# CLOSED CONTROL OF ASYMMETRICAL HALF-BRIDGE FLY BACK DC-DC CONVERTER WITH PI AND FUZZY CONTROLLER

[1]Parimi Venkatarao, [2]M.V.Sudarsan,
[1]MTECH Student Scholar, [2]Associate Professor & HOD
[1]Dept of EEE, Vignan's Lara Institute of Technology &Sciences ,Guntur ,AP
[2]Dept of EEE, Vignan's Lara Institute of Technology &Sciences ,Guntur ,AP

***Abstract*— Among various kinds of soft-switching converters, asymmetric PWM half-bridge converters have drawn attention due to their simplicity, inherent zero voltage switching (ZVS) capability, and fixed-frequency operation. This paper presents an analysis and reviews practical design considerations for an asymmetric half-bridge converter. It includes designing the transformer and selecting components. A step-by-step design procedure with a design example will help engineers design an asymmetric half-bridge converter. To provide condition of ZVS for switches in this model, we use a simple auxiliary circuit included one inductor coil coupled to the main coil and auxiliary coil. Because of the operation of ZVS switches, the diode reverse recovery problem does not occur. In addition, to provide a soft switching in this circuit, any additional switches are not used. Therefore, circuit becomes easier to implement and control. This work deals with design, modeling and simulation of the PI & Fuzzy controlled Asymmetrical Half-Bridge Fly back DC to DC converter systems. Open loop system is simulated with step change in input voltage. The output voltage in closed loop system is regulated using PI and Fuzzy controllers. The response of these two systems are compared. This converter has advantages like low EMI, less switching loss and improved dynamic response. The simulation results of PI & FLC Asymmetrical Half-Bridge Fly back DC to DC converter systems are presented in this paper. In order to confirm the theory analysis of Asymmetrical Half-Bridge Fly back dc-dc converter offered and simulation is done by Matlab/Simulink.***

***Index Terms*— hybrid-switching technique; asymmetrical half bridge flyback converter; universal input voltage range**

## I. INTRODUCTION

The effort to obtain ever-increasing power density of switched-mode power supplies has been limited by the size of passive components. Operation at higher frequencies considerably reduces the size of passive components, such as transformers and filters; however, switching losses have hindered high-frequency operation [1-3]. To reduce switching losses and allow high-frequency operation, resonant switching and soft-switching techniques have been developed [4-7]. The resonant switching method processes power in a sinusoidal manner by utilizing the resonance during the entire switching period. Generally, the output voltage is regulated by variable frequency control and the current or voltage waveform in the resonant network has a sinusoidal shape.

Meanwhile, soft-switching techniques utilize the resonance operation only during the switching transition to soften the switching characteristics of the devices. When the switching transition is over, the converter reverts to Pulse-Width-Modulation (PWM) mode [8-9]. Since resonant operation only occurs during the switching transition, the parameters of resonant components are not as critical as in a resonant converter. Moreover, the switching frequency is fixed and easily synchronized to the other power stages to minimize EMI.

However, the asymmetrical half-bridge flyback converter has several advantages over the active-clamp flyback converter. First, the voltage of the blocking capacitor is smaller. Second, the voltage stress of the two active switches is lower. And third, not only the magnetizing inductor and the leakage inductor of the transformer, but also the blocking capacitor of the converter store energy when the output diode is off, thus we have more energy-storing elements inside the circuit and consequently, the size of the transformer can be shrunk [10-12].

In this paper, the hybrid-switching technique is employed in the control of the asymmetrical half-bridge flyback converter. Hybrid-Switching is a technique that incorporates resonant operation into the conventional pulse-width modulation (PWM) circuit. This means there would be both resonant current and linear current within one switching cycle. The result of this is zero-voltage-switching (ZVS) can be achieved on the active switches and zero-current-switching (ZCS) can be achieved on the output diode [13-14].

Among various kinds of soft-switching converters, the asymmetric PWM half-bridge converter has drawn attention due to its simplicity and inherent zero voltage switching (ZVS) capability.

## II. OPERATING PRINCIPLE

Fig.1 shows the circuit diagram of the hybrid-switching asymmetrical half-bridge flyback converter. In this diagram, *S2*is the main switch; *S1* is the auxiliary active-clamp switch; *Cb* is the blocking capacitor; *T* is the transformer with a primary to secondary side turns ratio *n: 1*, with *Lm* and *Llk* are its magnetizing inductor and primary-referred equivalent leakage inductance, respectively; *Coss1*, *Coss2* and *Db1*, *Db2* are the equivalent parasitic capacitors and body diodes of the two switches; *Co* is the output capacitor, and *Ro* is the equivalent resistive load. The notations and directions of currents flowing within the circuit is also illustrated on the diagram.

Fig. 2 shows the circuit steady-state waveform of the converter during one switching cycle. Several assumptions are made to simplify the analysis, as follow:

1. The value of the magnetizing inductor Lm is much larger than the value of the leakage inductor Llk.
2. The output capacitor Co is large enough so that the output voltage ripple can be neglected.
3. Switches S1 and S2 can be seen as ideal Mosfets with parasitic capacitors Coss1, Coss2 and body diodes Db1, Db2.
4. The converter is working in steady-state; with D is the steady-state duty cycle on switch S1.

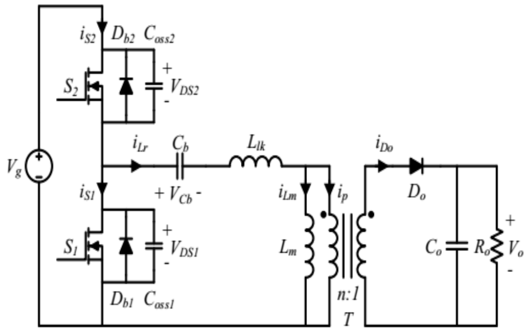


Fig.1. Hybrid-Switching open loop Asymmetrical Half-Bridge Fly back DC to DC Converter.

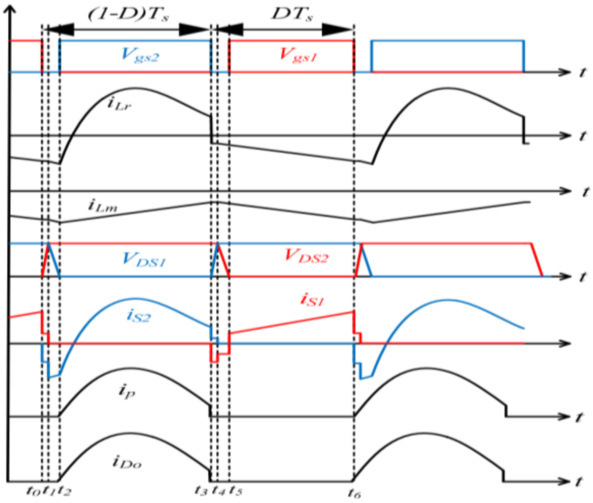


Fig.2. Steady-state waveforms during one switching cycle of the Hybrid-Switching Asymmetrical Half-Bridge Flyback DC to DC Converter

**Interval $T_0$ [$t_0$…$t_1$]:** At *t0*, the auxiliary switch *S1* is turned off. At this instance, the inductor current equals the magnetizing current *iLm* and is negative, it discharges the parasitic capacitor *Coss2* until *VDS2*=0 and charges the parasitic capacitor *Coss1* until*VDS1=Vg*. No energy is transferred from the primary side to the secondary side of the transformer.

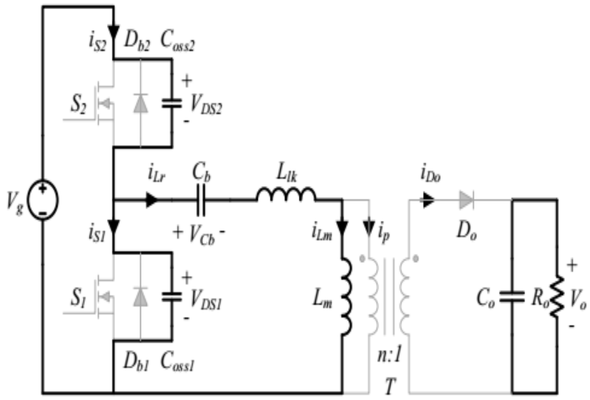

Fig.3. Interval $T_0$ [$t_0$…$t_1$]

**Interval $T_1$ [$t_1$…$t_2$]:** At *t1*, *VDS1=Vg* and *VDS2=0*, the body diode *Db2* starts to conduct because *iLr<0*. The magnetizing current starts to increase. From *t1*, the voltage drop across the Mosfet *S2* equals to 0. No energy is transferred from the primary side to the secondary side of the transformer.

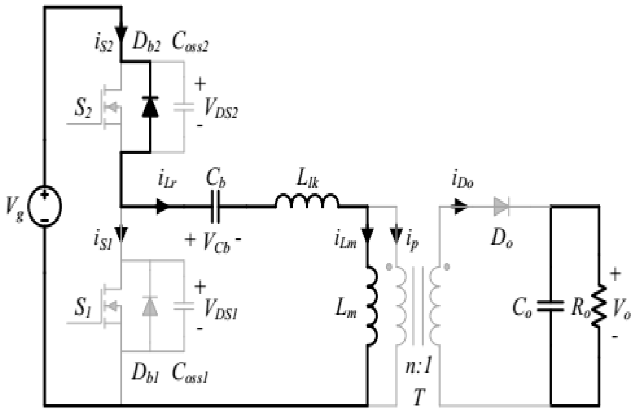

Fig.4. Interval $T_1$ [$t_1$…$t_2$]

**Interval $T_2$ [$t_2$…$t_3$]:** At *t2*, the switch *S2* is turned on. Since the voltage drop across *S2* equals to zero before switching on *S2*, in this case, Zero-Voltage-Switching on *S2* is achieved. In this interval, the circuit begins to resonate. The magnetizing current starts to increase linearly and consequently, energy is transferred from the primary side to the secondary side of the transformer. The output capacitor *C0* is charged only in this interval.

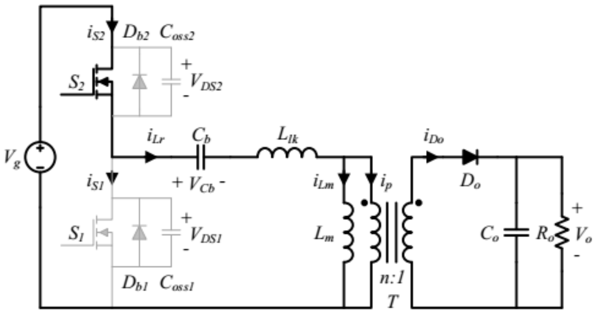


Fig.5. Interval $T_2$ [$t_2$…$t_3$]

**Interval $T_3$ [$t_3$…$t_4$]:** At $t_3$, the switch $S_2$is turned off. At this instance, the inductor current *iLr* equals the magnetizing current *iLm* and is positive, it discharges the parasitic capacitor *Coss1* until*VDS1=0* and charges the parasitic capacitor *Coss*$_2$until *VDS2=Vg*. No energy is transferred from the primary side to the secondary side of the transformer in this interval.

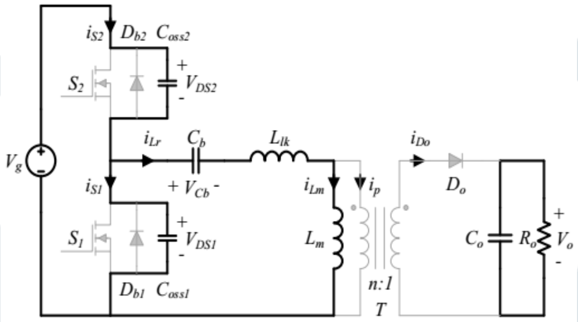


Fig.6. Interval $T_3$ [$t_3$…$t_4$]

**Interval T4 [t4…t5]:** At *t4*, *VDS2=Vg* and *VDS1=0*. Since *iLr>0*, the body diode *Db1* begins to conduct. The magnetizing current *iLm* start to decrease. The voltage drop across *S1* equals to zero.

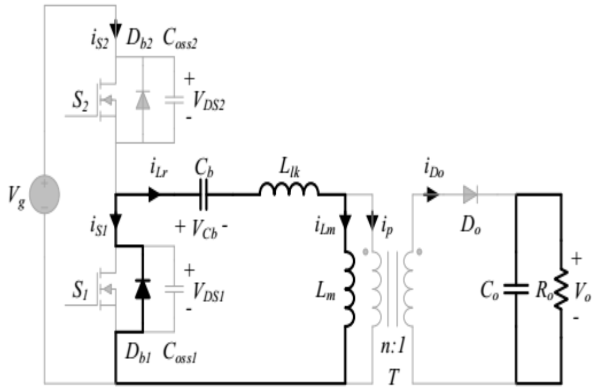


Fig.7. Interval $T_4$ [$t_4$…$t_5$]

**Interval T5 [t5…t6]:** At *t5*, the switch *S1* is turned on. Since the voltage drop across *S1* equals to zero before switching on *S1*, in this case, Zero-Voltage-Switching on *S1* is achieved. The magnetizing current still decrease and consequently, there is also no energy being transferred to the secondary side of the transformer.

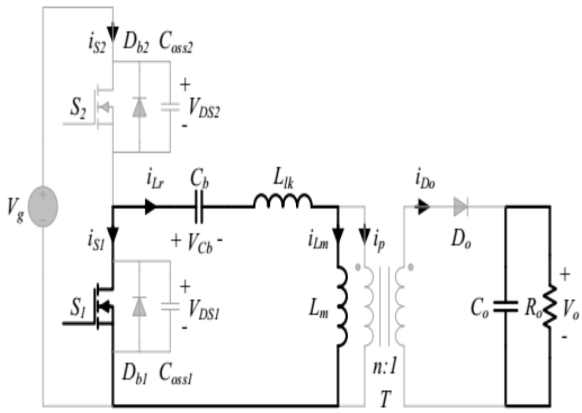


Fig.8. Interval $T_5$ [$t_5$…$t_6$]

## III. PROPOSED CLOSED LOOP CONTROLLING TECHNIQUE

Many applications, such as robotics and factory automation, require precise control of speed and position. Speed Control Systems allow one to easily set and adjust the speed of a motor. The control system consists of a speed feedback system, a motor, an inverter, a controller and a speed setting device. A properly designed feedback controller makes the system insensible to disturbance and changes of the parameters.

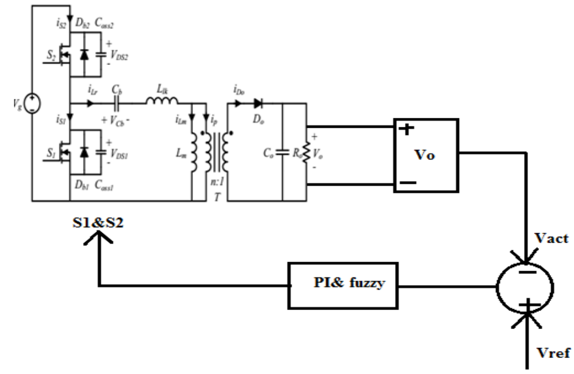


Fig.9. Hybrid-Switching Closed loop control of PI and Fuzzy based Asymmetrical Half-Bridge Fly back DC to DC Converter.

### A.PI Controller:

The purpose of a motor speed controller is to take a signal representing the demanded speed, and to drive a motor at that speed. Closed loop speed control systems have fast response, but become expensive due to the need of feedback components such as speed sensors. Speed controller calculates the difference between the reference speed and the actual speed producing an error, which is fed to the PI controller. PI controllers are used widely for motion control systems. They consist of a proportional gain that produces an output an output proportional to the input error an integration to make the steady state error zero for a step change in the input. PI controller is a generic control loop feedback mechanism (controller) widely used in industrial control systems – a PI is the most commonly used feedback controller and calculates an "error" value as the difference between a measured process variable and a desired set point. The controller attempts to minimize the error by adjusting the process control inputs. The PI controller calculation (algorithm) involves two separate constant parameters, and is accordingly sometimes called two-term control: the proportional, the integral values, denoted P, I. Heuristically, these values can be interpreted in terms of time: P depends on the present error, I on the accumulation of past errors, based on current rate of change. The weighted sum of these three actions is used to adjust the process via a control element such as the position of a control valve. There are several methods for tuning a PI loop.

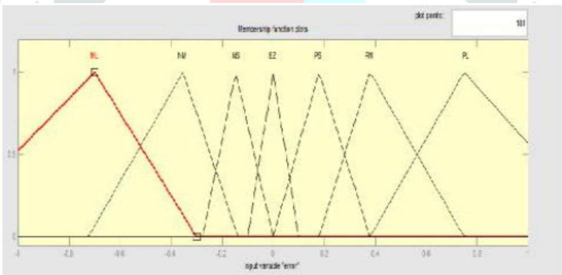

Fig.10. Membership functions of FLC

### B.FLC Controller:

Fuzzy logic is widely used in control technique. The term "fuzzy" refers to the fact that the logic involved can deal with concepts that cannot be expressed as "true" or "false" but rather as "partially true". Although alternative approaches such as genetic algorithms and neural networks can perform just as well as fuzzy logic in many cases, fuzzy logic has the advantage that the solution to the problem can be cast in terms that human operators can understand, so that their experience can be used in the design of the controller of BLDC. The linguistic variables are defined as (NB, NS, Z, PS, PB) which mean big, negative small, zero, positive small and positive big respectively. The membership functions are shown in Fig. 10.

| u | | e | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | NB | NM | NS | Z | PS | PM | PB |
| | PB | Z | PS | PM | PB | PB | PB | PB |
| | PM | NS | Z | PS | PM | PB | PB | PB |
| Δe | PS | NM | NS | Z | PS | PM | PB | PB |
| | Z | NB | NM | NS | Z | PS | PM | PB |
| | NS | NB | NB | NM | NS | Z | PS | PM |
| | NM | NB | NB | NM | NM | NS | Z | PS |
| | NB | NB | NB | NB | NB | NM | NS | Z |

Table 1. The decision table of FLC.

As seen from table 1, each interval of each variable is divided into seven membership functions: Negative Big (NB), Negative Medium (NM), Negative Small (NS), Zero (Z), Positive Small (PS), Positive Medium (PM) and Positive Big (PB).

## IV. MATLAB /SIMULATION RESULTS

***Case 1: Vin=120V***

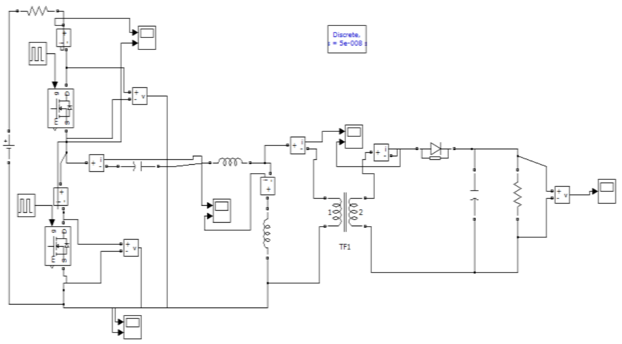

Fig.11 MATLAB/Simulation model of 120V input voltage

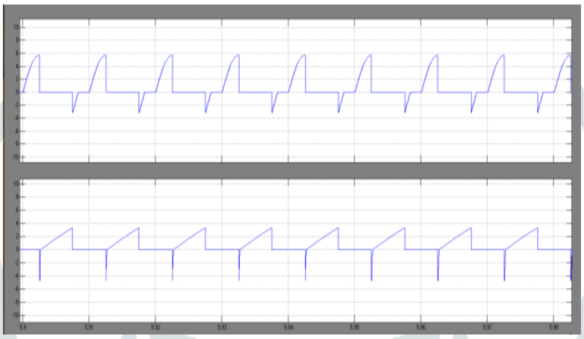

Fig.12 Simulation waveforms of Switch currents

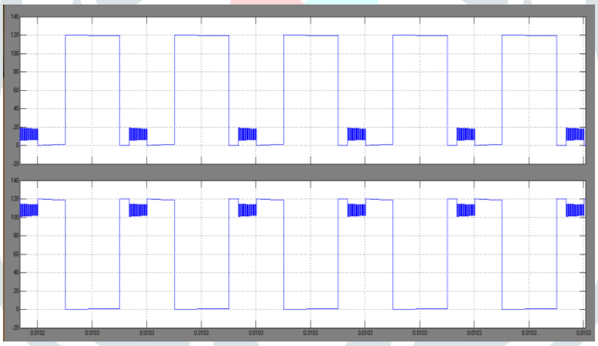

Fig.13 Simulation waveforms of Switch voltages

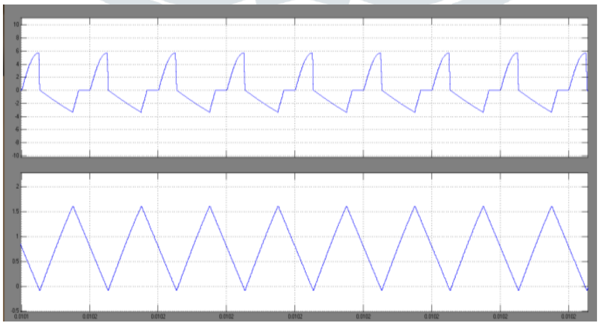

Fig.14 Simulation waveforms of Capacitor and inductor currents

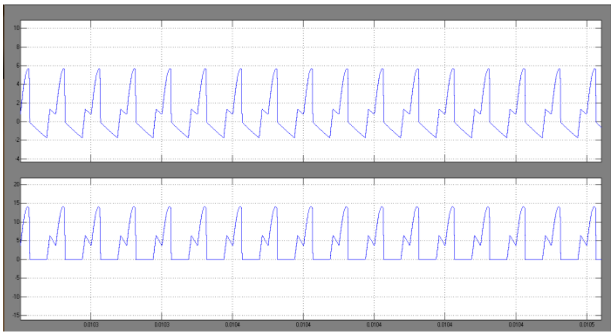

Fig.15 Simulation waveforms of primary and secondary winding currents

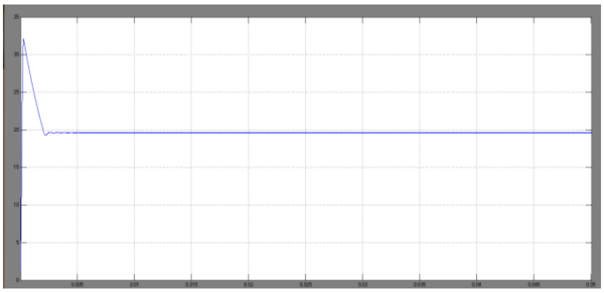

Fig.16 Output voltage waveform

***Case 2: Vin=200V***

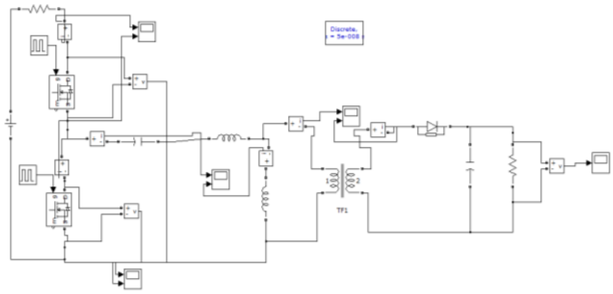

Fig.17 MATLAB/Simulation model of 200V input voltage

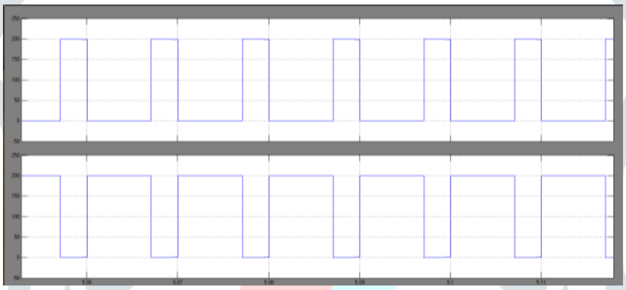

Fig.18 Simulation waveforms of Switch Voltages

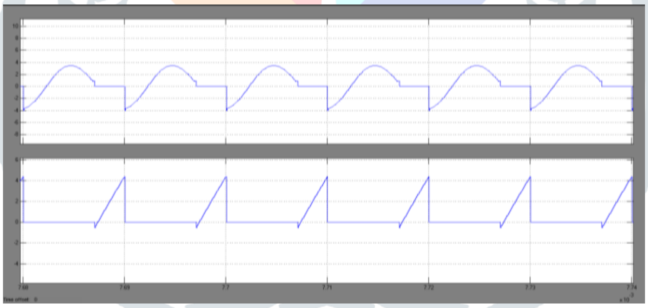

Fig.19 Simulation waveforms of Switch currents

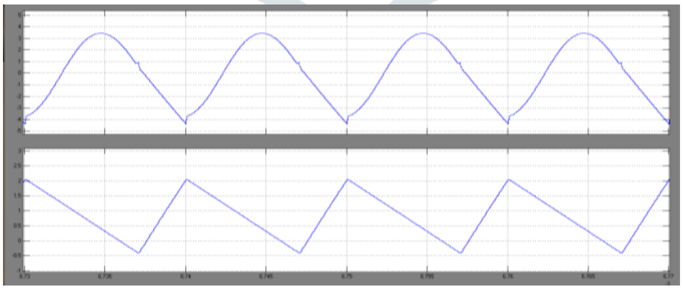

Fig.20 Simulation waveforms of Capacitor and inductor currents

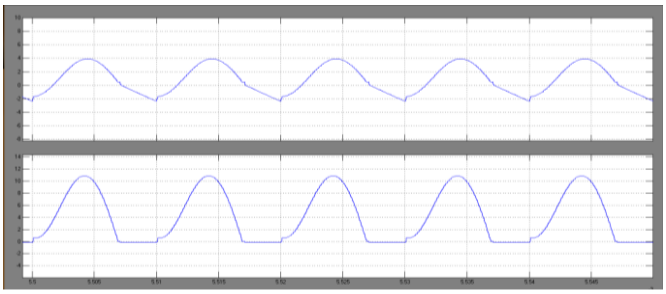

Fig.21 Simulation waveforms of primary and secondary winding currents

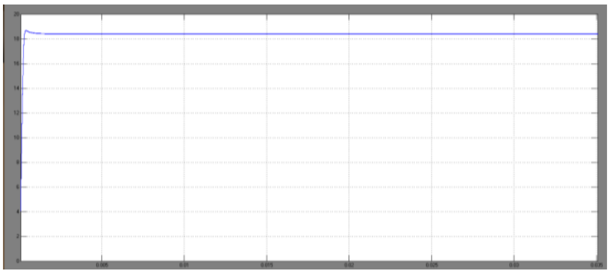

Fig.22 Output voltage waveform

*Case 3: Sudden load change*

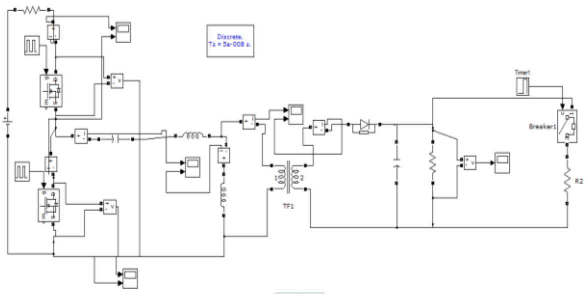

Fig.23 Matlab/Simulation circuit for sudden load change.

Fig.24 Output voltage waveform

*Case 4: By using PI controller*

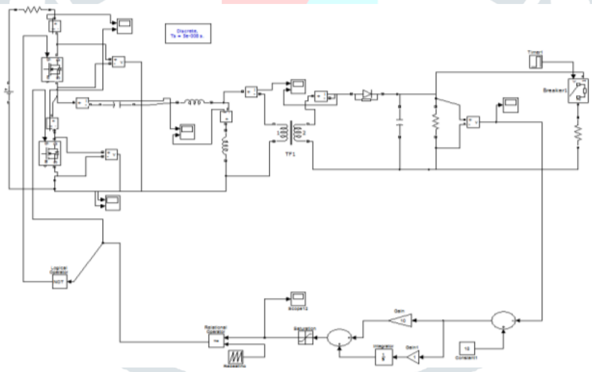

Fig.25 Matlab/Simulation circuit by using PI controller

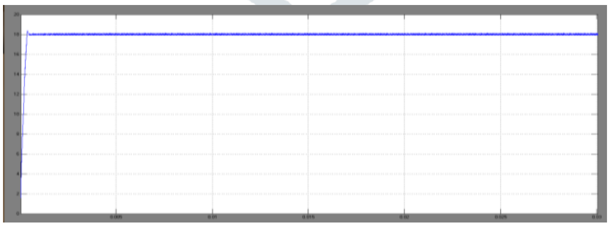

Fig.26 Output voltage waveform.

*Case 4: By using FUZZY logic controller*

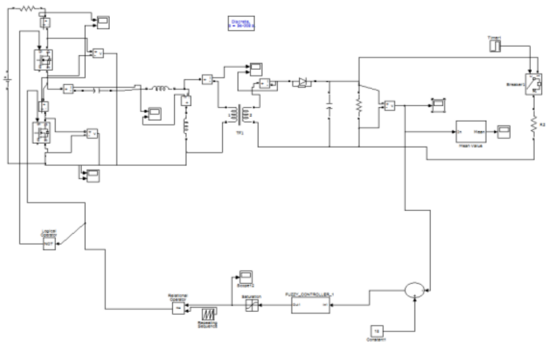

Fig.27 Matlab/Simulation circuit by using Fuzzy logic controller.

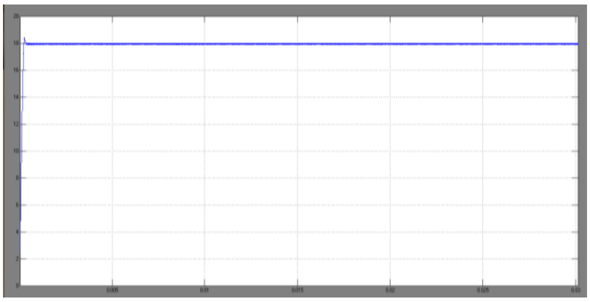

Fig.28 Output voltage waveform

## V. CONCLUSION

This paper presents design considerations of an asymmetric PWM half-bridge converter. To provide the ZVS conditions, a simple auxiliary circuit is used without an additional switch. The soft switching condition of switches for buck and boost modes is set in both directions. The asymmetrical half-bridge flyback DC-DC converter is gaining popularity because it has some advantages such as low cost, less components, higher power density, high efficiency and universal input voltage. This paper proposes a hybrid switching technique for the asymmetrical half-bridge flyback DC-DC converter. Therefore, the switching losses efficiency of this converter at heavy loads decreases and the recovery reverse body diode switch problems are solved. In addition, converter switches are switching PWM and complement each other. So, it makes to simplify the control circuit.

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