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Proportional Integral Derivative Control

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ABSTRACT

As it knows most of the quotidian types of control, problems are not simply to evaluate and considerate formal modelling based in traditional techniques. The process control makes the evaluation and executions more efficient in the industry. This article was made with the purpose to compare two types of control, one with FUZZY logic and second one PID control. Here we have developed temperature control system using fuzzy logic. The flyback converter with voltage doubler rectifier acts as an output module. To overcome the efficiency degradation during lightload due to load dependent soft switching of the ZVS,a control method using pulse width modulation(PWM)proportional to the load current is used. Comparison between Fuzzy logic controller & PID controller based on pulse width modulation is proposed and the results are analyzed. Thus comparing the result PID controller gives more accurate results than first Fuzzy logic controller.
Keywords : DC-DC Converter, ZVS(Zero Voltage Switching)

I. INTRODUCTION

This fuzzy logic was investigated in 1965 by Lotfy A. Zadeh. Engineer, in the Berkeley University (California). Associate a fuzzy set with a linguistic term is the easy way to understand the system behaviour. In the beginning, this kind of control the scientist population did not accept it but when Zadeh published more of his theories there was another scientist who contributed to the development of this theory. The Zadeh's goal was create an easier method to manipulate the imprecision the best way possible and associate with the human vague thought and their linguistic expressions. The PID control is the most conventional tool for control process; today the PID control is find it in all areas, and the design come in many different forms.

The PID control is important for the distributed control system. The structure of a PID controller is as simple as it's its weak point, that's because its range of control is limited. The goal of this project is compare what the fuzzy control can do against a PID, which it is a classical control. The comparisons are made with: error, stability, overshoot and response time. As a desirable solution to the above mentioned drawbacks this paper proposes DC-DC converts using active clamp technique and pulse width modulation control. It integrates a bidirectional boost convert with a series output module as a parallel input series output (PISO) configuration. This connection makes the bidirectional boost converter as up active clamp circuit. Therefore it uses the step up capability of the stacked output capacitors while maintaining the soft switching capability of the active clamp circuit.

However the proposed has a load-dependent ZVS condition, which is an inherit characteristic of the active clamp circuit. It causes hard switching at a light load and degrades conversion efficiency. To recover ZVS at a load, a control method using Pulse Width Modulation (PWM) is also proposed.

II. PID CONTROL

Since 1940, the PID control has been one of the most useful methods to control a process. Of course, the PID controller comes in different structures, with a different type of work method and various application fields. The PID controllers are required in large quantities because is one of the most used in industry. PID controller allows give options those are possibilities to change the dynamics of any system and be useful for the designer. The figure 2.1 shows schematics about classical control.

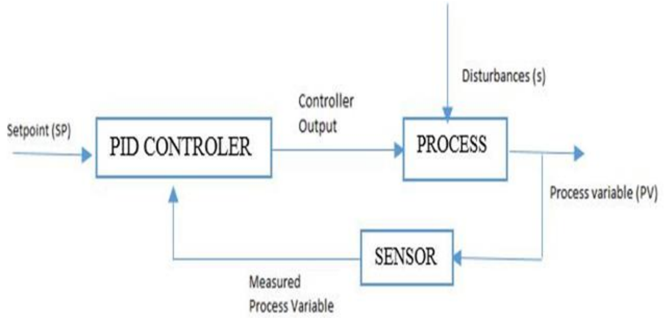

Fig. 2.1 Classical Control

A. Proportional Control

The proportional control output is the gain result of the proportional and the error, increasing the system velocity and decrease the error inside the process.

The output is showed by equation (1).

$$A_{out} = K_p * \varepsilon$$

Where:

A_{out}= Control Output

K_p= Proportional gain

ε= Process error signal

The effect of controlling the proportional gain is to reduce the rise time and the steady state error as well, when this happens, the tendency to oscillate will increase also.

B. Integral Control

Equal as the proportional gain, the integral control is the amplification of the process error signal but in the time. The integral gain corrects the error induced for proportional error and it has a slower answer but the error is almost zero.

The integral control disadvantage is the overshoot time for oscillations due to increase.

The integral gain is defined mathematically by equation (2).

$$A_{out} = K_i * \int \varepsilon \Delta t$$

A_{out}= Control Output

K_i= Integral gain

= Process control

ε= Process error signal

Δt= Time variation

C. Derivative Control

The derivative gain it is involved in reduce the overshoot time, decrease during sudden disturbances. The derivative control predicts the possible error in the control system.

The derivative gain is defined mathematically in equation (3).

$$A_{out} = K_d * \frac{\Delta\varepsilon}{\Delta t}$$

A_{out}= Control Output

K_d= Derivative gain

$\frac{\Delta\varepsilon}{\Delta t}$ = Error variation over time variation

Practically the derivative gain can show the rate of change in the control system, reducing the setting time and the overshoot.

D.PID CONTROL

A PID controller is a mechanism to control the error between an average and ideal value, so the correct process of the value.

A PID controller defined by mathematically (4)
u(t)=Kp[$\varepsilon(t)+1/Ti\int\varepsilon(t)dt+Td.d\varepsilon(t)/dt$]
PID controller used to deal with dynamics necessary having a fast input reaction (K_P), get down the steady state error until try to make it zero (K_i) and consider the rate of change increasing the stability and the setting time as well.

The table I shows few effects of coefficients.

Table I. Effects of coefficients.

Parameter	Responses speed	Stability	Accuracy
K_p	Increases	Deteriorate	Improves
K_i	Decreases	Deteriorate	Improves
K_d	Increases	Improves	No impact

To make the PID controller more accurate there are some methods to adjust the gain values.

E.Tuning Methods of Control Systems
The tuning methods, they are used to adjust the values and found them for the desired control response, however, the behaviour of many systems are never equal and the control could be different from one to another
Some of the tuning methods are:
Manual tuning method.
Ziegler and Nichols.
PID tuning software methods.
The most used methods presented for Ziegler and Nichols are the closed loop method knows as limit accurate, which allows calculate tuning parameters, following a procedure which comprise to put the integral derivative value to their minimum value and the obtained gain.

The figure 2.2 shows a continuous oscillation when the process reach the limit sensibility.

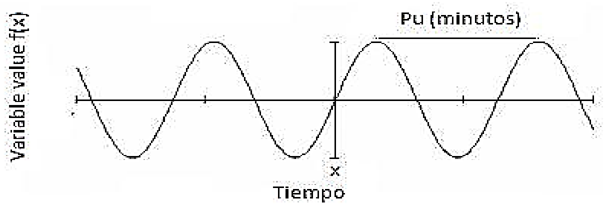

Figure 2.2 Continuous oscillations

Table II. The PID defined parameters

Control Parameters	Kp	Ti	Td
P	0.5*Ku		
PI	0.45*Ku	Pu/1.2	
PID	0.6*Ku	Pu/2	Pu/8

The other tuning method is the process reaction curve and used for open loop systems.Table II. Control Parameters for the “Limit Gain” by Ziegler- Nichols.

Generating a disturbance in the process reaction curve, the respond produce a quickstep little function change, is how this method works and it is show in the figure 4.1

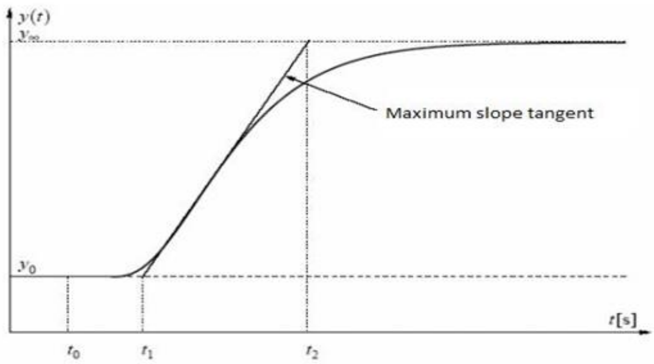

Fig 2.3. Process Reaction Curve

This method includes several parameters that can be measured as the dead time ($\tau_{dead} = t_1 - t_0$), the response time ($t_2 - t_1$) and the ultimate value when the system has reach the steady state ($Y\infty$).With the slope (R), the delay time (L) and Δp% what is the position variation, with this values it can be calculate the control parameters as it shows the table III.

Table III. Control parameters for the reaction curve method

Control Parameters	Kp	Ti	Td
P	100RL/Δp		
PI	110RL/Δp	L/0.3	
PID	83RL/Δp	L/0.5	0.5L

The Ziegler- Nichols methods was deduce empirically, both of them are base in a process response when is provoked a perturbation. To optimize the system is necessary to take the best and the worst conditions to have a wanted.

III. WORKING PRINCIPAL OF PID CONTROL

The block diagram of the proposed system is shown in fig6.1.
It consists of fly back converter and boost converter.

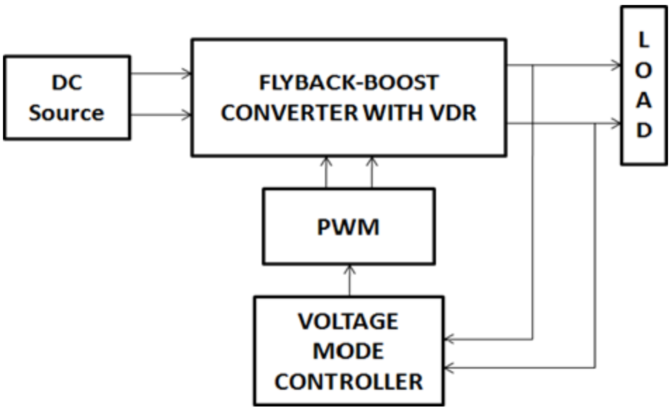

Fig 3.1 Block diagram

The soft switching is achieved by using zero voltage switching in order to reduce the switching losses. The bidirectional boost converter act as an active clamp circuit. VDR is adopted at the secondary side to clamp the output rectifier voltage stress. Also this VDR contributes the increase in a step-up ratio further. Thus the proposed converter has the high step-up capability with the help of ZVS Bidirectional Boost Converter with flyback converter and VDR. With the features of ZVS, the proposed converter can ensure the high operating frequency, high step-up ratio, low voltage stresses across the switches and output rectifiers soft switching of all switches, and so on.

The voltage mode controller utilizing the PID control law is executed for regulating the output voltage cycle by cycle, since the sampling pulse is updated with the updated pulse. To improve the efficiency degradation during light load condition, PWM control is used. According to the load, the pulse width modulator generates pulses according to which the converter is turned ON or OFF and regulates the output.

3.1. CIRCUIT DIAGRAM

A VDR is adopted at the secondary side to clamp the output rectifier voltage stress. To increase the device utilization and simplify the circuit, the common parts integration between the bidirectional boost converter and flyback converter is recommended. As shown in Fig6.2, a bidirectional boost converter and a flyback converter can be integrated easily since the inductor LA and switch Q1 become common parts for both bidirectional boost converter and flyback converter.

(a) High Step-Up Capability

Due to the stacked output capacitors, each output capacitor voltage is added and the overall output voltage can be extended as$V0=VCO1+VCO2$
That is, the output voltage of the converters is a sum of the output voltages of the boost converter and the flyback converter, which is suitable for high step-up applications.

(b) Switch Voltage Stress Clamping

The switch voltage stresses VQ1 and VQ2 can be clamped to the partial output voltage VCO1. Thus, additional protection circuit for the high voltage spike caused by a leakage inductor Llkg is not required.

(c) Soft Switching Capability

The ZVS boost converter act as an active clamp network, which is not connected to the input side but the output side. The soft switching characteristics are similar to achieve active clamp circuit. A main switch Q1 has a load-dependent ZVS condition relying on the value of the leakage Inductor Llkg, whereas an auxiliary switch Q2 has a wide ZVS load range resulting from a large boost inductor Lm. Thus, all switches can be turned on under ZVS condition if the energy stored in Llkg is sufficient.However, since ZVS condition of Q1 is load-dependent and lost at a light load due to the insufficient loss is inevitable. To improve the efficiency even at a light load, the pulse width modulation control is used which can recover the ZVS of Q1.

(d) Circuit Operator.

The switches Q1 and Q2 are turned ON and OFF alternatively. Due to the VDR , the circuit acts as a conventional forward converter when the switch Q1 is turned ON and a flyback-boost converter when Q1 is turned OFF. At the boosting phase, when Q1 is turned ON, the transferred current through a transformer charges a link capacitor Cb. At the powering phase, when Q1 is turned OFF, Cb is discharged. When switch Q1 is turned OFF, the current Ilkg(t) charges the junction capacitor of Q1 to VC01 and discharges that of Q2 to 0 V in a short time. After the junction capacitor Q1 is charged to VC01, the antiparallel diode of Q2 is conducted. Thus, no protection circuit is required, and the primary conduction loss can be reduced by using lower voltage –rated power switches. The conducting antiparallel diode provides the zero voltage across Q2 until it is turned ON.

The switch Q2, is turned ON under ZVS conditions and the diode D01 is reverse biased. The transferred current via the transformer charges the junction capacitor of D01 to VC02 and discharges that of D02 to 0V for a short time respectively. After completing the voltage transition from D02 to D01, the D02 is conducted and Cb is discharged. The current Ilkg(t) changes its direction from positive to negative and keeps negative slope until the switch Q2 is turned OFF. The current Ilkg(t) flows back to input source.

After the switch Q2 is turned OFF, the primary leakage current Ilkg(t) charges the junction capacitor of Q2 to VC01 and discharges that of Q1 to 0V respectively. After the junction capacitor of Q2 is charged to VC01, the anti parallel diode of Q1 is conducted.

The current Ilkg is linearly increased. This increasing current also provides the current snubbing effect of ID02.

Now, the switch Q1 is turned ON under ZVS condition.

The current Ilkg increases until it reaches the magnetizing current ILm. The transferred current via the transformer charges the junction capacitor of D02 to VC02 and discharges that of D01 to 0 V for a short time, respectively TABLE IV.

Table IV. Circuit Parameters

Input Voltage, V_1	12 V
Output Voltage, V_0	86.5V
Magnetizing Inductor, L_m	$280e^{-6}$
Leakage Inductor, L_{lkg}	$10e^{-6}$H
Output Capacitors, C_{01} and C_{02}	$10e^{-6}$F
Proportional Gain, Kp	25
Integral Gain, Ki	12
Derivative Gain, Kd	0.05

3.2. CONTROL STRATEGY

Two control strategies were discussed in this paper. They were pulse width modulation technique and PID control technique.

(a) Pulse Width Modulation Technique

To improve the output voltage, focused on reducing the switching losses, several methods are proposed. These techniques can be classified into two categories: The quasi resonant technique and the active clamp technique. To achieve the ZVS of the main switch at any load condition, a variable frequency control by adjusting the off-time with complementary gate signals has been proposed [39]. Since the auxiliary switch is turned ON for a short time before the main switch is turned ON, the recycled leakage energy can be used to achieve the ZVS of the main switch, which reduces the circulating energy effectively compared to the conventional complementary switching techniques.

The proposed light load pulse width modulation control is used in order to improve the output voltage and to reduce switching loss during light load condition. The PWM technique is used to generate signals or pulses for turning the switches ON or OFF. In PWM converters the control circuit regulates the output by fixing the switching frequency and varying the ON time of the switch. In this the output signal is compared with a carrier signal and generates a pulse, which is used to drive the switches.

(b) PID control law

In order to regulate the output voltage, voltage mode controller is used. The voltage mode control executes the PID control law. A PID controller is a generic control loop feedback mechanism widely used in industrial control systems. A PID controller attempts to correct the error between a measured process variable and a desired set point by calculating and then outputting a corrective action that can adjust the process accordingly.

The proportional term makes the change in output that is proportional to the current error value.

The proportional response can be adjusted by multiplying the error by a constant value, Kp called as proportional gain.

The integral term causes the steady-state error to reduce to zero, which is not the case for proportional-only control in general. The integral term is proportional to both the magnitude of error and the duration of the error. The magnitude of the contribution of the integral term to the overall control action is determined by the integral gain Ki.

The rate of change of the process error is calculated by determining the slope of the error over time and multiplying this rate of change by the derivative gain Kd. The lack of derivative action may make the system steadier in the steady state. This is because derivative action is more sensitive to higher-frequency terms in the inputs. Without derivative action, a PI-controlled system is less responsive to real and relatively fast alterations in state and so the system will be slower to reach set-point and slower to respond to perturbations than a well-tuned PID system. Hence a PID control law is used.

3.3. SIMULATION

The simulation of the flyback boost converter with voltage doubler rectifier is done using MATLAB and it is shown fig3. 3.

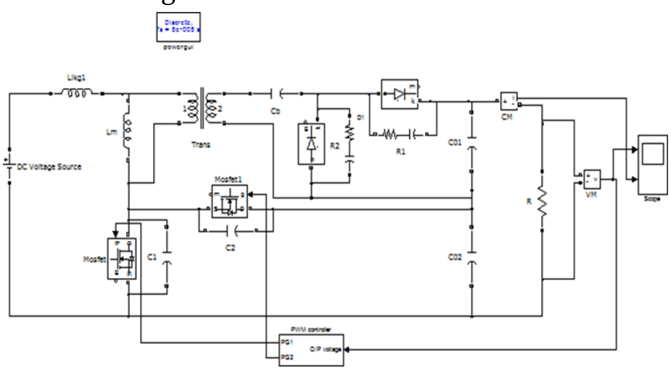

Fig 3.3

Simulation model of fly back boost converter with voltage doubler rectifier. In these two converters are designed. One is boost converter and the other is fly back converter. The MOSFET switch 1 and the magnetizing inductor Lm is common for both boost converter and fly back converter. The VDR circuit is also designed to regulate the output voltage. The load is connected across the output capacitors in parallel manner. The output voltage is fed as input to the PWM controller. The PWM controller generates the pulses to drive the MOSFET switches. Table 1 describes the parameters for the various components used in the simulation circuit.

A subsystem is created for the control process. The output voltage is given as the input to the subsystem. Inside the subsystem the PID control law and PWM controller are present.

The output voltage and the reference voltage are summed together and it is given to the PID controller. The regulated output voltage is fed as input to the PWM controller. The PWM controller compares the input signal with a carrier signal and generates output signal which is demuxed and used as pulses for two switches.

SIMULATION RESULTS

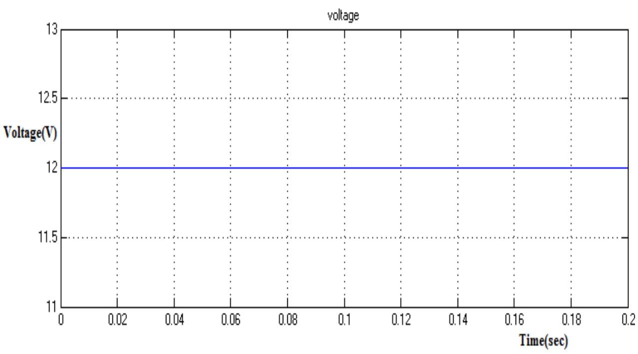

Fig 3.4. Input voltage waveform

The input given is 12 V which is shown in fig3.4.

For 10 ohm load the output voltage is 86.5 V and the output current is 8.65 A. The output voltage and current waveforms are shown fig 3.5.

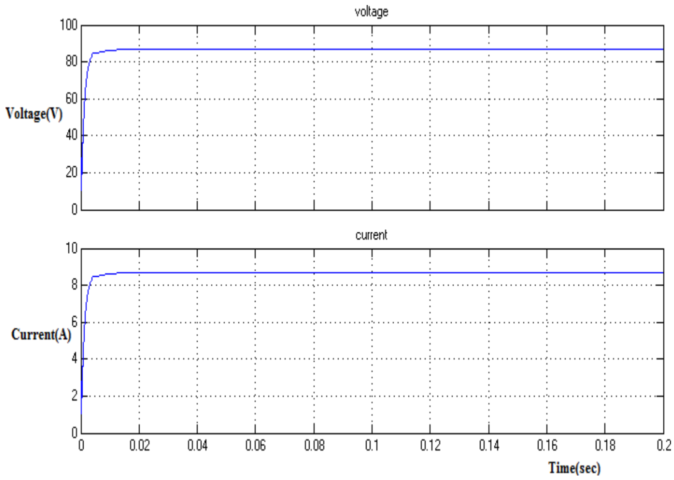

Fig 3.5. Output Waveform

Thus, even at the light load condition the output voltage is stepped up appropriately without any distortions or losses.

IV.CONCLUSION

In this dissertation fuzzy temperature controller is defined and implemented in microcontroller without using any special software tool. Unlike some fuzzy controllers with hundreds or even thousands of rules running on computer systems. A unique FLC using a small number of rules and simple implementation is demonstrated to solve a temperature control problem with unknown dynamics or variable.

Fuzzy logic provides a completely different way to approach a control problem. This technology is not difficult to apply and the results are usually quite interesting .Thus Fuzzy logic is one of the most interesting approach to control the temp in microcontrollers.

In this thesis we have shown the control behaviour of many fuzzy control system including temperature plant. Then we tabulated the final results of the above mentioned various control system.

Non isolated high step up DC-DC converter with pulse width modulation technique is presented in this paper. The voltage doubler rectifier is used to step up the voltage. This simple and effective techniques gives many desirable feature for high efficiency and high step up applications.

The proposed converter topology and control techniques can be a promising solution for high step-up applications.

Here we have compared the result obtained by both PID (PROPORTIONAL INTEGRAL DERIVATIVE) and Fuzzy logic control.Thus PID (PROPORTIONAL INTEGRAL DERIVATIVE) control gives us the best result than Fuzzy control.

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