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# Full Bridge DC-DC Boost Converter with PI Controller for Fuel Cell Applications

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***Abstract:***
*Fuel cells are considered to be one of the most promising sources of energy because of their high efficiency, low environmental impact and scalability. Unfortunately there are more complications with fuel cell operations. Voltage generated by fuel cell is very low and varies with variation in load. For proper operation of fuel cell based system we need a power conditioner. Power conditioner converts output of fuel cell, 24V DC to 230V AC suitable for residential applications. This paper presents design and analysis of full bridge dc-dc boost converter with PI controller; generate constant output voltage with load variations. Boost converter with PI controller converts output of fuel cell (24V) to constant 400V, which is suitable for inverter.*

***Keywords:*** *Fuel cell, DC-DC converter, PI controller, MATLAB*

## 1. Introduction
The conventional fossil fuel energy sources as petroleum, natural gas and coal, which meet most of the world's energy demand, today are being depleted rapidly. Also they create a lot of pollution for our environment. Fuel cell is one of the great sources of renewable energy. It running on pure hydrogen is pollution free, giving off only electricity, water and heat. To convert the output of the fuel cell to usable ac voltage, a power conditioner is required.

## 2. Fuel Cell Overview
Among from the different green power technologies e.g. wind power, photovoltaic, micro turbines and fuel cells, the fuel cell based distributed generation is considered to as one of the most promising technology due to high operating frequency, reliability and potential capability [1], [2].
The PEM fuel cell is one of the best fuel cell for residential and commercial applications due to low operating temperature, quick start up and high power density. The open circuit voltage of a single cell is about 0.7V to 1.2V. To produce desire-operating voltage some of the fuel cells are connected in series and parallel. Normally, fuel cell stack available in market gives 26V-50V output voltage.
A fuel cell is an electrochemical device that converts oxygen and hydrogen into electricity. It is very much like a battery that can produce electricity while being charged continuously. Because there is no combustion in the fuel cell, fuel is converted to electricity more efficiently than any other electrical generating technology available today. There are no moving parts in the fuel cell stack, making them more reliable. Operation of fuel cell as shown in fig.

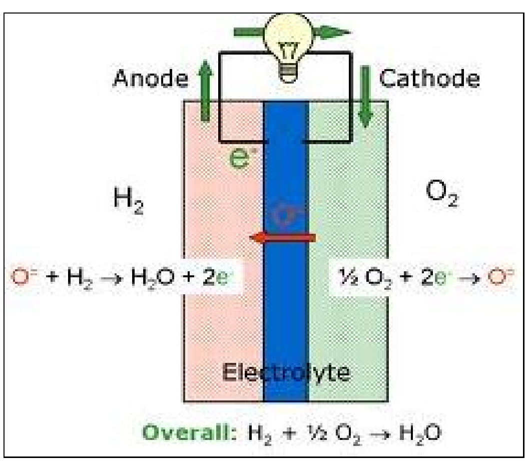


*Figure 1: shows the V-I characteristics of single fuel cell*

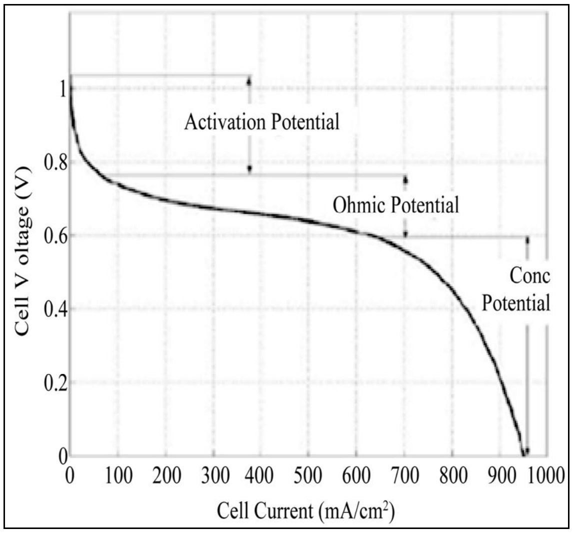


*Figure 2*

At low current level, increase in output voltage is mainly due to activity of slowness of chemical reaction; this region is called active polarization. The second region is mainly due to internal resistance of all the component of fuel cell, this is called ohmic region. At very high current density voltage falls down because of the reduction of gas exchange efficiency. This is mainly due to over flooding of water in catalyst, this is called concentration region. Output voltage of the fuel cell depends upon all these losses. Due to these losses output voltage decreases with increase in load. To overcome these problems fuel cell require a power conditioner unit, which converts unregulated dc voltage into usable ac voltage.

**3. Proposed Circuit Configuration**

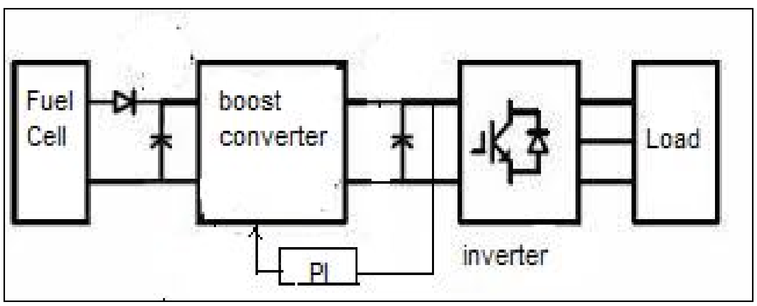


*Figure 3*

Fig. shows the block diagram of proposed circuit. Fuel cell based system needs a power conditioner unit, which is a combination of dc-dc boost converter and dc-ac inverter, for proper operation.

- DC-DC converter: It is a integral part of power conditioning unit which convert unregulated low voltage of fuel cell into regulated high voltage. PI controller is used for controlling of boost converter and generates constant voltage with load variations [4]. A full bridge topology was selected for designing of boost converter because it offers the best distribution of switch stresses and good controllability of duty cycle/boost ratio.
- Control strategy: Closed loop system is more stable than open loop system. The feedback loop of proposed converter is implemented in simulation using proportional integral control.

PI control method consist of two actions:

- Proportional action: It involves multiplying the error with a constant i.e. proportional gain constant (Kp) and adding the product to the controlled quantity. This term produce output value proportional to the current error value.
- Integral action: It involves integrating the error value over a period of time and then multiplies with a constant i.e. integral gain constant (Ki) and adding the product to the controlled quantity. Integral action brings the controlled variable back to the reference value in the presence of disturbance i.e. it eliminates steady state error.

PI controller reduces steady state error to zero and the system becomes more stable. It improves the overall performance of system and increases its efficiency. Now the system produces constant output voltage with load variations.

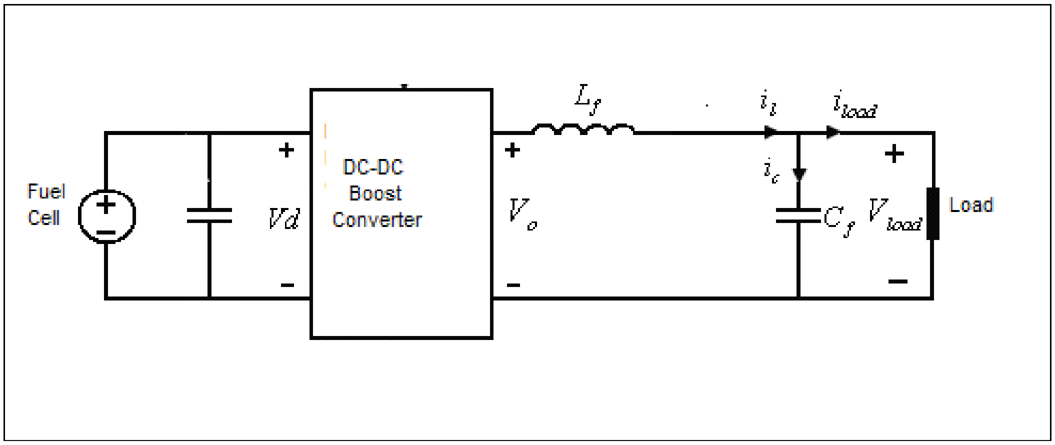


*Figure 4: Shows the fuel cell connected dc-dc boost converter with L-C filter*

The fig. Shows block diagram of proposed system. The control circuit of a boost converter consists of two loops: the first loop is a fast internal Current loop to reduce the THD of the output voltage and increases the speed of the response; the Second loop is a slow external voltage loop, which provides output voltage regulation. The internal current loop may be the filter inductor current loop or the filter capacitor current loop. Capacitor current feedback improves the dynamic response of the system [3].

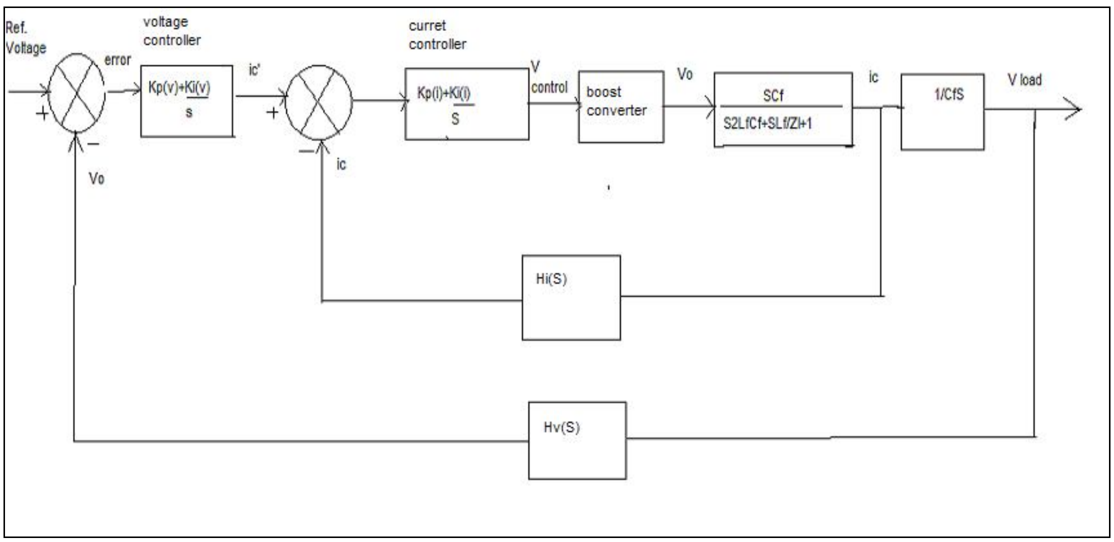


*Figure 5*

*3.1. Boost Converter Parameter Selection*

In order to generate 400V constant dc voltage which is suitable for inverter to produce 230V, 50Hz AC voltage for residential and grid applications, parameters of boost converter should be properly selected. Boost converter design parameters are given in the table

| **Parameters** | **Value** |
|---|---|
| Fuel cell | 24V, 1.2KW (PEMFC) |
| Output voltage | 400V |
| Input inductance, Lin | 10uH |
| Input capacitance. Cin | 120mF |
| Switching frequency of converter | 30KHz |
| Transformer turn ratio | 1:14 |
| Filter inductance, Lf | 150uH |
| Filter capacitance, Cf | 0.01F |
| Load resistance, R | 200ohm |
| Proportional gain of voltage controller, Kp | 0.001 |
| Integral gain of voltage controller, Ki | 0.000001 |
| Proportional gain of current controller, Kp | 1 |
| Integral gain of current controller, Ki | 1 |

*Table 1: Parameters of boost converter*

*3.2. Simulink Diagram*

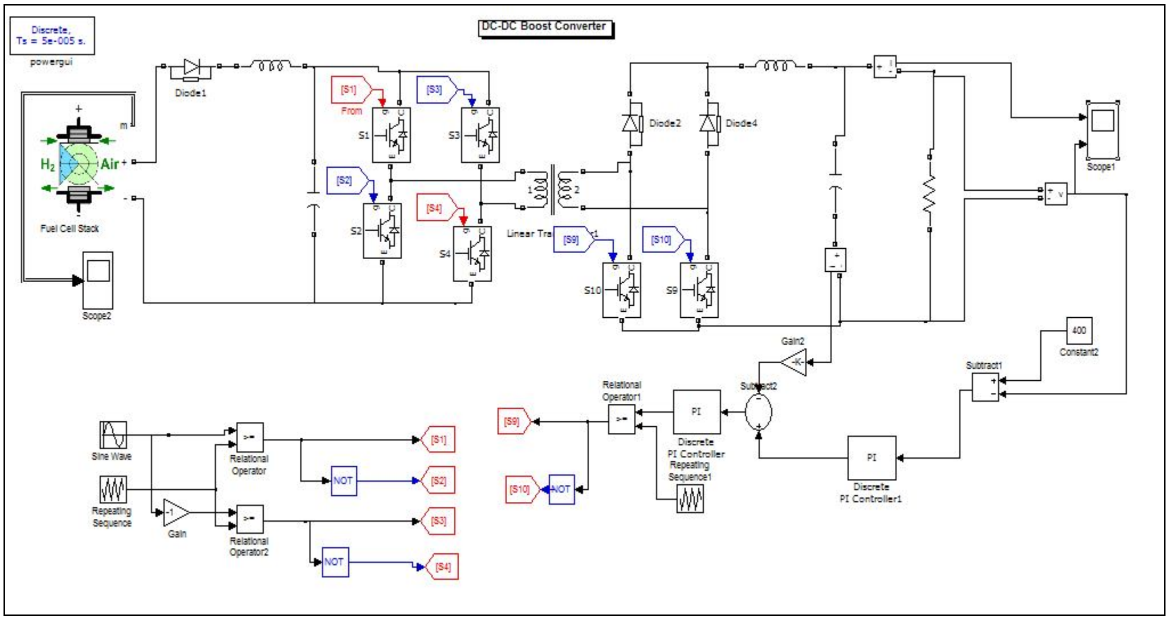


*Figure 6: Simulink Diagram*

*3.3. Simulation Result*

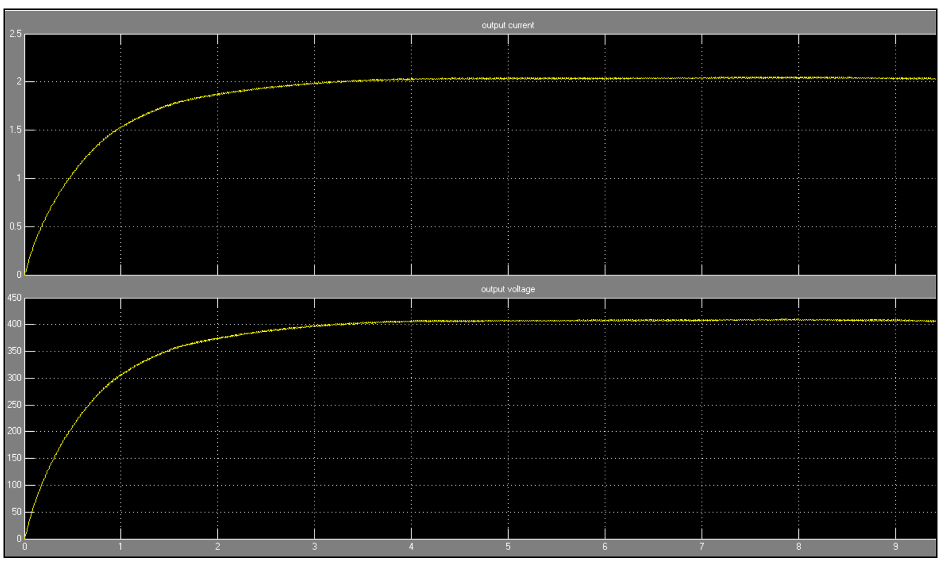


*Figure 7: Simulation Result*

## 4. Conclusion

In this paper controlling of dc-dc boost converter is presented to produce constant dc output voltage with load variations. Multiple loop feedback system with two PI controllers is used for controlling of boost converter. This method gives more accurate result than single controller. Boost converter, converts fuel cell output (24V) into constant 400V, which is independent of load variations.

## 5. References

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