The Feasibility of Linking the Fuel Cells with Public Electrical Grid on the Voltage Level: a Simulation Study

Mahdi A. Abdul-Hussain, Eman Ali Ehsan, Roshen T. Ahmed, Salah M. Ali

Abstract- Fuel cells technology is probably one of the substantial entries in the field of electricity production. Fuel cells becomes one of the important pillars for energy sources in many industrial applications due to the efficiency and low price compare with other energy sources. This paper investigates the effectiveness of connecting the fuel cells with the public electrical grid on the voltage level based on simulation study. Simscape power systems package in MATLAB was utilized to conduct the simulation. An electrical grid model with 30kVA and 4500 fuel cell components were selected from the software library for constructing a virtual hybrid power plant. Subsequently, the voltage level of the grid was examined with the existence/absence of the fuel cells connection. The simulation results shows that the connection of the fuel cells have increased the voltage level with assurance of grid stability. It is concluded that integrating the fuel cells with the future power plant offer a complementary source of power to the public electrical grid.

Keywords: Fuel cells; Public electrical grid; Voltage level; Simulation study.

I. INTRODUCTION

In spite of the decreasing in reserve of coal and fossils energizes the demands for electrical power still in continuous growing [1]. This rising demand for energy is causing more burning of fossil fuels increased global environmental problems such as global warming, climate change and environmental pollution [2]. The fluctuation of oil prices in world markets over the past years has caused the collapse of the global economy and pressure on the national economic security of countries [3]. This instilled the quest for finding another approach to create electric power. At times it is additionally hard to transmit energy to the remote and uneven spots that are far away for the primary producing station [4]. The shift to alternative and renewable energies has become a reality, and many countries are turning to increasing the share of energy generated from renewable sources at the expense of fossil fuels [5].

One of the most important sources of renewable energy is solar energy, which is available for free at most times of the year and around the world. The utilization of this energy provides wide uses in remote areas not reach the national network [6 & 7]. What is defective solar energy is the extreme impact of weather conditions such as humidity [8 & 9], wind [10], and dust [11 & 12] on the performance of solar systems of all kinds [13].

Keeping in mind the end goal to enhance vitality proficiency and power quality issues; the utilization of energy unit (FC) vitality is thought to be an essential asset [14]. At present, power module era is picking up an expanded significance as a sustainable power sources application in light of particular points of interest, for example, effortlessness of designation, high steadfastness, nonappearance of fuel cost, low support and absence of clamor and wear because of the nonattendance of moving parts. Facilitate, no contamination is discharged with FC i.e. 100% ecological neighborly [15].

Fuel cells can be ordered into five unique classes in light of the electrolyte science [16]:

1. Proton exchange membrane fuel cell (PEMFC):
2. Solid oxide fuel cell.
3. Molten carbonate fuel cell.
4. Solid oxide fuel cell phosphoric acid fuel cell.
5. Aqueous alkaline fuel cell.

These sorts of energy components, PEMFCs are quick strong oxide energy unit created as essential source in mobile dispersed era (DG), in light of their high vitality thickness, low working temperature, and firm and basic structure. In this paper, the solid oxide fuel cells are used and the DC voltage output of the fuel cells is utilized alongside the unidirectional lift converter to stay away from unwavering quality decay by stacking 4500 cells in series which gives 1.457x104 volt [17].

The fuel cell module demonstrates utilized as a part of this proposed work is acknowledged in MATLAB and Simulink. An Inverter was used to change over DC yield Voltage to AC; which generates power as a direct current (DC). It requires control transformation units to change over the power from DC to AC. This power could be associated with the dispersion system of a utility grid [18].

There are different applications, where it is important to have the capacity to control stream in both headings between the AC and DC sides. For every one of these cases control molding units are utilized. Control Conditioning Units (PCUs) are characterized for the most part as electronic units that change DC energy to AC control, AC energy to DC control, both bi-directional power electronic converters, or change over DC control at one voltage level to DC control at another voltage level [19].

When utilizing PCUs in Fuel Cell control frameworks, the information energy of the framework shifts ceaselessly with time. Energy components control frameworks can utilize the power molding units for this reason and furthermore to keep the costly electrochemical units, for example, energy component or electrolyze from harm, to venture up voltage for electrochemical units, to transform, to direct, and to wave-shape the yield voltage from all parts [20].

Fuel units have many points of interest over ordinary power producing hardware: high proficiency, low outflows, sitting adaptability, high unwavering quality, low upkeep, magnificent part-stack execution, seclusion, and multi-fuel capacity. Because of their proficiency and ecological favorable circumstances, power module advancements are seen as an alluring 21st century answer for vitality issues [21].

II. THEORETICAL BACKGROUND

A- A GENERAL TOPOLOGY OF THE FUEL CELL INTEGRATION

The fuel cell combination is given by utilizing a unidirectional DC/DC converter (to acquire directed high voltage DC), an inverter and a channel to oblige the DC voltage to the required AC voltage (single or three stages). Two-way dc / dc (double bolt), Figure 2 used as part of the request for charging / discharging for batteries (provided in the request to build a dynamic display security and enhance the stack flow). The transformer converts the one-way unidirectional DC to the power components package. Because of the negative current, the cell coup can occur and damage the power unit stack. The current magnification must be shown by the power module stack because the exchange adapter lift (unidirectional dc / dc transform) is low.

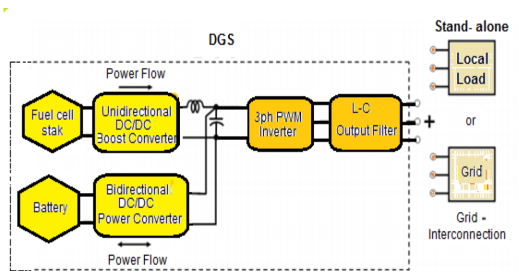

Figure 1 The Two Directional DC/DC Converter (double arrow)

Power unit voltage, battery stand and toponome to DC to DC cause conversion to be chosen differently [16, 17].

In this article, the low DC voltage yield the energy component is utilized alongside the unidirectional lift converter to evade unwavering quality weakening by stacking various arrangement cells. A low voltage battery for reinforcement is associated in parallel with the high voltage side DC transport through a bidirectional buck/support converter since challenges in battery administration probably essentially lessened. Moreover, a detached full-connect direct to direct current DC control converter is helped low yield DC voltage of the energy component since it's a philosophy to reasonable a secondary force requisitions.. In DGS view the battery connected in parallel to the energy component, two applications are promising in industry as delineated in Fig. 1: an independent AC control supply and a lattice interconnection.

B- CONTROL SYSTEM VOLTAGE REGULATION

The inverter output is constant as per set value changing modulation ratio. The control system used is shown below and its principle depend on abc-dq0-abc transformation. Phase terminal voltages Va , Vb , Vc of the inverter are measured permanently.

$$V_d = \frac{2}{3}\left[V_a Sinwt + V_b Sin\left\{wt - \frac{2\pi}{3}\right\} + V_C Sin\left\{wt + \frac{2\pi}{3}\right\}\right] \quad (1)$$

$$V_q = \frac{2}{3}\left[V_a Coswt + V_b Cos\left\{wt - \frac{2\pi}{3}\right\} + V_C Cos\left\{wt + \frac{2\pi}{3}\right\}\right] \quad (2)$$

$$V_0 = \frac{1}{3}\left[V_a + V_b + V_C\right] \quad (3)$$

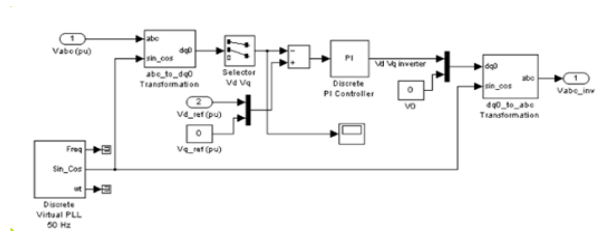

Figure (2): Voltage Controller Schematic Diagram

The base voltage V_{ref} value is 1, which is compared V_d , and V_q is equal with 0. Many error signals are supplied to PI controller, which finally fancied qualities of V_d ,V_q for the inverter. Using dq0 to abc inverse transformation (equation 3-5) three phase signal voltages are generated and these three-phase signal voltages are fed into PWM where they are compared with internally generated triangular signals. The required pulses to trigger IGBTs are produced.

$$V_a = \left[V_d Sinwt + V_q Coswt + V_0\right] \quad (4)$$

$$V_b = \left[V_d Sin\left\{wt - \frac{2\pi}{3}\right\} + V_q Cos\left\{wt - \frac{2\pi}{3}\right\} + V_0\right] \quad (5)$$

$$V_C = \left[V_d Sin\left\{wt + \frac{2\pi}{3}\right\} + V_q Cos\left\{wt + \frac{2\pi}{3}\right\} + V_0\right] \quad (6)$$

C- FUEL CELL MODEL

The modeling of the solid oxide fuel cells $1.457^{x}10^{4}$ volt is developed. Applying Nerrnst s equation and Ohms Low to consider ohmic misfortunes, the stack yield Voltage is repressed by the accompanying expression:

$$V_0 = N_0\left[E_0 + \frac{RT}{2F}\left(\ln\frac{P_{H2}P_{02}^{0.5}}{P_{H_2O}}\right)\right] - rI \quad (7)$$

Where E : reaction voltage free energy (V)

R : gas constant (J/kmol-K)

r : stack ohmic losses (Ω)

III. METHODOLOGY

A- *FUEL CELLS CONFIGURATION*

A regular arrangement of a self-ruling energy unit framework is depicted in Figure (1). As appeared, the energy component plans comprise of many principle parts: Quantity of repairs, and power molding unit (PCU). The PCU is utilized to change over DC yield Voltage to AC which produces control as an immediate current. It requires control transformation units to change over the power from DC to AC. This power could be associated with the transmission and appropriation system of an utility lattice. There are different applications, where it is important to have the capacity to control stream in both headings between the AC and DC sides. For every one of these cases control molding units are utilized. Control molding unit are characterized by and large as electronic units that change DC energy to AC power [17].

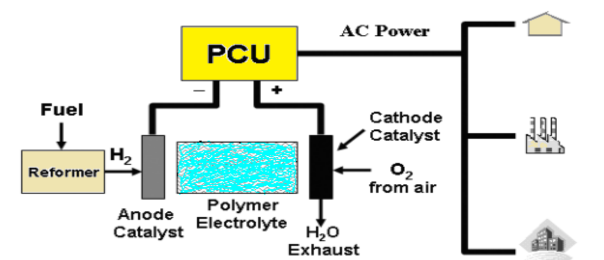

Figure (3): Configuration of the Fuel Cell System

B- *POWER CONDITIONING MODELING UNIT*

Power Conditioning unit is utilized to change over DC yield Voltage to AC. which produce control as an immediate current (DC), require control change units to change over the power from DC to AC. This power could be associated with the transmission and dissemination system of an utility framework. There are different applications, where it is important to have the capacity to control stream in both headings between the AC and DC sides. For every one of these cases control molding units are utilized. Control molding unit are characterized for the most part as electronic units that change DC energy to AC control.

A converter is typically Placed between power module and inverter, Similarly as. appeared in Figure 4. The DC-DC converter apply two capacities i.e. it goes about as the DC confinement for the inverter that produces adequate input voltage for the inverter so that the required extent of the alternating voltage can be created. The inverter can be either single-stage or three-stage contingent upon the utility association [4].

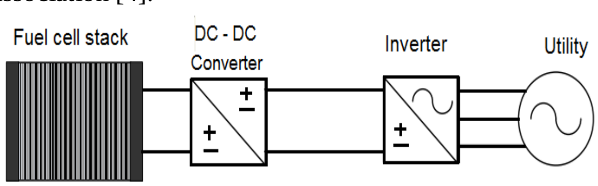

Figure (4): Cascaded Fuel Cell DC-DC and DC-AC Inverter

A power molding framework for an energy component with a DC-DC/DC-AC inverter can be developed with a blend of the converters examined over A case of an energy component framework with power hardware interfacing into a three-stage utility framework appeared in Figure (5) where a detached DC-DC connect converter and a three-stage hard exchanging voltage-source inverter are utilized.

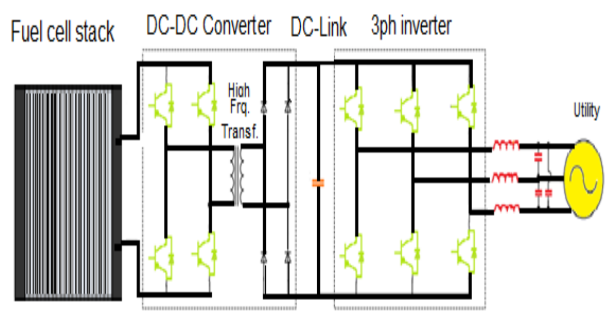

Figure (5): Cascaded DC-DC/DC-AC Converter Topology

IV. RESULTS AND DISCUSSION

After successful implementation of solid oxide fuel cells, many such units are connected together to form a fuel cells stack. Based upon such integration the investigated fuel cell stack system distribution at the 3 phase breaker as shown in Fig (6) 4500 cells potential of each one 1.457v are integrated into the medium (33kv) voltage grid [20], the PCU containing energy converters that change low voltage DC starting to a high voltage DC or potentially an alternating alternate AC, This sort can work persistently the length of the essential reactant and oxidant streams are kept up and it has higher vitality stockpiling ability.

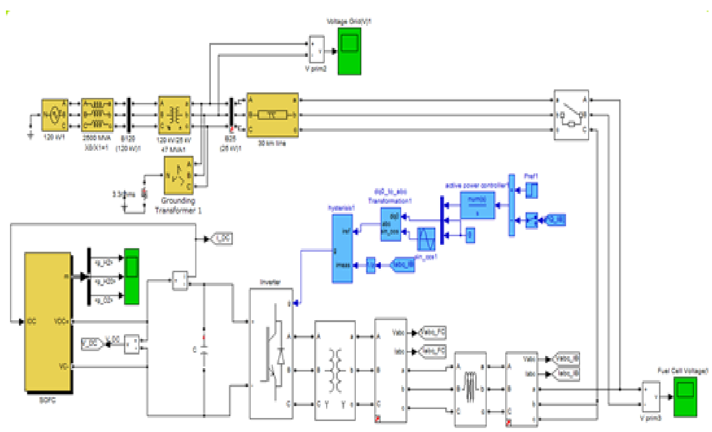

Figure (6): Integrated into the Medium Voltage Grid (4500 cells potential)

Figure (6) shows a 4500 cells potential of each one 1.2V are integrated into the medium voltage grid and in Fig. (7) Shows the voltage produced from the grid without Fuel Cell system [21, 22].

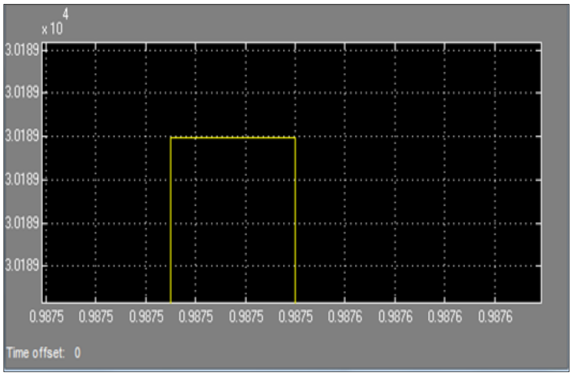

Figure (7): Voltage pattern grid without Fuel Cell System

The figure above show the voltage of the grid without connecting the fuel cell system, therefore; the voltage curve show a constant results which is about V=30.189 kV. On the other hand; when the simulation was done for the fuel cell system only, the voltage curve showed a result which is about V=14.57 as presented in Figure (8) bellow.

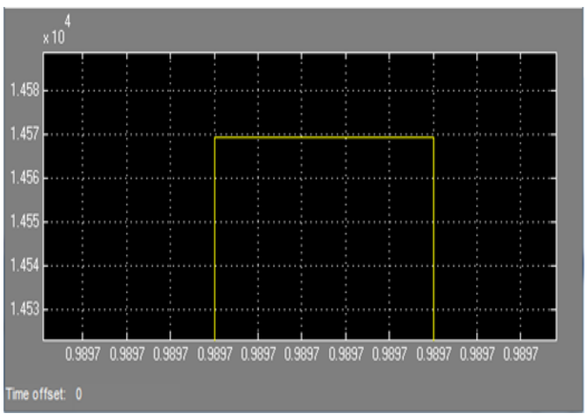

Figure (8): The performance of Fuel Cell Voltage level of 4500 cells in series

Accordingly, another simulation have been tried by connected the Fuel Cells system together with the grid; the voltage curve show a clear increasing which was about V=35.33kV as shown in Figure (9) bellow [23].

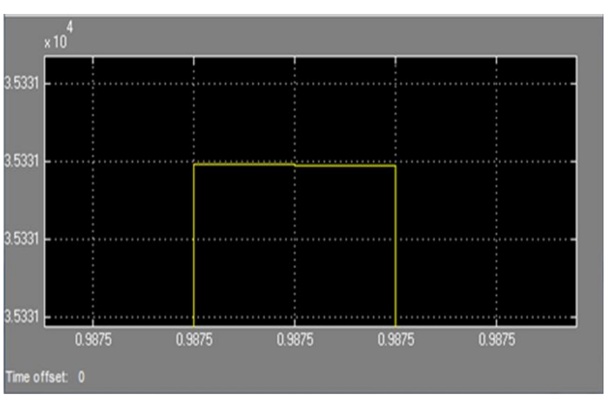

Figure (9): The voltage pattern of the grid with Fuel Cell System

Previous simulation explain impacting of the fuel cell system on the grid voltage improving by increase the voltage when use renewable energy which can give advantages to the grid especially in the stability of the grid when the load increasing so we can protect the grid voltage from being dropped.

V. CONCLUSION

Reproduction comes about demonstrated beneficial outcome of energy components framework on voltage quality when the power devices were associated with an electrical dispersion open lattice. Likewise its can restrain the variety of the state factors voltage and recurrence decides the nature of the electrical network and additionally controls the voltage plunges cause by the sudden association and disengagement of the substantial load in the medium voltage framework. Fuel cell have many favorable circumstances over ordinary power producing hardware: high effectiveness, low outflows, siting adaptability, high unwavering quality, low upkeep, phenomenal part-stack execution, seclusion, and multi-fuel ability. Due to their proficiency and ecological focal points, power device advancements are seen as an appealing 21st century answer for vitality issues [24]. Another preferred standpoint can be added with respect to the system solidness which is demonstrate an astounding expanding when energy unit framework utilized as in the medium voltage matrix. The outcomes demonstrate that the association of the cells with dispersion voltage lattice has been increment the system strength and enhance the voltage level for clients and power providers. Amid such changes, framework strength can be safeguarded through extra dynamic and receptive power commitment. It is imperative to research whether energy units could add to enhance framework condition through reproduction techniques. It implies that immediate association of the power devices can prompt matrix strength.

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Biography

Dr. Mahdi Ali Abdul-Hussain is a lecturer working now as a researcher in Energy and Renewable Energies Technology Center in university of technology, his PhD. is in Electrical engineering from University of Damascus,Syria,(https://scholar.google.com/citations?hl=en&user=0pimbYEAAAAJ).

Mrs. Eman Ali Ehsan is a Lecturer working now as a researcher in Energy and Renewable Energies Technology Center in university of technology, her BSc. and MSc. is in Chemical engineering from University of technology, Baghdad/IRAQ. (https://scholar.google.com/citations?hl=en&user=0Cr5ll8AAAAJ).

Roshen Tariq Ahmed is an Assistance Lecturer working now as a researcher in Energy and Renewable Energies Technology Center in university of technology, he received his BSc. and MSc. is in Control engineering from University of technology, Baghdad/IRAQ. (https://scholar.google.com/citations?hl=en&user=LX4U6nQAAAAJ).

Dr. Salah M. Ali is currently working as a research fellow in the Institute of Noise and Vibration, University Technology Malaysia, Kuala Lumpur, Malaysia. He received his BSc. degree from University of Technology, Baghdad (2006), followed by MSc. (2009) and PhD (2016) in Mechanical Engineering from Malaya University and University Technology Malaysia respectively. His current research interests include Machinery Condition Monitoring & Fault Diagnosis, Vibration, Acoustic Emission, Signal Processing, Artificial Intelligence and Machine Learning.