



ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 3, March 2016

Modeling of Solid Oxide Fuel Cell

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ABSTRACT: Fuel mobile technology is a notably incipient energy-preserving era that has the potential to compete with the traditional subsisting technology facilities. a few of the sundry onsite technology or dispensed technology or localized generation technologies to be had, fuel cells are being utilized as a potential supply of power due to the fact they don't have any geographic inhibitions and may be located everywhere on a distribution gadget. Gasoline cells have wide variety of blessings which make them superior than different technology. The perpetual electricity supply to the load as per the authoritative ordinance is supplied by way of the combination of the gasoline cellular machine. In this paper, the SOFC model has been evolved and set up inside the Mat lab-Simulink surroundings. In this work, the steady nation and dynamical operation of SOFC technologies has been analyzed.

KEYWORDS: SOFC, Geographic boundaries, consistent nation, Dynamic Operation.

I. INTRODUCTION

The efficiency is engendered by the gasoline cells through the electrochemical reaction among hydrogen and oxygen. The conversion performance is excessive and leaves handiest di-hydrogen monoxide and heat as the via-products that is the primary motivation for the incrementing the interest on this generation [6]. Gas Cells offer lower emission and higher performance than Diesel Engine however are at risk of be sumptuous for lots packages. The first gasoline cell unit was discovered and developed through Sir William Grove 1842 [12] with the usage of four primitive cells making use of hydrogen and oxygen. But, it turned into not used truly till the 1960's whilst NASA demonstrated a potential fuel cell software. After such demonstrations, business organizations became fascinated with this era because of its energy satisfactory, high efficiency, modularity and the environmental advantages.

Fuel cells could probably supersede the inner combustion engine and many other power technology contrivances used these days. Decreased emissions of greenhouse gases and incremented performance are of the essential motives that gasoline cells are being earnestly researched as a supersession to the inner combustion engine. A fuel cellular (FC) is an electrochemical electricity conversion system, in which chemical power is immediately converted into the electrical electricity and heat. The primary benefits of this era are excessive efficiency without a doubt at partial load, low emissions, and noiselessness (because of nonexistence of shifting additives), and free adjustable ratio (50 kW to 3 MW) of electric and heat technology. The rudimentary structure of fuel cells consists of a dyad of electrodes, one advantageous and bad, and an electrolyte. The gasoline utilized inside the fuel cellular is conventionally hydrogen, but fuel cell withal calls for oxygen. The hydrogen is furnished to the anode in which the gas is oxidized, liberates the electrons, which directed via the outside circuit. On the cathode, the oxidant is reduced, consuming electrons from the external circuit. Ions which have peregrinated via the electrolyte to balance the flow of electrons via the external circuit. The anode-cathode reactions and the composition and path of the glide of the mobile ion vary with the form of gasoline cell.

All gasoline cells engender a direct current handiest, the voltage relying on mobile voltage and the quantity of cells related in series. Furthermore, the voltage varies with the weight and additionally to a degree with time as the gasoline cell stack a long time. To obtain AC current, the gasoline cellular system ought to have power conditioning device inclusive of inverter to address DC to AC conversion and modern-day, voltage, and frequency manage. Gasoline cells have high reliability because the range of shifting additives is low. It includes auxiliary system which includes enthusiasts and pumps. The target for existence duration of gas cells is conventionally given as 40000 h for the stack

and as a minimum two times the range of hours for the device. This target has been reached for a minimal number of gas cells but in trendy it nevertheless remains to be tested.

II. STRONG OXIDE GASOLINE CELL

strong Oxide gasoline cellular (SOFC) is one kind of high temperature gas mobile that looks to be one of the maximum promising era to provide the efficient and smooth energy engenderment for huge variety of packages (from minuscule units to immensely big scale strength flowers). Stable oxide gasoline cellular relies at the concept of oxide ion migration thru an oxygen ion conducting electrolyte from the oxidant electrode (cathode) to fuel electrode (anode) side. Discern 1 suggests the essentialstandard of the SOFC. It operates at temperatures in the range of (600-1000) °C, which makes them extraordinarily green in addition to fuel bendy. In case of SOFC the electrolyte is a dense solid substances that involves ceramic materials like Yttrium-stabilized zircon dioxide whose function is to forestall electrons from crossing over at the same time as sanctioning passage to the charged oxygen ions.

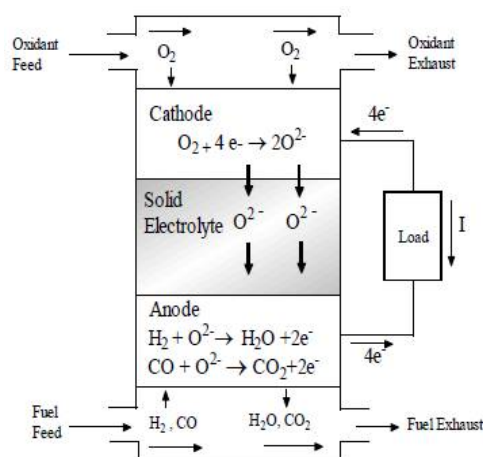
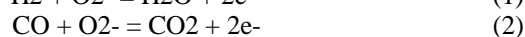
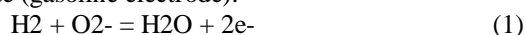


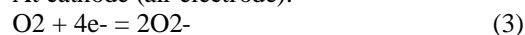
Figure 1 Basic Electrochemistry of an SOFC

The discount reaction is carried out at the cathode where molecular oxygen reacts with the electrons provided from outside circuit to the engender oxide ions. The oxygen ions peregrinates thru the strong electrolyte to anode. Inside the anode aspect, they amalgamate with the hydrogen molecule to engender the di-hydrogen monoxide, carbon-di-oxide and electrons. The electrons permeate the externally connected circuit to attain the cathode and engendering electric energy within the procedure. Di-hydrogen monoxide is engendered by using the recombination of oxygen ions and electrons with hydrogen at the anode, in preference to PEMFCs in which di-hydrogen monoxide is engendered on the cathode. Under operation, Both an oxygen ion-conducting electrolyte or a proton accomplishing electrolyte may be utilized by the SOFC. Here the SOFC with the oxygen ion-accomplishing electrolyte (SOFC-O₂⁻) has been considered in place of with proton-carrying out electrolyte (SOFC-H⁺) as stable Oxide gasoline cells are predicated on idea of an oxygen ion engaging in electrolyte. The excessive temperature operation of SOFC enables it to work with hydrogen in addition to hydrocarbon-predicated gases as gas. In advisement, SOFCs has the excessive tolerance to gas impurities which include natural fuel. They sanction inner reforming, and withal use much less extravagant catalysts for the dissociation of the oxidant. The chemical reactions positioned in the SOFC that are without delay worried inside the engenderment of electricity are as follows.

At anode (gasoline electrode):



At cathode (air electrode):



Overall cellular response:



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III. MODELING OF SOFC

Stable Oxide fuel Cells (SOFC) are categorically fascinating due to the fact they're the maximum efficient in terms of fuel enter to electricity output. This era is great relevant in the MG. The high working temperature engenders warmness ideal nicely to cogeneration applications. SOFC do no longer comprise noble metals and do no longer make use of liquid electrolytes that can reason quandaries and be extravagant [10]. The stack model could be predicated on the following posits. The gases are ideal. The stack is alimeted with hydrogen and air. If the natural fuel is utilized as the gasoline, the dynamics of the fuel processor must be included in the version, upstream of the hydrogen inlet, as a first-order transfer characteristic [2]. The switch function benefit must mirror the transmutions in composition taking place in the course of the technique.

The channels that bring the gases along the two electrodes have an excellent-tuned quantity, but their lengths are minuscule, so that it's far simplest compulsory to define one single strain fee of their interior. The exhaust of each channel is thru a single orifice. The ratio of pressures between the interior and outdoors of the channel is astronomically gigantic sufficient to keep in mind that the orifice is choked. The temperature is stable always. The best supply of losses is ohmic, because the working conditions of interest are not proximate to the higher and lower extremes of cutting-edge. The Nernst equation can be implemented. Via Nernst's equation output gas cellular dc voltage V_{fc} throughout stack of the fuel mobile [5] at present day I_{fc} is given by way of the (five) where,

- V_{fc} -gas cell stack voltage(V),
- N_0 -wide variety of cells in stack,
- E_0 -standard reversible cellular capability(V),
- I_{fc} -Stack modern(A)
- r - Inner resistance of the stack (Ω),
- R -Ecumenical fuel consistent (J/molK),
- T -Stack Temperature(ok),
- F -Faraday's constant(C/mol).

The expression for partial pressure of hydrogen as [5]. [6] In which, ϕ is the fee of gadget pole related to the hydrogen glide, expressed in seconds and is given as the partial strain for the reactant, oxygen and product, di-Hydrogen monoxide may be expressed as follows,[7] and [8] Wherein

- Valve molar regular for di-hydrogen monoxide [kmol/(s atm)]
- Valve molar steady for hydrogen [kmol/(s atm)]
- Valve molar constant for oxygen [kmol/(s atm)]

Gas utilization is the ratio among the gas drift that reacts and the enter fuel waft. Hence, we've (9). It's been shown that the fuel usage ranging from zero. Eight to 0.nine provides the better overall performance and obviates overused and underused gas situations. Considering the above distinct gasoline situations, $UF > 0.9$ can motive anion harm to the cell due to gas starvation and $UF < 0.7$ ends in better cell voltage swiftly. For the precise hydrogen enter drift, the authoritative ordinance modern-day of gas cell device can be restrained inside the variety given as: (10)

The choicest usage factor postulated for this version is zero. 85[17]. The gasoline utilization may be set at this price with the aid of regulating the enter fuel float relying at the true output current recorded inside the gas mobile gadget. Ergo, the fee of gas enters flow, depending on fuel cellular output current is given as [11]. From the overall gasoline cellular reaction [4], the stoichiometric ratio of hydrogen to oxygen is two to 1. Oxygen extra is always taken to allow hydrogen react with the oxygen extra plenary. Their simulation in gasoline cell machine indicates that r_{H-O} should be kept round 1.a hundred forty five so one can hold the fuel mobile strain difference under 4 kPa below mundane operation.

The chemical response is modeled as a primary-order transfer feature with a 5S time regular because of the gasoline processor is conventionally gradual as it is associated with the time to transmute the chemical response parameters after a vicissitude in flow reactions. The electric replication time within the gas cells is normally expeditious and particularly associated with the celerity at which the chemical reaction is capable of renovating the

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

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charge that has been tired through the weight. This is withal modeled as a primary-order switch characteristic however with a 0.eight s time constant.

Predicated on [8] and the above discussions, the SOFC gadget dynamic version that is proposed by way of [14] is summarized in [11] and [12]. The block diagram of dynamic version of a SOFC is proven in parent 2. The extraordinary version parameters along with most gas usage, minimum gas utilization, most beneficial fuel utilization gas machine replication time, and electrical replication time and so forth as mentioned in table 1. The efficiency engendered by the fuel cellular is then given by the subsequent cognition:

$$P_{fc} = V_{fc} I_{fc}$$

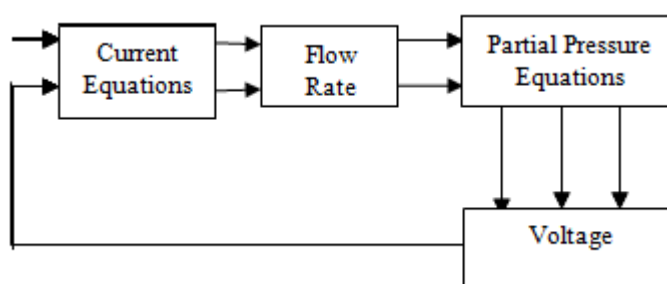


Figure 2 Block diagram for dynamic model of SOFC

Table 1 Parameters of the SOFC

Variable	Representation	Value
T	Absolute temperature	1273K
F	Faraday's constant	96487C/mol
E ₀	Standard reversible cell potential	1.18V
N _o	Number of cells in stack	384
K _r	Constant	0.996×10 ⁻⁶
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	8.43X10 ⁻⁰⁴ (Kmol/s atm)
K _{O₂}	Value molar constant for oxygen	2.52X10 ⁻⁰³ (Kmol/s atm)



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K_{H_2O}	Value molar constant for water	$2.8 \times 10^4 \left(\frac{Kmol}{s \ atm} \right)$
τ_{H_2}	Response time for hydrogen flow	26.1s
τ_{H_2O}	Response time for water flow	78.3s
τ_{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	5s
rHo	Ratio of hydrogen to oxygen	1.145
R	Universal Gas Constant	8314 J/(kmolk)

IV. SIMULATION RESULTS

It is assumed that the stand-alone SOFC system is operating with constant rated voltage 333.8 Volts and power demand 70 kW. All parameters of the system are the same as in Table.

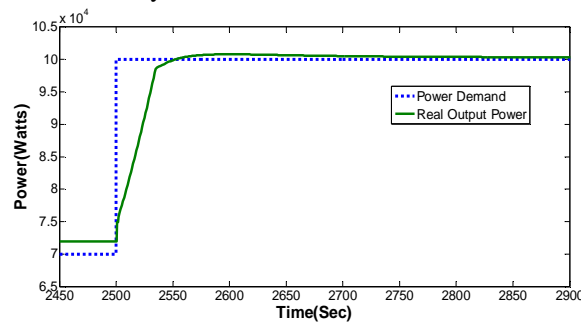


Figure 2 Response of SOFC when increasing power demand from 70KW to 100KW

At $t = 2500$ sec, there is a step increase of the power demand from 70 kW to 100 kW. Figure shows thermodynamic response of this system. Figure 3 shows the dynamic response of the SOFC when there is a decreasing in power demand from 70 kW to 40 kW.

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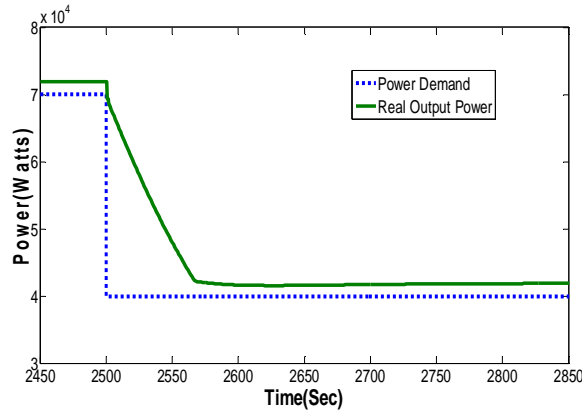


Figure 3 Response of SOFC when decreasing power demand from 70KW to 40KW

Results show that the SOFC has some slow dynamic response, so that using SOFC alone may be not suitable for systems that need a fast dynamic response. Figure 4 illustrates the response of the fuel cell pressure difference between hydrogen and oxygen. We can notice that it increases to the peak value of 3.5 kPa when the power demand increased from 70KW to 100KW, which is less than the maximum safety pressure difference 8 kPa. It can return to the normal operating pressure difference value around 0 kPa.

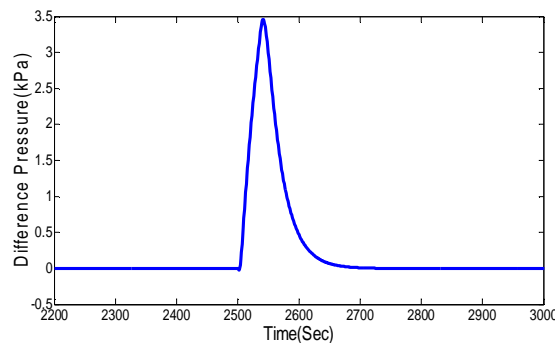


Figure 4 Response of pressure difference between hydrogen and oxygen

In Figure 5 the fuel utilization response is presented, due to increase in the power demand, the fuel utilization increases to the maximum fuel utilization U_{max} in about 2500 s. After staying at U_{max} for about 25 s, it decreases to optimal fuel utilization U_{opt} .

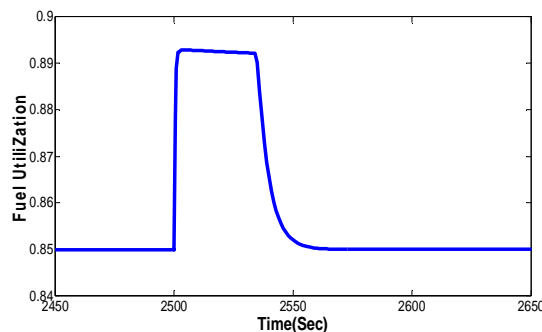


Figure 4 Response of Fuel Utilization



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V. CONCLUSIONS

In a business electricity generation, gasoline mobile is one in every of most vital assets of distributed power within the future. Modeling and simulation examine of a SOFC energy system is investigated in this paper. A confirmed SOFC dynamic version is used to version the gas cellular gadget. The model may be utilized in future applications for the evaluation of hybrid electricity systems. A hybrid strength gadget includes a mixture of or extra energy technology to do the best use in their operating traits and to acquire higher efficiencies than the ones can be obtainable from a unmarried strength supply. In addition, we are able to integrate gas cells with wind power and sun strength era for lower back-up strength era and strength storage. Getting better efficiencies combined with low emissions hybrid systems are likely to be the selection for the following era of superior energy technology systems.

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