

Technical and Economical Analysis of Power Management System for Electric and Hydrogen Vehicles Charging Station Using Solar Powered, Hydrogen and Fuel Cell Technology

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Abstract--- For a Hydrogen and Electric vehicles, a novel power management system (PMS) charging station using diesel energy battery bank (BB), conversion system (DECS) and photovoltaic (PV) with hydrogen unit(HYG) and fuel cell unit(FC) is proposed in this project. Proposed PMS system's control objectives of are: (i) to ensure battery management based on irradiance condition of PV as well as Diesel generation capacity, Hydrogen level and Fuel cell capacity, (ii) to decrease system's power loss (high efficient) (iii) to enhance the system reliability and power quality. In this project, we proposed the power management and stability improvement of a Electrical Vehicle connected system with a large-scale Diesel generator (DG)-photovoltaic (PV) and Fuel cell (FC) with hydrogen unit, an energy-storage unit based on battery is implemented. For hydrogen and electric vehicles, off-grid charging system is designed by this project. At same time, it is possible to charge, hydrogen and electric vehicles. On charging station, they appears like two hydrogen and electrical load demand. Solar panels are used to power charging station. An additional converter unit is implemented using bidirectional buck boost converter for battery, hydrogen and fuel cell unit used. With respect to grid's reliability enhancement, minimization of loss, sharing of load, management of battery, for operating conditions, better operational performance is exhibited by proposed PMS method. MATLAB/SIMULINK environment is used for simulating proposed system.

Keywords--- DECS, HYG, PV, FC, PMS, MATLAB.

I. INTRODUCTION

In this project, we proposed the power management and stability improvement of a Electrical Vehicle connected system with a large-scale Diesel generator (DG)-photovoltaic (PV) and Fuel cell (FC) with hydrogen unit ,an energy-storage unit based on battery is implemented. In this project, power charging station for EV & HV through PV, diesel generator, batteries and fuel cell as well electrolyser with hydrogen storage tank system is controlled by a proposed and a new control method and selected combined topology.

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For resources like fuel cells, hydrogen storage, biomass, hydro, solar and wind, various applications are developed in addition to renewable energy resources (RES's) development. To power vehicle charging stations, buildings, homes, electric grid, these applications can be used. For RES's various applications like gas production, water desalinations and water production are defined. Powering of electric vehicles charging station is RES's interesting application.

Other types of RES's wind turbine and solar panels are used for powering electric vehicles charging station. RES's is converted as hydrogen in charging station and stored. Fuel-cell electric vehicles consumes this stored hydrogen. Energy storage systems are used in charging stations in order to support it. In vehicles, homes and networks, a new as well as interesting energy called renewable hydrogen can be used.

For modern societies and cities, major requirements corresponds to a hydrogen and electric vehicle's charging station development and design. Electricity is obtained by converting hydrogen in hydrogen fuel cell vehicles by using onboard fuel cell. In order to deal with issues of traditional vehicle's environment pollution and energy storage, fuel cell vehicles can be used. With zero emission, proper torque and power can be produced by a fuel cell vehicle. In future, it can be used as promising feature of cars. In vehicles, hybrid system's efficiency and lifecycle can be enhanced by using a fuel cell having super capacitor and battery.

Various points must be considered while designing, developing and deploying charging stations. Points may include, drive comfort, facilities of charging, capacity and location. Over recent decade, more attention is attracted by charging station deployment and design. In various point of view like optimum planning, grid capacity of vehicle, charging station's optimum location are addressed.

There may be an off-grid or grid tied operation of charging station. Electrical network is connected to a charging station in grid-tied operation and from grid it receives power. Solar panels and wind turbines are additional power producers, which are included in charging stations. Charging stations connected to grid are supplied by these generating systems. Above mentioned generating system or grid power are used by charging station. Technical or Economic conditions dictates the operation pattern. On operation of electric network in grid tied, impact is made by charging station. There is a need to model and consider these impacts.

Electrical utility grid is not connected with off-grid charging stations. Wind-solar systems with energy storage systems are distributed energy resources, which are used for powering them. Important issue corresponds to an off-grid charging stations operation and design. Further investigation is required by this. There is no proper modelling and investigation of off-grid charging stations.

Charging station for off-grid hydrogen and electric vehicles are set up and designed by proposed optimum algorithm. There are two loads in proposed charging station. They are hydrogen and electrical load demand. Solar system is used for powering charging station. Solar systems output power is divided into two classes. Electrical vehicles are charged by one class and hydrogen vehicles are charged by another class. Water electrolyzer is used for converting solar power into hydrogen. Hydrogen vehicles are supplied by this.

In hydrogen storage system, in a reservoir, stored surplus hydrogen. If solar energy is not available, electrical demand is supplied by diesel generator in charging station. In charging station, fuel cell runs on hydrogen is added. Under unavailability and intermittency of solar energy, electric load is supplied by a electricity produced by a fuel cell. Diesel generator and fuel cell's optimum operation is used to deal and include uncertainty parameters. On solar system, cost of diesel generator and solar system investment is minimized by proposed model. Diesel generator's cost of operation is also minimized by this.

II. LITERATURE SURVEY

In 2018, David Martinez and Ramon Zamora., an alkaline electrolyser which is directly coupled with photovoltaic module is implemented using a MATLAB/Simulink/Sims cape in this work. Meteorological average daily irradiance and temperature data for a typical summer and winter day in Auckland, New Zealand, is used in a 15-hour simulation duration to show characteristic responses of the system. In addition to the steady state output, boundary conditions are applied to the referenced mathematical models to include the transient performance, governed by the photovoltaic module internal parameters. The simulation results show that the steady state output of the proposed implementation matches the general response of similar systems reported in previous published papers. Overall electrolyser efficiency of 68.48% for summer and 63.32% for winter is in accordance with results from the referenced studies.

In 2018, Eunji Yoo,et,al., In Korea, for fuel-cell electric vehicle (FCEV), various H₂ production pathways well-to-wheel greenhouse gas analysis results, collection data and methods are provided by this study. Coke oven gas purification, electrolysis, steam methane reforming and naphtha cracking. 32,571 to 249,332 g-CO₂ eq./GJ or 50.7 to 388.0 g-CO₂ eq./km are the results of FCEV's well-to-wheel (WTW) greenhouse gas emissions based on pathway of H₂ production. Landfill gas can be used by carbon credit. Due to this, low value of GHG emission is produced by landfill gas (on-site) pathway. Power generation process of Korean grid mix (on-site) pathway with electrolysis has high emission factor. Due to this, its GHG emission is high. In Korea, other power train vehicles like electric vehicle (EV), hybrid electric vehicle (HEV) and internal combustion engine vehicle (ICEV) are used to compare results.

In 2017, Yousef Allahvirdizadeh, Mustafa Mohamadian, Mahmoud-Reza HaghiFam, In developing countries, major concern includes electrification of remote (or rural) area . In a remote area, for a standalone micro grid, various energy control methods are investigated in detail by this paper. Primary energy source of micro grid corresponds to a solar energy. In order to enhance load reliability and to avoid energy lack, a backup system that comprises a fuel-cell stack is hybridized by considering PV system's stochastic nature. For energy storage, alternative is formed by a electrolyzer with integrated super capacitor and battery bank.

If maximum state of charge is reached by battery bank, PV system's surplus production of energy is absorbed by electrolyzer. Deep discharge and overcharging of battery bank is avoided by fuel cell system refueling by stored hydrogen that satisfies average demand shortage. Energy control methods with high response time is studied mainly in this paper. Life span of storage units, energy sources, super-capacitor or battery SOC, efficiency of micro grid, dynamic performance, consumption of fuel, flow of energy are controlled by this.PI-type fuzzy logic control

method, external energy maximization method, equivalent consumption minimization method, ANFIS-based control method, rule-based fuzzy logic control method, state machine control method are included in this.

Rule-based fuzzy logic control and state machine control methods are designed by an effective method. During various battery SOCs, it's investigated energy control methods performances. It also presented, all methods, comparison of performance and results of simulation under various conditions of operation. For assessment, battery (bank) state of charge, fuel (and the fuel-cell) efficiency and fuel consumption factors are used.

In 2017, Sanae Dahbi et, al., Implementation of diversified control algorithms on an architecture built platform is proceed by autgiirs. Systems are supervised by this designed algorithms. Two energy sources are used to supply alternative load. They are national electric grid and photovoltaic (PV). Main source corresponds to a photovoltaic (PV) and emergency source corresponds to a national electric grid. For hydrogen as clean storage production, en electrolysis, DC/AC inverter and DC/DC converters are used by authors. Control algorithm is in-built in every converter. Optimum production of hydrogen, guarantees specific control accompanied by electrolysis. In order to supply alternative RL load, conventional control method pulse width modulation is used to control DC/AC inverter.

In 2017, Ghada Boukettaya et al., A worldwide supervisory procedure for a smaller scale matrix control age framework that contains wind and photovoltaic age subsystems, a flywheel stockpiling framework, and residential burdens associated both to the cross breed control generators and to the lattice, is created in this paper. The targets of the boss control are, right off the bat, to fulfill much of the time the heap control request and, furthermore, to check stockpiling and lattice imperatives to forestall power outage, to diminish vitality expenses and ozone harming substance outflows, and to expand the life of the flywheel. For these reasons, the boss decides online the activity method of the diverse age subsystems, changing from most extreme power transformation to control guideline. Choice criteria for the chief dependent on real factors are exhibited. At long last, the exhibition of the chief is broadly surveyed through PC reproduction utilizing a thorough nonlinear model of the contemplated framework.

In 2016, W. Kellogg et al., Investigated network connected system or stand-alone system by utilizing photovoltaic (PV) or hybrid wind power generation system. In Montana, for a hypothetical site, stand-alone system is constructed by combining battery storage with generation of PV and wind power. In order to minimize customer's total annual cost and for meeting annual load, there must be a proper sized storage and generation unit of hybrid system. In Northwestern US, for a typical residential home, hourly load demand is used for numerical study which is used to compute optimum solutions. It uses, data of solar radiation and hourly speed of wind.

In 2016, Hamidreza Ghoddami et al., An integrated wind-photovoltaic-battery hybrid system is proposed by this paper. Simple power management method is a major feature of it. Minimum number of power-electronic convertors only required by this. Need of dump load is eliminated by this. When compared with three stand-alone system set, with distribution network, easy integration is enabled by this and it offers a highly effective and low cost system.

Following are enabled by proposed hybrid system with power management method. For tight regulation of batter current, power outputs of photovoltaic (PV) and wind are controlled rapidly. Black-start capability in off-grid operation. Operation in connected grid. Transition from off grid to grid connected mode can be done in a safety

manner. It does not require host grid communication. Power sharing and plug and play capabilities are exhibited by this. For multi-generator remote electrification systems, it can be used. In PSCAD/EMTDC software environment, simulation in tie domain, demonstrates the proposed hybrid system's effectiveness.

III. PROPOSED MODULE

3.1 Proposed Topology & Its Principle

- Design and operation of a PMS for a EV and HV charging station connected with PV-DG-HU-FC unit is proposed.
- A Control loop has been used for the power management of the EV and HV connected system. The control loop estimates the available power at the sources and a target a power savings at different hours of the day.
- System's electricity cost minimization is the power management method's major goal. At same time system stability is also analyzed.

3.1.1. Existing System Drawbacks

The available system exhibits drawbacks such as

- Imbalance power.
- Power demand.
- Power flow management is not monitored.
- System Performance Reduced.
- Less Efficiency.

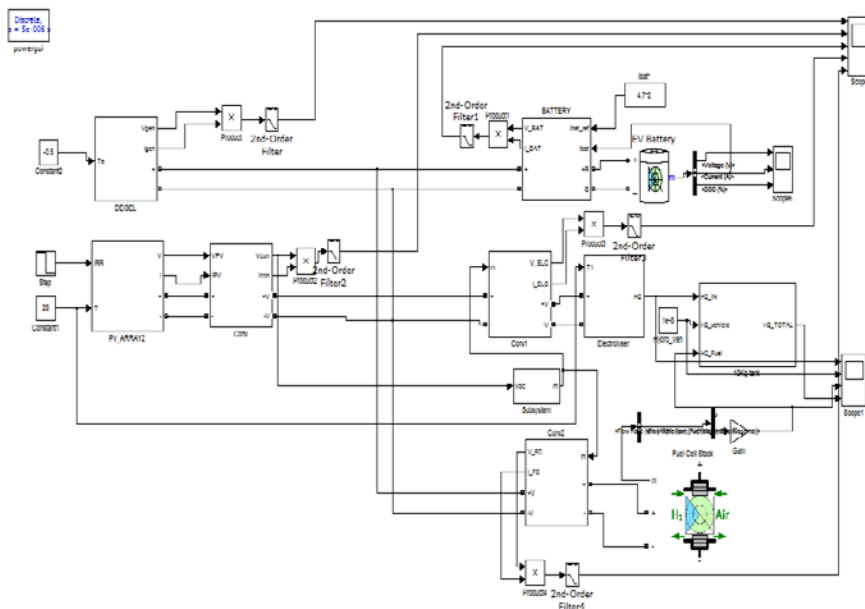


Figure 3.1: Proposed System's block diagram

3.2 Description of Proposed System's Block Diagram

- At same time, for hydrogen and electric vehicles, optimum off-grid charging station can be designed.

- At same time, hydrogen and electric vehicles, diesel generator, fuel cell, water electrolyzer, storage system of hydrogen, solar panels optimum cooperation can be achieved.
- For charging station, optimum proper solar power is designed. Hydrogen storage system is utilized in an optimum way in order to smooth solar energy uncertainty. It includes, fuel cell, hydrogen storage and water electrolyzer.
- Under emergency condition, demand is supplied by fuel cell and diesel generator's optimum operation.
- Under uncertainty of parameters like power consumption of hydrogen and electric vehicles, solar energy, it is possible to achieve and optimize, all above mentioned items.

3.2.1 Proposed System Advantages

- Power flow management is controlled.
- Cost of design is low.
- System Performance improved.
- Overall Stability improved.
- Overall Efficiency of the system improved.

IV. SIMULATION RESULTS

4.1 About MATLAB

MATLAB R2011a is a software of user friendly. Project simulation can be done using this. For programming, visualization, numerical computation, it is used as interactive environment and it is high level language. It possible to create applications and models, develop an algorithm, analyze a data using MATLAB. Various mechanisms can be explored by in-built math functions, tools and languages. When compared with conventional programming languages including C/C++ or Java™ and spreadsheets, solution is attained in a fast way. In computational biology, computational finance, measurement and test, control systems, video and image processing, signal processing, and in array of applications, MATLAB is used.

In academia and industry, MATLAB is used by billions of scientist and engineers. It is a language used for technical computing. Multi domain dynamic systems can be analyzed, simulated, modelled using a programming language tool called Simulink. It is data flow graphical programming language. A graphical block diagramming tool, is a basic primary interface of it. Block libraries are set up by this which may be customized. With remaining environment of MATLAB, stronger integration is provided by this. Scripted or MATLAB is run by it. For Model based design and multi domain simulation, in digital signal processing and control theory, Simulink is more frequently used.

4.1.1 Simulink

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For dynamic system simulation and modelling, solvers, customizable block libraries and graphical editors are yielded by Simulink. With MATLAB®, Simulink can be combined. Various MATLAB algorithms can be incorporated into model by this combination. For more analysis, results of simulation can be exported to MATLAB. Figure 4.1 shows the Simulation Diagram of PMSG based Current Control Structure with MATRIX Converter & SVPWM.

4.2. Simulation Diagram of Proposed Method

Figure 4.1 illustrates the simulation diagram of PV-PMSG-battery-hydrogen tank-fuel cell energy system for EV & HV charging station.

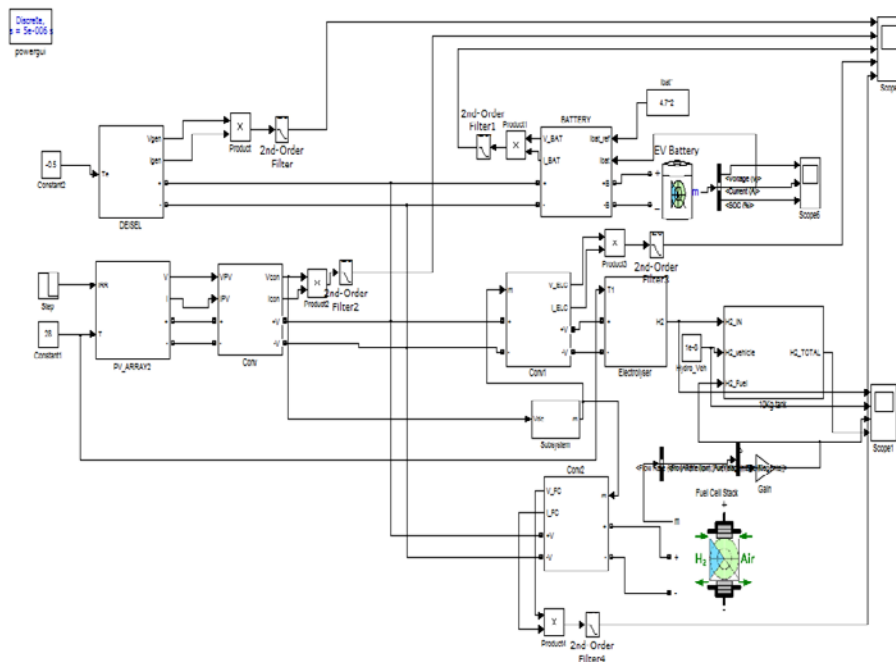


Figure 4.1 Simulation Diagram of PV-PMSG-Battery-Hydrogen Tank-Fuel Cell Energy System for EV & HV Charging Station

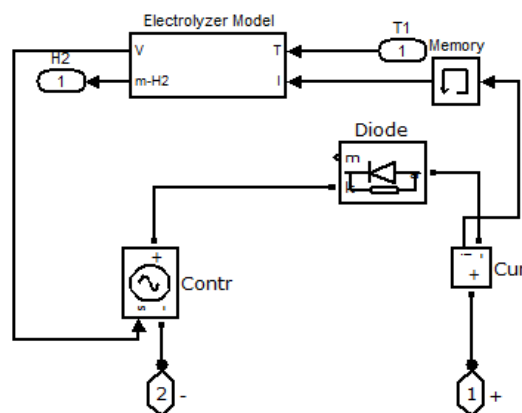


Figure 4.2 Simulation Diagram of Electrolyzer Model

There are hydrogen loading (hydrogen vehicles), electric loading (electric vehicles), diesel generator, hydrogen storage, water electrolyzer (hydrogen generation), solar system in charging station.

Two design variable set is designed by mathematical model. For diesel generator and solar system, optimum rated power is designed using first part. For hydrogen storage, fuel cell, diesel generator, optimum operation pattern is computed using second part.

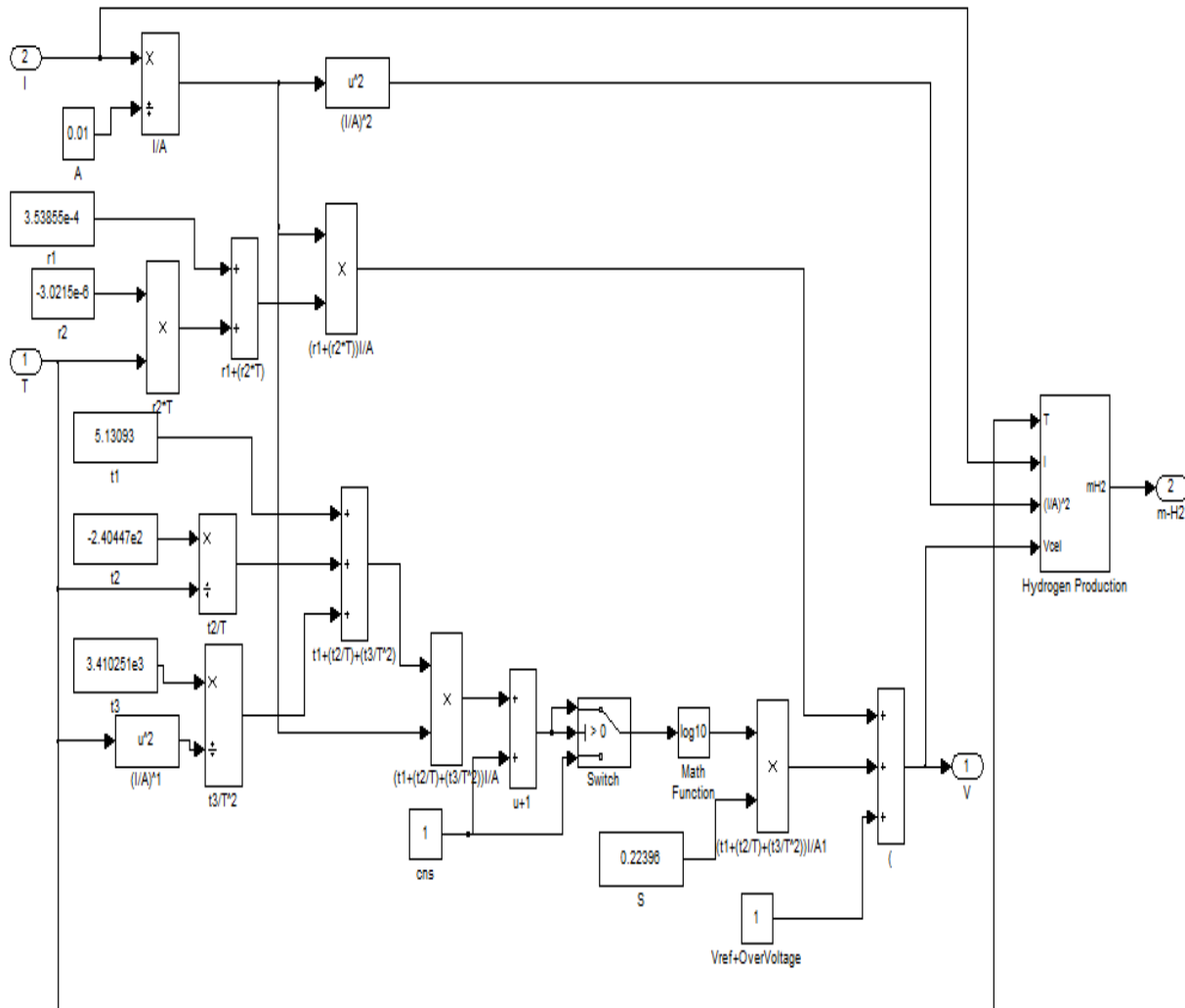


Figure 4.3: Simulation Diagram of Internal Design Model of Electrolyzer

There are various sources of input energy like solar PV, DG, FC are integrated in few applications. These applications have some requirements, which can be satisfied by a converter.

With single stage method, load's demand power can be provided by this converter and it does not have any storage system for energy. So, if input power is less than output power, required load demand may not be satisfied by this system.

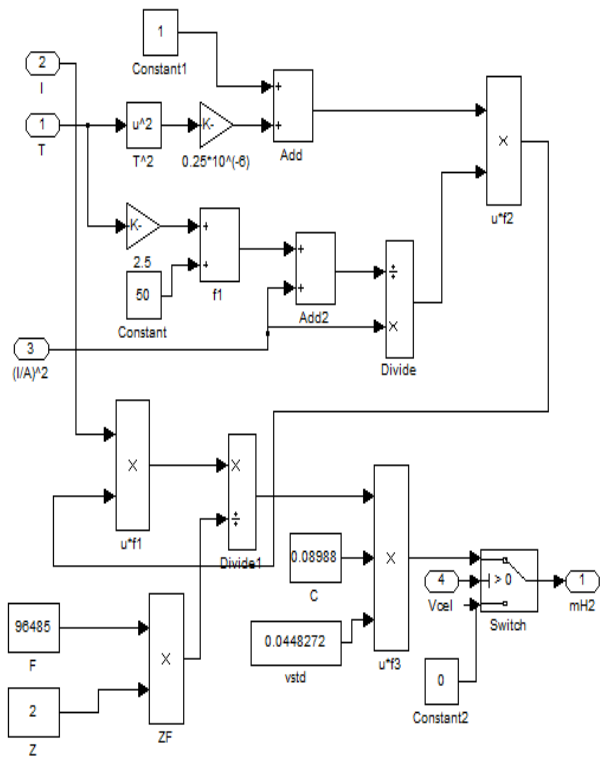


Figure 4.4: Hydrogen Production Unit's simulation diagram

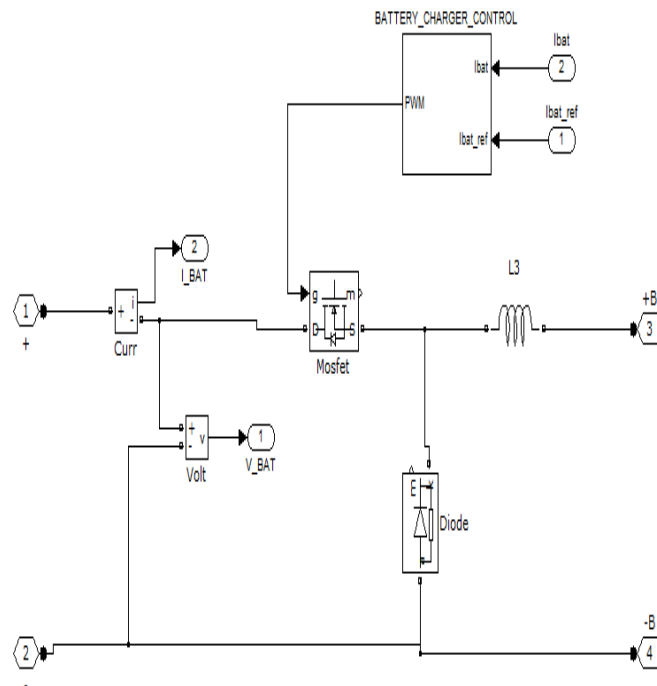


Figure 4.5: Simulation Diagram of Battery Charger Unit

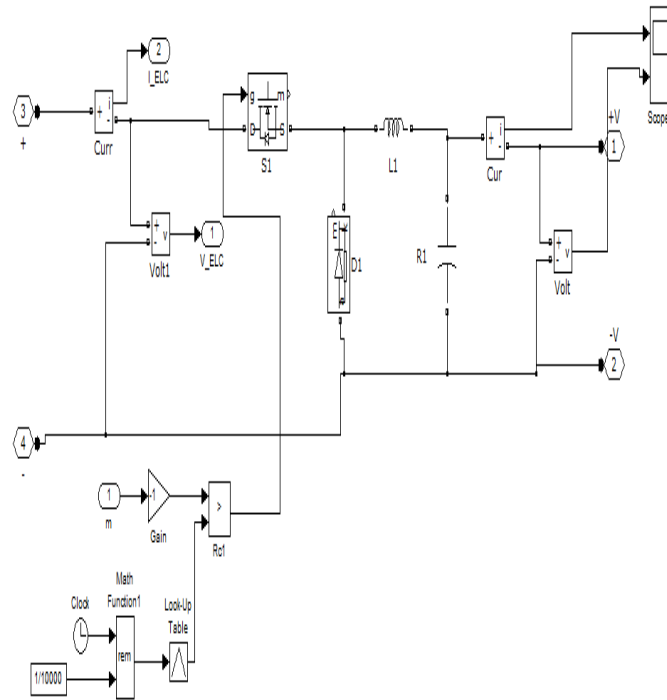


Figure 4.6: Fuel Tank Unit's simulation Diagram

Zero power is assigned to a diesel generator and fuel cell, if more power is generated for hour by a solar energy. Solar energy supplies electrical load. Fuel cell and diesel generator's cost of operation is reduced by this optimum operation. For two sections, this solar system output power is allocated as shown. Electrical loading is supplied with electricity by one section and electricity required for running hydrogen production and water electrolyzer is given by another section.

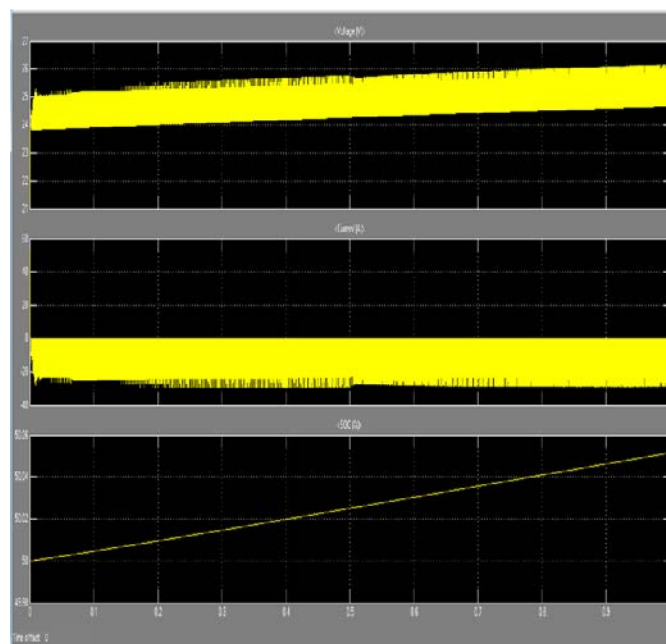


Figure 4.7: Battery Voltage/Current/SOC (%) output waveform

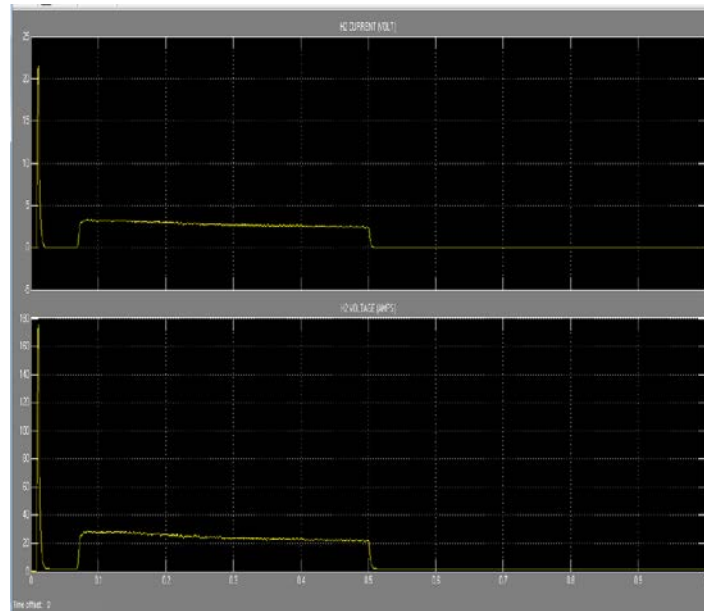


Figure 4.8: Hydrogen unit output waveform

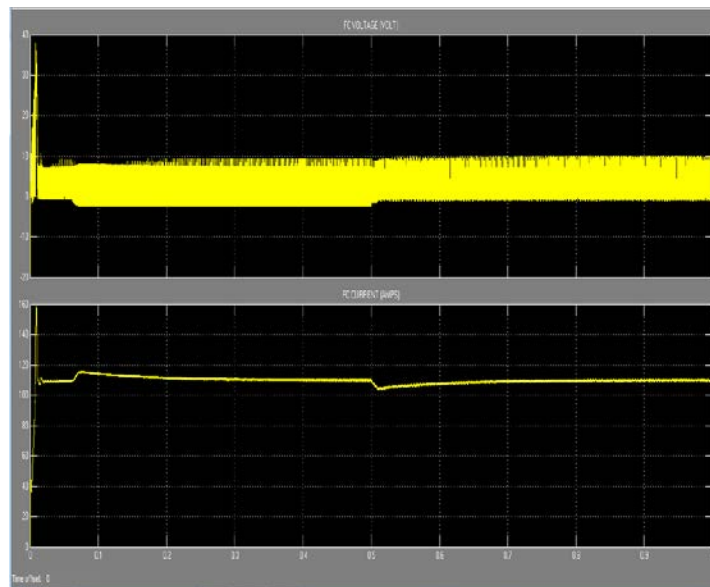


Figure 4.9: Fuel Cell Unit output waveform

If required electricity is not generated by solar system, electrical loading can be supplied by electricity produced by fuel cell via consuming hydrogen. Operation of fuel cell is like a generating system of electricity and hydrogen-burning load. Solar energy produced hydrogen in charging station using water electrolyzer. Hydrogen-burning vehicles and fuel cell consumes the hydrogen.

Difference between total generated and consumed hydrogen corresponds to net hydrogen at every hour. Hydrogen reservoir supplies initial hydrogen, if solar energy is near to zero or zero during initial hours. There is a 4kg of initial hydrogen. In hydrogen form, solar energy is converted and stored. During requirement, this stored energy is used by restoring it.

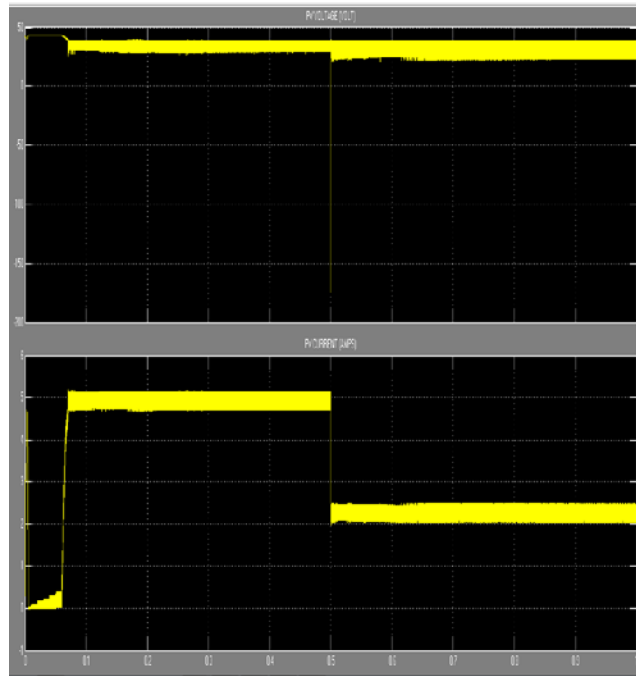


Figure 4.10: PV Cell Unit output waveform

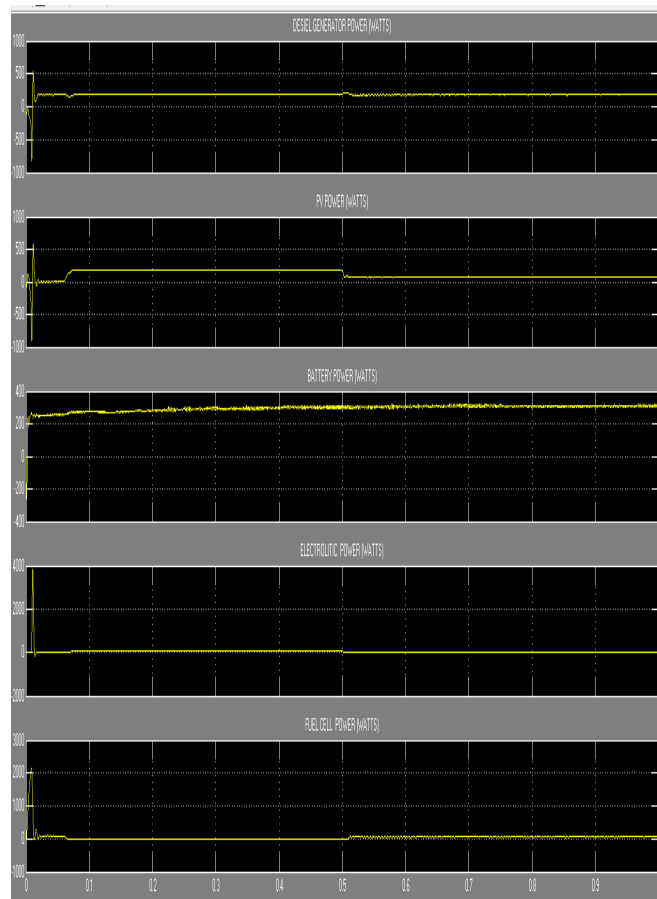


Figure 4.11: Diesel/PV/Battery/Electrolizer/Fuel cell Power output waveform

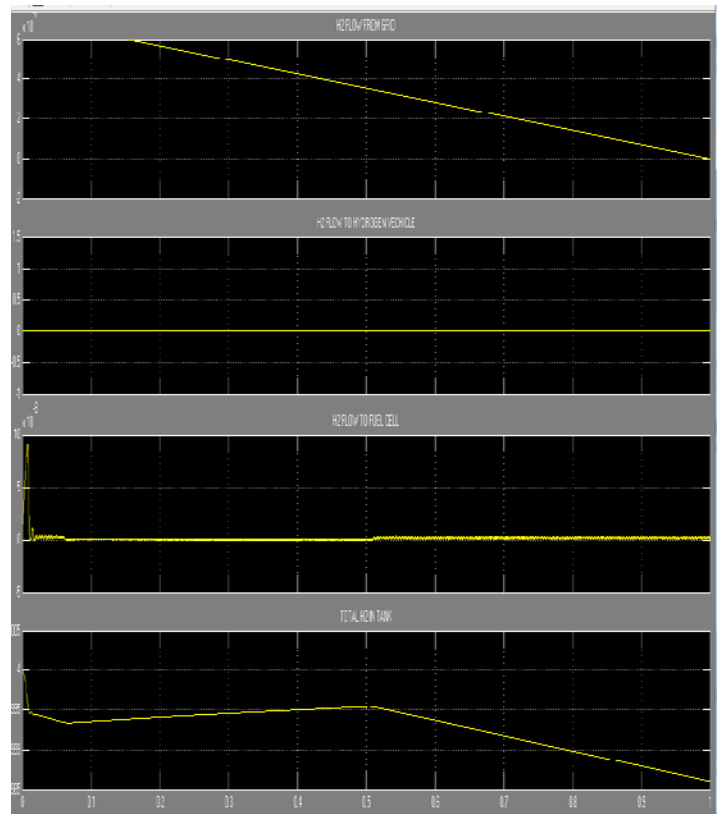


Figure 4.12: Total Hydrogen System Flow output waveform

V. CONCLUSION

For EV and HV charging station, intelligent power management system (IPMS) is proposed in this work. Based on available source's priority, source are selected to load. For hydrogen and electric vehicles, off-grid solar powered charging station is proposed by this work. Hydrogen vehicles, electric vehicle, diesel generator, hydrogen storage, water electrolyzer, fuel cell, solar system are installed in charging station. For solar system, optimum power rating is computed by a proposed mathematical model and for hydrogen storage, fuel cell and diesel generator optimum operation pattern also computed.

Around 85% of charging station cost is covered by solar system installation cost as demonstrated by results of simulation. Diesel generator cost is about 5% and remaining 10% is required by electrolyzer system and fuel cell including hydrogen tank unit. Proper operation of fuel cell and diesel generator ensures balance between parameters of unavailability and intermittency. Parameters includes, consumed power of hydrogen vehicles, consumed power of electrical vehicles and solar energy. If diesel generator and fuel cell provides electrical load for hours, solar energy may be zero.

In order to supply electrical loading, around 7 % of solar energy is used and for producing hydrogen, around 93% of solar energy is used. With respect to charging station's reliability enhancement, loss minimization, load sharing, battery management, better performance in operation is shown by proposed PMS scheme. In future, accurate cost of investment can be computed using various models.

In economic model, depreciation period may be considered for computing equivalent annual cost. Cost can be reduced by considering sustainability and systematic solutions.

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