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A NEW NON CONVENTIONAL ENERGY SOURCES FED HDGS

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ABSTRACT

A combination of PV and FC sources forms a good pair with promising features for HDGS applications. A new, hybrid integrated topology, fed by photovoltaic (PV) and fuel cell (FC) sources and suitable for distributed generation applications, is proposed. It works as an uninterruptible power source that is able to feed a certain minimum amount of power into the grid under all conditions. PV is used as the primary source of power operating near maximum power point (MPP), with the FC section (block), acting as a current source, feeding only the deficit power.

1. INTRODUCTION

Renewable energy sources (solar, wind, fuel cell etc) are considered as alternative energy sources to conventional fossil fuel energy sources due to environmental pollution and global warming problems. However, control problems arise due to large variances of output under different insolation or wind speed levels. To overcome this problem, photovoltaic system can integrate with other power generators or storage systems such as battery bank and fuel cells. The feasibility of photovoltaic fuel-cell systems has been successfully demonstrated for both grid-connected and stand alone applications [1].

In this research work, design and control strategy of an autonomous photovoltaic fuel-cell energy system has been developed and simulations have been performed in order to supply electricity to a DC-load without being connected to the electric grid. The photovoltaic module produces electricity to meet the requirements of a load. When there is enough solar radiation available, the external load can be powered totally by the photovoltaic electricity. For continuous supply of power to the load, a battery bank is used with the photovoltaic module.

During the period of low insolation, auxiliary electricity is required. A fuel-cell system formed by a water electrolyzer, a hydrogen storage system, and a fuel-cell stack works as a back-up system. Excess electricity generated in the photovoltaic module is sent to an electrolyzer to produce hydrogen, which is stored for a period of time. When required, it is converted back into electricity using the fuel cell. The fuel cell can be considered as a back-up generator to meet the load requirement. The system behavior is simulated with a time resolution in the minute-range. All the developed models are based on physical and chemical principles, as well as empirical parameters. The system control is designed to optimize the input and output currents for the different components of the overall system during a period of one year. The research work as a whole includes modeling and optimization of the components and the determination of an appropriate control strategy.

2. HDGC TOPOLOGY

For this research work, the photovoltaic module has been used as the main source of power generation. A battery bank is employed to store energy. A fuel-cell stack is used as back-up source of power. The photovoltaic module with the battery, the load and the electrolyzer are connected directly. During operation, the fuel cell is also connected directly to the load. The idea behind this kind of system is to operate the load with photovoltaic electricity by storing it in battery bank during high insolation periods. The electrolyzer produces H2 using excess photovoltaic energy; which is stored for the time being and the fuel cell converts H2 back to electricity during the months of low insolation. The battery storage system is used for short-term storage of electricity and to supply power to load. A schematic diagram of the system is shown in Fig.1.

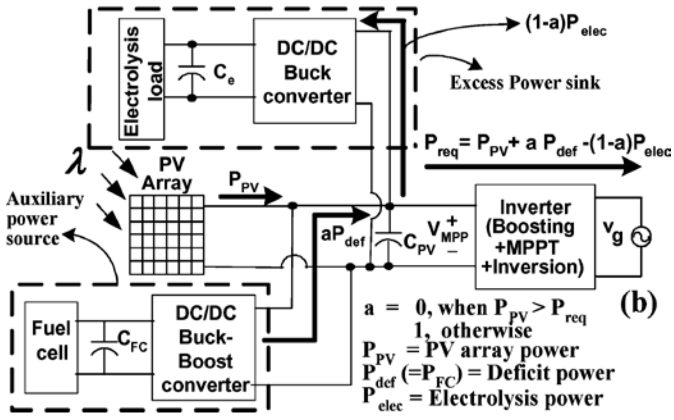

Fig 1. HDGS topology

The paper presents a hybrid PV/FC renewable energy scheme for supplying an isolated community with electrical energy. In order to obtain electricity from the hybrid green system at an economical price, its topology and control design must be optimized in terms of coordinated operation and layout configuration. Many topologies are currently available for integrated green system configurations, depending on the use of interface converters based on

common DC/common AC bus interface architecture. 126 Solar panels can be connected in parallel or in series to obtain required photovoltaic power rating. The power obtained by this way is DC in nature and it should be converted to AC for some AC type loads. Therefore, DC to AC converters are required for such load types. Electrical energy is not only required during day time, but also at night. This key requirement puts forwards the possible use of other renewable green energy sources, such as fuel cells in integrated micro co-generation schemes [8,9]. The Electrochemical voltage behaviour of the fuel cell is commonly modeled using the simple equivalent first order (RC). This circuit consists of three passive circuit elements that result in a first order approximation of the dynamic response of the electrochemical capacitor. The circuit includes the double layer capacitance RC in series with ohmic resistance. The equivalent series resistance that represents the energy lost due to the distributive resistance of the electrolyte, electronic contacts and the porous separator [5,6].Hydrogen itself is a clean and emission free fuel. Currently Hydrogen technology is concentrating on the storage methods, efficient and safe Fuel Cell Batteries. Enhancing the output efficiency and improving the performance of fuel cell are among main research topics. The industrial applications of fuel cell technology are still limited to hybrid electric vehicles. Little papers are dealing with the power system application of fuel cell and system interactions. Therefore, the interaction of fuel cell with power system components and switching electronic drives, choppers and controllers are crucial.

The generated electrical energy in fuel cell could be directly connected to the common DC bus through DC-DC-Chopper to convert the stored energy in hydrocarbon to DC electrical

energy [4,5]. In integrated green energy power system, Fuel cell and solar are fully used as the main energy sources to supply the hybrid DC and AC type loads. Fig.(1) Integrated (FC-PV) Green Energy Scheme for Electricity Supply Figure (1) shows the scheme of the studied system with common DC/ common AC collection bus interface. The scheme uses a primary common DC bus collection with an added secondary common AC bus for feeding any AC loads and public grid interface. The proposed hybrid green energy scheme is digitally simulated for different operation conditions and load excursions. The proposed control scheme comprises multi-loop dc-coupled coordinated dynamic error driven controllers with supplementary regulation loops to control the different subsystems [6,7].

3. OPERATING MODES OF PROPOSED SYSTEM

The proposed system is designed to meet a certain minimum active power demand (P_{req}) from the grid side. PV is the main source, which is continuously made to track the MPP, while feeding the required amount of power into the grid. The FC source, with buck boost type dc–dc converter, acts as a current source in parallel with the PV source.

It is only used to supplement the PV source during low or zero insulation. Thus, FC supplies only the deficit power into the grid. On the other hand, any “excess power” generated by the PV source is conditioned and diverted to an auxiliary application such as electrolysis, to produce hydrogen, which can be stored for later use by the FC source. This results in an optimal utilization of the available sources, rendering a highly economical system. The aforesaid description leads to the following three modes

In which the proposed system operates:

1) Mode-I: Only PV mode (only PV provides power).

2) Mode-II: Hybrid mode (both PV and FC provide power).

3) Mode-III: Only FC mode (only FC provides power).

These operating modes are summarized in Table 1.

TABLE 1

Operating modes of the proposed HDGS

Operating mode	Applicable condition	Active source(s)	Active power converter
I	$P_{ex}=P_{pv}-P_{req}\geq 0$	Only PV	Buck* (for $p_{ex}>0$)
II	$P_{def}=P_{req}-P_{pv}>0$	PV AND FC	Buck-boost
III	$P_{pv}=0$	Only FC	Buck-boost

Here Buck converter is optional. It depends upon the excess power application.

4. FEATURES OF PROPOSED SYSTEM

Due to its unique hybrid integrated nature, the proposed configuration offers several desirable features as follows

1) It obviates the requirement of a boost converter stage for conditioning the PV power
2) Out of the two capacitors C_{dc} and C_{PV}
3) Presence of FC in parallel reduces the fluctuations in the PV voltage due to changing environmental conditions. This, in turn, reduces the fluctuations in the power fed into the grid. Consequently, the grid voltage profile improves.
4) Elimination of dips and surges in the PV voltage increases the speed of MPPT.
5) In two-stage systems, usually, both PV array and dc capacitor (C_{dc}) voltages are sensed for MPPT and power control, respectively. In the proposed system, C_{dc} (or C_{PV}) appears right across the PV terminals due to elimination of the dedicated boost stage on the PV side .Hence, only one sensor is adequate.
6) It eliminates the requirement of extra hardware for communication and coordination between various sources to generate and use the available energy optimally.
7) The special configuration, in which the PV and FC sources are connected, ensures that the FC section works as a current source irrespective of the voltage magnitude at its output. This facilitates an appropriate adjustment of the PV voltage for PV's operation close to MPP.
8) Proposed configuration is a compact, low-cost, and reliable solution for HDG applications.

5. SIMULATION RESULTS

The proposed configuration, along with the control scheme, is simulated using the MATLAB/SIMULINK. PV and FC sources are realized in the MATLAB Function with the help of their governing equations. FC steady state response is considered with the assumption that the FC source is coupled with an ultra capacitor to improve its transient response. The inverter and the boost converter are simulated in the SIMULINK using the state equations. Specifications of the PV and FC sources, used in the simulations, are as follows:

PV source:
Open circuit voltage, $V_{oc} \approx 125\ V$;
short-circuit current, $I_{sc} = 7.6\ A$.
FC source:
$V_{oc} = 69\ V$;
$I_{sc} = 42\ A$.

The system is required to feed 500 W (=P_{req}) into the grid. The inverter system is designed for 1 kW power. Fig.5.1 shows the simulation results of the basic HDGS configuration without excess power control. The power drawn from the FC automatically decreases, such that $P_{PV}(t) + P_{FC}(t) = P_{req}$. As the PV source operates near MPP, an optimal utilization of the two sources is ensured. At t = 3s onwards, λ value improves further and the entire P_{req} is supplied by the PV. P_{FC} reduces to zero. Any excess power generated by the PV is also fed into the grid, because there is no excess power diversion. It is observed that the proposed system is able to supply the required power (P_{req}) under all conditions and for all the three modes as shown in the figure. In addition, there is a smooth transition between the various modes while maintaining P_{req}.

CASE 1:

Fig. 2 to fig 5 shows simulation results obtained by incorporating excess power control. The excess PV power (P_{ex}) is diverted for electrolysis application through a buck converter. This prevents any grid voltage surge in mode-I due to pumping. of excess power into the grid. Further, P_{req}. is always fed into the grid with PV array operating near MPP. A small-step increment in the environmental conditions near 7.9 s shows corresponding increase in diverted power in steady state with the PV array operating at MPP.

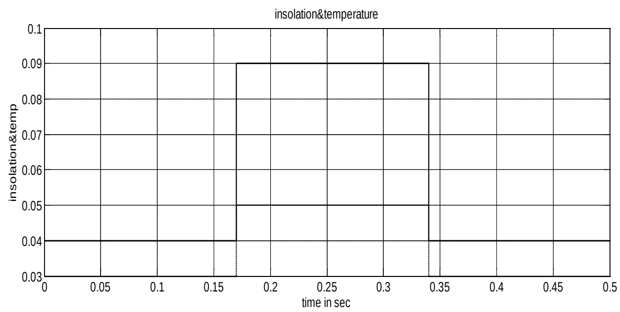

Fig 2 Insolation and Temperature

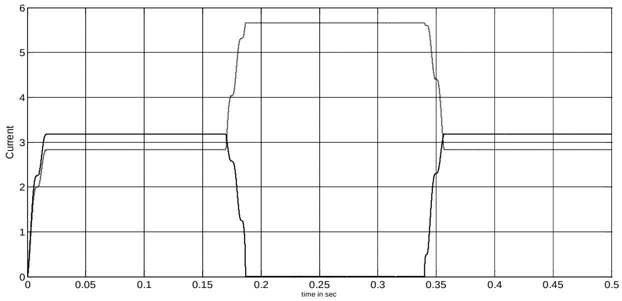

Fig: 3 PV and FC current

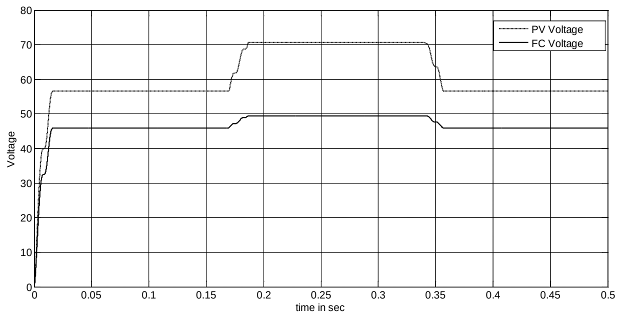

Fig 4 PV and FC voltage

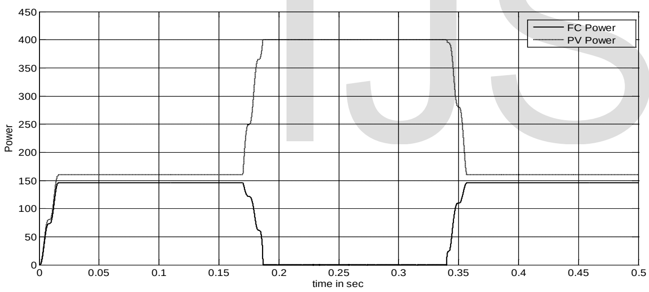

Fig : 5 PV and FC Power

CASE 2: WITHOUT FUEL CELL

To demonstrate the usefulness of placing an FC source in parallel with the PV source, simulations were performed with and without the FC source in the circuit, for a step change in insolation. Fig. 6 to fig 9 shows the results. It is observed that the presence of FC eliminates the transient dips in the PV array voltage and current, which, in turn, improves the MPPT speed and efficiency of the system. Further, the grid current total harmonic distortion (THD) during the transients is lower in the presence of the FC.

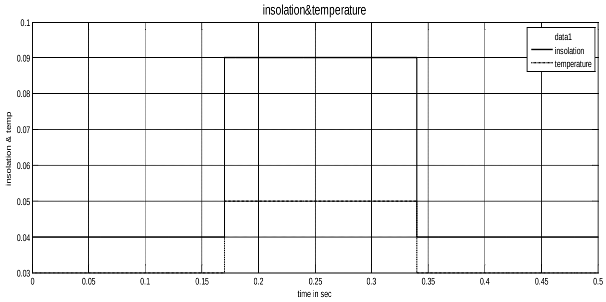

Fig : 6 Insolation and temperature

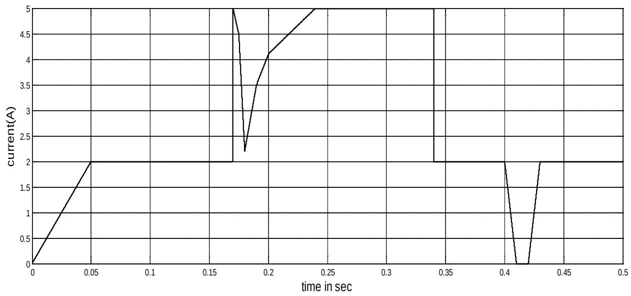

Fig 7 PV current

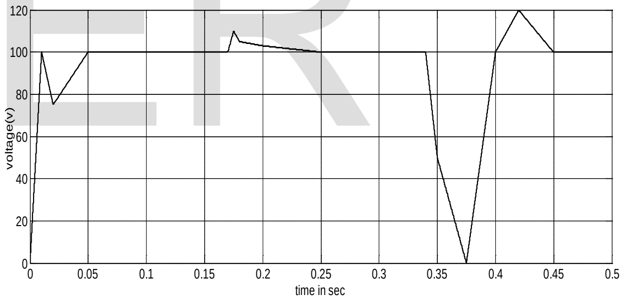

Fig 8 PV voltage

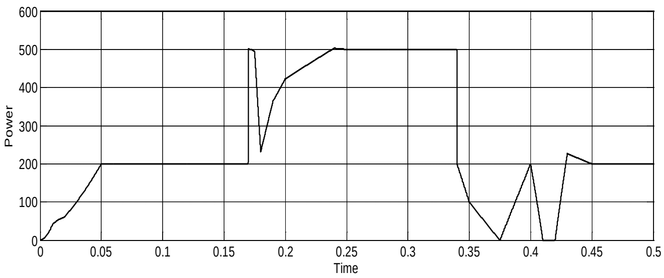

Fig 9 PV Power

6. CONCLUSION

A compact topology, suitable for grid-connected applications has been proposed. Its working principle, analysis, and design procedure have been presented. The topology is fed by a hybrid Combination of PV and FC sources. PV is the main source, while FC serves as an auxiliary source to compensate for the uncertainties of the PV source. The presence of FC source improves the quality of power (grid current THD, grid voltage profile, etc.) fed into the grid and decreases the time taken to reach the MPP.

A good feature of the proposed configuration is that the PV source is directly coupled with the inverter (and not through a dedicated dc–dc converter) and the FC block acts as a current source. Considering that the FC is not a stiff dc source, this facilitates PV operation at MPP over a wide range of solar insolation, leading to an optimal utilization of the energy sources. The efficiency of the proposed system in mode-1 is higher (around 85% to 90%) than mode 2 and 3 (around 80% to 85%). A laboratory prototype of the proposed system has shown encouraging results in terms of efficiency, complexity, reliability, EMI concerns, and other features.

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