Modelling and Analysis of a Photovoltaic Fuel Cell Hybrid and Standalone System

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***Abstract*: It has been well-proven that a physical phenomenon power supply must be integrated with different power sources, whether or not utilized in either an entire or grid-connected mode. Stand-alone power systems are very fashionable, especially in remote sites. The system under study during this dissertation may be a stand-alone hydrogen PVFC hybrid installation, which is constituted of a photovoltaic generator, an alkaline water electrolyser, a proton exchange membrane (PEM) electric cell, a brief term super capacitor storage, and gas storage tanks. this method is meant to be a future competitor of hybrid PV/Diesel systems, especially from an environmental point of view (low noise and nil emission) and operational costs point of view. The reduced scale mitigates loss allowing the power produced to do more with better control, giving greater security, reliability, and design flexibility. This paper explores the performance and cost viability of a hybrid grid-tied microgrid that utilizes Photovoltaic (PV), batteries, and fuel cell (FC) technology. The concept proposes that each community home is equipped with more PV than is required for normal operation. As the homes are part of a microgrid, excess or unused energy from one home is collected for use elsewhere within the microgrid footprint. The surplus power that would have been discarded becomes a community asset, and is used to run intermittent services.**

***Keywords*: Hybrid system, photovoltaic, fuel cell, standalone system**

I. Introduction:

The conventional fuel energy sources like fossil fuel, fuel, and coal that meet most of the world's energy demand nowadays unit being depleted quickly. Also, their combustion products unit inflicting international issues just like the atmospheric phenomenon and pollution that unit posing nice danger for our surroundings and eventually for the entire life on our planet. In present scenario India has been rapid growing economy with a median GDP rate of growth projected around 6 percent over the past 20 years, still the event aspect of rural areas is yet alarming. Though country have gotten an unlimited hydro voltage but thanks to major river water distribution conflicts these can't be harnessed. Thus, so as promote the event in remote areas there's a requirement to develop a sustainable and efficient energy system to accommodate the persistent electricity problems in these areas .The renewable energy sources (solar, wind, tidal, geothermal etc.) are attracting more attention as an alternate energy. Among the renewable energy sources, the photovoltaic (PV) energy has been wide employed in low power applications. it's also the foremost promising candidate for analysis and development for giant scale users because the fabrication of low price PV devices becomes a reality. Photovoltaic generators that directly convert radiation into electricity have many significant blessings like being inexhaustible and pollution free, silent, with no rotating parts, and with size-independent electric conversion efficiency. Thanks to harmless environmental effect of PV generators, they're replacement electricity generated by alternative polluting ways during which and even lots of in vogue for electricity generator wherever none was out there before. With increasing penetration of star physical phenomenon devices, varied anti-pollution equipment are often operated by solar PV power; as an example, water purification by natural science process or stopping desert expansion by PV water pumping with tree implantation. From Associate in nursing operational purpose of read, a PV power generation experiences large variations in its output power thanks to intermittent climate. Those phenomena may cause operational problems at the power station, like excessive frequency deviations. In many regions of the globe, the unsteady nature of radiation means strictly PV power generators for off grid applications must be large and thus expensive. One method to beat this problem is to integrate the physical phenomenon plant with alternative power sources like diesel, electric cell (FC), or battery back-up.
The diesel back-up generator for PV power is in a very position to form sure supply like PV power as a results of the cell grid is characterized with many engaging options like potency, fast load-response, modular production and fuel flexibility. Its feasibility in co-ordination with a PV system has been successfully realized for both grid-connected and stand-alone power applications. Thanks to the fast responding capability of the cell grid, a photovoltaic-fuel cell (PVFC) hybrid system is also ready to solve the photovoltaic's inherent problem of intermittent power generation. Unlike a voltaic battery, which also represents a gorgeous back-up option, like fast response, modular construction and adaptableness, the electric cell power can produce electricity for unlimited time to support the PV power generator. Therefore, never-ending supply of prime quality power generated from the PVFC hybrid system is possible day and night. Environmental impacts of the cell power generation unit comparatively little in distinction to alternative fuel power sources. Therefore, the cell grid incorporates a pleasant potential for being coordinated with the PV generator to disembarrass the photovoltaic power's fluctuations.

II. Methodology:

The investigated stand-alone hydrogen PVFC hybrid system is intended to be totally selfsufficient for generating, storing and supplying wattage to local loads. it's simulated to predict its performance before implementation. this method is commonly installed in rural and remote areas. Thus, it’s important within the design to optimise the system configuration, component sizes and control settings. Design via simulation allows studying the various options, considering various influencing parameters and effectively fulfils the system/user requirements. Mathematical models of the system components are interconnected to make a general illustration of the entire system, through a central supervisory controller that defines the approach within (Hardik Patel1, 2016)which parts move to simulate the operation of the entire system. during this chapter, a stand-alone hydrogen PVFC hybrid system are going to be simulated. All the components of the system are modelled and validated within the previous two chapters. A comparison between different system topologies, like DC and AC coupled, with different PCU types at two different locations on the premise of the energy point of view is studied.

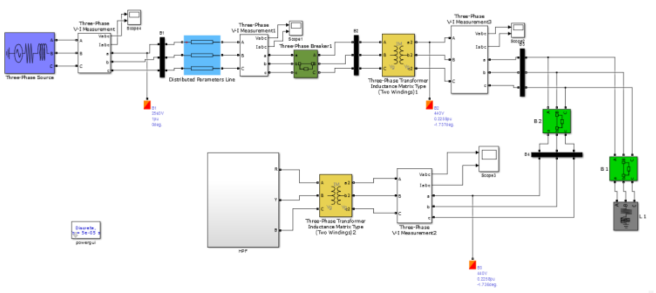

Figure 2.1: Simulink model

A number of hybrid system simulation packages, like MATLAB TRNSYS, INSEL, HYBRID2 etc, are developed by different research teams during the last twenty years. Most of those software tools simulate given and predefined hybrid systems supported a mathematical description of the component operation characteristics and system energy flow. The accuracy of the simulation reflects the accuracy with which the performance of a system is evaluated by a simulation model. However, it must be realized that in design and analysis studies, the accuracy of the simulation model is just one among the factors that determine the accuracy of the simulation. Accurate information’s about the designed system, the load, weather data, and therefore the flexibility of the simulation tools are factors influencing the accuracy of simulation. Hence, choosing efficient simulation tools and preparing the acceptable data is deliver reliable and useful simulation results. In this work, a simulation program called Matlab program includes much technical advancements, making it a decent choice for complex multi-domain simulation. additionally, advanced mathematical models not included within the standard Matlab library can easily be added to its library. The library of this program is developed in co-operation with the Matlab is ready to simulate any fundamental measure of interest. This feature allows studying the short- additionally because the long-term PVFC hybrid system performance.

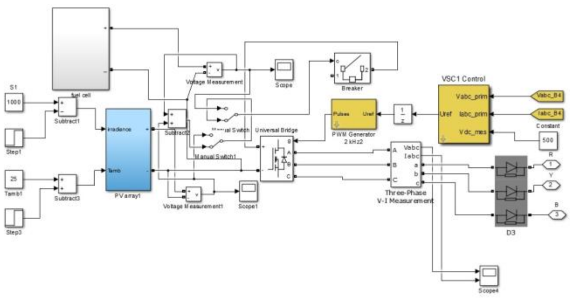

Figure 2.2: PVFC hybrid system

The important required weather data for the hydrogen PVFC hybrid system analysed during this work are the radiation, [W/m²] and so the ambient temperature, [°C]. These data should be supplied to the simulation model on an hourly basis.

The developed simulation model provides sufficient information about the performance of each component and thus the system. During the program execution, all necessary system variables needed for a performance analysis ar recorded during a simulation file. for example, hourly values of hydrogen fuel produced by electrolyser unit, hydrogen fuel consumption by cell back-up generator, generated cell energy to cover the deficit energy from the PV generator to satisfy the user load demand, generated PV energy, etc are delivered. Moreover, a yearly total system energy balance is estimated. These output results is analysed to cover all performance aspects of the overall system.

An important property of any power system simulation program is that energy is balanced within each time step throughout the entire simulation run [Dumbs-99]. The total amount of produced energy (PV generator, fuel cell, and storage output) must equal the total amount of consumed energy (user load, electrolyser, storage input, and losses). Checking the energy balance at each time step assures that the model is internally consistent. The overall energy balance equation is given by:

$$p_{PV} + P_{fc} - P_{load} - P_{el} \pm P_{sCap} - \sum_i L_i = 0$$

P_{PV} PV generator output power,[W]
P_{fc} outpur power from PEM fuel cell,[w]
P_{load} user load power demand,[W]
P_{el} input power to alkaline water electrolyser,[W]

$\pm P_{sCap}$ supercapacitor discharge or charge power,[W] and
$\sum_i L_i$ all power losses in the system,[W]

The power losses Li in the energy balance equation for the system under study comprise only the losses in the power conditioning units during energy conversion between the different units of the system. Power line losses are neglected.

- **Assumptions of the System Simulations**

The main assumptions made within the simulation of the hydrogen PVFC hybrid system are:
1. Normally, the H2/O2 PEM cell contains a far better performance than the H2/Air PEM cell, but requires oxygen storage or a purification system. during this work, H2/Air PEM cell are visiting be used within the simulated system. Thus, no oxygen purification or storage systems are required.

2. Some hydrogen losses are expected like hydrogen losses within the electrolyser or cell during start-up and shutdown, hydrogen losses within the vessel, and hydrogen losses within the cell during operation, but these won't be included within the simulation.

3.Many parasitic loads are handled by an auxiliary power supply [Ulleberg-98], like power needed for water cooling pump for the electrolyser or cell, protective current for the electrolyser during standby operation, hydrogen purification system, and data acquisition and system. These parasitic powers are omitted from the simulation of the system. The inclusion of those losses would finally end in numerous results, but won't affect on the alternatives required from the simulation to work the system optimally.

III. Results:

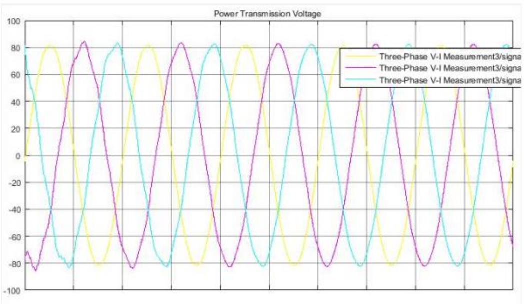

Figure 3.1: Three phase power transmission voltage

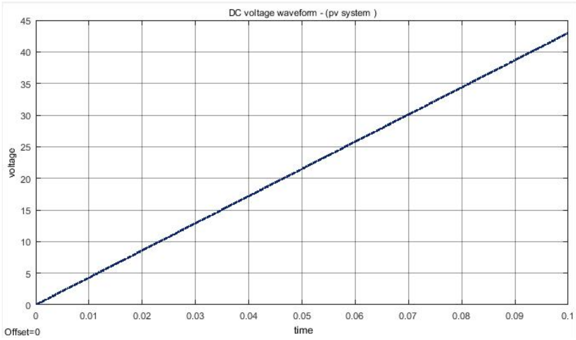

Figure 3.2: DC voltage

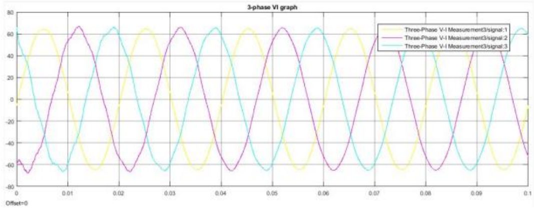

Figure 3.3: Three phase VI graph

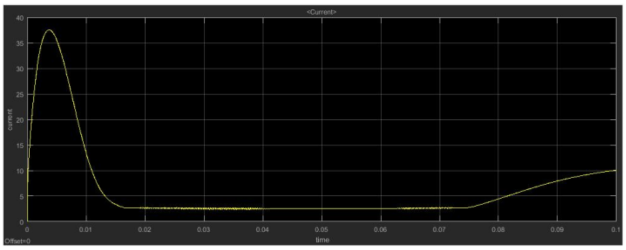

Figure 3.4: Current plot

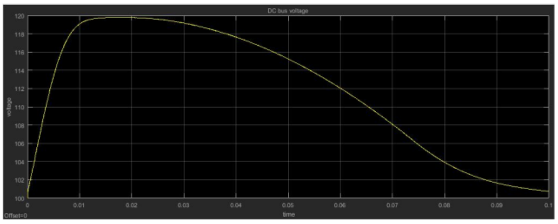

Figure 3.5: DC bus voltage

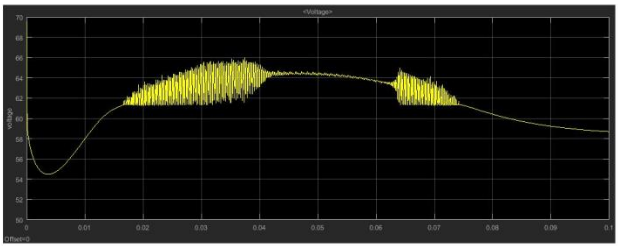

Figure 3.6: Fuel cell voltage

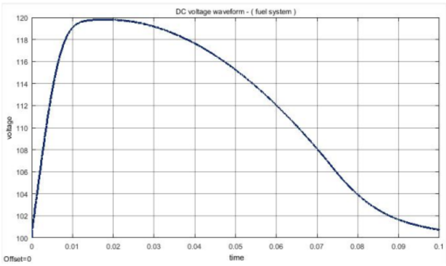

Figure 3.7: DC voltage waveform

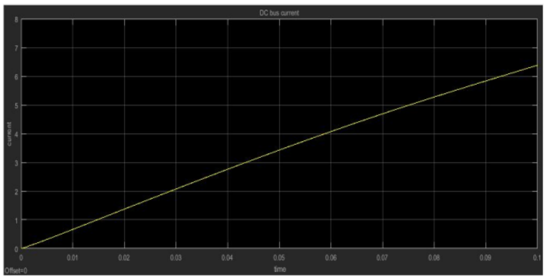

Figure 3.8: DC bus current

IV. Conclusion:

The main challenge for grid-connected system as well as the stand-alone system is the intermittent nature of solar PV and fuel sources. By integrating the two resources into an optimum. Combination, the impact of the variable nature of solar and fuel resources can be partially resolved and the overall system becomes more reliable and economical to run. This definitely has bigger impact on the stand-alone generation. Integration of renewable energy generation with battery storage and diesel generator back-up systems is becoming a cost-effective solution for stand-alone type. The fuel battery-diesel hybrid configuration can meet the system load including peak times. Energy management strategies should ensure high system efficiency along with high reliability and least cost. Good planning with accurate forecasting of weather pattern, solar radiation and fuel speed can help in reducing the impact of intermittent energy. Voltage and frequency fluctuation, and harmonics are major power quality issues for both grid-connected and stand-alone systems with bigger impact in case of weak grid. This can be resolved to a large extent by having proper design, advanced fast response control facilities, and good optimization of the hybrid systems. The paper gave an overview of different research works related to optimal sizing design, power electronics topologies and control for grid-connected and stand-alone hybrid solar PV and fuel systems. Solar PV and fuel hybrid system can be connected in a common DC or common AC bus whether they are working in a grid-connected mode or a stand-alone mode.

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