ISSN: 2278-4632
Vol-10 Issue-5 No. 9 May 2020

A review paper on

GRAPHICAL MODELING AND SIMULATION FOR FUEL CELL

SAKSHI SHARMA [1], MR. DEEPAK SHARMA[2]

*1- B.Tech. Student, *2- Asst. Professor, Department of Electronics & Communication

Poornima Institute of Engineering and Technology, Jaipur, Rajasthan

milisharma1825@gmail.com[1], deepak_382@poornima.org[2]

Abstract- *A cell is an electrochemical cell that mixes the energy of a fuel and an oxidant into electricity by combining a redox reaction. There are many diffrences between a battery and a fuel cell as in a fuel cell a contiune fuel and oxygen work as a constant source of energy . In batteries, energy generally comes from metals and their ions or oxides which are generally already present in batteries, with the exception of flux batteries[4]. As long as fuel and oxygen are supplied, the cell can generate electricity continuously. Fuel cells are of many types. All fuel cell generally consist of a cathode ,anode and a electrolyte solution .Electrolyte solutions allows hydrogen ions to travel into it[1]. All the fuel cell consist a cathode at which catalyst reacts and they form water and ions .Hereby we are proposing a method by which we can analyze efficiency of a fuel cell and this method known as graphical method of graph theory . Supervisors are believed to be able to determine efficiency gains without requiring a thorough understanding of standard methods for evaluating thermal efficiency. In order to analyze the fuel cell system, the entire system is divided into several subsystems, the dependencies between them are evaluated and a diagram of the system is developed[6].*

Keywords-*FCS,GTA,Matrix,Diagraph,Graph theory,MADM,Fuel cell.*

I-Introduction -In this paper we are going to apply graph theory on a fuel cell system for this purpose we are identifying fuel cell component like anode material cathode material anode catalyst cathode catalyste and electrolyte after identifying these components the whole system will be converted into Diagraph and for these Diagraph will be converted into matrix the parameters to be studied will be placed on the diagonal of the matrix and there effects will be analysed by rest of the matrix elements.There are many types of fuel cells. However, they all work in the same general way. They consist of three adjacent parts: anode, electrolyte and cathode. Two chemical reactions occur at the interface of three different parts. The end result of these two reactions is the consumption of fuel, the production of water or carbon dioxide, and the generation of electrical current that can be used to power electrical equipment, often called a load. The performance of a true time cell system can't be measured by single parameter and also measuring scales for various performance parameters are different. In sight of this, there's a requirement to develop a simplified and accurate methodology for deciding which is capable of simultaneously measuring all performance parameters contained by one scale and leads to the shape of single numerical index[8]. Graph Theory and matrix approach is found to be suitable to develop one composite performance index applicable for cell system. The index have potential to be used for system selection or monitoring the performance of the cell in real time within the new emerging competitive market. Fuel cell may be an upcoming technology and its overall cost is low as compare to standard technology. It's an honest source of energy because it directly converts most of the energy into electricity. A spread of fuel cells

ISSN: 2278-4632
Vol-10 Issue-5 No. 9 May 2020

is available within the market and every sort of cell has different characteristics. Therefore, a Multi Attribute deciding (MADM) technique is required to pick the simplest suitable option out of the available options. In literature variety of techniques are available for analyze different fuel cells and Graph Theoretic Approach (GTA) is one among the approach. The choice of a cell is suffering from some factors which are chosen on the idea of application. Factors are selected on the idea of fuel cell's description and their analysis with GTA is completed by making an appropriate model within the sort of a graph or matrix[10].

II- Architecture Study of fuel cell using graph theory -There are many types of fuel cells like proton exchange fuel cell Molten carbonate fuel cell etc.Every fuel cell consist of 3 main component anode.cathode and electrolyte .After internal reactions in a fuel cell co_2 is formed ,water is formed and fuel is consumed during the reaction.and hence all results into electricity. At the anode side a catalyst will react with fuel generally hydrogen is used as a catalyst element now this catalyst will convert fuel into ions as well as electrons . Now the created electrons will act as free electrons and by the movement of these electrons electricity will generate .Furtehr the created ions will travel towards cathode by using electrolyte . Once it will reach to cathode it will further collide with next ions , normally o_2, to create H_2O or CO2[15].

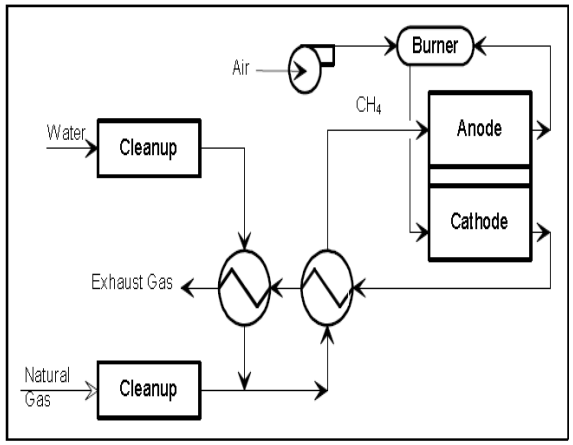


Figure 1(a) Working model of a cell

The design of a cell depends upon many aspects some of the aspects are as given :

The electrolyte material, , it is made up off many substances like potash, salt which are made by carbonates. [19]

Most important is fuel and normally hydrogen is used as a fuel.

Anode is made up of a anode catalyst .Usually platinum is used as anode catalyst which breaks fuel into ions and its components.

Next section is cathode catalyst which is normally nickel and its main use is it separate the waste the waste normally in the form of water .[20]

Gas diffusion layers .Main use of these this it blocks the oxidization.

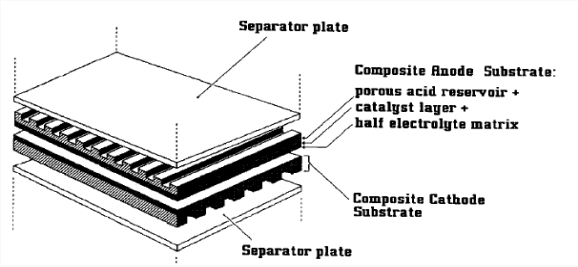


Figure 1(b) fuel cell stack

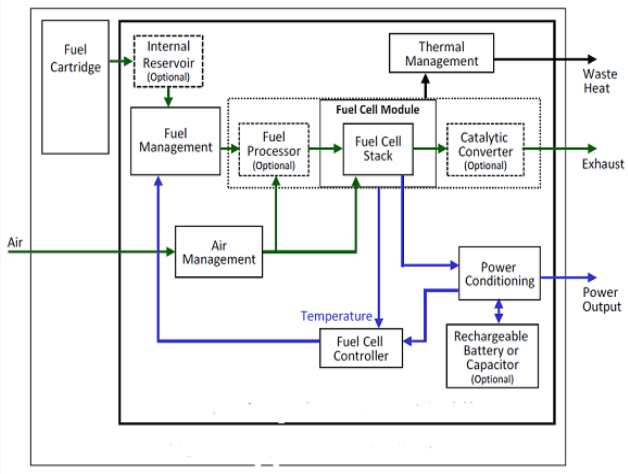


Figure 2 Block diagram of Working of a fuel cell

A solid oxide fuel cell is shown in figure . Fuel is supplied from the fuel tank. Than passing fuel to internal tanks and fuel management systems. Air and fuel mix in fuel cell processors.Fuel is supplied from the fuel tank. Than passing fuel to internal tanks and fuel management systems. Not much air and fuel are mixed in the fuel cell processor. Interlinking fuel cell

ISSN: 2278-4632
Vol-10 Issue-5 No. 9 May 2020

stacks.
Not much air and fuel are mixed in the fuel cell processor. The fuel cell stacks are interconnected. Regulated power gets its output through a power conditioning unit. The power is supplied by a capacitor or battery[2.]

Air management and temperature management play an important role in battery function. Platinum, nickel, perovskite are used as catalysts, but platinum is more preferred. Electrodes are a very important part of a fuel cell. In fuel cell stacks, separators are used to separate the anode and cathode. The catalyst layer, semi-electrolyte matrix and composite anode substrate are sandwiched between two separators.

Overview of graph theory-In graph theory we used a systematic approch by which we can study system and its componets .This method is better than the conventional methods like edge diagram method etc. Graph theory work as a modal which is associated with those system whose performance depend upon other componets .[9].

We use a existing system and its comparison will be done by proposed system and than decision will be taken . A number of the MADM methodologies are discussed below. A true life FCS system is very complex in nature. In present technological analysis its being found appropriate to divide FCS in six subsystems.

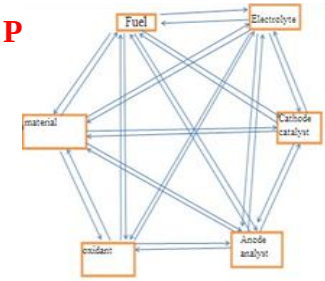
1. Fuel
2. Electrolyte
3. Anode catalyst
4. Cathode catalyst
5. Oxidant
6. Cathode and anode material

All of those six systems are connected to every other directly or indirectly. System structure is to be converted into digraph representation for the Glair is a component of fuel processor and fuel stack while fuel is that the part of fuel processor system. In FCS system single cells are connected serial connection and it'll form a stack. In between two plates cooling plates, membrane electrode assemblies are used. Within the present analysis cell controller, power conditioning unit and thermal management system is attach with cell module . As these subsystems also are very big, so hereafter they're going to be referred as systems. Let each of the six system of cell be represented by vertices Si's (i=1,2,3,4,5,) and

interconnection between two systems (Si, So) is represented by edges can's (imp=1,2,3,4,5,6 and i≠j) connecting the 2 vertices Si and Sj.within the cell system of these six systems are connected by cathode catalyst, anode catalyst, cathode material, anode material, electrolyte and fuel. In the given figure we can see the effects as system is shown by vertex and edges[5].

Graphical and matrix analysis of FCS-A graph in which directional edges are mentioned named as digraph. The digraph permits to analyse FCS performance and provides a sense of interactions between the systems. By using graph theory a graphical model of a system is developed which is known as as attribute graph and then graphical model is converted into matrix model called as attribute matrix. Finally a function is developed by using this matrix which is named variable permanent function VPF'[11].

A.)Matrix depiction-A digraph is such an illustration that's simple to convert into matrix illustration. Matrix illustration of a digraph provides additional elaboration to digraph so as that it represents itself in process form. For a general example with n system can be explained as general example with n system can be explained as- The diagonal elements represent the contribution of systems in FCS. It's referred to as system inheritance. It's totally different completely different} for various systems. The off diagonal parts represent interdependencies of each system with alternative systems. This type of matrix is



ISSN: 2278-4632
Vol-10 Issue-5 No. 9 May 2020

additionally mentioned as variable permanent matrix (VPM).

B.)Complete perform and development

$$\underset{\sim}{E} = \begin{array}{c} \begin{matrix} i & j & k & \cdots & m & n & \text{Systems} \end{matrix} \\ \begin{bmatrix} S_i & c_{ij} & c_{ik} & \cdots & c_{im} & c_{in} \\ c_{ji} & S_j & c_{jk} & \cdots & c_{jm} & c_{jn} \\ c_{ki} & c_{kj} & S_k & \cdots & c_{km} & c_{kn} \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ c_{mi} & c_{mj} & c_{mk} & \cdots & S_m & c_{mn} \\ c_{ni} & c_{nj} & c_{nk} & \cdots & c_{nm} & S_n \end{bmatrix} \begin{matrix} i \\ j \\ k \\ \cdots \\ m \\ n \end{matrix} \end{array}$$

representation-it's declared earlier that GTA is 3 step analysis and permanent perform development and illustration is last step of the tactic . The mixture of letter and matrix illustration is modified by ever-changing the labels of their nodes however the elemental plan of illustration remains the same. Analysis might be endless method and to resolve this issue permanent perform illustration of matrix in 1) inserted. The permanent function development and representation is standardized expansion of matrix function in combinatorial mathematics (Deo, 2007). The representation of stable function and elaboration is obtained within the same way because the determinant representation. during a determinant representation and structural formation where sign appears alternatively due to using Lagrange's expansion whereas during a variable permanent function all the minus signs are replaced by positive signs.

Per Tic -

[S1S2 S3 S4 S5 S6 - c13c31 S2 S4 S5 S6 - c46c64 S1S2 S3 S5

c56 c65 S1S2 S3 S4 - c34 c43 S1S2 S5 S6 - c45c54 S1S2 S3 S6

- S1S2 S3 c45c56 c64 - S1S2 S3 c46 c65c54 - S1S5 S6 c23c34c42

- S4 S5 S6 c12 c23c31 S1S2 c34c43 c56c65 - S2 S6 c13c31 c45c54-S2

S4 c13c31 c56 c65 - S2 S5 c13c31 c46 c64 - S1 c56 c65 c23c34c42

- S2 c13c31 c46 c65c54 - S2 c13c31 c45c56c64

- S4 c56c65 c12c23c31 - S5 c46 c64 c12 c23c31 -

S6 c12 c23c31 c45c54 c12 c23c31 c45c56c64 c12 c23c31 c46 c65c54]

Table2:Assessment values which are depending each other at Diagonal Element

S No.	Conditional values for parameters	Inter dependent values
1	Highly effec tive	5
2	Effective	4
3	Moderate	3
4	Low	2
5	Very low	1

(b). Characteristic System Structure Matrix-The characteristic of FCS can be analysed using a matrix whose Eigen values can be calculated as follows-

B_c= {SI-A_c}

Here I is called as identity matrix and S is the characteristic matrix of a subsystem systems, representing its characteristic structural features. This matrix for system structural graph of FCS is expressed as:

$$B_c = \{SI - A_c\} = \begin{bmatrix} S & -1 & -1 & -1 & -1 & -1 \\ -1 & S & -1 & -1 & -1 & -1 \\ -1 & -1 & S & -1 & -1 & -1 \\ -1 & -1 & -1 & S & -1 & -1 \\ -1 & -1 & -1 & -1 & S & -1 \\ -1 & -1 & -1 & -1 & -1 & S \end{bmatrix}$$

The determinant of characteristic system structure matrix is also called as characteristic system structure polynomial and written as:

ISSN: 2278-4632
Vol-10 Issue-5 No. 9 May 2020

$$\det\{B_C\}=S^6-5S^4+4S^3+4S^2-6S+2$$

Variable Characteristic System Structure Matrix (VCSSM) of FCS-

. Let us also define a diagonal matrix D_c, with its variable diagonal elements S_i (i=1,2,3,4,5,6) representing the characteristic structural feature of six distinct systems. For system structural graph of CCPP (Figure 3.3) the VCSSM $T_c = [D_c - F_c]$ is

Table 1: Assessment factors affecting the fuel cell

$$T_c = [D_c - F_c] = \begin{bmatrix} S_1 & -C_{12} & -C_{13} & -C_{14} & -C_{15} & -C_{16} \\ -C_{21} & S_2 & -C_{23} & -C_{24} & -C_{25} & -C_{26} \\ -C_{31} & -C_{32} & S_3 & -C_{34} & -C_{35} & -C_{36} \\ -C_{41} & -C_{42} & -C_{43} & S_4 & -C_{45} & -C_{46} \\ -C_{51} & -C_{52} & -C_{53} & -C_{54} & S_5 & -C_{56} \\ -C_{61} & -C_{62} & -C_{63} & -C_{64} & -C_{65} & S_6 \end{bmatrix}$$

$$\begin{aligned} Per[T_c] = {} & [S_1S_2S_3S_4S_5S_6 - (c_{13}c_{31})(S_2S_4S_5S_6) - (c_{46}c_{64})(S_1S_2S_3S_5) \\ & - (c_{56}c_{65})(S_1S_2S_3S_4) - (c_{34}c_{43})(S_1S_2S_5S_6) - (c_{45}c_{54})(S_1S_2S_3S_6) \\ & - S_1S_2S_3(c_{45}c_{56}c_{64}) - S_1S_2S_3(c_{46}c_{65}c_{54}) - S_1S_5S_6(c_{23}c_{34}c_{42}) \\ & - S_4S_5S_6(c_{12}c_{23}c_{31}) + S_1S_2(c_{34}c_{43})(c_{56}c_{65}) + S_2S_6(c_{13}c_{31})(c_{45}c_{54}) \\ & + S_2S_4(c_{13}c_{31})(c_{56}c_{65}) + S_2S_5(c_{13}c_{31})(c_{46}c_{64}) + S_1(c_{56}c_{65})(c_{23}c_{34}c_{42}) \\ & + S_2(c_{13}c_{31})(c_{46}c_{65}c_{54}) + S_2(c_{13}c_{31})(c_{45}c_{56}c_{64}) + S_4(c_{56}c_{65})(c_{12}c_{23}c_{31}) \\ & + S_5(c_{46}c_{64})(c_{12}c_{23}c_{31}) + S_6(c_{12}c_{23}c_{31})(c_{45}c_{54}) + (c_{12}c_{23}c_{31})(c_{45}c_{56}c_{64}) \\ & + (c_{12}c_{23}c_{31})(c_{46}c_{65}c_{54})] \end{aligned}$$

Conclusion-

Graph theory and matrix model is employed to calculate efficiency of a cell . For efficiency and performance measurement a way is employed and result's calculated in terms of index .Effect of design parameters on sub-systems is additionally quantified for efficiency analysis. After quantification of inheritance and interdependencies of sub-systems and parameters, efficiency for FCS is obtained to be that's in close approximation to the results available in literature i.e. 80.27% with the similar parameters.Similar analysis is carried for various configurations of cell . Effect of design parameters on cell efficiency is additionally observed by changing the TIT and other design parameters also. Results obtained are in satisfactory similar of the results available in literature. Therefore, it's concluded that GTA are often used for calculating the efficiency of cell . The graph theoretic methodology developed for FCS is extended for the analysis of an in depth loop systems.

Thus, equation (1) may be written for the maximum value of fuel cell performance index as Rmaximum=

S. No.	Analysis of parameters	Value designate
1	Acutely weak	1
2	weak	2
3	Little	3
4	Lower than moderate	4
5	Moderate	5
6	Higher than moderate	6
7	Large	7
8	Huge	8
9	Notable	9

$$\begin{pmatrix} 9 & 4 & 5 & 5 & 3 & 4 \\ 4 & 9 & 4 & 4 & 3 & 2 \\ 5 & 4 & 9 & 3 & 2 & 3 \\ 5 & 4 & 2 & 9 & 2 & 3 \\ 3 & 2 & 3 & 3 & 9 & 4 \\ 3 & 4 & 2 & 3 & 4 & 9 \end{pmatrix}$$

For the minimum value of fuel cell the given equations can be shown as Rminimum=

ISSN: 2278-4632
Vol-10 Issue-5 No. 9 May 2020

$$\begin{pmatrix} 1 & 4 & 5 & 5 & 3 & 4 \\ 4 & 1 & 4 & 4 & 3 & 2 \\ 5 & 4 & 1 & 3 & 2 & 3 \\ 5 & 4 & 2 & 1 & 2 & 3 \\ 3 & 2 & 3 & 3 & 1 & 4 \\ 3 & 4 & 2 & 3 & 4 & 1 \end{pmatrix}$$

$$\text{EfficiencyFCS} = \frac{\text{IndexValue}_{\text{realtimedesign}}}{\text{IndexValue}_{\text{idealcasedesign}}} = \frac{408694}{512281} = 79.77\%$$

REFERENCES

[1]. Sanchit Khurana, Mark LaBarbera, Mark V. Fedkin, Serguei N. Lvov, Harry Abernathy, Kirk Gerdes, "Performance evaluation of a liquid tin anode solid oxide fuel cell operating under hydrogen, argon and coal", Journal of Power Sources vol.-274 pp. 1049-1054, 2015.

[2]. Yongping Hou, Bowen Wang, Zhihua Yang, "A method for evaluating the efficiency of PEM fuel cell engine", journal homepage: www.elsevier.com/locate/apenergy, pp. 1181–1186, 2011.

[3]. Bernt Thorstensen KeraNor AS, Brobekkveien 104A, N-0582 Oslo, Norway, "A parametric study of fuel cell system efficiency under full and part load operation", Journal of Power Sources vol-92 pp.9-16, 2001

[4]. Pere Margalef, Tim Brown, Jacob Brouwer, Scott Samuelsen, "Efficiency of poly-generating high temperature fuel cells", Journal of Power Sources 196 pp. 2055–2060, 2011.

[5]. Richard O. Stroman, Gregory S. Jackson, Yannick Garsany, Karen Swider-Lyons, "A calibrated hydrogen-peroxide direct-borohydride fuel cell model", Journal of Power Sources vol.-271 (2014) pp. 421-430, 2014.

[6]. Sanying Hou, Shijun Liao*, Ziang Xiong, Haobin Zou, Dai Dang, Ruiping Zheng, Ting Shu, Zhenxing Liang, Xiuhua Li, Yingwei Li, "Improvement of proton exchange membrane fuel cell performance in low-humidity conditions by adding hygroscopic agarose powder to the catalyst layer", Journal of Power Sources vol-273 pp. 168-173, 2015.

[7]. Felix Fleischhauer, Raul Bermejo, Robert Danzer, Andreas Mai, Thomas Graule, Jakob Kuebler, "High temperature mechanical properties of zirconia tapes used for electrolyte supported solid oxide fuel cells", Journal of Power Sources vol-273, pp. 237-243, 2015.

[8]. Edison Franco-Junior, Ana Carolina G. Lopes, Hugo B. Suffredini, Paula Homem-de-Mello, "Simple model to study heterogeneous electrocatalysts", Journal of Power Sources vol.-273, 360-367, 2015.

[9]. F. Bresciani*, C. Rabissi, M. Zago, R. Marchesi, A. Casalegno, "On the effect of gas diffusion layers hydrophobicity on direct methanol fuel cell performance and degradation", Journal of Power Sources vol.-273 pp. 680-687, 2015.

[10]. Ramin M.H. Khorasany, Alireza Sadeghi Alavijeh, Erik Kjeang*, G.G. Wang, R.K.N.D. Rajapakse, "Mechanical degradation of fuel cell membranes under fatigue fracture tests", Journal of Power Sources vol.-274 pp.1208-1216, .2015.

[11]. Linstone HA, "Eight basic pitfalls: a checklist, in Linstone, HA and Turoff, M (Eds), The Delphi Method": Techniques and Applications, Addison-Wesley, Reading, MA, 573-81, 1975.

[12]. Kulkarni S, "Graph theory and matrix approach for performance evaluation of TQM in Indian industries", The TQM Magz, 17(6), 509–26, 2005.

[13]. Anbanandam, R.; Banwet, D.K.; Shankar R., "Evaluation of supply chain collaboration: a

ISSN: 2278-4632
Vol-10 Issue-5 No. 9 May 2020

case of apparel retail industry in India", *International Journal of Productivity and Performance Management, 6(2),* 82-98, 2011.

[14]. Andrè, J., Antoni, L., Petit, J-P, "Corrosion resistance of stainless steel bipolar plates in a PEFC environment: A comprehensive study", *International Journal of hydrogen energy*, 35, 3684-3697, 2010.

[15]. Babu, B.J.C, Durai Prabhakaran, R.T., and Lystrup, A, "Modelling of safety factors in the design of GRP composite products", "International Journal of Materials Engineering Innovation", 1(3-4), 350-373, 2010.

