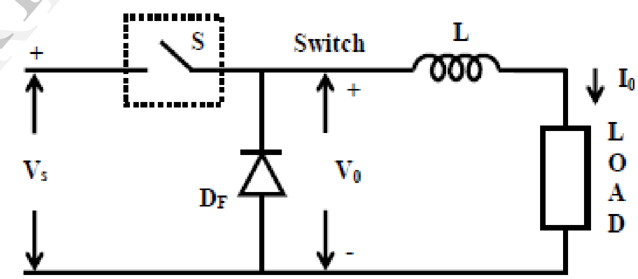


Figure 1: Buck converter (DC-DC)

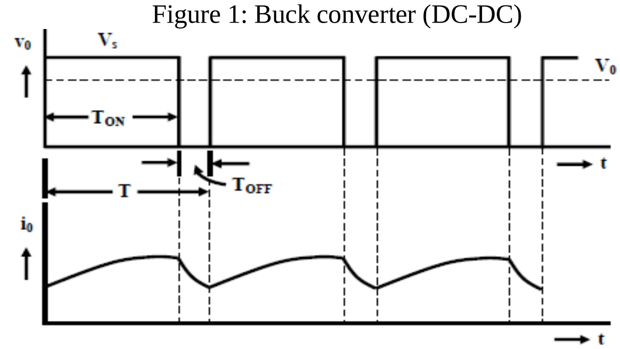


Figure 2: Output voltage and current waveforms

The output voltage and current waveforms of the circuit (Fig. 1) are shown in Fig. 2. The output voltage is same as the input voltage, i.e., VO=Vs., when the switch is ON during the period called ON period. During the next time interval called OFF period the output voltage is zero, i.e., as the diode, now conducts. The OFF period is $T_{OFF}=T-T_{ON}$, with the time period being $T=T_{ON}+T_{OFF}$. The frequency is f=1/T. With T kept as constant, the average value of the output voltage is,

$$V_0 = \frac{1}{T}\int_0^T V_0 dt = \frac{1}{T}\int_0^{T_{ON}} V_s dt = V_s\left(\frac{T_{ON}}{T}\right) = kVs,$$

The duty ratio is k = ($T_{ON}$/T) range being 1.0 ≥ k≥ 0.0 normally, due to turn-on delay of the device used, the duty ratio (k) is not zero, but has some positive value. Similarly, due to requirement of turn-off time of the device, the duty ratio (k) is less than 1.0. So, the range of duty ratio is reduced. It may be noted that the output voltage is lower than the input voltage. Also, the average output voltage increases, as the duty ratio is increased. So, a variable dc output voltage is obtained from a constant DC input voltage. The load current is assumed to be continuous as shown in Fig. 2. The load current increases in the ON period, as the input voltage appears across the load, and it (load current) decreases in the OFF period, as it flows in the diode, but is positive at the end of the time period, T.

**Boost Converter**: A boost converter (DC-DC) is shown in Fig. 3. Only a switch is shown, for which a device belonging to transistor family is generally used. Also, a diode is used in series with the load. The load is of the same type as given earlier. The inductance of the load is small. An inductance, L is assumed in series with the input supply. The position of the switch and diode in this circuit may be noted, as compared to their position in the buck converter.

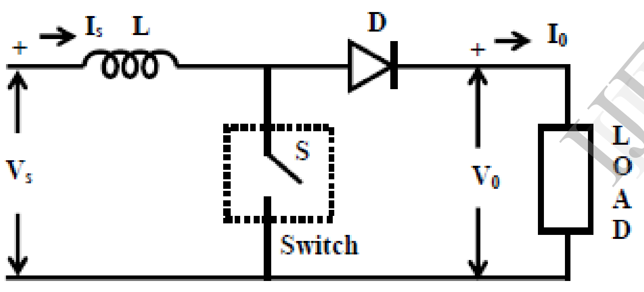


Figure 3: Boost converter (DC-DC)

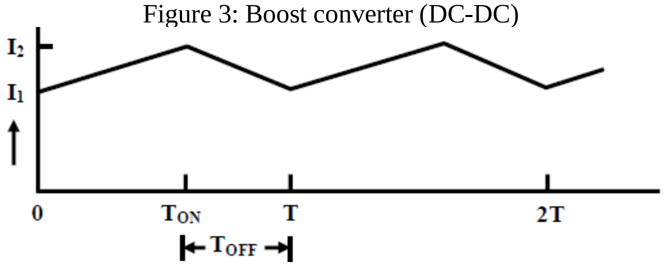


Figure 4: Waveforms of source current ($I_s$)

The operation of the circuit is explained as follows. Firstly, the switch, S is turned ON during the period, $T_{ON} \geq t \geq 0$. The output voltage is zero ($V_0$=0), if no battery (back emf) is connected in series with the load, the current from the source ($I_s$) flows in the inductance L. The value of current increases linearly with time in this interval, with (di/dt) being positive. As the current through L increases, the polarity of the induced emf is taken as say, positive, the left hand side of L being +ve. The equation for the circuit is,

$$V_s = L\frac{di_s}{dt} \;\; or \;\; \frac{di_s}{dt} = \frac{v_s}{L}$$

the switch, S is put OFF during the period, $T \geqslant t \geqslant T_{ON}$, the current through L decreases, the induced emf reverses, the left hand side of L being -ve. The current ($I_s$=$I_0$) decreases linearly in the time interval, $T_{OFF}$. The equation for the circuit is,

$$V_s = V_0 - L di_s/dt \text{ or } di_s/dt = (V_0 - V_s)/L$$

The source current waveform is shown in Fig.4. As stated earlier, the current varies linearly from $I_1(I_{min})$ to $I_2(I_{max})$ during the time interval, $T_{ON}$. So, using the expression for dis/dt during this time interval, $I_2-I_1=I_{max} - I_{min} =(Vs/L)T_{ON}$. Similarly, the current varies linearly from $I_2(I_{max})$ to $I_1(I_{min})$ during the time interval $T_{OFF}$. So, using the expression for dis/dt during this time interval, $I_2-I_1=I_{max}-I_{min}=[(V_0-V_s)/L]T_{OFF}$. Equating the two equations, $(V_s/L)T_{ON} = [(V_0-V_s)/L]T_{OFF}$, from which the average value of the output voltage is,

$$V_0 = V_s\left(\frac{T}{T_{OFF}}\right) = V_s\left(\frac{T}{T-T_{ON}}\right) = V_s\left(\frac{1}{1-(T_{ON}/T)}\right) = Vs\left(\frac{1}{1-k}\right)$$

The time period is $T=T_{ON}+T_{OFF}$, and the duty ratio is, k= ($T_{ON}$/T) with its range as 1.0 ⩾ k⩾ 0.0. The ON time interval is $T_{ON}$ = kT. As stated in the previous case, the range of k is reduced. This is, because the minimum value is higher than the minimum (0.0), and the maximum value is lower than the maximum (1.0), for reasons given there, which are also valid here. As shown in Fig 4, the source current is assumed to be continuous. The expression for the output voltage can be obtained by using other procedures. In this case, the output voltage is higher than the input voltage, as contrasted with the previous case of buck converter (DC-DC). So, this is called boost converter (DC-DC), when a self-commutated device is used as a switch. The variation (range) of the output voltage can be easily computed.

**Buck-Boost Converter**: A buck-boost converter (DC-DC) is shown in Fig. 5. Only a switch is shown, for which a device belonging to transistor family is generally used. Also, a diode is used in series with the load. The connection of the diode may be noted, as compared with its connection in a boost converter. The inductor, L is connected in parallel after the switch and before the diode. The load is of the same type as given earlier. A capacitor, C is connected in parallel with the load. The polarity of the output voltage is opposite to that of input voltage here. When the switch, S is put ON, the supply current ($I_s$) flows through the path, $V_s$, S and L, during the time interval, $T_{ON}$. The currents through both source and inductor ($I_L$) increase and are same, with ($di_L$/dt) being positive. The polarity of the induced voltage is same as that of the input voltage. The equation for the circuit is,

$$V_s = L\frac{di_L}{dt} \quad or, \frac{di_L}{dt} = \frac{V_s}{L}$$

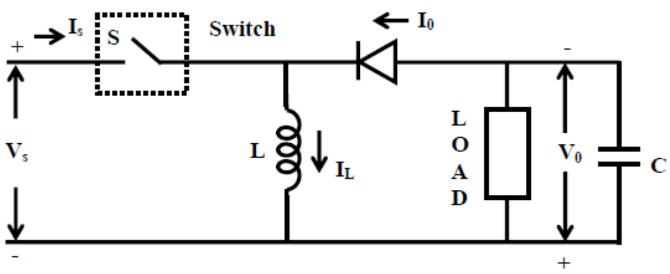


Figure 5: Buck-boost converter (DC-DC)

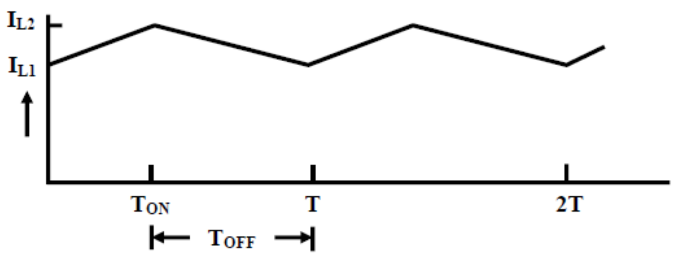


Figure 6: Inductor current ($I_L$) waveform

Then, the switch, S is put OFF. The inductor current tends to decrease, with the polarity of the induced emf reversing. ($di_L/dt$) is negative now, the polarity of the output voltage, $V_0$, being opposite to that of the input voltage, $V_s$. The path of the current is through L, parallel combination of load & C, and diode D, during the time interval, $T_{OFF}$. The output voltage remains nearly constant, as the capacitor is connected across the load. The equation for the circuit is,

$$L\frac{di_L}{dt} = V_0 \quad or, \frac{di_L}{dt} = \frac{V_0}{L}$$

The inductor current waveform is shown in Fig. 6. As stated earlier, the current varies linearly from $I_{L1}$ to $I_{L2}$ during the time interval, $T_{ON}$. Note that $I_{L1}$ and $I_{L2}$ are the minimum and maximum values of the inductor current respectively. So, using the expression for $di_L/dt$ during this time interval, $I_{L2}-I_{L1}=(Vs/L)\,T_{ON}$. Similarly, the current varies linearly from $I_{L2}$ to $I_{L1}$ during the time interval, $T_{OFF}$. So, using the expression for $di_L/dt$ during this time interval, $I_{L2}-I_{L1}=(V_0/L)\,T_{OFF}$. Equating the two equations, $(V_s/L)\,T_{ON}=(V_0/L)T_{OFF}$, from which the average value of the output voltage is,

$$V_0 = V_s\left(\frac{T_{ON}}{T_{OFF}}\right) = V_s\left(\frac{T_{ON}}{T - T_{ON}}\right) = V_s\left(\frac{(T_{ON}/T)}{1-(T_{ON}/T)}\right) = V_s\left(\frac{K}{1-k}\right)$$

It may be observed that, for the range $0.5 \geq k > 0.0$ the output voltage is lower than the input voltage, thus, making it a buck converter (DC-DC). For the range $1.0 \geq k > 0.5$, the output voltage is higher than the input voltage, thus, making it a boost converter (DC-DC). For k=0.5, the output voltage is equal to the input voltage. So, this circuit can be termed as a buck-boost converter. Also it may be called as step-up/down chopper. It may be noted that the inductor current is assumed to be continuous. The range of k is somewhat reduced due to the reasons given earlier. The expression for the output voltage can be obtained by using other procedures.

**Cuk Converter**: The main applications of this circuit are in regulated DC power supplies, where a negative polarity output may be desired with respect to the common terminals of the input voltage and the average output is either higher or lower than the dc input voltage. The typical schematic circuit for the Cuk Converter is as shown in Fig. 11. The capacitor $C_1$ acts as a primary means to store and transfer the power from input to output. The voltage $V_{c1}$ is always greater than either input or output voltage. The average output to input relations are similar to that of a buck-boost converter circuit. The output voltage is controlled by controlling the switch-duty cycle. The ratio of output voltage to input voltage is given by:

$$\frac{V_0}{V_{in}} = D.\frac{1}{1-D} = \frac{I_{in}}{1_0}$$

Where, $V_0$ and $V_{in}$ are the output and input voltages, respectively. The term $I_0$ and $I_{in}$ are the outputs and input currents, respectively. The term D is the duty ratio and defined as the ratio of the on time of the switch to the total switching period. This shows the output voltage to be higher or lower than the input voltage, based on the duty-ratio D.



**Analysis of CUK Converter**

The advantages and disadvantages of three basic non-isolated converters can be summarized in terms of features as given below

(i) Buck Converter

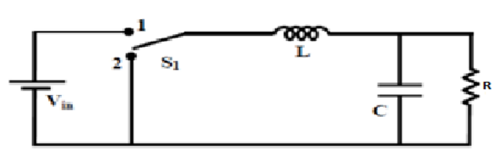


Fig. 7: Circuit schematic of a buck converter

Features of a buck converter are

- ➢ Pulsed input current, requires input filter.
- ➢ Continuous output current results in lower output voltage ripple.
- ➢ Output voltage is always less than input voltage.

(ii) Boost Converter

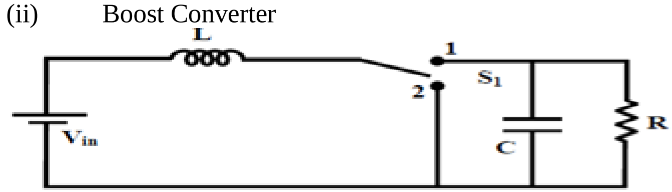


Fig. 8: Circuit schematic of a boost converter

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 2 Issue 7, July - 2013

Features of a boost converter are

- Continuous input current, eliminates input filter.
- Pulsed output current increases output voltage ripple.
- Output voltage is always greater than input voltage.

(iii) Buck - Boost converter

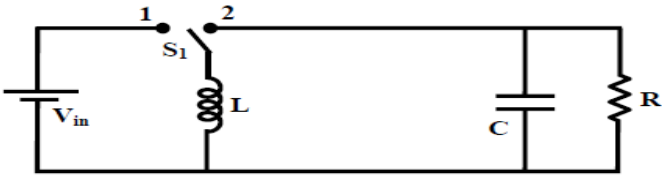


Fig. 9: Circuit schematic of a buck-boost converter

Features of a buck - boost converter are

- Pulsed input current, requires input filter
- Pulsed output current increases output voltage ripple
- Output voltage can be either greater or smaller than input voltage.

It will be desirable to combine the advantages of these basic converters into one converter. CuK converter is one such converter. It has the following advantages.

- Continuous input current.
- Continuous output current.
- Output voltage can be either greater or less than input voltage.

CuK converter is actually the cascade combination of a boost and a buck converter.

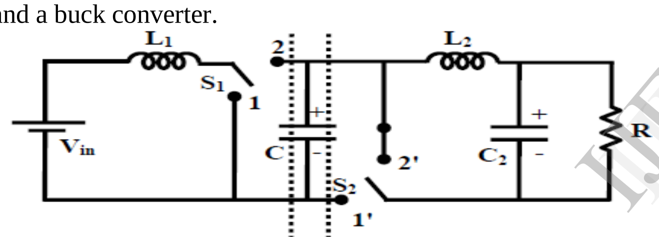


Fig. 10 Circuit schematic of a boost-buck converter

$S_1$ and $S_2$ operate synchronously with same duty ratio. Therefore there are only two switching states.

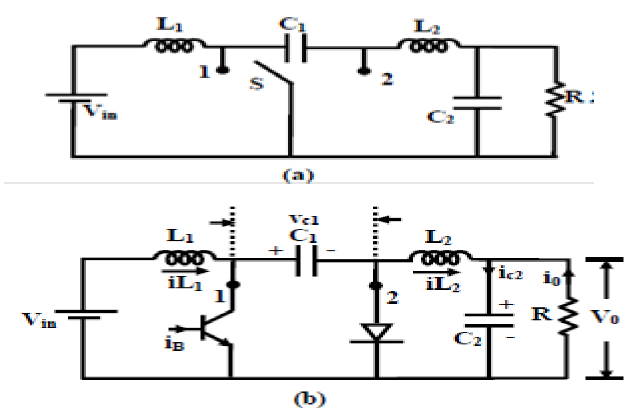


Figure 11 Schematic and Circuit Representation of Cuk Converter. (a) Schematic diagram (b) Circuit diagram.

**Charge-pump converter**: All of the converters we have looked at so far have depended for their operation on storing energy in the magnetic field of an inductor. However there is another type of converter which operates by storing energy as electric charge in a capacitor, instead. Converters of this type are usually called change pump converters they are a development from traditional voltage doubling and voltage multiplying rectifier circuits. The basic circuit for a voltage doubling charge-pump converter is shown in Fig.12, and as you can see, it mainly uses four MOSFET switches and a capacitor C1-usually called the charge bucket capacitor.

Operation is fairly simple. First Q1 and Q4 are turned ON, connecting C1 across the input source and allowing it to charge to Vin. Then these switches are turned OFF, and Q2 and Q3 are turned ON instead. C1 is now connected in series with the input voltage source, across output reservoir capacitor C2. As a result some of the charge in C1 is transferred to C2, which charges to twice the input voltage. This cycle is repeated at a fairly high frequency, with C2 providing the load current during the part of the cycle when Q2 and Q3 are turned off. As you can see all of the energy supplied to the load in this type of converter flows through C1, and as ripple current. So again this capacitor needs to have a relatively high value, have low ESR (Equivalent Series Resistance - to minimize losses) and be able to cope with a heavy ripple current. A slightly different circuit configuration from that shown in Fig.8 can be used to deliver an inverted voltage of the same value as Vin, instead of a doubled voltage. This type of converter finds use in generating a negative supply rail for electronic circuits running from a single battery. On the whole, though, the fact that charge-pump converters rely for their operation on charge stored in capacitor tends to limit them to relatively low current applications. However for this type of operation they are often cheaper and more compact than inductor-type converters.



**Isolating converters**

All of the converters it was noticed so far that they have virtually no electrical isolation between the input and output circuits; in fact they share a common connection. This is fine for many applications, but it can make these converters quite unsuitable for other applications where the output needs to be completely isolated from the input. Here's where a different type of converter tends to be used - the isolating type. There are two main types of isolating converter in common use: the "fly back" type and the "forward" type. Like most of the non-isolating converters, both types depend for their operation on energy stored in the magnetic field of an inductor or in this case, a transformer.

**Flyback converter**: The basic circuit for a flyback type converter is shown in Fig.9. In many ways it operates like the buck-boost converter, but using a transformer to store the energy instead of a single inductor. When MOSFET Q1 is switched on, current flows from the source through primary winding L1 and energy is stored in the transformer's magnetic field. Then when Q1 is turned off, the transformer tries to maintain the current flow through L1 by suddenly reversing the voltage across it generating a 'flyback' pulse of back-EMF. Q1

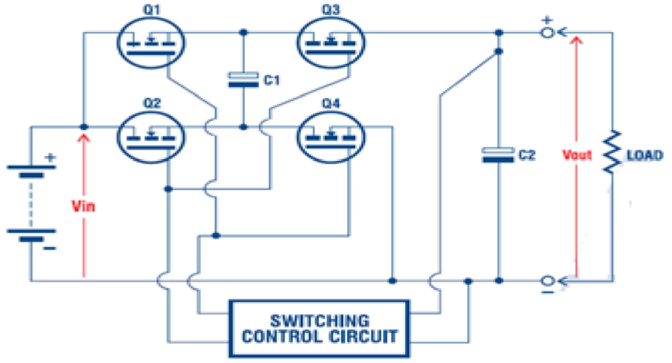


Figure12: A basic Charge-Pump converter which doubles the input voltage

is chosen to have a very high breakdown voltage, though, so current simply can't be maintained in the primary circuit. But because of transformer action an even higher flyback pulse is induced in secondary winding L2. And here diode D1 is able to conduct during the pulse, delivering current to the load and recharging filter capacitor C1 (which provides load current between pulses). So as you can see, the flyback converter again has two distinct phases in its switching cycle. During the first phase Q1 conducts and energy is stored in the transformer core via the primary winding L1. Then in the second phase when Q1 is turned off, the stored energy is transferred into the load and C1 via secondary winding L2. The ratio between output and input voltage of a fly back converter is not simply a matter of the turn's ratio between L2 and L1, because the back-EMF voltage in both windings is added to the flyback transformer to allow sensing of the flyback pulse amplitude (which is reasonably close to the output voltage Vout). This voltage can be then fed back to the MOSFET switching control circuit, to allow it to automatically adjust the switching to regulate the output voltage.

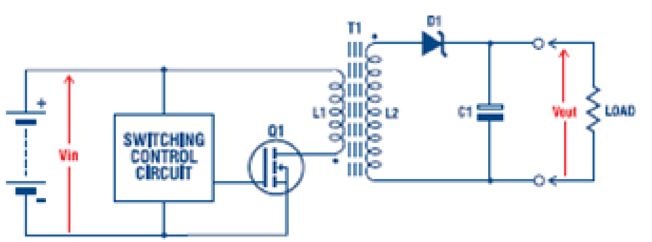


Figure 13: The Fly back converter, which offers isolation as well as a high voltage step-up factor. It's mainly used for lower power applications.

**Forward converter:**

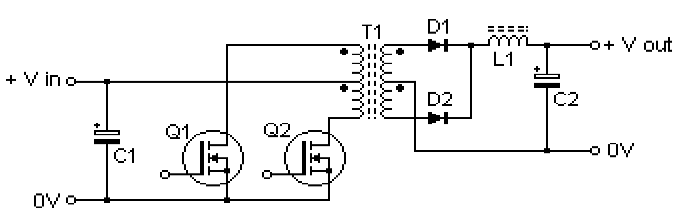


Figure 14: The Push-Pull Converter

In contrast with the flyback converter, where there are two distinct phases for energy storage and delivery to the output, the forward converter uses the transformer in a more traditional manner, to transfer the energy directly between input and output in the one step. The most common type of forward converter is the push-pull type as shown in Fig14. As you can see there are now two switching MOSFETs, Q1 and Q2, connected to either end of a centre-tapped primary winding on the transformer. The positive side of the input voltage source is connected to the centre tap. In operation, the switching control circuit never turns Q1 and Q2 ON at the same time; they are turned ON alternately. And since their sources are connected back to the negative side of the input voltage, this means that the input voltage is first connected across one half of the primary winding, and then across the other. So current flows first in L1, and then in L2. This cycle is repeated over and over, continuously and at a relatively high rate, often many tens or even hundreds of kilohertz. So in effect, the action of Q1 and Q2 is to convert the DC input voltage into a high frequency AC square wave. As a result the transformer's secondary delivers the same AC square wave, with a peak voltage (during each half-cycle) equal to:

$$V_{ac}(pk) = Vin \times (L3/L1)$$

Where L3 and L1 (=L2) are half the number of turns on each winding, not the inductance. So if secondary winding L3 has 10 times the number of turns as each side of the primary, the transformer's peak output voltage will be 10 times the input voltage. As you can see, diodes D1-D2 are connected directly across the secondary winding as a center tapped full wave rectifier. So the AC square wave that appears across L3 will be rectified back into high voltage DC, to feed the load and maintain the charge on filter capacitor C2. And if we ignore the diode voltage drops, the DC output voltage $V_{out}$ will be equal to the peak AC output from the transformer or in other words,

$$V_{out} = V_{in} \times (L3/L1)$$

If you like, then, the forward converter is basically just a way of being able to use a transformer for DC, by converting the DC energy into AC so the transformer can handle it. After being transformed the AC is then rectified back into DC. Needless to say, once we have the energy in the form of AC we can use the transformer to do pretty well anything we want, step it up, step it down, or any combination of the two. This becomes simply a matter of manipulating the turns on the secondary winding, adding other secondary windings if we want to have multiple outputs, and so on. Because the forward converter reverses the polarity of magnetic flux in the transformer core for each alternate half-cycle, there's much less tendency to cause saturation than in the flyback converter. So the transformer can be significantly smaller, for the same power level. This together with the tighter and more predictable relationship between input and output voltage makes the forward converter much more suitable for high power applications. One important application for forward converters is in car hifi amplifiers, where they are used to step up the relatively low battery voltage to higher voltage supply rails, to allow the amplifiers to develop higher power output. Another common use for the forward DC-DC converter is as the heart of many modern multi-voltage switch mode power supplies, as found in computers, TV sets and many other types of electronic equipment. In these cases the incoming AC mains voltage is generally rectified straight away to produce 340V DC (in the case of 240V mains voltage), which is then used to drive the forward converter. There may be three, four or even more secondary windings on the transformer, to produce the various low voltage DC supplies needed by the electronic circuitry.

## III. Modes of Operation

The operation of DC-DC converters can be classified by the continuity of inductor current flow. So DC-DC converter has two different modes of operation that are (a) Continuous conduction mode (CCM) and (b) Discontinuous conduction mode (DCM). A converter can be design in any mode of operation according to the requirement.

**Continuous Conduction Mode**: When the inductor current flow is continuous of charge and discharge during a switching period, it is called Continuous Conduction Mode (CCM) of operation shown in figure 15(a). The converter operating in CCM delivers larger current than in DCM. In CCM, each switching cycle $T_s$ consists of two parts that is $D_1T_s$ and $D_2T_s(D_1+D_2=1)$. During $D_1T_S$, inductor current increases linearly and then in it ramps down that are decreases linearly.

**Discontinuous Conduction Mode**: When the inductor current has an interval of time staying at zero with no charge and discharge then it is said to be working in Discontinuous Conduction Mode (DCM) operation and the waveform of inductor current is illustrated in figure 15(c). At lighter load currents, converter operates in DCM. The regulated output voltage in DCM does not have a linear relationship with the input voltage as in CCM. In DCM, each switching cycle is divided into of three parts that is $D_1T_S$, $D_2T_S$ and $D_3T_S$ ($D_1+D_2+D_3=1$). During the third mode i.e. in $D_3T_S$, inductor current stays at zero.

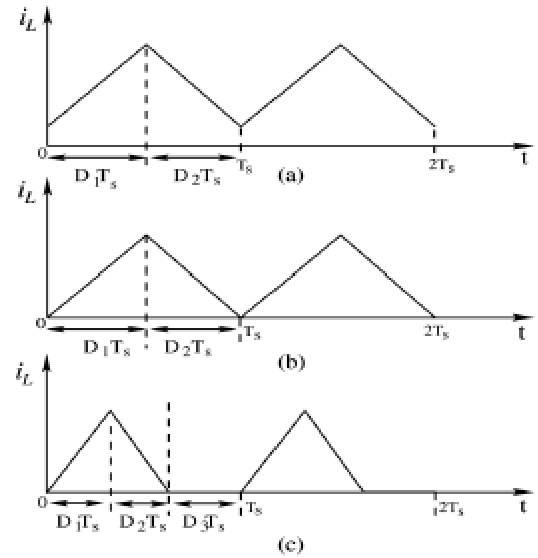


Figure 15 Inductor current waveform of PWM converter (a) CCM (b) boundary of CCM and DCM (c) DCM

## IV. Related Work

In switching mode power supplies, as the switching frequency increases for high power density and with small size, switching losses associated with the turn-on and turn-off of the devices in the power converter are increased. These losses are so significant that the operations of the power converters at high frequency are limited. To overcome these problems, a number of full, quasi-, and multi-resonant DC-DC converter topologies have been investigated in the literature. It was also seen that, DC-DC converters such as the conventional forward and flyback converters have a severe difficulty in surge occurrence due to leakage inductance of the transformer and the reverse-recovery problem of output diodes. The range of applications for DC-DC converters is large, with many variations. Interest in converters is commensurately quite high.



Table 1 Summary of current research work in DC-DC Converter.

| Author | Year | Work Summary | Results |
|---|---|---|---|
| Andersen et al [7] | 2013 | Design and implementation of on-chip switched capacitor converters in deep submicron Technologies. | High power density and efficiency achieved using deep trench capacitors |
| Mehrdad Ahmadi Kamarposhti et al [8] | 2013 | Neural network control scheme of a DC-DC Converter Buck Boost DC variable voltage to generate a DC motor drive | Controller has better performance compared to PI controller is using |
| Patitapabana Pani et al [9] | 2013 | High efficiency DC-DC Buck converter designed in 0.18- m CMOS process to get regulated 1.3–1.6 V output from 3.3 V input supply | Improved Power efficiency |
| Romulo Antao et al. [10] | 2013 | Addresses the challenges of developing High Power chargers and proposes a modular, easily scalable and efficient implementation of a switch-mode DC-DC converter for performing | Modularity allows the use of medium power devices to implement efficient systems with higher power capabilities and, ultimately, reduce the EV batteries charging times. The flexibility of the proposed system also |

| | | | |
|---|---|---|---|
| | | the constant-current/ constant-voltage battery charging process. | overcomes the in definition regarding the maximum power specifications of the charging protocols. |
| Iskender et al.[11] | 2013 | Soft switching techniques in DC-DC converter are to reduce the power loss of switches in converters. | The number of elements affects negatively the cost and the volume of the converter |
| J. Kamala and B. Umamaheswari [12] | 2012 | Design issues in the implementation of Application Specific Integrated Transducer Interface Module-Control Architecture (AS ITIM–CA) using DC-DC converter systems | Hardware utilization is lower for AS ITIM-CA comparing with TIM(Transducer Interface Module) based controller. |
| Ramos Hernanz et al.[13] | 2012 | Analysis and Modeling of Buck, Boost and Buck-Boost | Simscape toolbox is much slower and the results don't fit so good to the results desired as SimPowerSystems, although the starting values are the same. |
| Jong-Pil Lee et al[14] | 2012 | A detailed analysis on coupled inductor and the effect of coupled inductor on current ripple reduction is investigated | coupling coefficient should be high enough to effectively reduce inductor current ripple and enough leakage inductance is also required to minimize output current ripple of the converter |
| Nanda R Mude, Prof. Ashish Sahu [15] | 2012 | Highlights nonlinear aspects of buck converter, non linear controller like sliding mode controller and hybrid type of controller SMC (sliding mode controller) PID | From performance comparison of SMC with PI and PID it was found that it has large settling time.<br>When less cost, less accuracy and less complexity is required, than PI or PID control method can be used |
| R. D. O. Reiter et al [16] | 2012 | Presents the control system design of a DC-DC converter with a three-phase high frequency transformer for dual-stage grid-connected PV applications | Steady-state results demonstrate the high rejection capability in PV array current of harmonics with twice the mains frequency. |
| M. M. Abdel Aziz et al [17] | 2012 | Investigated Proportional integral derivative (PID) controllers, Fuzzy logic controllers (FLC), parallel combination of PID and FLC, and FLC tuned by PI controller | FLC tuned by PI controller is superior to the other control strategies because of fast transient response, minimum steady state error and good disturbance rejection under various variations of the operating conditions |
| Nittala S K Sastry et al [18] | 2012 | The reduction of ripple by the use of fuzzy logic controller in a single phase buck converter. | Comparing with control techniques available for a DC-DC buck converter like Sliding mode control, Current mode control and Voltage mode control, Fuzzy logic control is the better one as it is mainly based on heuristic knowledge of the system |
| H. Feshki Farahani [19] | 2011 | A controller for a DC-DC converter using Fuzzy concept. Then, this algorithm is simulated in MATLAB software. After that, the mentioned algorithm is implemented on a BUCK DC-DC converter using an 8-bit microcontroller. | Fuzzy controller has faster dynamic when compared with the PI digital classic one. |



Increased use of single supply powered systems, stiffening performance requirements and battery operation have increased converter usage. Historically, efficiency and size have received heavy emphasis. In fact, these parameters can be significant, but often are of secondary importance. A possible reason behind the continued and overwhelming attention to size and efficiency in converters proves surprising. Simply put, these parameters are (within limits) relatively easy

ISSN: 2278-0181
Vol. 2 Issue 7, July - 2013

to achieve. Size and efficiency advantages have their place, but other system-oriented problems also need treatment. Low quiescent current, wide ranges of allowable inputs, substantial reductions in wideband output noise and cost effectiveness are important issues. This section summarizes about all the major work being done in the design of DC-DC converters with brief description of the work summary and result accomplished by each of the techniques. It can be seen that there are multiple techniques are applied with pros and cons in majority of the techniques. However, it guides the novel researcher to carry out design of their new theories on DC-DC converters. (See Table 1)

## V. CONCLUSION

Global energy consumption tends to grow continuously. To satisfy the demand for electric power against a background of the depletion of conventional, fossil resources the renewable energy sources are becoming more popular. This paper has introduced the review of technical specification of DC-DC converters, its topologies, its mode of operations and some of the recent studies conducted in the same field. It can be seen that high gain DC-DC converters are the key part of renewable energy systems. The designing of high gain DC-DC converters is imposed by severe demands. Designers face contradictory constraints such as low cost and high reliability. The main problem for the operator is to maximize the energy yield and to minimize the maintenance. For these reasons the converters must be distinguished by high efficiency over wide input power and voltage range. High voltage gain (usually ten-fold) is required to produce sufficient DC bus voltage level. Additionally they should operate at wide temperature range expressing low Electromagnetic Compatibility emission and be immune to environmental conditions. Such demands create severe constraints for DC-DC boost converter designing which are key parts in terms of efficiency of overall renewable energy systems.



## REFERENCES

[1] http://en.wikipedia.org/wiki/DC-to-DC_converter

[2] Pulse-width modulation. Retreived from http://fab.cba.mit.edu/classes/MIT/961.04/topics/pwm.pdf, 2000

[3] Willis, M.J., Proportional-Integral-Derivative Control, Retreived from http://www.appdigitech.com/PID_doc.pdf

[4] Young, K.D., Utkin, V.I., A Control Engineer's Guide to Sliding Mode Control, 328, IEEE Transactions On Control Systems Technology, Vol. 7, No. 3, May 1999

[5] Ramirex, H.S., Differential geometric methods in variable-structure control, International Journal of Control system, vol.48, No.4., pp-1359-1390.

[6] Tse, M., Switch Mode Power Supplies: From Circuit Theory to the Workbench, Department of Electronic & Information Engineering, Hong Kong Polytechnic University, Retreived from http://cktse.eie.polyu.edu.hk/NSR/presentation/SMPS-lecture-1.pdf

[7] Andersen, T., A 4.6 W/mm2 Power Density 86% Efficiency On-Chip Switched Capacitor DC-DC Converter in 32nm SOI CMOS, Proceedings of the International Solid-State Circuits Conference (ISSCC 2013), San Francisco, USA, February 17-21, 2013.

[8] Kamarposhti,M.A., Tayebbifar, Mohammad Shaker, Pegah Nouri, The Control of Buck Boost DC-DC Converters for DC Motor Drives on variable DC Voltage by Using Neural Network, Life Science Journal 2013;10(5s)

[9] Pani, P., Subhramanya Kumar, B.V.V., High efficiency DC-DC Buck converter Architecture suitable for embedded applications using switched capacitor, International Journal of Engineering Science Invention ISSN (Online): 2319 – 6734, ISSN (Print): 2319 – 6726, Volume 2 Issue 4 ǁ April. 2013 ǁ PP.15-19

[10] Antao, R., Gonçalves, T., Martins, R.E., Modular Design of DC-DC Converters for EV battery fast-charging, International Conference on Renewable Energies and Power Quality (ICREPQ'13) Bilbao (Spain), 20th to 22th March, 2013

[11] Iskender, I., Ghasemi, M., Mamizadeh, A. , Soft switching analysis in DC-DC boost converters, International Journal on "Technical and Physical Problems of Engineering" (IJTPE), March 2013 Issue 14 Volume 5 Number 1 Pages 132-137

[12] Kamala, J. , and Umamaheswari, B., Application Specific Integrated Transducer Interface Module – Control Architecture for DC-DC Converters, International Journal of Electrical, Electronics and Computer Engineering 1(2): 1-5(2012)

[13] Hernanz, J.A.R., Campayo, J.J. , Echavarri, O., Calculation and simulation of the main DC-DC converters used in photovoltaic systems, International Journal on "Technical and Physical Problems of Engineering" (IJTPE), March 2013 Issue 14 Volume 5 Number 1 Pages 144-148

[14] Shin, D., Lee, J.P., Lee, K.J., Yoo, D.W., and Yoo, J.Y., Analysis and Design of Coupled Inductor for Two-Phase Interleaved DC-DC Converters, JPE, 2012

[15] Mude, N.R., Sahu, A., Adaptive Control Schemes For DC- DC Buck Converter, International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622, Vol. 2, Issue 3, May-Jun 2012, pp. 463-467

[16] Reiter, R. D. O., Pinheiro, J. R. , Péres, A., Digital controller for an isolated Step-Up DC-DC converter based on three-phase high-frequency transformer for grid-connected PV applications, International Conference on Renewable Energies and Power Quality (ICREPQ'12)

[17] Aziz, M.A., Mahfouz, Khorshied, M., Simplified approaches for Controlling DC-DC power Converters, International Journal of Engineering Science and Technology (IJEST), Vol. 4 No.02 February 2012

[18] Sastry, N., Pattnaik, S., Singh, V., Reduction of Ripple in a single phase buck converter by Fuzzy logic control, International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622, Vol. 2, Issue 3, May-Jun 2012, pp.2202-2204

[19] Farahani, H.F., Designing and Implementation of a Fuzzy Controller for DC-DC Converters and Comparing With PI Digital Controller, Australian Journal of Basic and Applied Sciences, 5(7): 276-285, 2011 ISSN 1991-8178