Research Journal of Engineering Sciences ISSN 2278 – 9472
Vol. **2(8),** 18-21, August **(2013)** *Res. J. Engineering Sci.*

Review Paper

Overview of control Techniques for DC-DC converters

Sujata Verma, S.K Singh and A.G. Rao
National Institute of Electronics and Information technology (NIELIT) Gorakhpur, INDIA

Available online at: www.isca.in
Received 5th August 2013, revised 13th August 2013, accepted 25th August 2013

Abstract

DC-DC converters are used to convert one DC voltage to other. These converters are drastically used in industry as well as in research. One of the main limitations of these converters is unregulated supply of voltage and current. To overcome these problems there are various control techniques used in combination with these converters. In this review we summarized few of these control techniques. Some well known control techniques are Voltage mode control (VMC), Current mode control (CMC), PID, Sliding mode (SM) control and fuzzy logic control. We have also paid attention on the advantages and disadvantages of these techniques with basic operating principle.

Keywords: DC-DC converters, DC voltage, current, control techniques, operating principle.

Introduction

DC-DC converters are one of the important electronic circuits, which are widely used in power electronics[1-3]. The main problem with operation of DC-DC converter is unregulated power supply, which leads to improper function of DC –DC converters. There are various analogue and digital control methods used for dc-dc converters and some have been adopted by industry including voltage- and current-mode control techniques[2,4]. The DC-DC converter inputs are generally unregulated dc voltage input and the required outputs should be a constant or fixed voltage. Application of a voltage regulator is that it should maintains a constant or fixed output voltage irrespective of variation in load current or input voltage. Various kinds of voltage regulators with a variety of control schemes are used to enhance the efficiency of DC-DC converters. Today due to the advancement in power electronics and improved technology a more severe requirement for accurate and reliable regulation is desired[5]. This has led to need for more advanced and reliable design of controller for dc-dc converters. There are various types of DC-DC converters required for particular purpose like

Buck, Boost, Buck and Boost, Cuk and flyback. These all DC-DC converters have their specific configurations to complete their tasks. Varieties in DC-DC converter required different type of controlling techniques because single technique cannot be applied to all converters as the all have different specifications. Aim of this paper is to have an overview of all the control techniques used to facilitate the performance of various kinds of DC-DC converters. We will briefly discuss the basic concept, advantages and disadvantage of each control technique throughout this review.

Voltage mode control of DC-DC converters

It is a type of single loop controller connected to a reference voltage, so at first output voltage is measured and compared to a reference voltage (figure-1). This VMC method is used in research as well as in industry due its easy implementation[6,7]. It uses measured output and reference voltage to generate the control voltage. After this the control voltage is used to determine the switching duty ratio by comparison with a constant frequency waveform. This duty ratio is used to maintain the average voltage across the inductor. This will eventually bring the output voltage to its reference value and which help in the delivery of constant voltage without any variation.

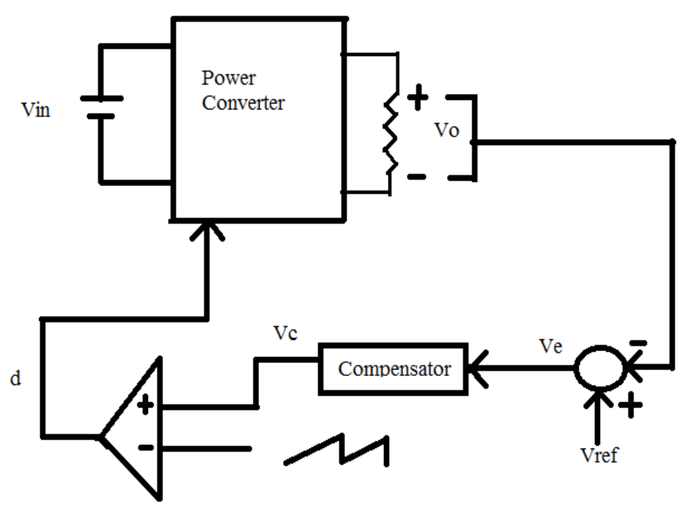

Figure-1
Voltage mode control of power converter

There are various drawbacks in VMC method: i. Poor reliability and stability of the main switch. ii. It is less in reliability, stability, or performance when several converters in parallel supply with one load. iii. It is not simple and often inefficient methods of keeping the main transformer of a push- pull converter operating in the centre of its linear region. iv. It is a very slow system, as respond is much longer of switching cycles.

Current mode control of DC-DC converters

It is more complex than VMC as it contain dual loop including voltage and current control loops (Figure- 2). There are various application of CMC for different application[8-10]. After sensing the inductor current it is used to control the duty cycle. An error signal is produced after comparing the output voltage *Vo* with fixed reference voltage *Vref* and this error signal is used to generate control signal *ic*. The next step is to sense inductor current and compared with control signal *ic* to generate the duty cycle of particular frequency and drive the switch of the converter[4].

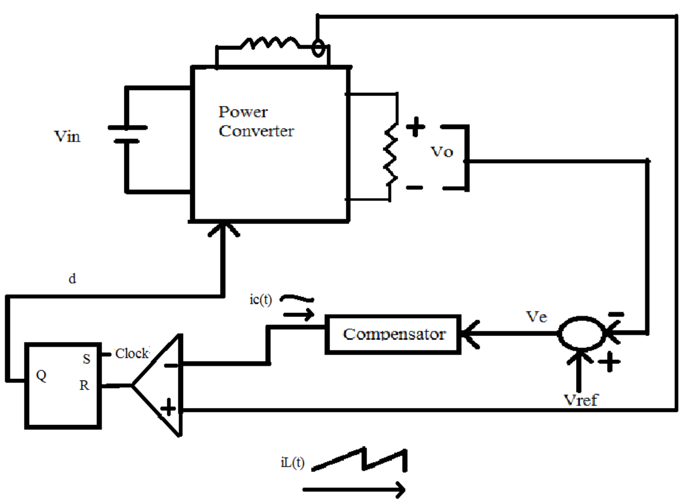

Figure-2
Current mode control of DC-DC converters

All response depend on the position of feedback loop as if the feedback loop is closed, the inductor current is proportional to the control signal *ic* and the output voltage becomes equal to reference voltage *Vref*. Irrespective of the various advantages of CMC it also has some drawbacks as:

Advantages of current mode control techniques: i It shows the improved transient response as from the begging it reduces the order of the converter to a first order system. ii. Good and improved performance in line regulation. iii. It is more suitable for converters operating in parallel. iv. Overload is opposed by self protection. v. Main switch adopt more protection. vi. Main transformer core is present in the centre of its B-H curve as a result of Anti-saturation. vii. Disadvantages of current mode control techniques. viii. It is very unstable when duty ratio exceeds 0.5 in the peak current mode- control. ix. Presence of Sub-harmonic oscillations.

PID Controller

PID control is one of the oldest and classical control technique used for DC-DC converters[11, 12]. It uses one of its families of controllers including P, PD, PI and PID controllers (figure-3). These different combinations will gives us various ways to regulate dc power supply in these converters. But here we will discuss only PID in details. Due to the various advantages of PID it is widely used for industrial applications in the area of power electronics. One of the main causes for the use of this classical technique still in industrial applications is easy implementation of tuning method like Ziegler-Nichols tuning procedure by which we can easily optimise proportional, integral and derivative term of this control method needed to achieve a desired closed-loop performance.

A proportional integral derivation controller (PID Controller) is a generic control loop feedback mechanism widely used in industrial control system as well as in research. This approach is often viewed as simple, reliable, and easy to implement. PID controllers are

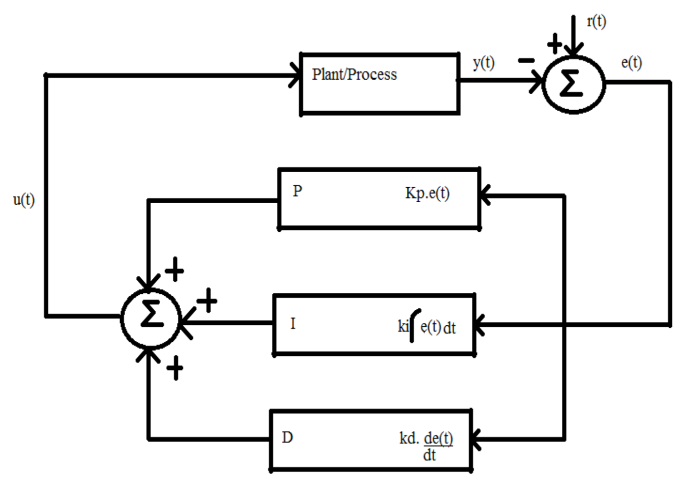

Figure-3
Block diagram of PID controller

Commonly used as controllers for boost converters in PV. Some important advantages and disadvantages of PID control technique are:

Advantages of PID controllers: i. It is easy and simple to implement. ii. Easy to understand. iii. Reliable for linear systems.

Disadvantages of PID controllers: i. It does not reliable and satisfactorily in case of non-linear systems. ii. It shows longer rise time when overshoot in output voltage decreases. iii. It suffers from dynamic response and produces overshoot affecting the output voltage regulation of converter.

Sliding mode controllers

SM controller is a type of non-linear controller. It is employed and adopted for controlling variable structured systems (VSSs). It is very easy to implement as compared to other types of nonlinear and classical controllers[13-14]. Two important steps in SM control is to design a sliding surface in state space and then prepared a control law to direct the system state trajectory starting from any arbitrary initial state to reach the sliding surface in finite time, and at the end it should arrive to a point where the system equilibrium state exists that is in the origin point of the phase plane. There are three important factors responsible for the stability of SM controllers, existence, stability, and hitting condition. Sliding Mode control principle is graphically represented in figure-4.

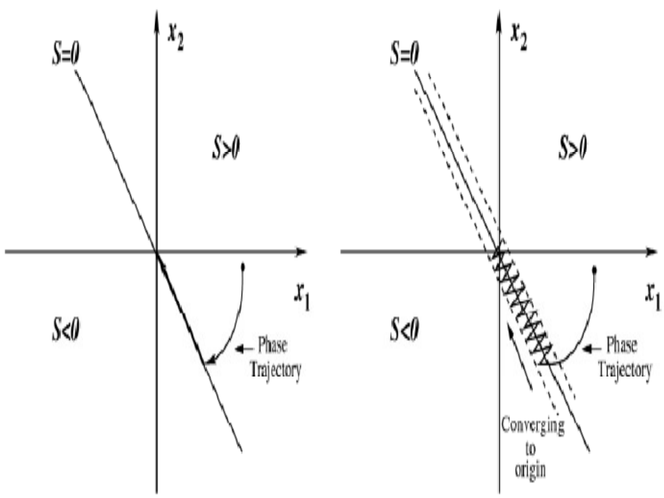

Figure-4
Graphical representation of SM control S=0 represent the sliding surface and $x1$ = the voltage error variable and $x2$ = voltage error dynamics respectively

The sliding line divides the phase plane into two main regions shown in the figure. Each region is represent by a switching state and when the trajectory comes at the system equilibrium point, in this case the system is considered as stable system. A unique feature of an ideal sliding mode control technique is that it operates at infinite switching frequency. But practical SM controllers are operated at finite switching frequencies only which represent a quasi-sliding mode.

Advantages of SM controllers: i. It shows good stability for large line and load variations. ii. High robustness. iii. Fast dynamic response. iv. Simple and easy implementation.

Disadvantages of SM controllers: i. SM controlled converters suffers from switching frequency variation. ii. These controllers are not available in integrated-circuit (IC) forms for their power-electronic applications. iii. There is no systematic procedure available for the design of sliding mode controllers.

Fuzzy logic controller

The nature of Fuzzy control is non-linear and adaptive and it is a practical alternative for a variety control applications[15-17]. The concept of Fuzzy Logic (FL) was conceived by Lotfi Zadeh, a professor at the University of California at Berkley. According to him, it not as a control methodology, but as a way of processing data by allowing partial set membership function rather than crisp (figure-5). There are four main elements in the fuzzy logic controller system structure named as: Fuzzifier, Rule base, Inference engine and defuzzyfier. The working of fuzzy logic controller structure can be easily understood from the block diagram (figure-5). Its working is divided in 3 main steps: i. Fuzzification. ii. Inference. iii. Defuzzification.

In this process, at the first step crisp set used as input data or non-fuzzy data, after this it is converted to a fuzzy set using fuzzyfier by the help of linguistic variables, fuzzy linguistic terms and membership functions.

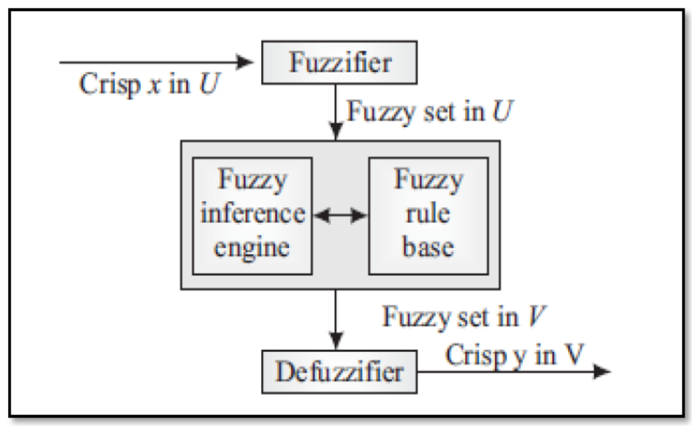

Figure-5
Overview of fuzzy logic control process

The most important thing regarding fuzzy logic is that a numerical value does not have to be fuzzified using only one membership function. Membership functions vary such as Triangular, Gaussian, Trapezoidal, Generalized Bell and Sigmoidal. Rule base is the backbone of fuzzy logic controllers.

Rule Base: i. The purpose of rule base is to control the output variable. ii. A fuzzy rule is a simple IF-THEN rule with a specific condition and conclusion, represented by the matrix table. iii. *error* and *change in error* are the two variables taken along the axes, and the conclusions are within the table.

Advantages of Fuzzy Logic Controller: i. Low-cost implementations based on cheap sensors, low-resolution analog-to-digital converter. ii. This systems can be easily upgraded by adding new rules to improve performance or add new features. iii. Fuzzy control can be used for the improvement of traditional controller systems. iv. It provides a robust performance under parameter variation and load disturbances. v. It has wider range of operating conditions than PID. vi. Can be operate with noise and disturbance of different natures. vii. Developing the fuzzy controller is much cheaper than developing a model based or other controllers for the same work.

Conclusion

In this review we provided an overview of control techniques used for DC-DC converters. We briefly explained the basic concepts of each control techniques. We highlighted the advantages and disadvantages of each technique. We can conclude that each control techniques have their own limitations and drawback. It depends on our need that what kind of control technique is needed for particular purpose. There is still scope for the development of more reliable and efficient control technique.

References

1. Matsuo M., Matsui K., Yamamoto L. and Ueda F., A comparison of various DC-DC converters and their application to power factor correction, in Industrial Electronics Society, IECON 2000, 26th Annual Confjerence of the IEEE, **2,** 1007-1013 **(2000)**

2. Mohan N., Undeland T. M. and Robbins W. P., Power Electronics - Converters, Applications, and Design (3rd Edition), ed: John Wiley and Sons.

3. Qun Z. and Lee F.C., High-efficiency, high step-up DC-DC converters, Power Electronics, IEEE Transactions on, **18,** 65-73 **(2003)**

4. Rashid M.H., Power Electronics: Circuits, Devices and Applications vol. (3rd Edition), Prentice Hall **(2003)**

5. Forsyth A.J. and Mollov S.V., Modelling and control of DC-DC converters, *Power Engineering Journal,* **12,** 229-236, **(1998)**

6. Saggini S., Mattavelli P., Ghioni M. and Redaelli M., Mixed-Signal Voltage-Mode Control for DCand#x2013;DC Converters With Inherent Analog Derivative Action, Power Electronics, *IEEE Transactions on,* **23,** 1485-1493 **(2008)**

7. Matsuo H., Kurokawa F., Etou H., Ishizuka Y. and Changfeng C., Design oriented analysis of the digitally controlled DC-DC converter, in Power Electronics Specialists Conference, PESC 00. IEEE 31st Annual, **1,** 401-407 **(2000)**

8. Hao P. and Maksimovic D., Digital current-mode controller for DC-DC converters," in Applied Power Electronics Conference and Exposition, APEC 2005, Twentieth Annual IEEE, **2,** 899-905 **(2005)**

9. Midya P., Greuel M. and Krein P.T., Sensorless current mode control-an observer-based technique for DC-DC converters, in Power Electronics Specialists Conference, PESC'97 Record., 28th Annual IEEE, 197-202 **(1997)**

10. Trescases O., Lukic Z., Wai-Tung N. and Prodic A., A low-power mixed-signal current-mode DC-DC converter using a one-bit and Delta; and Sigma; DAC," in Applied Power Electronics Conference and Exposition, APEC '06. Twenty-First Annual IEEE, 5 **(2006)**

11. Kapat S. and Krein P.T., PID controller tuning in a DC-DC converter: A geometric approach for minimum transient recovery time, in Control and Modeling for Power Electronics (COMPEL), 2010 IEEE 12th Workshop on, 1-6 **(2010)**

12. Wu Z., Zhao J. and Zhang J., Cascade PID Control of Buck-Boost-Type DC/DC Power Converters, in Intelligent Control and Automation, WCICA 2006, The Sixth World Congress on, 8467-8471 **(2006)**

13. Mattavelli P., Rossetto L., Spiazzi G. and Tenti P., General-purpose sliding-mode controller for DC/DC converter applications," in Power Electronics Specialists Conference, PESC '93 Record., 24th Annual IEEE, 609-615 **(1993)**

14. He Y. and Luo F.L., Sliding-mode control for dc-dc converters with constant switching frequency, Control Theory and Applications, IEE Proceedings, 153, 37-45 **(2006)**

15. Eker İ. and Torun Y., Fuzzy logic control to be conventional method, *Energy Conversion and Management,* **47,** 377-394 **(2006)**

16. Carbonell P., Garcera G. and Hilario A., Fuzzy gain scheduling control of switch-mode DC/DC converters, in Industrial Electronics, 1999. ISIE '99. Proceedings of the *IEEE International Symposium on,* **1,** 403-407 (1999)

17. Shamim-Ul-Alam M., Quamruzzaman M. and Rahman K.M., Fuzzy logic based sliding mode controlled dc-dc boost converter, in Electrical and Computer Engineering (ICECE), International Conference on, 70-73 **(2010)**