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Electricity Generation by using a Hybrid System (Photovoltaic and Fuel Cell)

[1]Haider Ahmed Mohmmed, [2]Othman M. Hussein Anssari and [3]Layth Mohammed Abd Ali
[1]College of Engineering (COE), University of Kufa, Najaf, Iraq
[2]Information Technology Research and Development Centre (ITRDC), University of Kufa, Najaf, Iraq
[3]Quality Control Laboratory (LQC), University of Kufa, Najaf, Iraq

Abstract: In this study, present a modeling and administrative control for fuel cell with a solar cell as a hybrid power system. The design includes using Photovoltaic (PV) and Ultra-Capacitor (UC) with a Fuel Cell (FC) system is a possible solution to provide sufficient power supplies for residential areas there after reducing the accumulated losses from power transfers to these places. Operations of four modes for the proposed hybrid system are defined for the proposed supervisory control and each model for the PV, FC and UC are developed. The proposed hybrid power system is simulated and analyzed based upon the modeling and the supervisory control algorithm in MATLAB/Simulink environment.

Key words: Hybrid system, Photovoltaic (PV), Fuel Cell (FC), Ultra-Capacitor (UC), renewable energy, supervisory control

INTRODUCTION

Human continues investment in all forms of energy to provide him with the bulk of his energy needs. Where the need for them is enormous as a result of the use of technology (Electrical appliances) to meet daily needs. Energy is produced using fossil fuels in most countries it is an in accessible substance (non-renewable energy). Therefore, alternative sources of energy (renewable energy) have been sought. Non-renewable energy sources are extracted from the Earth (fossil) such as oil, gas, coal, etc., renewable energy sources are on several types including (Valenciaga *et al*., 2001):

- Solar energy
- Wind energy
- Water resources
- Tidal energy
- Biofuel energy

Finding alternatives from the earliest concerns of countries as to the energy of great importance in daily life the following are some differences between renewable and non-renewable energy. Energy generation from non-renewable sources almost by water heating and converting it into steam by burning oil, gas or coal. The process is inefficient as its efficiency varies between 35-80%. Energy generation from renewable sources (Generation of energy from Sun raise, wind or water sources) the process is efficient while the efficiency ratio is between 60-85% (Uzunoglu and Alam, 2006) (Table 1).

Table 1: Difference between renewable or non-renewable energy

Non-renewable energy	Renewable energy
Their sources are decreasing	Their sources are not decreasing
Production costs are high	Production costs are less
Working period is comparatively less	Working period is comparatively more
Engineering cadres, specialized technicians are comparatively more	Engineering cadres, specialized technicians are comparatively less
Almost large areas to build stations are needed	Almost large areas to build stations are not needed
Lower efficiency	Higher efficiency
Harmful to environment	Friendly to environment

MATERIALS AND METHODS

Solar energy: One of the most important sources of renewable energy is solar energy it is clean and environmentally friendly. Solar energy is the exploitation of the rays and heat that are emitted from interactions in the Sun. The radiation and heat are comes from Sun to the Earth through space and then distributed to different places, concentrated more on areas close to the equator (Kim *et al*., 2008).

Solar energy works by absorbing solar panels into sunlight-most of the optical spectrum in addition to ultraviolet and infrared radiation and converting it into electrical energy. When photons collide with a solar cell the atoms lose their electrons in a mechanism called photovoltaic effect. Solar panels consist of many cells these cells are made of semi conductors such as silicon it is designed in 2 layers positive and negative layers which is known as electric field.

The solar inverter takes the current from the solar system and turns it into an alternating current. Solar reflectors have captured solar energy industries

Corresponding Author: Haider Ahmed Mohmmed, College of Engineering (COE), University of Kufa, Najaf, Iraq

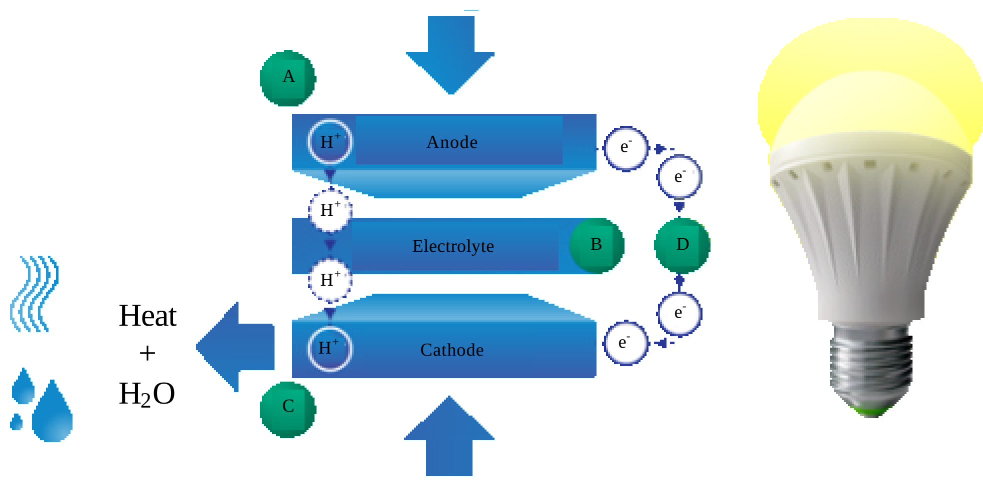

Fig. 1: Fuel cells combine the hydrogen and oxygen elements to produce electricity

(Zhou *et al*., 2007). When installing solar panels in homes, the Sun shines on these panels and then these panels turn the sunlight into a constant current this current flows into the inverter which in turn converts electricity from DC-AC, electricity can then be used in homes (Rajashekara, 2005).

Solar energy technologies: Solar energy technologies are used to produce electricity, heat, light, hot water and heating and cooling processes. There are a variety of technologies developed such as (Abd and Haider, 2018; Thounthong *et al*., 2006).

- Photovoltaic power systems
- Solar water heating systems
- Solar electric systems
- Passive solar heating systems and daytime lighting
- Solar systems for heating and cooling

Fuel cell: The reliance on fossil fuels has long been considered dangerous because of persistent and serious environmental problems as well as other disadvantages. The search for alternative sources of energy (especially, alternative to oil) such as the using of solar energy to generate electricity using of tidal energies and sea waves can be used as kinetic energies in electrical energy using fallen water from water falls to generate electricity and replace many alternative energy sources with conventional fuels (Abd and Issa, 2018).

These alternative sources cannot be applied in most countries depending on specific geographical or climatic conditions. In countries where clouds are abundant it is not possible to rely on solar energy and countries that are not near the sea cannot rely on the energy of tides, fuel cells provide a solution and are a good alternative in the future (Andersen *et al*., 2002). The fuel used in these cells is hydrogen, natural gas or methanol with the usage of oxygen or air, fuel cells are a picture of the process of converting chemical energy stored in hydrocarbons into direct electrical energy (Fig. 1).

Fuel cells combine the hydrogen and oxygen elements to produce electricity which the cell receives from an external source (not a component of the fuel cell itself) which gives these cells importance compared to batteries which distinguishes fuel cells from conventional batteries (Ansari *et al*., 2018). Components of conventional batteries are the basis of power generation where the chemical reaction of the components of the battery to produce electricity and this process continues until the end of the chemicals reacting, the battery stops until it is re-energized, fuel cells are constantly operating because their fuel, hydrogen and oxygen come from external sources. Fuel cells are flat chips each producing a single voltage. This means that the more chips used more voltage (Hamelin *et al*., 2001).

Fuel cell work: The fuel cell is a tool to convert chemical energy into electrical energy which through chemical reactions, converts hydrogen and oxygen into water. This process produces electrical energy. The idea of the fuel cells working depends on the transfer of hydrogen atoms from the anode to the oxygen atoms in the cathode and as they pass and interact an electric current is generated and the reaction is the water (Fig. 2).

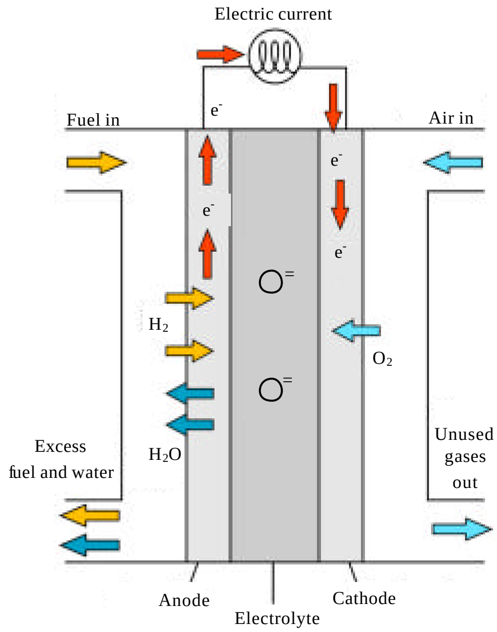

Fig. 2: Fuel cell work

Cathode area: The oxygen is pushed to the cathode and passes through the catalyst which splits the oxygen atom into negative ion (Abd and Issa, 2014).

Anode area: The hydrogen atoms are compressed and pushed to the fuel cell by the anode. When the hydrogen enters the anode it passes through the catalyst. This catalyst splits the hydrogen atom into an ion of positive hydrogen, resulting in 2 electrons. These electrons are the cause of electric power generation and then the circuit completes its path as positive hydrogen ions rush to the negative charge of the oxygen ions to unite and form the water (BPS., 2019). The single cell of fuel cells produces approximately 0.7 V, more than one cell is connected, respectively, to obtain the required voltage value. Applications of fuel cells:

- Automotive field
- Electronics field
- Generation of electricity

RESULTS AND DISCUSSION

Figure 3 shows which the max loads changing from 8-8.4 kW with 14 sec as cutting period. In this case, we conclude max. load near to 11 kW and the photovoltaic system is accessible in 24 h with Sun rays. The peak interval of the demand conclude 80 sec while that request load 8.5 kW. The peak power of FC system and

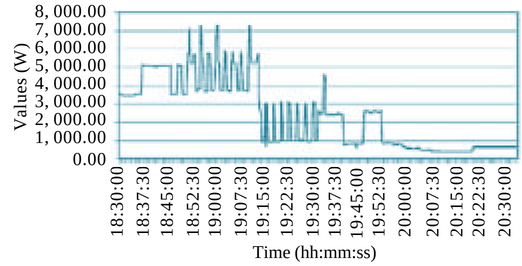

Fig. 3: The 2600-ft 2 real power

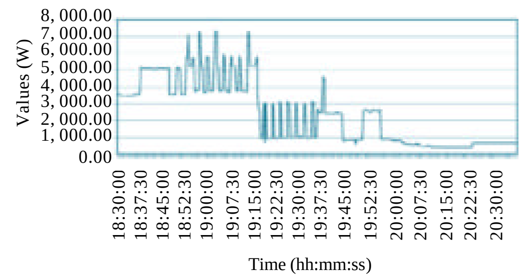

Fig. 4: The current of fuel cell and voltage down variations of load

the photovoltaic system. The energy can stock 0.6 *90*75^2/3600 = 84.375 Wh that can keep the energy ranking of the additional capacitor 70 Wh if use FC system with additional capacitor don't need bidirectional converter, 16 additional capacitor (total 2800/15 = 186.67) are required duo to 38/2.5 V = 15.2. With meet the additional load required 70.7 Wh, at min. About 216 additional capacitor in parallel and add more capacitor are anticipated due to 16 additional capacitor in series could stock 0.6*180*3662/3600 = 38.88 Wh and 35 additional capacitor can achieving just 65.8 Wh little than max. power required 70 in this case.

The Simulink is achievement an Ballard 6 kW FC stack MKS-E composed of 35 cell. evry cell has 233 cm' energetic area (Abd and Issa, 2014). The current and voltage, the more important parameters it use for similarity. The load with change between 0 and 150 a imposed on the PGS-105B system which the data are indicated. The load details shown in Fig. 4 which the resistance was change between 0.118-4.16 through the Simulink interval in Fig. 5 shown voltage reduces to 26 V if just FC worked. the current can be increased because of reduce in voltage over the inner resistor for the FC. Figure 6 shown that administrative control doesn't allow to reduce voltage in a hybrid system of FC below 35 V. Particularly utilizing uni-directional converter will recompense the reducing voltage in FC and enhances efficiency in the system without utilizing the converter.

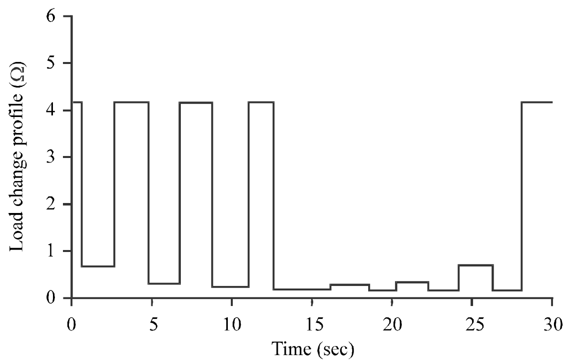

Fig. 5: Variation of load profile

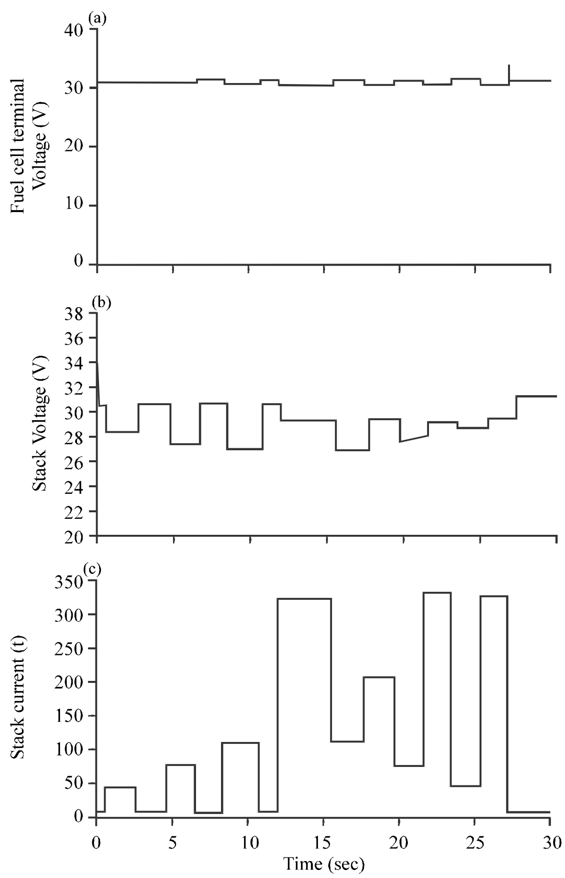

Fig. 6: Current and voltage of fuel cell power system: a) Voltage with the bi-directional converter; b) Voltage without the bidirectional converter and c) Current

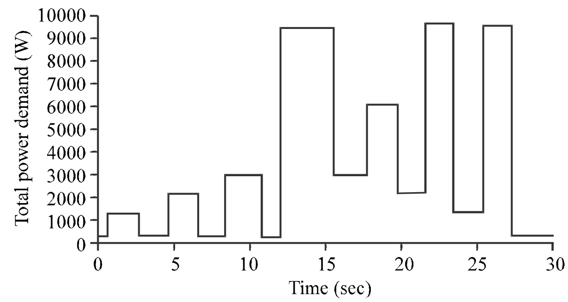

Fig. 7: Sum power required

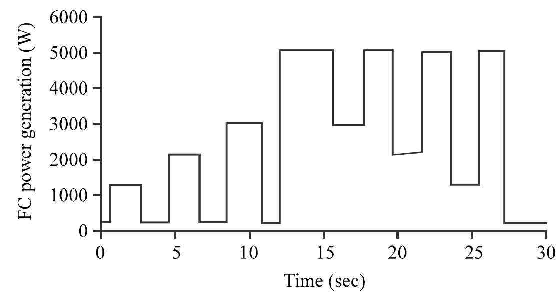

Fig. 8: Power obstetrics of fuel cell

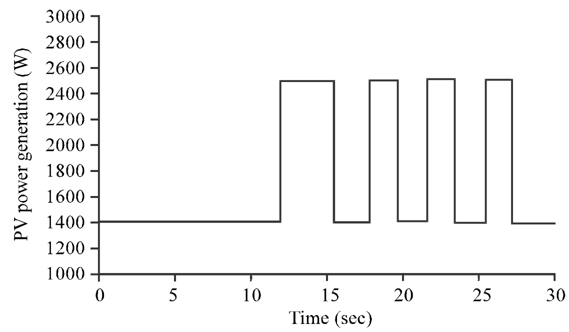

Fig. 9: Photovoltaic power obstetrics

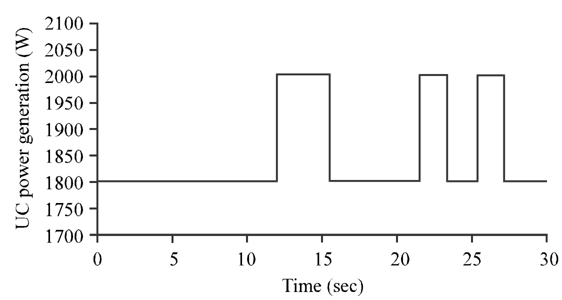

Fig. 10: Ultra-capacitor power obstetrics

Figure 7 and 8 represent the load outlines as the current over 310 A and the power requirement is 10 kW because of the reducing voltage.

Figure 9 shows that the ultra-capacitor design can close up residual 2.6 kW if the required power ambit 7.8-10 kW whenever the utmost load power is 9.6 kW. Figure 10 shows the upmost value 2.1 kW of ultra-capacitor design sufficient to equipped the required power. Figure 11 shows the voltage of ultra-capacitor.

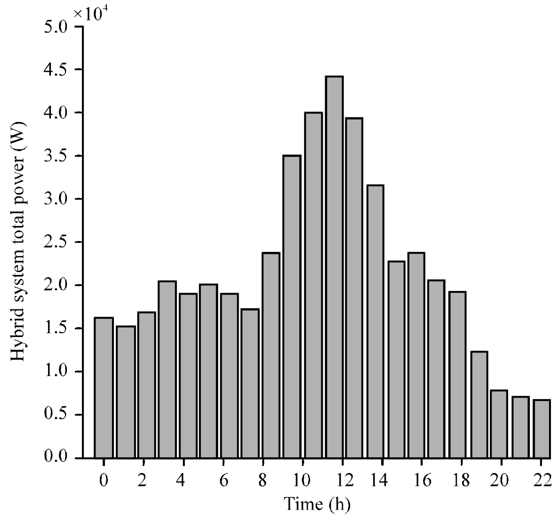

Fig. 11: The voltage of ultra-capacitor

CONCLUSION

A modeling and supervisory control for a proposed hybrid power system are presented in this study which includes from a FC system, PV system and an ultra-capacitor for stand-alone stationary power applications. During MATLAB/Simulink simulation and results comparison, shows that the proposed hybrid system with the supervisory control improves the dynamic response of the fuel cell system as well as significantly compensate the voltage drop of the FC system due to the load changes reducing the ultra-capacitor size of the system. The proposed supervisory control strategy of the PEM fuel cell system, the PV system and the UC system together, paves a way to supply safe electricity for independent residential areas by alternative energy.

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