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# Fuel Cell Fed BLDC Motor Drive

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***Abstract :*** *Fuel cell provides ultra clean, high efficient electric energy rather than other energy resources. It is suitable for hybrid electric vehicle application since it does not emit any pollutant. Hence the fuel cell is used as source in this paper. A non isolated resonant PWM ZVZCS high step up DC-DC converter is used to boost the voltage level obtained from the full cell. This converter reduces the switching loss, eliminates the diode reverse recovery problem thereby increases the step up ratio and efficiency. The boosted voltage is given to the three phase inverter circuit to supply the stator current of BLDC motor. This model is simulated using MATLAB software and performance parameters were analyzed.*

***Keywords -*** *Resonant PWM, ZVZCS, high step up, step up ratio*

## I. INTRODUCTION

Fuel cell is the clean and green technology that provides affordable, clean energy. When a hydrogen rich fuel enters into the stack, the electrochemical reaction takes place to produce electricity. The byproduct obtained from the cell is water, heat. It is reliable because it provides electrical energy continuously as long as hydrogen rich fuel such as natural gas or renewable biogas is given to the cell continuously. Hence this technology is used as the source in this paper.[33 If the Conventional DC-DC converter is operated at higher switching frequency, the switching loss , on state conduction loss will get increased. The various converter topologies were introduced , among these converters non isolated resonant PWM converter shows the reduced switching loss, on state conduction loss, and diode reverse recovery problem is completely eliminated. The auxiliary capacitor size is also reduced by 20 fold. Hence a non isolated high step up resonant PWM DC-DC converter is used in this drive. [36]

The output DC voltage is fed to the three phase inverter. To reduce the total harmonic distortion value below 5%, amalgamated PWM technique were used in this drive.[1] The switch used in the three phase inverter is MOSFET. Since MOSFET is able to operate at higher switching frequency with reduced switching loss and on state conduction loss. [35]

## II. PROPOSED SYSTEM

Fig. 1 shows the circuit diagram of the proposed system. In the proposed system, fuel cell is used as the source. The Voltage obtained from the fuel cell is not enough to drive the BLDC motor if it is directly converted to AC voltage.[37]

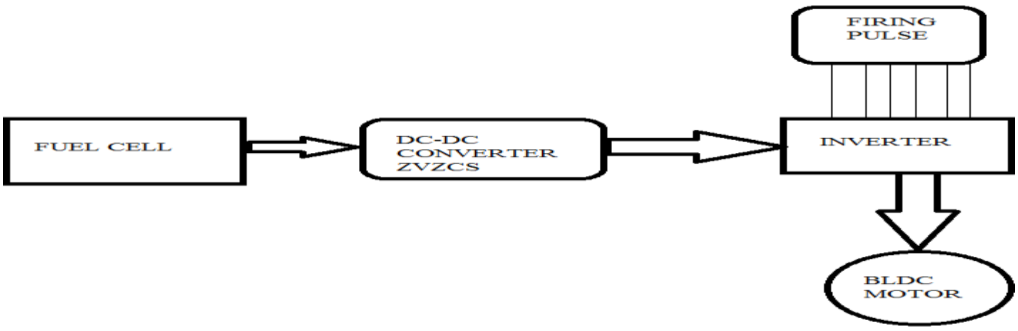



Fig 1.Proposed system

A resonant PWM high step up DC-DC converter is used to boost the DC-DC voltage. This voltage is given to the three phase inverter where normal 120 degree mode operation takes places.[36] The BLDC motor stator is energized by the inverter voltage. The inverter may be triggered with recent PWM techniques to reduce THD values within required level. This drive can be implemented in closed loop with the use of recent controllers for fast response. [34]

***2.1 Resonant PWM DC-DC Converter Mode Of Operation***

*Mode 1:*

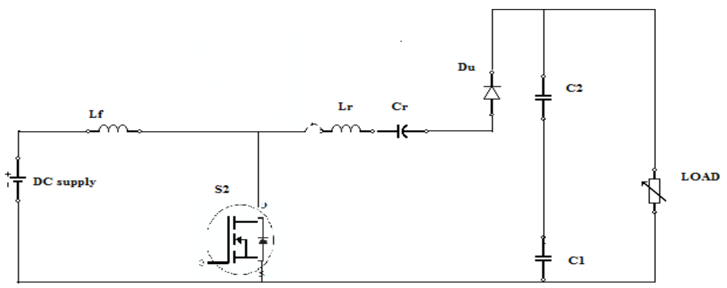



Fig 2: operating mode 1

This mode begins when upper switch SU which was carrying the current of difference between iLf and iLr is turned OFF. SL can be turned ON with ZVS if gate signal for SL is applied before the current direction of SL is reversed. Filter inductor current iLf and auxiliary current iLr starts to linearly increase and decrease, respectively, as follows.[39]

$$iLf = \frac{Vi}{Lf}(t - to) + iLf(to) \qquad (1)$$

$$iLr = \frac{Vcr{,}min - Vo}{Lr}(t - to) + iLr(to) \qquad (2)$$

This mode ends when decreasing current iLr changes its direction of flow. Then DU is turned OFF under ZCS condition.

*Mode 2:*

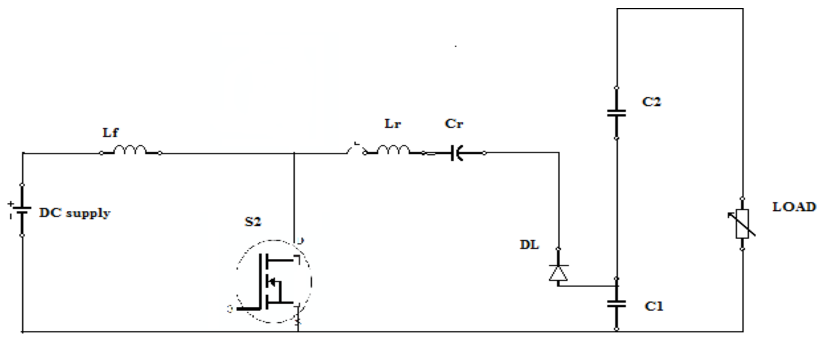



Fig 3: Operating mode 2

This mode begins with Lr–Cr resonance of the auxiliary circuit. Fig 3 shows equivalent circuit of this resonant mode. [40] Current iLf is still linearly increasing.[30]

The voltage and current of resonant components are determined, respectively, as follows:

$$iLr = -iCr = \frac{Vr2}{z} \sin(\omega r (t - t1)) \quad (3)$$

$$vCr(t) = Vr,2[\cos(\omega r(t - t1)) - 1] + vCr(t1) \quad (4)$$

$$Vr,2 = Vcr,min - Vc1, Z = \sqrt{Lr/_{Cr}} \; and \; \omega r = 1/\sqrt{LrC} \quad (5)$$

This resonance mode ends when iLr reaches to zero. Note that DL is turned OFF under ZCS condition

*Mode 3:*

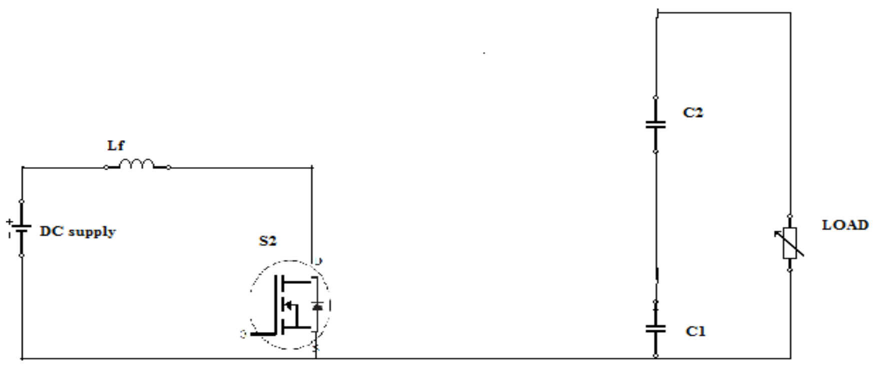



Fig 4: Operating mode 3

There is no current path through the auxiliary circuit during this mode. Output capacitors supply the load. At the end of this mode the turn-off signal of SLis applied [41]. It is noted that the turn-off current of SL,ISL,offis limited to filter inductor current at t3, ILf,max, which is much smaller than that of PWM method.[29]

*Mode 4:*

This mode begins when lower switch *SL* is turned OFF. *S*U can be turned ON with ZVS if gate signal for *SU* is applied before the current direction of *SU* is reversed.[42]

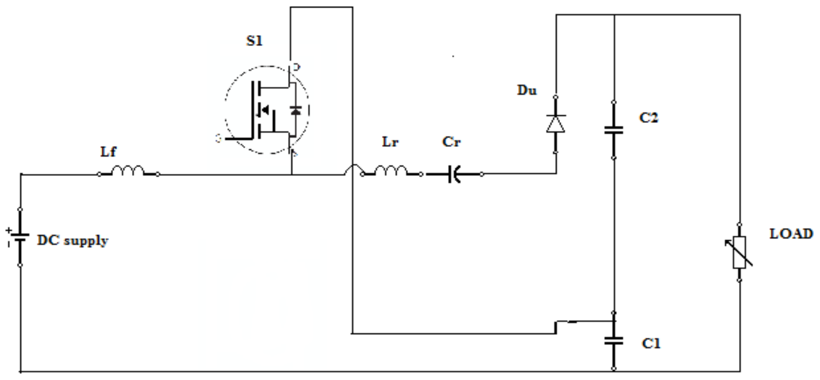



Fig 5: Operating mode 4

Filter inductor current iLfstarts to linearly decrease since voltage VLf becomes negative Like Mode 2, the other *Lr–Cr* resonance of auxiliary circuit is started, and *DU* starts conducting. Equivalent circuit of resonant mode is shown in fig. The voltage and current of resonant components are determined, respectively, as follows:[43]

$$iLf = \frac{Vi-Vc1}{Lf}(t-t3) + iLf(t3) \qquad (6)$$

$$iLr = -iCr = \frac{Vr4}{z}\sin(\omega r(t-t3)) \qquad (7)$$

$$Vr4 = Vcr,max - Vc2 \qquad (8)$$

This mode ends when iLr is equal to iLf.

*Mode 5:*

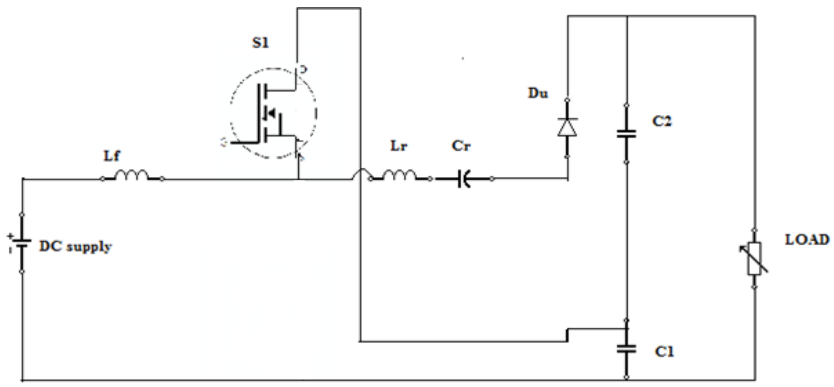



Fig 6.: Operating mode 5

After *iLr*equals *iLf*, *iSU changes* its direction, then this mode begins [28]. At the end of this mode, turn-off signal of *SU* is applied and this mode ends.

## III. VOLTAGE CONVERSION RATIO

To obtain the voltage gain of the proposed converter[27], it is assumed that the voltage across C1 and C2 are constant during the switching period Ts . The output voltage is given by

$$Vo = Vc1 + Vc2 \qquad (11)$$

$$Vo = \frac{N+1}{1-D}Vi - \Delta V \qquad (12)$$

$$Vo = \frac{2}{1-Deff}Vi = \frac{2}{1-D}Vi - \Delta V \qquad (13)$$

where effective duty *D*effand voltage drop Δ*V* are expressed using duty loss Δ*D*

$$Deff = D - \Delta D \qquad (14)$$

$$\Delta V = \frac{2\Delta DVi}{(1-D)(1-Deff)} \qquad (15)$$

VC 1 that is the same as output voltage of the general boost converter can be expressed as

$$Vc1 = \frac{1}{1-D} Vi \qquad (16)$$

$$Vc2 = \frac{1}{1-D} Vi - \Delta V \qquad (17)$$

$$IDL, av = \frac{V0}{Ro} = \left| \frac{2}{Ts} \int_0^{\frac{Tr}{4}} (Vcrmin - Vc1) \frac{\sqrt{Cr}}{\sqrt{Lr}} \sin(\omega rt) \,.\, dt \right| \qquad (18)$$

$$IDU = \frac{Vo}{P.Ro} = \frac{1}{2}(1 - D - \Delta D).IL2, peak \qquad (19)$$

$$IDU = \frac{Vo}{P.Ro} = \frac{1}{2}(D + \Delta D).IL2, peak \qquad (20)$$

*VCr*,minand , *VCr*,maxof capacitor voltage *VCr* can be approximated by

$$Vcrmin \approx Vc1 - \frac{V0}{2CrRofs} \qquad (21)$$

$$Vcrmax \approx Vc1 + \frac{V0}{2CrRofs} \qquad (22)$$

## IV. SIMULATION RESULTS

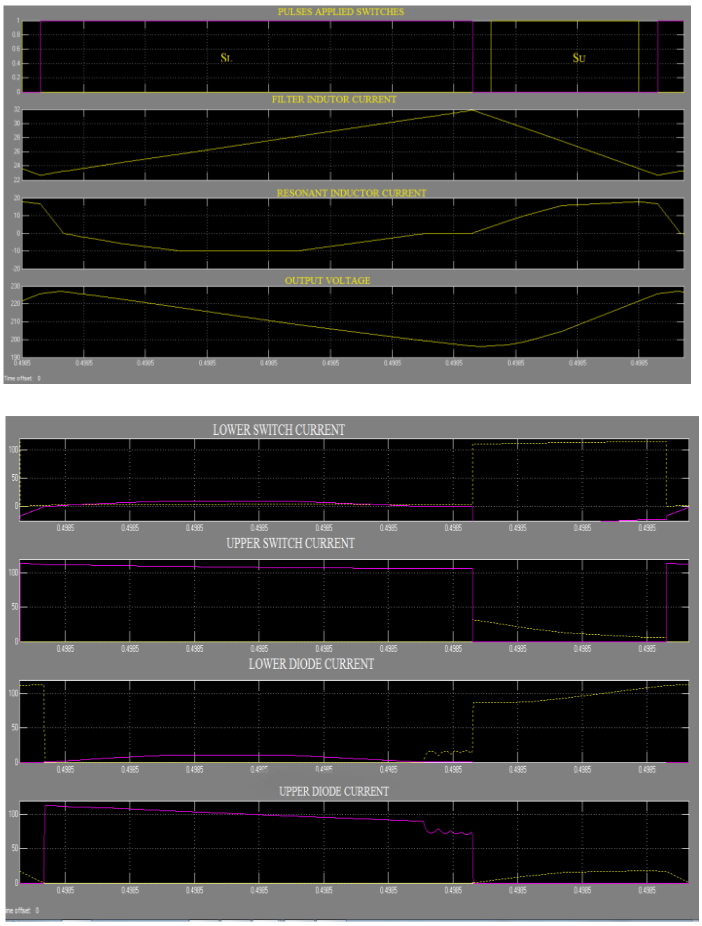



Fig 14. Output waveforms of proposed converter

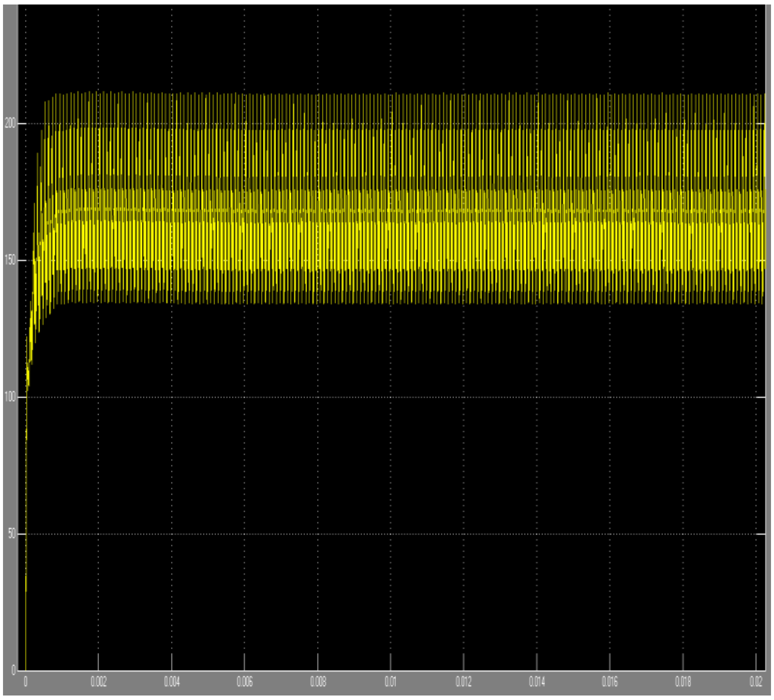


Fig 15. DC-DC converter Output voltage waveform.

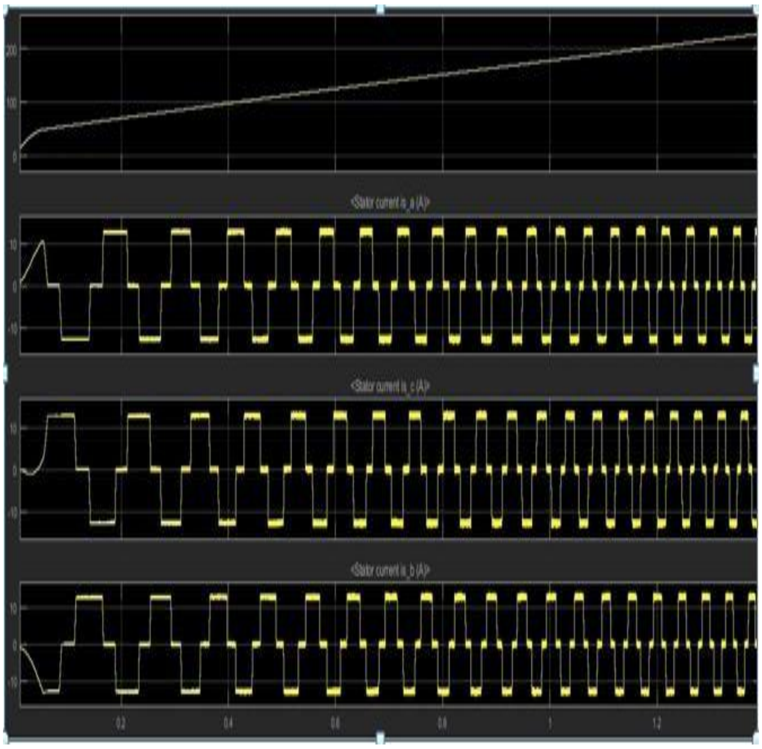
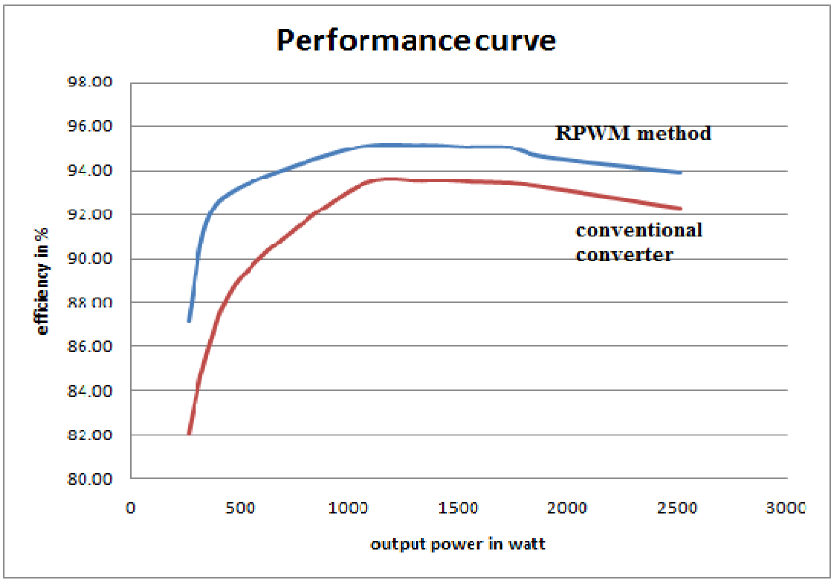
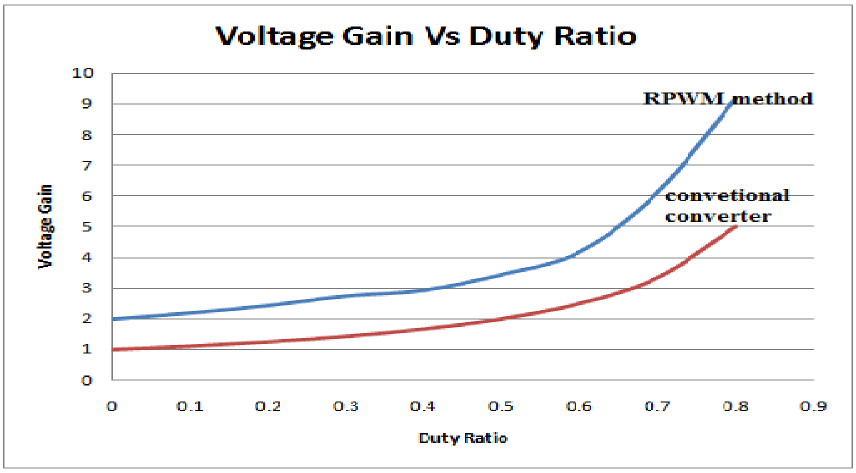


Fig 16. BLDC motor speed curve and inverter output

***4.1 Performance Curve***




## V. CONCLUSION

The proposed system is simulated using MATLAB software. The result shows the acceptable result . The resonant PWM high step up DC-DC converter gives high voltage gain and higher efficiency compared to conventional converter. The conventional PWM technique was used in inverter switches to trigger. We can use recent PWM techniques in the inverter switches to reduce the THD level further. the proposed system can be implemented in closed loop with the recent controller

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