# Dynamic Modelling of Solid Oxide Fuel Cell using MATLAB Simulation

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*Abstract*---In the near future some fuel cell systems could be an accessible and attractive alternative to conventional electricity generation and vehicle drives. fuel cell systems can be made in mw to kw capacities; hence a wide range of applications can be covered by this type of fuel cell. This is a major advantage of this type of fuel cell, because once the technology was developed it can be more or less easily scaled up or down for various applications. fuel cell has attracted a great deal of attention as a potential power source for automobile and stationary applications due to its low temperature of operation, high power density and high energy conversion efficiency. In this Paper Matlab-simulink of model of solid oxide fuel cell (SOFC) .

**Key Words:** SOFC Fuel Cell, Matlab-Simulink, Model

## I. INTRODUCTION

A Fuel Cell is an electrochemical energy conversion device which converts the chemicals Hydrogen and Oxygen into water and in the process, it produces electricity.[6] In its simplest form, a single fuel cell consists of two electrodes - an anode and a cathode - with an electrolyte between them. At the anode, hydrogen reacts with a catalyst, creating a positively charged ion and a negatively charged electron. The proton then passes through the electrolyte, while the electron travels through a circuit, creating a current. At the cathode, oxygen reacts with the ion and electron, forming water and useful heat. This single cell generates about 1.18 volts, just about enough to power a single light bulb. When cells are stacked in series the output increases, resulting in fuel cells anywhere from several watts to multiple megawatts. There are many different types of Fuel Cells, each with their own unique operating characteristics.[1]

## II. WORKING PRINCIPLE OF SOFC FUEL CELL

The SOFC is a high-temperature operating fuel cell which has high potential in stationary Applications. The efficiency of SOFC is in the range of 45-50%. It is a solid-state device that uses an oxide ion conducting non-porous ceramic material as an electrolyte. Since the electrolyte is a solid, the cells do not have to be constructed in the plate-like configuration typical of other fuel cell types. Corrosion is less cells do not have to be constructed in the plate-like configuration typical of other fuel cell types. Corrosion is less compared to MCFC and no water management problems as in PEMFCs due to the solid electrolyte. High temperature operation removes the need for a precious-metal catalyst, thereby reducing the cost. It also allows SOFCs to reform fuels internally. The electrolyte used is a ceramic oxide (yttrium stabilized zirconium). The anode used is nickel-zirconia cermet's and the cathode is a strontium doped lanthanum magnetite. The use of ceramic materials increases the cost of SOFCs. High operating temperature requires stringent materials to be used which further drives up the cost. Intermediate-temperature SOFCs cannot be used for all applications. Higher temperature is required for fuel cell micro-turbine hybrid systems. However, for smaller systems intermediate temperature SOFCs would be ideal.

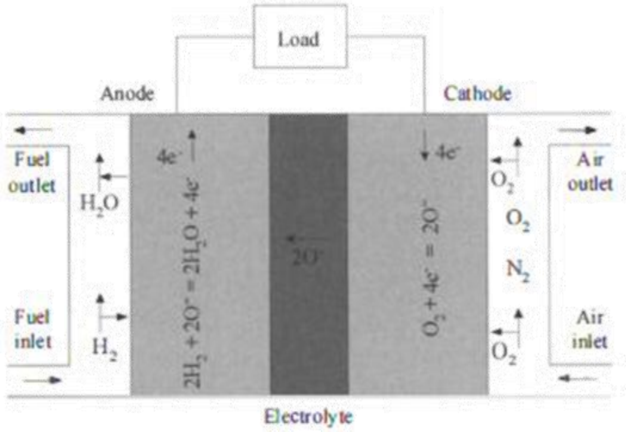


Fig. 1: Working Principle of SOFC Fuel Cell

Since SOFCs have fuel-flexibility, the input to the anode can be hydrogen, carbon monoxide or methane. Hydrogen or carbon monoxide may enter the anode. At the cathode, electrochemical reduction takes place to obtain oxide ions. These ions pass through the electrolyte layer to the anode where hydrogen is oxidized to obtain water. In case of carbon monoxide, it is oxidized to carbon dioxide. In this analysis, a reduced model of the fuel cell has been taken into account, neglecting the activation and concentration losses as well as the double charging effect. The loss due to internal resistance of the stack is basically due to the resistance to the flow of ions in the electrolyte as well as the material of the electrode. In general, it is mainly caused by the electrolyte. Figure shows the typical volt-amp characteristics of SOFC. Fuel cells have drooping voltage characteristics: an increase in the load current causes a decrease in the stack voltage. The number of cells is taken to be 450 and the standard cell potential is 1.18V.

## III. MODELING OF SOFC FUEL CELL

The modeling of SOFC is carries out based on the assumptions made that the fuel cell temperature is made to be constant; the fuel cell gasses are ideal and the Nernst's equation applicable to the cell.

By Nernst's equation output fuel cell dc voltage Vfc across stack of the fuel cell at current I is given by the

$$V_{fc} = N_0\left[E_0 + \frac{RT}{2F}\ln\left[\frac{pH_2\,pO_2^{.5}}{pH_2o}\right]\right] - rI_{fc}$$

Where
Vfc – Operating dc voltage (V)
E0 – Standard cell potential (V)
r – Internal resistance of stack

 

R – universal gas constant (J/ mol K)
T – Stack temperature (K)
F – Faraday's constant (C/mol)

The main equations describing the slow dynamics of a SOFC can be written as follows.

$$P_{ref} = V_{fc} * I_{ref}$$
$$\frac{dI_{fc}}{dt} = \frac{1}{T_e}[-I_{fc} + I_{ref}]$$
$$\frac{dq_{H_2}^{in}}{dt} = \frac{1}{T_f}[-q_{H_2}^{in} + \frac{2k_r}{U_{opt}} I_{fc}]$$
$$\frac{dP_{H_2}}{dt} = \frac{1}{\tau H_2}[-P_{H_2} + \frac{1}{K_{H_2}}[q_{H_2}^{in} - 2k_r I_{fc}]]$$
$$\frac{dp_{o2}}{dt} = \frac{1}{\tau O_2}[-P_{O_2} + \frac{1}{K_{O_2}}\left[\frac{1}{r_{H_2O}} Q_{H_2}^{in} - 2k_r I_{fc}\right]$$
$$\frac{dp_{H_2O}}{dt} = \frac{1}{\tau_{H_2O}}[-P_{H_2O} + \frac{2k_r I_{fc}}{K_{H_2O}}$$

qH2 – Fuel flow (mol/s)
qO2 – Oxygen flow (mol/s)
KH2 – Molar constant for hydrogen (kmol/s atm)
KO2 – Molar constant for oxygen (kmol/s atm)
KH2O – Molar constant for water (kmol/s atm)
ƭH2 – Response time for hydrogen (s)
ƭO – Response time for oxygen (s)
ƭH2O – Response time for water (s)
Ƭe – Electrical response time (s)
Ƭf – Fuel response time (s)
Uopt – Optimum fuel utilization
rHO – Ratio of hydrogen to Oxygen

The block diagram representation of the SOFC dynamic model is shown in the Figure.

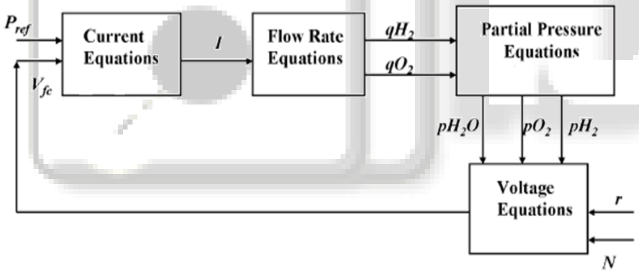


Fig. 2: Block diagram

## IV. Simulation Results

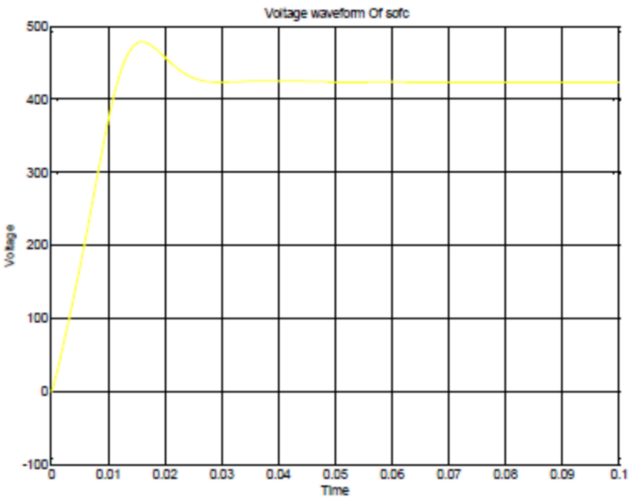


Fig . 2: Voltage Waveform SOFC Fuel Cell

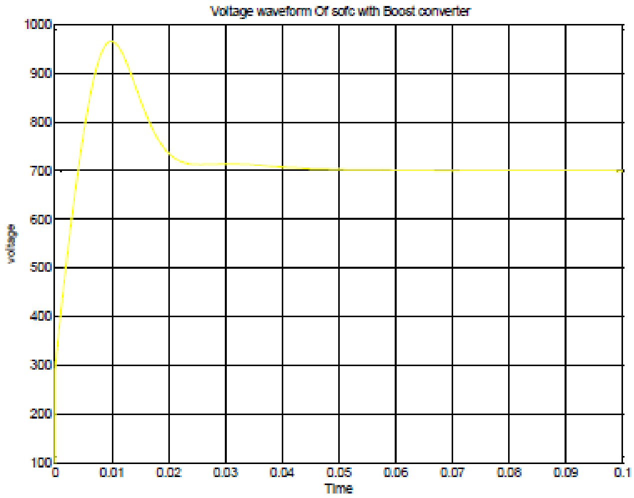


Fig .3: Voltage Waveform SOFC Fuel Cell with Boost Converter

From the above simulation results it can be identified to meet the load changes in the power system can be effectively be controlled by incorporating the FC system as they are fed constant output voltages. The FC output can be controlled by controlling the internal parameters of the fuel cell

## V. Conclusion

In this Paper MATLAB simulation of SOFC Fuel cell has done. by designing of vsc inverter with control strategy. then fuel cell will be integrated with utility grid.

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## Appendix

| Variable | Representation | Value |
|---|---|---|
| T | Absolute temperature | 1273K |
| F | Faraday's constant | 96487C/mol |
| R | Universal gas constant | 8314J/(Kmol K) |

 

| | | |
|---|---|---|
| $E_o$ | Standard reversible cell potential | 1.18V |
| N | Number of cells in stack | 450 |
| $K_r$ | Constant $K_r$ =N/4F | .996*10 Kmol/(s A) |
| $U_{max}$ | Maximum fuel utilization | 0.9 |
| $U_{min}$ | Minimum fuel utilization | 0.8 |
| $U_{opt}$ | Optimum fuel ratio | 0.85 |
| $K_{H2}$ | Value molar constant for hydrogen | 8.43*10 Kmol/(s atm) |
| $K_{O2}$ | Value molar constant for oxygen | 2.81*10 Kmol/(s atm) |
| $K_{Ho2}$ | Value molar constant for water | 2.52*10 Kmol/(s atm) |
| $\tau_{H_2}$ | Response time for hydrogen flow | 26.1s |
| $\tau_{H_2O}$ | Response time for water flow | 78.3s |
| $\tau_{O_2}$ | Response time for oxygen flow | 2.91s |
| R | Ohmic loss | 0.126 Ω |
| $T_e$ | Electric response time | 0.8s |
| $T_f$ | Fuel processor response time | 0.03s |
| $r_{HO}$ | Ratio of hydrogen to oxygen | 1.145 |