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DC-DC Boost Converter Using Different

Controller

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ABSTRACT: Interleaved power converters can be very beneficial for high performance electrical equipment applications. Reductions in size and electromagnetic emission along with an increase in efficiency, transient response, and reliability are among the many advantages to using such converters. Fuzzy Logic is a linguistic approach which emerges to design simple, complex and embedded systems with control inputs. A fuzzy logic uses linguistic variables which states IF A AND B THEN C" this rules is used for computation rather than a complex mathematical formula. This paper describes the design of a fuzzy logic controller using voltage output as feedback for significantly improving the dynamic performance of boost dc-dc converter. The fuzzy logic controller has been implemented to the system by developing fuzzy logic control algorithm. The design and calculation of the components especially for the inductor has been done to ensure the converter operates in continuous conduction mode.

KEYWORDS: DC-DC Convertors, DC-DC Boost Convertors, Fuzzy Logic Controller, ANFIS, PID .etc.

I. INTRODUCTION

Nowadays, the control systems for many power electronic appliances have been increasing widely. Crucial with these demands, many researchers or designers have been struggling to find the most economic and reliable controller to meet these demands. The idea to have a control system in dc-dc converter is to ensure desired voltage output can be produced efficiently as compared to open loop system. A simple boost convertor converts a low level DC voltage to high level DC voltage which reduces the ripple factors in both input and output circuit. In many industrial applications, it is required to convert a fixed-voltage dc source into a variable-voltage dc source. A dc-dc converter converts directly from dc to dc and is simply known as a dc converter. A dc converter can be considered as dc equivalent to an ac transformer with continuously variable turns ratio. Like transformer, it can be used to step down or step up a dc voltage source. (Muhammad H. Rashid, 2004) Dc converters widely used for traction motor in electric automobiles, trolley cars, marine hoists, and forklift trucks. They provide smooth acceleration control, high efficiency, and fast dynamic response. Dc converter can be used in regenerative braking of dc motor to return energy bake into the supply, and this feature results in energy 5 saving for transportation system with frequent stop; and also are used, in dc voltage regulation. There are many types of DC-DC convertor which is buck (step down) converter, boost (step-up) converter, buck-boost (step up- step-down) convertor. (Muhammad H. Rashid, 1993) DC conversion is of great importance in many applications, starting from low power applications to high power applications. The goal of any system is to emphasize and achieve the efficiency to meet the system needs and requirements. Several topologies have been developed in this area, but all these topologies can be considered as apart or a combination of the basic topologies which are buck, boost and flyback (Rashid, M. H., 2007) For low power levels, linear regulators can provide a very high-quality output voltage. For higher power levels, switching regulators are used. Switching regulators use power electronic semiconductor switches in On and Off states. Because there is a small power loss in those states (low voltage across a switch in the on state, zero current through a switch in the off state), switching regulators can achieve high efficiency energy conversion.



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II. DC-DC CONVERTERS

In many industrial applications, it is required to convert a fixed-voltage dc source into a variable-voltage dc source. A dc-dc converter converts directly from dc to dc and is simply known as a dc converter. A dc converter can be considered as dc equivalent to an ac transformer with continuously variable turns ratio. Like transformer, it can be used to step down or step up a dc voltage source. (Muhammad H. Rashid, 2004) Dc converters widely used for traction motor in electric automobiles, trolley cars, marine hoists, and forklift trucks. They provide smooth acceleration control, high efficiency, and fast dynamic response. Dc converter can be used in regenerative braking of dc motor to return energy bake into the supply, and this feature results in energy 5 saving for transportation system with frequent stop; and also are used, in dc voltage regulation. There are many types of DC-DC convertor which is buck (step down) converter, boost (step-up) converter, buck-boost (step up- step-down) convertor. (Muhammad H. Rashid, 1993) DC conversion is of great importance in many applications, starting from low power applications to high power applications. The goal of any system is to emphasize and achieve the efficiency to meet the system needs and requirements. Several topologies have been developed in this area, but all these topologies can be considered as apart or a combination of the basic topologies which are buck, boost and flyback (Rashid, M. H., 2007) For low power levels, linear regulators can provide a very high-quality output voltage. For higher power levels, switching regulators are used. Switching regulators use power electronic semiconductor switches in On and Off states. Because there is a small power loss in those states (low voltage across a switch in the on state, zero current through a switch in the off state), switching regulators can achieve high efficiency energy conversion.

III.FUNCTIONS OF DC-DC CONVERTERS

The DC-DC converter has some functions. These are:

- i. Convert a DC input voltage Vs into a DC output voltage Vo.
- ii. Regulate the DC output voltage against load and line variations.
- iii. Reduce the AC voltage ripple on the DC output voltage below the required level.
- iv. Provide isolation between the input source and the load (if required).
- v. Protect the supplied system and the input source from electromagnetic interference 6.
- vi. The DC-DC converter is considered as the heart of the power supply, thus it will affect the overall performance of the power supply system. The converter accepts DC and produces a controlled DC output.

IV.OPERATION OF DIFFERENT DC-DC CONVERTERS

4.1 Boost DC/DC Converter

Boost DC/DC Converter The boost converter is one of the most important nonisolated step-up converters. A boost converter is a power converter with an output dc voltage greater than its input dc voltage [1]. It is a class of switching-mode power supply (SMPS) containing at least two semiconductor switches (a diode and a transistor) and at least one energy storage element. Filters made of inductor and capacitor combinations are often added to a converter's output to improve performance. Boost converter is a dc-to-dc converter that steps up the dc voltage from its fixed low level to a desired high level.



Figure 1: A basic Boost DC-DC Converter

DC/DC Controller DC-to-DC converters have been dominating controlled by analogue integrated circuit technology and linear system control design techniques. In recent years, with rapidly development of advanced high-speed digital circuits, digital control will slowly replace the currently used analogue controller in high frequency switching



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converters. The intelligent power supplies are expected to play an important role in aerospace, communication, and automobile industries in the near future [2]. Conventionally, PI, PD and PID controller are most popular controllers and widely used in most power electronic closed loop appliances however recently there are many researchers reported successfully adopted Fuzzy Logic Controller (FLC) to become one of intelligent controllers to their appliances [3]. With respect to their successful methodology implementation, control closed loop boost converter and opened loop boost converter will compare the efficiency of the converters. This kind of methodology implemented in this paper is using fuzzy logic controller with feed back by introduction of voltage output respectively. The introduction of voltage output in the circuit will be fed to fuzzy controller to give appropriate measure on steady state signal. The fuzzy logic controller serves as intelligent controller for this propose. This methodology can be easily applied to many dc-dc converter topologies such as Buck, Boost and Buck-Boost. L. A. Zadeh presented the first paper on fuzzy set theory in 1965. Since then, a new language was developed to describe the fuzzy properties of reality, which are very difficult and sometime even impossible to be described using conventional methods. Fuzzy logic control is built up by a group of rules based on the human knowledge of system behaviour. Matlab/Simulink simulation model is built to study the dynamic behaviour of dc-to-dc converter and performance of proposed controllers.

V. OPEN LOOP DC-DC BOOST CONVERTER

In open loop boost converter, there is no feedback from output to input contrary to the closed loop which has a feedback circuit. So, the output of an open loop boost converter is not regulated. Open loop control of Buck and Boost Converter is used to obtain a required DC output voltage. The switching frequency and duty cycle decides the output voltage. During ON time the switch is closed and the current flows through switching device, inductor and it close the path with DC source.



Figure 4- Open loop control of Boost Converter

VI.FUZZY LOGIC CONTROLLER

Fuzzy Logic Controller (FLC) is constitutes a way of converting linguistic control strategy into an automatic by generating a rule base which controls the behaviour of the system. Fuzzy control is control method based on fuzzy logic. Fuzzy provides a remarkably simple way to draw definite conclusions from vague ambiguous or imprecise 12 information. It suitable for applications such as the speed control of dc motor which is has non linearities. (Siler, W. and Ying, H) FLC have some advantages compared to other classical controller such as simplicity of control, low cost and the possibility to design without knowing the exact mathematical model of the process. Fuzzy logic incorporates an alternative way of thinking which allows modelling complex systems using higher level of abstraction originating from the knowledge and experience. Fuzzy logic can be described simply as computing words rather than numbers" or "control with sentence rather than equations." (Siler, W. and Ying, H, 1989) The applications of fuzzy logic are usually for household appliance such as washing machine and rice cooker. Fuzzy also been used in industrial process such as cement kilns, underground trains and robots.design of fuzzy logic controller can provide desirable both small signal and large signal dynamic performance at same time, which is not possible with linear control technique. Thus, fuzzy logic controller has been potential ability to improve the robustness of dc-to-dc converters. The basic scheme of a fuzzy logic controller is shown in figure 2 and consists of four principal components such as: a fuzzyfication interface, which converts input data into suitable linguistic values; a knowledge base, which consists of a data base with the necessary linguistic definitions and the control rule set; a decision-making logic which, simulating a human decision process,



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infer the fuzzy control action from the knowledge of the control rules and linguistic variable definitions; a defuzzification interface which yields non fuzzy control action from an inferred fuzzy control action [4]. The fuzzy control systems are based on expert knowledge that converts the human linguistic concepts into an automatic control strategy without any complicated mathematical model [5]. Simulation is performed in boost converter to verify the proposed fuzzy logic controllers.



Figure 2: General structure of the fuzzy logic controller on closed-loop system

5.1 Structure of Fuzzy Logic

The fuzzy control systems are based on expert knowledge that converts the human linguistic concepts into an automatic control strategy without any complicated mathematical model [5]. Simulation is performed in boost converter to verify the proposed fuzzy logic controllers.



Figure 3: Block diagram of the Fuzzy Logic Controller (FLC) for dc-dc converters



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- **Input** The inputs are most often hard or crisp measurement from some measuring equipment is converted into fuzzy values for each input fuzzy set with the fuzzification block. (Jan Jantzen 1998)
- **Fuzzification** The first block inside the controller is fuzzification which converts each piece of input data to degrees of membership by a lookup in one or several membership functions. The fuzzification block matches the input data with the conditions of the rules to determine. There is degree of membership for each linguistic term that applies to the input variable. (Jan Jantzen 1998)
- **Rule Base**-The collection of rules is called a rule base. The rules are in "If Then" format and formally the If side is called the conditions and the Then side is called the conclusion. The computer is able to execute the rules and compute a control signal depending on the measured inputs error (e) and change in error.(dE). In a rule based controller the control strategy is stored in a more or less natural language. A rule base controller is easy to understand and easy to maintain for a non- specialist end user and an equivalent controller could be implemented using conventional techniques. (Jan Jantzen 1998)
- **Defuzzification** -Defuzzification is when all the actions that have been activated are combined and converted into a single non-fuzzy output signal which is the control signal of the system. 14 The output levels are depending on the rules that the systems have and the positions depending on the non-linearities existing to the systems. To achieve the result, develop the control curve of the system representing the I/O relation of the systems and based on the information; define the output degree of the membership function with the aim to minimize the effect of the non-linearity (Jan Jantzen 1998)
- **Output-**The output is output gain that can be tuned and also become as an integrator .The output crisp value can be calculated by the centre of gravity or the weighted average [7].

VII. CLOSED LOOP CONTROL OF BOOST CONVERTER USING PID CONTROLLER



Figure 5- Boost Converter Using PID Controllers



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Domain	Parameters	Desired Value	Effect of Parameter
Time Domain	Rise Time (T_r)	Lower is Better	Lower value makes system's response faster
	Maximum Overshoot (M_p)	Lower is Better	Lower value makes system more stable
	Settling Time (T_s)	Lower is Better	Output settles faster to final values if it has lower value
	Steady State Error (e_{ss})	Lower is Better (Zero required)	Output reaches to desired value if steady state error is zero
Frequency Domain	Phase Margin (PM)	Higher is better	System becomes more stable (More stability margins)
	Gain crossover frequency (ω_g) & Phase crossover frequency (ω_p)	$\omega_p > \omega_g$	$\omega_p > \omega_g$ makes system stable

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Figure 6-ParametersBoost Converter Using PID Controllers

The boost converter is designed using the equations as given in and are shown in Table 1. Design values of PID controllers are shown in the Table 2. The converter output voltage is regulated at desired voltage level with lesser settling and rise time using FOPID controller compared with PID controller. The output voltage ripple drastically reduced with FOPID controller as in the case of buck converter. The overshoot is reduced considerably with the use of FOPID controller. The undershoot and the slew rates are improved with the FOPID controllers over PID controllers. The fractional order based PID controllers or $PI \lambda D \mu$ controllers consists of fractional integrator and fractional derivative that helps to improve the output of closed loop systems [9]. The transfer function of the fractional order PID controller shown in Figure 4 is given below,

 $GC(s) = U(s) E(s) = KP + KIs - \lambda + KDS \mu$

VII. CLOSED LOOP BOOST CONVERTER ANFIS

The ANFIS derives its name from adaptive neuro-fuzzy inference system. ANFIS method is based on the combination of artificial neural network and Fuzzy logic control. It combines the advantages of ANN and capability in learning from process and fuzzy logic control capability in handling uncertain information. This makes ANFIS capable of approximating nonlinear and uncertainties system without requiring pure mathematical. Fuzzy logic controller has the limitation that is not expert by itself. In fact, it needs and expert and provide the best performance. Therefor if expert assigns the wrong rule, then Fuzzy Logic controller may be provide poor performance even than the PID controller. Furthermore, most of the times we don't have sufficient knowledge about the behaviour of the system. Therefore, while the implementation of Fuzzy Logic controller, we are not sure about its correct rules. so, In order to overcome the limitation of fuzzy logical controller, artificial neural network can be used a make the fuzzy logic controller expert by itself. As we know that artificial neural network requires Input and output data only for it training. Therefor all we need is the input and output data of the system only. Based upon this system Input and output data, ANN learns the system behaviour, applies the correct rules and assign the correct membership function value to obtain the best performance. Among the ANN, Fuzzy, and ANFIZ is the most easiest and accurate technique to get the best results.



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Fig shows. The ANFIS structure it can be noticed that the ANFIS consists of 5 layers and each layer is connected through the weight. In the first layer (input) layer the received input data is mapped into membership function to determine the membership degree of that input. In the second layer fuzzy Rules are used to relate between input and output. The third layer normalize the output and passes to the fourth layer. The fourth layer maps the output data and provides the outputs membership function. In the fifth layer, the output are added to provide a single output this is the whole procedure of the ANFIS.

VIII. CONCLUSION

A simple algorithm based on the prediction of fuzzy logic controller, possibly using the fuzzy rules parameter, is showing to be more convenient than the circuit without fuzzy. As the 20 V input on the output voltage for the closed loop circuit (with fuzzy logic controller) with 0% overshoot shows the better performance compared to the open loop circuit (without fuzzy logic controller) whereby it has 80% overshoot. Moreover, the value of the output current also improving corresponds to the system and produce a constant value for the output current as 0.5 A. This scenario would not happen to the output current of the open loop circuit. Using a closed loop circuit with fuzzy logic controller, it is confirmed that the boost dc-dc converter gives a value of output voltage exactly as circuit requirement. Hence, the closed loop circuit of boost dc-dc converter controlled that by fuzzy logic controller confirmed the methodology and requirement of the proposed approach. These studies could solve many types of problems regardless on stability because as we know that fuzzy logic controller is an intelligent controller to their appliances.

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