ANALYSIS OF CLOSED LOOP SWITCH MODE FLYBACK CONVERTER WITH DIFFERENT CONTROLLER

VIBHA JANARDHAN, S.P.DUBEY

Abstract— **This paper presents performance comparisons of linear PID controller and non-linear fuzzy logic controller in flyback converter with voltage mode control. The comparisons are conducted through simulation on the 170V/160W, 50 Hz flyback converter with 41V output voltage. The controller is used to change the duty cycle of the switch (MOSFET) in the converter. Based on the analyzing effects of the flyback converter circuit a non-linear fuzzy logic controller is able to achieve faster response, more robust under different operating conditions and its output performance is more accurate than the linear PID controller with aspects to the transient analysis and dynamic condition performances. MATLAB/SIMULINK is used for implementation and simulation results show the performance improvement.**

Index Terms— **component; flyback converter, voltage mode control, Proportional Integral and Derivative controller (PID) Fuzzy logic controller.**

I. INTRODUCTION

For efficient conversion of electrical power is becoming a switched-mode dc-dc converters are some of the most widely used power electronics circuit and it's also reveals high conversion efficiency and flexible output voltage. A DC-DC flyback converter is a switching power supply topology widely used in applications that require power below 2OOW, modem low-power office equipment, such as computer monitors, printers, AC/DC adapters, etc.

The flyback converter unit combines the actions of an isolating transformer, an output capacitor, and a flywheel diode in a single transformer. As a result of this magnetic integration, the circuit provides extremely cost-effective and efficient stabilized DC output.

DC-DC flyback converters exhibit nonlinear characteristics. The causes of nonlinearity in the power converters include a variable structure. The flyback converter controller is based on voltage mode control scheme, in this a single voltage feedback path in which the duty ratio is controlled by comparing the waveform obtained from the resulting error voltage from the operational amplifier with an external ramp which is fixed signal value.

The linear controller PID is analysed but due to any change in system and any parameter variations or even load disturbances the output response of the system is very fluctuate. [1-6].

To control non linear systems satisfactorily non-linear controllers fuzzy logic controllers (FLC),in which the control design is not need any mathematical procedure of the system and it's based only simple linguistic rules of the type: "*if the output voltage error is positive and its rate of change is negative, then reduce slightly the duty-cycle*", and so on.

In this present work, the transient response of voltage mode controlled flyback converter is analyzed. MATLAB/SIMULINK 2010a software is adapted to replicate the nonlinear behaviours of the flyback converter.

II. FLYBACK CONVERTER

A flyback converter due to minimum number of semiconductor and magnetic components, it's providing the inherent output short circuit protection, an isolation, and start-up by a single switch. In this type of power supply converter, a transformer is used to store energy, rather than a single inductor. It has two discrete phases for energy storage and output delivery. A Semiconductor switches MOSFET is used as a switch in flyback converter. A simplified equivalent circuit diagram of a switched mode flyback converter supply is shown in figure.1.

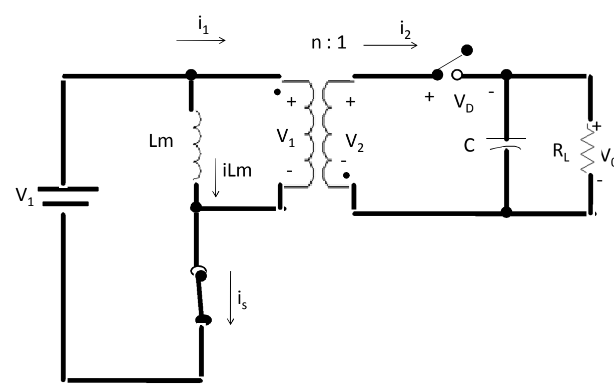

Fig.1. Equivalent circuit diagram of flyback converter

III. MODES OF CIRCUIT OPERATION

Mode1

When the switch (MOSFET) is turned on, the primary current i_1 flows, while the diode is reverse biased preventing a flow of secondary current i_2. During this MOSFET's turn on period,

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VIBHA JANARDHAN, Electrical and Electronics Department, Rungta College of Engineering and Technology, Kohka-Kurud Road Bhilai (C.G.) India

S.P.DUBEY, Electrical and Electronics Department,Rungta College of Engineering and Technology , Kohka –Kurud Road Bhilai (C.G.) India

energy is stored in the transformer with a load current being supplied by the output capacitor. The principles of operation are shown in the figure1.

The diode current

$$i_D = i_2 = 0 \quad (1)$$

$$I_1 = i_2 / -n = 0 \quad (2)$$

The voltage across the magnetizing inductance L_m

$$V_{Lm} = V_1 = L_m \cdot \left(\frac{d}{dt} iLm\right) \quad (3)$$

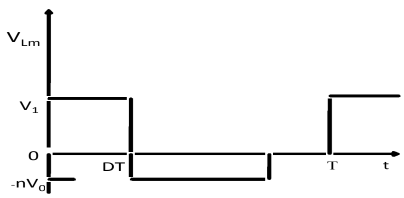

Fig.2. voltage across the inductances

The switch current

$$i_s = i_{Lm} = (V_1 / Lm).t + i_{Lm}(0) \quad (4)$$

At time t=0, $i_{Lm}(0)$ is the initial current in the magnetizing inductance .The peak-to peak value of the ripple current through the magnetizing inductance L_m is

$$\Delta i_{Lm} = \frac{V_1 DT}{Lm} = \frac{V_1 D}{fs.Lm} \quad (5)$$

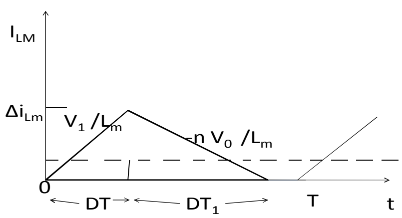

Fig.3. Current through magnetizing inductance

The transfer function of the flyback converter is

$$Mv_{DC} = \frac{V0}{V1} = \frac{I0}{I1} = \frac{D}{n(1-D)} \quad (6)$$

Mode 2

When the switch (MOSFET) is tuned off, the primary current ceases to conduct. The collapsing magnetic field in the transformer causes a polarity of the secondary voltage to reverse. The diode is now forward biased enabling a flow of secondary current. During this turn off period, energy stored in the transformer is released to the output capacitor and load.

The secondary voltage

$$v_2 = V_O \quad (7)$$

$$V_1 = -n\, v_2 = -nV_0 \quad (8)$$

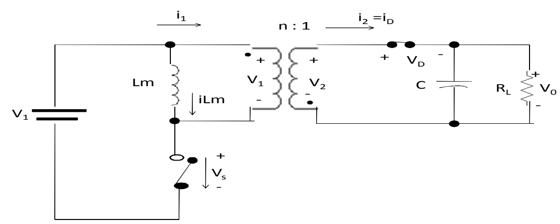

Fig.4. Equivalent circuit of flyback converter in mode2

The current through the magnetizing inductance

$$I_{Lm} = -n\frac{V0}{Lm}(t-DT) + \frac{V1D}{fsLm} + i_{Lm}(0) \quad (9)$$

Switch voltage

$$Vsmax = V1max + nVo = \frac{nVo}{Dmin} \quad (10)$$

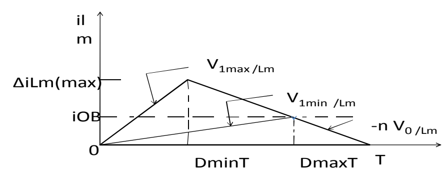

Fig.5Waveform of the current through the magnetizing inductance.

The energy transferred from the input dc voltage source V_1 to the magnetizing inductance during one cycle for the boundary case is

$$W_{OB} = \frac{Lm(max)\, \Delta iLm(max)2}{2} \quad (11)$$

The total power output at the boundary

$$P_{oB} = \frac{WoB}{T} = f_s W_{oB} = \frac{fs.Lmmax\, \Delta i2Lm\,(min)}{2} \quad (12)$$

IV. VOLTAGE MODE CONTROLLER

The switch mode flyback converter has two PWM methods for controlling the output voltage. This two standard PWM control techniques are voltage mode control and current mode control.

In voltage mode control with the linear controller PID are shown in the figure 6. The basic principle of voltage mode control an error amplifier amplifies the difference between a reference voltage V_i and output voltage V_0. The resulting error voltage V is then compared with a saw-tooth voltage, a PWM signal to drive the switch (MOSFET) to maintain the constant output voltage. Here error amplifier works as PID controller. The amplifier produces a control voltage that is compare to constant amplitude saw-tooth waveform.

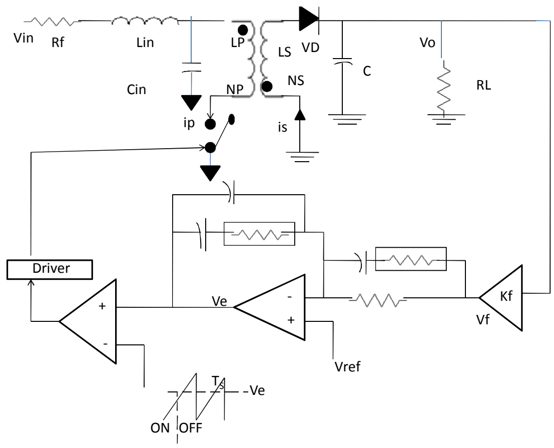

Fig.6 closed loop feedback for VMC using PID controller. This control mechanism allows a pulse width of the gate drive signal. The duty ratio of the PWM signal depends on the value of the control voltage. The control of the switch duty ratio adjusts the voltage across the inductor and hence the inductor current brings the output voltage to its reference value.

PID controllers are more sensitive to operating point and parameters variation and its region is small operating regions. Simulation of PID controllers depends on its three variable terms proportional terms K_P, integral terms K_I and derivative terms K_D. These three variables are chosen as by hit and trial methods and it's not being exactly accurate, because K_P, K_I and K_D are dependent on each other.

V. BASICS OF FUZZY LOGIC CONTROLLERS

Fuzzy logic control is a new addition to control theory. FLC is one of the most successful applications of, fuzzy set theory. Design of fuzzy logic controllers is based on expert knowledge of the switch mode flyback converter system instead of a precise mathematical model and it takes less time. It is adaptive in nature and can also exhibit increased reliability, robustness in the face of changing circuit parameters, saturation effects and external disturbances and so on.

The general structure of an FLC is represented in figure 7 and comprises four principal components:

1. A fuzzification interface which converts input data into suitable linguistic values;
2. Knowledge base which consists of a data base with the necessary linguistic definitions and control rule set;
3. A decision making logic which, simulating a human decision process, infers the fuzzy control action from the knowledge of the control rules and the linguistic variable definitions

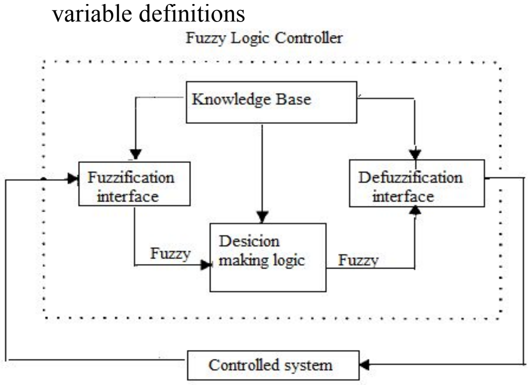

Fig.7 A basic configuration of FLC

4- A defuzzification interface which yields a non fuzzy control action from an inferred fuzzy control action.

There are two inputs for the fuzzy controller for the flyback converters. The first input is the error in the output voltage given by (1), where ADC[k] is the converted digital value of the *k*th sample of the output voltage and Ref is the digital value corresponding to the desired output voltage. The second input is the change in error.

$$e[k] = Ref - ADC[k] \quad (13)$$

$$ce[k] = e[k] - e[k-1] \quad (14)$$

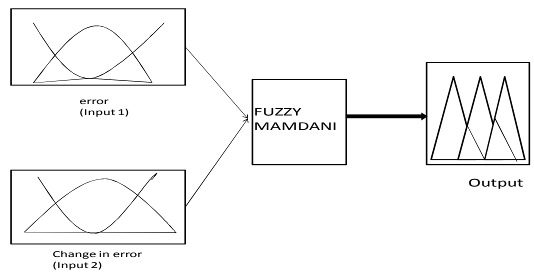

Fig.8. Membership functions for e and ce.

The fuzzy controller utilizes triangular membership functions on the controller input. The triangular membership function is chosen due to its simplicity.

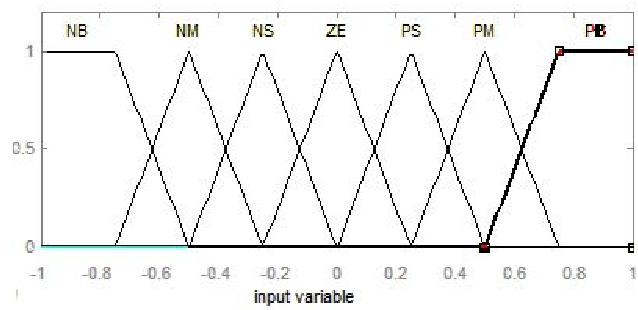

Fig.9. Membership functions of the input linguistic variables.

Fuzzy control rules are based on the Mamdani rule –based system. Control rules are given below.

error(e)

change in error(ce)	NB	NM	NS	ZE	PS	PM	PB
NB	NB	NB	NB	NB	NM	NS	ZE
NM	NB	NB	NB	NM	NS	ZE	PS
NS	NB	NB	NM	NS	ZE	PS	PM
ZE	NB	NM	NS	ZE	PS	PM	PB
PS	NM	NS	ZE	PS	PM	PB	PB
PM	NS	ZE	PS	PM	PB	PB	PB
PB	ZE	PS	PM	PB	PB	PB	PB

Fig.10. Rule table for flyback converter operation

VI. SIMULATION RESULTS

The SIMULATION results shows for the voltage mode control flyback converter with the different controller. The stable waveform verifies that the voltage mode control maintains the stable operation under a large duty cycle without the need of slope compensation.

For the simulation purpose the model parameters are given below:

TABLE 1

Parameter	Ranges
Input voltage	90-230V
Output Voltage	41V
Load Resistance	10 ohms
Line frequency	50 Hz
Total Output power	160W(< 200W)
Switching frequency	250kHz

VII. FLYBACK CONVERTER WITH PID CONTROLLER

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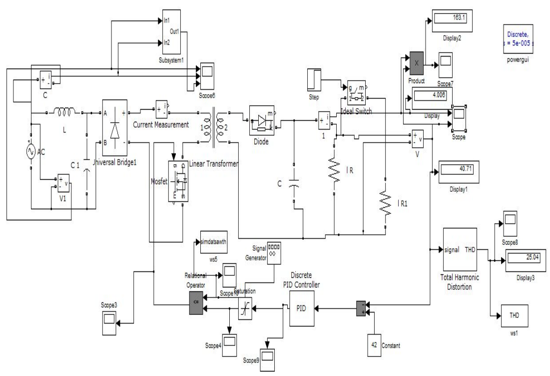

Fig.11.Simulation diagram for PID Ccontrolled flyback converter.

(a)-Simulation response for power factor control

The sinusoidal input current i_s is inherently generated, and its current amplitude I_s =Vs/WL is proportional to the controllable phase (φ) without sensing current and current loop. Additionally, the sinusoidal input current i_s is in phase with the input voltage V_s. The result shown by the simulated figure 12, the input current and voltage waveform and its related input power factor waveform, The input power factor of the switch mode flyback converter is 0.998.

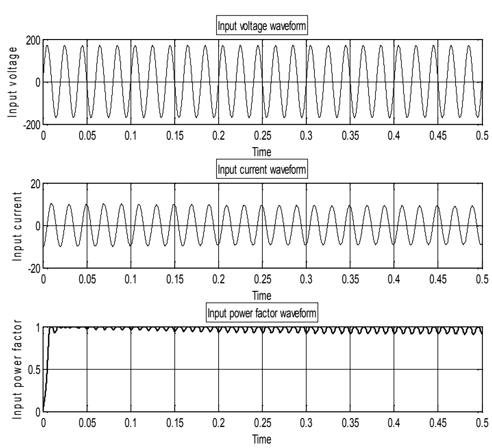

Fig.12.Input waveform for power factor control.

(b)-Simulation response for transient condition of PID controlled flyback converter

For the circuit parameters in Table (1) the simulated waveforms are plot in figure13 the output voltage and current waveform respectively. The output voltage and output current of the system are 41V and 3.9A respectively given by the PID controlled flyback converter. The transient parameters are listed inTable(2)

TABLE 2

S.No.	Parameter	Value
1.	Rise time	0.68 sec.
2.	Peak time	0.9 sec.
3.	Overshoot	0.2138%
4.	Settling time	1.2 sec.

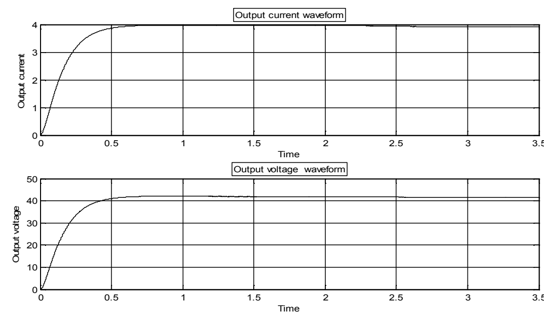

Fig.13.Output current and voltage waveform of PID controlled flyback converter.

(c)-Simulation response for Dynamic condition of the PID controlled to flyback converter

To verify the dynamic performance of the proposed linear PID controller some simulated results are shown in the figure14, where the load resistance is suddenly changed from 10.5 Ω to10.5||200 Ω at t= 0.8 second.

In order to support sufficient power regulate the output voltage and the input current magnitude by the controller. During this test the reference voltage of the converter is 42V.

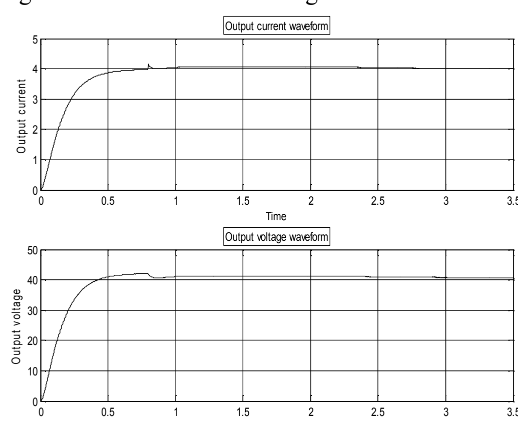

Fig.14.Output current and voltage waveform during dynamic condition of PID controlled flyback converter.

VIII. FLYBACK CONVERTER WITH FUZZY LOGIC CONTROLLER

In fig. shown the performance of Fuzzy controlled flyback converter.

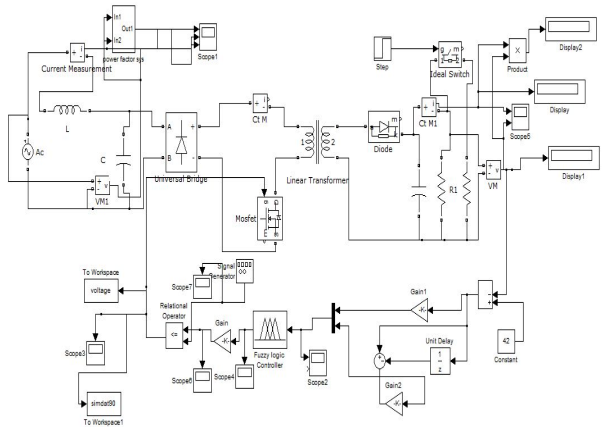

Fig.15.Simulation diagram for fuzzy logic controlled flyback converter.

(a) Simulation response for input power factor correction

The simulated results as shown by the figure16 taken on the input side, which shows the input current waveform i_s , is less distorted and as close as possible with the input voltage waveform V_s. The simulated waveform shows figure16 the input side power factor nearly 1.

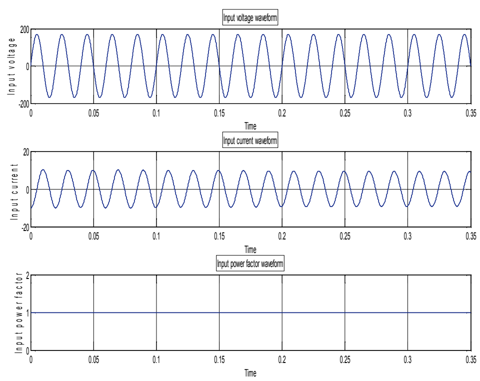

Fig.16. simulation response for input power factor.

(b) Simulation response for transient condition of fuzzy logic controlled flyback converter

The output voltage and output current of the system are 42V and 3.9A respectively given by the fuzzy controlled flyback converter. The transient responses of the fuzzy controlled flyback converter are listed in Table 3.

TABLE 3

Sr.No.	Parameters	values
a)	Rise Time	0.45 Sec.
b)	Peak Time	0.65 Sec.
c)	Overshoot	0.0124%
d)	Settling Time	0.9Sec.

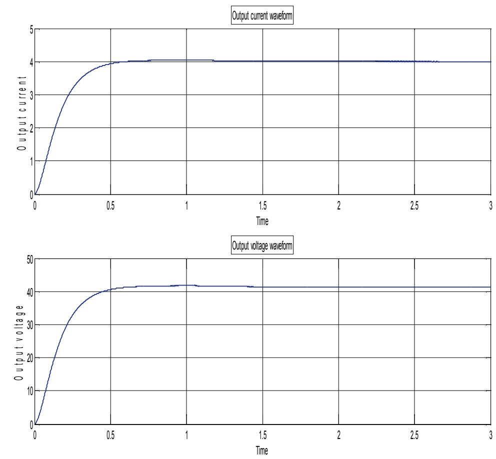

Fig.17.Simulation response for transient condition in fuzzzy controlled flyback converter.

(c) Simulation response for dynamic condition of the fuzzy logic controlled flyback converter

In the dynamic condition the load resistance is suddenly changed from10.5 Ω to10.5||200 Ω at t= 0.8 second. The output voltage and current values are changed to regulate the sufficient power output in the system. The simulated waveforms are shown in the figure 18.

IX. PERFORMANCE COMPARISION

Comparison has been made between the performance of PID controlled and fuzzy logic controlled flyback converter and is presented in a table 4. It clearly shows the improved performance of fuzzy logic controller over PID controller in terms of rise time, peak time, overshoot and overall system stability.

TABLE 4

Sr.NO.	PARA-METER	PID CONTROLLER	FUZZYLOGIC CONTROLLER
1.	Rise Time	0.68 Sec.	0.45 Sec.
2.	Peak Time	0.9 Sec.	0.65 Sec.
3.	Overshoot	0.2138%	0.0124%
4.	Settling time	1.2 Sec.	0.9 Sec.
5.	Input Power Factor	0.998	1

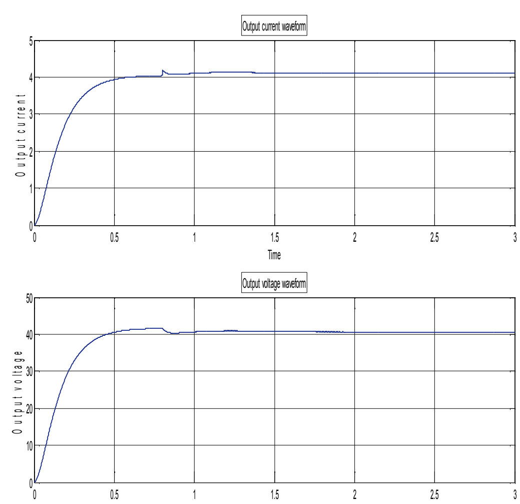

Fig.18. Simulation response for dynamic condition in fuzzzy controlled flyback converter.

CONCLUSION

This paper has presented the application of voltage mode control in a flyback converter with different controller. The use of voltage mode control eliminates the need of slope compensation and alleviates the noise immunity issue in the current mode control.

The simulation results show the comparison of the two controllers. Hence we can conclude that for non-linear complex structure of the converter the fuzzy logic controller gives better transient response of the system in terms of faster output response, less rise time, less peak time and overshoot and is less dependence on the operating point of the converter.

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