# ENERGY MANAGEMENT SYSTEM FOR A REMOTE RENEWABLE FUEL CELL SYSTEM

## PROJECT REPORT

**Submitted in partial fulfilment of the Requirements for the degree of**

**BACHELOR OF TECHNOLOGY**

**IN**

**ELECTRICAL AND ELECTRONICS ENGINEERING**

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**SRI VENKATESWARA UNIVERSITY COLLEGE OF ENGINEERING**
**TIRUPATI**
**2018-2022**

**SRI VENKATESWARA UNIVERSITY COLLEGE OF ENGINEERING**

**DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING**

# CERTIFICATE

This is to certify that the project entitled "**ENERGY MANAGEMENT SYSTEM FOR A REMOTE RENEWABLEFUEL CELL SYSTEM**" has been carried out under my supervision in the **Department of Electrical and electronics Engineering**, **Sri Venkateswara University College of Engineering.**

The work is comprehensive, complete and fit for evaluation carried out in partial fulfilment of the requirements for the award of **Bachelor of Technology** in **Electrical and electronics Engineering** during the academic year 2021-22.

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## BONAFIDE CERTIFICATE

This project bonified work titled i.e. "**ENERGY MANAGEMENT SYSTEM FOR A REMOTE RENEWABLEFUEL CELL SYSTEM** " was carried out by our project member under the guidance of

**Shri. M. Vijaya Kumar Naik** Faculty in Electrical and Electronics Engineering.

This is done to the best of my knowledge. The work reported here in does not form part of any other project report or dissertation on the basis of which degree or award was conferred on an earlier occasion or any other candidate.

We do not copy from any other sources for the implementation of this project and to make this project report.

# ACKNOWLEDGMENT

I would like to express my profound gratitude to my esteemed guide **Shri. M. Vijaya Kumar Naik** Faculty, Department of electrical and electronics engineering, Sri Venkateswara University college of engineering Tirupati , for this valuable advice and inspiring guidance for successful completion of this work

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My profound thanks to **Prof. T. Gowri Manohar**, **Head of the Department for Electrical and Electronics Engineering** S.V.U College of Engineering for his assistance in completion of work.

# CONTENT

# ABSTRACT

This study proposes an energy management algorithm for a renewable fuel cell system aiming to maintain the balance between the supply and the demand of a remote community load. In most cases, such communities receive power from off-grid systems due to their location as opposed to main electric utilities. For years diesel generators have been the favourite power source for these places, however, the trend is now on the use of renewable off-grid systems. Different renewable off- grid systems can be considered depending upon the available renewable resources.

However, all of them required energy storage facilities to deal with the unpredictable nature of their outputs power. This paper focuses on a system including a PV array, an electrolyser, a hydrogen tank and a Proton exchange membrane (PEM) fuel cell.

The objective is to develop an energy management system to reduce power losses and to maintain the balance between the supply and the demand depending on the availability of power.

Matlab/Simulink software is used to model and simulate the system. The scenario presented in this study shows that the proposed energy management algorithm permits to balance the share of energy between the PV array and the fuel cell to the load.

# INTRODUCTION

Power utilities in several countries are established around large centralised power plants using either fossil fuels or nuclear reactants as the principal source of energy. These units are generally situated far from cities and involve transmission and distribution systems to convey power to the consumers. Alternative solutions need to be proposed to allow energy access to remote areas. In Africa for instance, such areas are usually subjected to severe poverty and little development activities [1].

Islanded or off-grid systems are the most cost-effective solutions as opposed to the grid extension. These systems can provide power for different applications in these areas including houses, community services, water pumping and purification systems, telecommunications, etc.

In a typical islanded power system, the electricity can be provided either from a single or multiple source which can be renewable for instance wind turbine, photovoltaic panels, and micro hydro, fuel cell, etc. or non-renewable. In some countries, diesel generators are the favourite types for remote areas power supply. However, these technologies can impose economic and social problems on the local population. Furthermore, diesel engines in general, are the major contributors of greenhouse gas emissions

Furthermore, these technologies can provide benefits for remote areas ranging from energy access and security, and socioeconomic development, on top of creating opportunities for jobs creation, and contributing in reducing poverty.

Renewable islanded power systems are classified in three topologies based on the energy technology. These are topologies are:

- single energy technology power system,
- hybrid power system,
- single technology power system with energy storage system

Of the three topologies, renewable single energy technology power system is the less reliable system due to the intermittent nature of renewable generators. Deploying renewable hybrid configuration can enhance the system flexibility as the power supply is based on two or more sources. Adding an energy storage technology to the system can further increases the reliability of the system [3]. Different hybrid energy systems can be considered depending upon the available renewable resources.

This paper focuses on a system including a PV array, an electrolyser, a hydrogen tank and a Proton exchange membrane (PEM) fuel cell.

Generall y, in such configuration, the PV unit operates as the primary source to supply power to the load and any excess is used to produce hydrogen via the electrolyser. This hydrogen is then stored into a tank and used to generate power through the PEM fuel cell whenever the PV array generate less or zero power to meet the load demand.

The challenging side when integrating different energy sources is how to control each of them. This is achieved through an energy management strategy. The most common strategies use rule, filtration and fuzzy logic approaches. Reported energy management algorithms focus on aspects such as preventing the battery from deep discharge, reducing the peak power demand, charging/discharging cycle and dynamic stress level of battery, minimizing operational cost of a system, maintaining stable DC voltage, frequency regulation, reducing the loss of power supply possibility, reducing the operation and maintenance cost and improving the system efficiency

# LITERATURE SURVEY

| S.NO | Author,Year | Journal | Title of paper | Inference drawn |
|---|---|---|---|---|
| **1.** | C. Wang, S. Member, M. H. Nehrir, and S. Member 2008 | IEEE | "Power Management of a Stand-Alone Wind / Photovoltaic / Fuel Cell Energy System," | This paper proposes an AC-linked hybrid wind/photovoltaic (PV)/fuel cell (FC) alternative energy system for stand-alone applications. Wind and PV are the primary power sources of the system, and an FC-electrolyzer combination is used as a backup and a long-term storage system. An overall power management strategy is designed for the proposed system to manage power flows among the different energy sources and the storage unit in the system. |
| **2.** | S. N. M, O. Tremblay, M. Ieee, L. Dessaint, and S. M. Ieee 2009 | IEEE Access | "A Generic Fuel Cell Model for the Simulation of Fuel Cell Vehicles," | This paper presents a novel approach to fuel cell modeling. The model is developed with the objective to facilitate the simulation of fuel cell power systems and requires only few variables from manufacturer datasheets. The user would need to extract data from the datasheet in order to perform the simulation and does not need to perform experimental tests on a real stack. |
| **3.** | Raji, A.K., Kahn 2013 | IEEE Transcation Of industry | Can Fuel Cell Systems be efficient and effective as domestic distributed generation units? | Access to sustainable energy and its affordability are key indicators of better standard of living. The economics of extending grid electricity to low density rural areas of South Africa forbid such undertaking. Platinum group metals (PGMs) are the key catalytic materials used in most fuel cells, and with more than 75% of the world's known platinum reserves found within South African borders, there is great potential for socio-economic benefits to be obtained from these natural resources. |
| **4.** | Longe, OM, Ouahada, K, Ferreira, HC.: Chinnappen S. 2014 | IEEE | Renewable energy sources microgrid design for rural area in South Africa. | Approximately 1.4 billion people around the world lack access to electricity, of which 85% are rural dwellers, mostly living in Sub-Saharan Africa. In South Africa, 55% of rural dwellers lack access to electricity. The Umhlabuyalingana Local Municipality is the least electrified municipality in the country with an electrification rate of 20%. It is therefore taken as a case study. |

# PROBLEM IDENTIFICATION

Power utilities in several countries are established around large centralized power plants using either fossil fuels or nuclear reactants as the principal source of energy. These units are generally situated far from cities and involve transmission and distribution systems to convey power to the consumers.

In a typical islanded power system, the electricity can be provided either from a single or multiple source which can be renewable for instance wind turbine, photovoltaic panels, and micro hydro, fuel cell, etc. or non-renewable. In some countries, diesel generators are the favorite types for remote areas power supply. However, these technologies can impose economic and social problems on the local population.

Diesel engines in general, are the major contributors of greenhouse gas emissions.

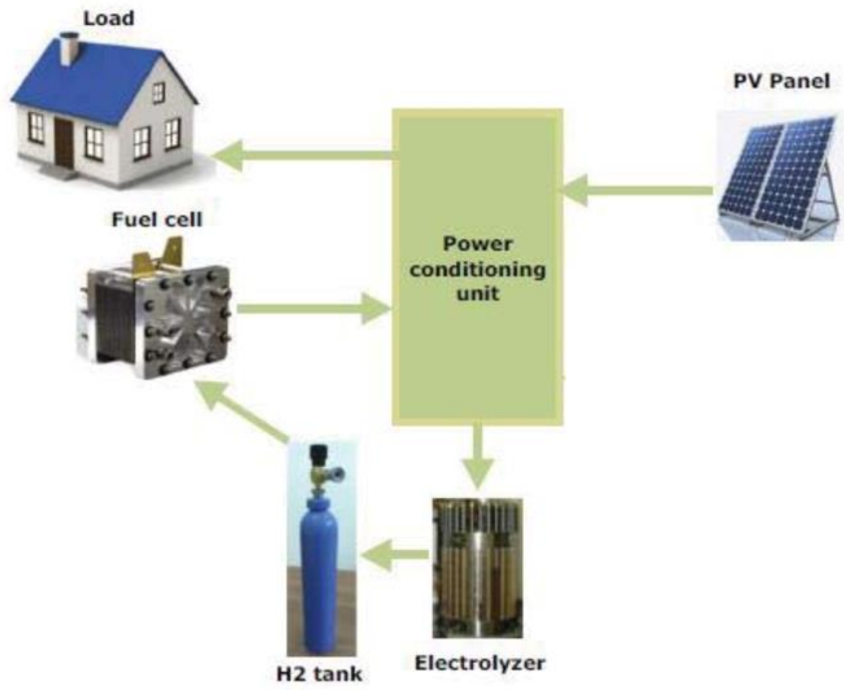
Renewable single energy technology power system is the less reliable system due to the intermittent nature of renewable generators

# PROPOSED METHODOLOGY

In this method, the focus is on maintaining the balance between the supply and the demand of a remote renewable fuel cell system. Matlab/Simulink software is used to model and simulate the system.

## System description:

A layout of a renewable fuel cell system is shown in Fig 1; the system includes components such as photovoltaic array, a fuel cell stack and an electrolyser, a hydrogen tank and power conditioning and management unit. The role of power management unit is to enable the coordination between the different energy sources involved.




The system operates such that depending on the available solar resources, the PV generate power to meet the load and produce hydrogen through the electrolyser.

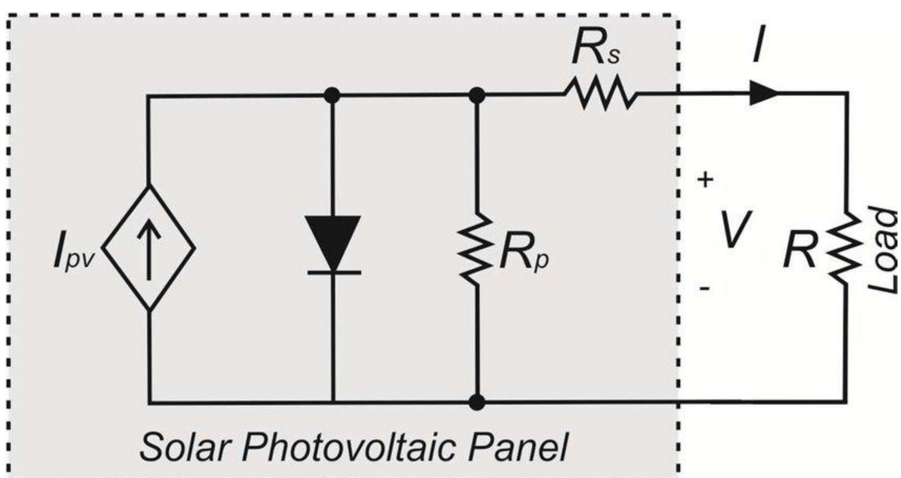
The produced hydrogen is then stored into a tank and used whenever needed. The load considered in this study is of a community building situated in a remote area.

The PV system is designed to meet the 1.056 kW load demand of the community facility (9.6 Ω suppled at 110 V), as well as provides 3 kW for hydrogen production.

## System modelling:

### *Photovoltaic system:*

Photovoltaic system is built around photovoltaic cells, the most used cell model is based on a one diode model depicted in the equivalent circuit in Fig.




This circuit consists of a photon represented by a current source and a p-n junction represented by an anti-parallel diode in parallel with a shunt and series internal resistances $R_S$ and $R_P$. The parameters in the equivalent circuit are defined as follows:

Series resistance $R_S$ express the losses caused by the electrical contact and the resistivity of the cell materiel, the shunt resistance $R_p$ is related to the losses generated by the p-n junction, Diode current $I_D$ is the current in the diode when it is directly polarised, photovoltaic current $I_{Ph}$ is the current generated by the solar cell due to the sunlight incidence into it., Output current I is the existing current at the terminals of the solar cell.

## Fuel cell :

The type of fuel cell selected in this study is a PEMFC (proton exchange membrane fuel cell) which is the most used and most available fuel cell in the market [5]. The model adopted in this study is an electrical model including both the dynamic and the steady state behaviour of a PEMFC.

## Electrolyser :

Hydrogen can be produced in different ways, some of the methods used involve removal of hydrogen from hydrocarbons and the production from the steam reforming of natural gas. Hydrogen can also be produced through electrolysis of water. In such a case, the electrolyser is the machine used for the conversion.

## Hydrogen storage tank :

Hydrogen can be stored using different methods, the most common storage approaches of storing hydrogen include compressed hydrogen storage, liquid hydrogen storage, and metal hybrid storage

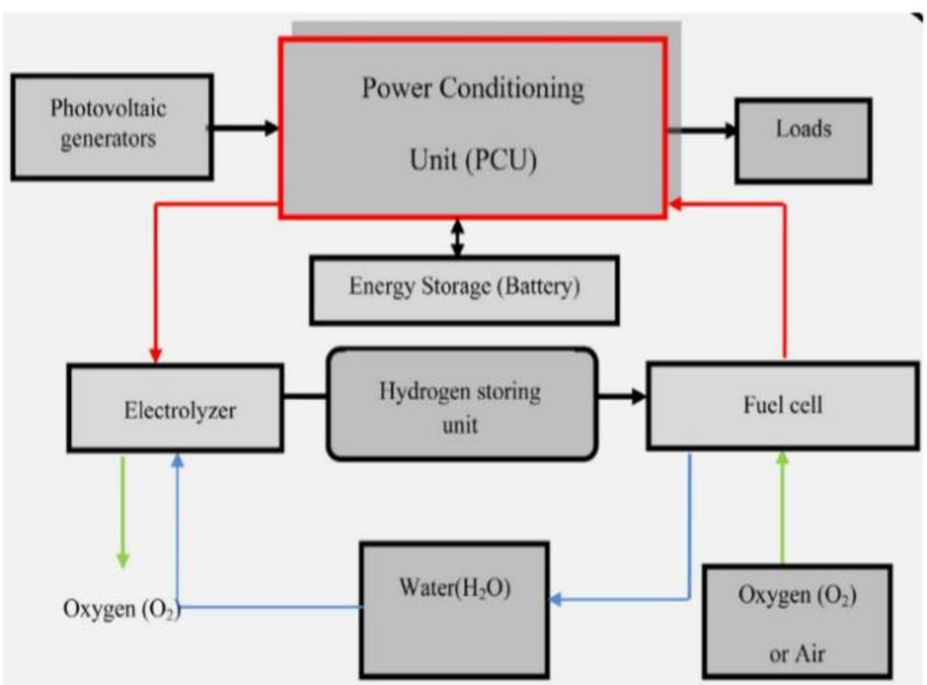
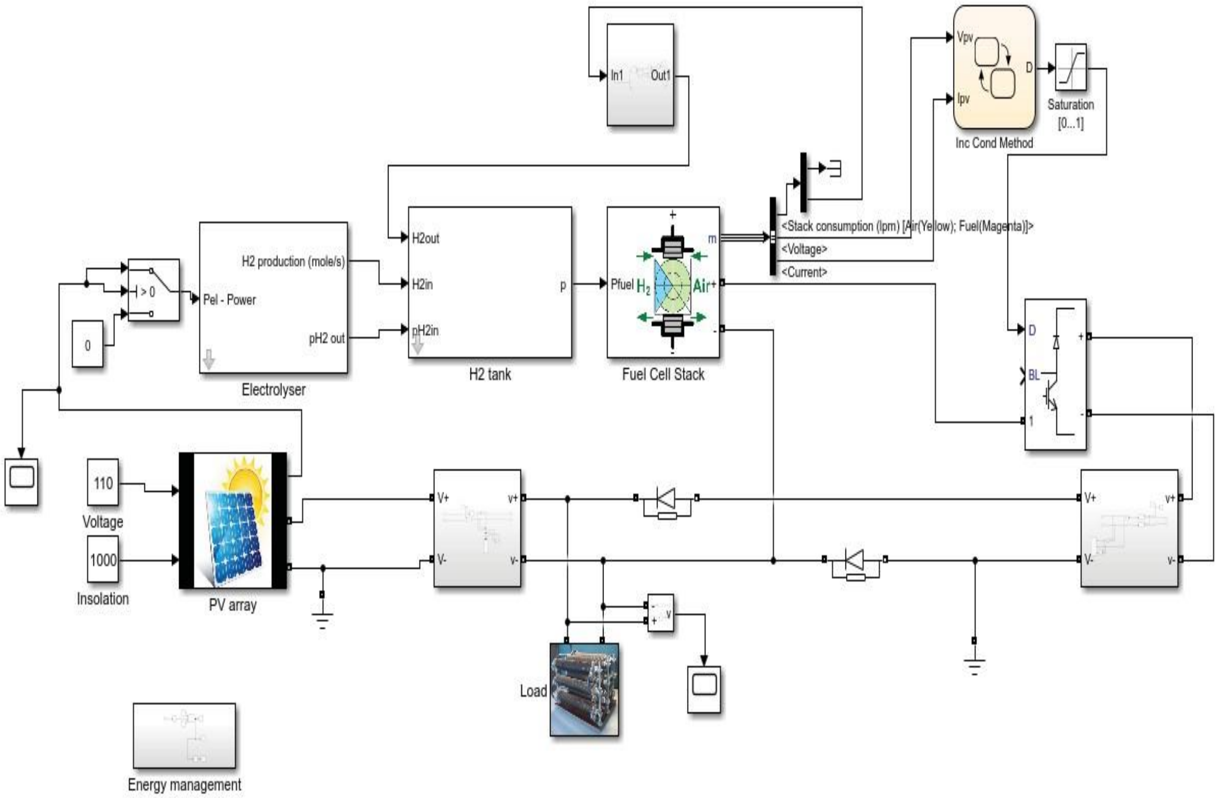



**Fig. Renewable fuel cell system layout**

**Simulink model:**




## SCOPE FOR FUTURE DEVELOPMENT

The purpose of the DG system is to supply power to its local load in addition to the grid power/ transfer the surplus power to the utility grid.

To generate high quality power, the current that DG transfers to the grid should be balanced, sinusoidal and have low THD.

Because of the grid voltage distortion and nonlinear local load that exists in power system

A model of grid connected DG system is developed. In this model ,first consider VSI of the DG is modeled as a voltage source(Vi) and the

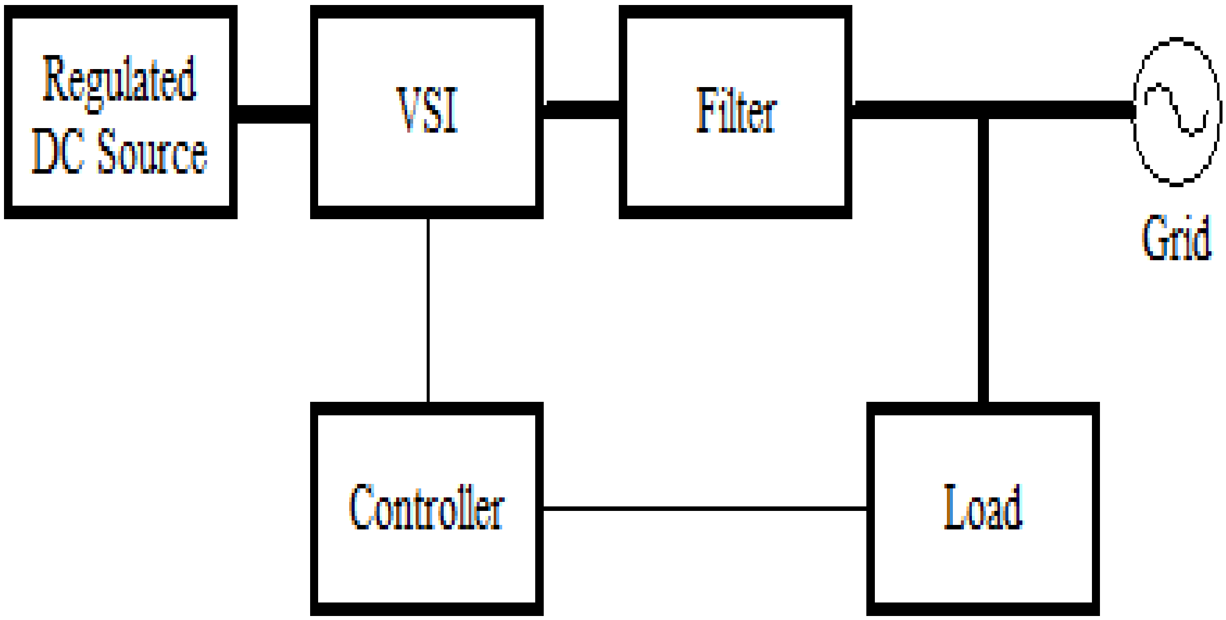



**Fig.Schematic diagram of grid connected system**

inverter transfer a grid current $I_g$ to the utility grid(Vg) with local load(no load condition)to load.

The system consists of a DC source, voltage source inverter (VSI), an output LC filter, local load and utility grid

## ADVANTAGES

**Benefits of implementing renewable fuel cell systems**:

- **Effectiveness**: temperature represents an important parameter that dictates the efficiency of a heat engine. Fuel cells do not involve any combustion process and thus are free from such Type of limitation. For this reason, these are highly efficient with respect to combustion Engines.

- **Pollutions free:** fuel cells do not pollute our environment because they do not generate any Contaminants. They produce water and heat as a by-product, which can be used for other Purposes.

- **Simplicity:** fuel cells are very simple, reliable, and noiseless because their functioning is Independent of any moving parts. They have long life, which can be as large as 40,000h.
  Furthermore, these can be stacked in modular form to match any power requirement.

- **Providing Combined Heat and Power CHP:**

  CHP is defined as the generation of heat and power from a single fuel cell with the Perspective of using both commodities [20]. Taking advantage of the fact that fuel cells generate heat alongside electricity. Heat can be recovered and use for Heating Ventilation and Air Conditioning (HVAC) equipment, knowing that this equipment is one of the major consumers of electricity

- Improving public health and environmental quality

- Creating jobs and other economic benefits

- Better power factor

- Reliability

- Continous power supply for the load

# CONCLUSION

Renewable generators based on solar and wind are generally characterized by intermittent power outputs. In the context of islanded micro grids, these generators caused unbalance and inefficient system operation. In such a case, ab backup power source is often used to overcome these issues.

This study proposed an energy management strategy for an energy system composed of a PV array and fuel cell system to meet the load demand of a community building located in a remote area. The objective was to develop a control strategy to maintain the balance between the supply and the demand.

The scenario presented in this study shows that the proposed energy management algorithm permits to balance the share of energy between the PV array and the fuel cell to the load. Further research will focus on increasing the system complexity and using intelligent methods for energy management algorithm development.

# REFERENCES

[1] M. Gopaul, “the Significance of Rural Areas in South Africa for Tourism,” no. November, pp. 1–143, 2006.

[2] A. Boute, “Off-grid renewable energy in remote Arctic areas: An analysis of the Russian Far East,” Renew. Sustain. Energy Rev., vol. 59, pp. 1029–1037, 2016.

[3] D. N. Luta and A. K. Raji, “Potential benefits of renewable fuel cell systems for rural communities’ power supply,” in 2nd EAI International Conference for Research, Innovation and Development for Africa, 2017.

[4] D. N. Luta and A. K. Raji, “Optimal sizing of hybrid fuel cellsupercapacitor storage system for off-grid renewable applications,” Energy, vol. 166, pp. 530–540, 2018.

[5] S. O. Amrouche, D. Rekioua, and T. Rekioua, “Overview of energy storage in renewable energy systems,” in 2015 3rd International Renewable and Sustainable Energy Conference (IRSEC), 2015, pp. 1–6.

[6] A. K. Raji and M. T. E. Kahn, “Can Fuel Cell Systems Be Efficient and Effective As Domestic Distributed Generation Units ?,” in Domestic Use of Energy Conference (DUE), 2003.

[7] S. N. M, O. Tremblay, M. Ieee, L. Dessaint, and S. M. Ieee, “A Generic Fuel Cell Model for the Simulation of Fuel Cell Vehicles,”