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# Integration of Hybrid Renewable Energy Source into Smart Micro-Grid

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***Abstract*—It is evident that Global industrialization and quality of life has enhanced, due to which requirement of energy has increased a lot. The electrical power is generated by various ways and integrated with power grid. Hybrid energy is playing a major role in power generation throughout the world. The grid connected photovoltaic power generation capacity has increased besides problems of uncertainty and various in weather. Due to the strong requirement of renewable energies, the significance of strong prediction and integration such as integration of renewable energies with the grid is increasing day by day. Renewable energy sources are known to support system hydrogen generation. Hence, the newly developed idea is the ability to supply the load without any compensation by the wind turbine or PV panel's solution in offing. Solar irradiation and surplus energy storage problem can be solved by using other renewable energy sources and storage systems such as electrolyzer, hydrogen storage tank, fuel cell and battery. On comparison, using CUK converters other than buck and boost have a better control of power through grid-connected hybrid energy system.**

***Index Terms*— CUK converters, DC-DC Converters, Battery Bank, , Photovoltaic panel, , Maximum power point tracking (MPPT), Electrolyzer, EMS.**

## I. INTRODUCTION

Hybrid power systems with renewable energy sources are most widely used to reduce the pollution from conventional electric power sources. Because the source of hybrid power plants have small ratings maximum up to 10 MW, these system are mostly connected at the distribution voltage level. In India wind and solar energy sources are available all over the year at free of cost whereas tidal and wave are coastal area. Although the energy produced by wind during night can be used directly without storage.[2] Battery is needed to store solar and wind energy produced during the day. In addition to the technical consideration, cost benefit is a factor that has to be incorporated into the process of optimizing a hybrid energy system. Among various type of renewable energy sources, solar energy as well as wind energy have become the most promising and attractive because of advancement in power electronic technique. Photovoltaic (PV) sources are used nowadays in many applications as they own the advantage of being maintenance and pollution free. In the past few years, solar energy source demand has grown consistently due to the following factors

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1. Increasing efficiency of solar cells
2. Manufacturing technology improvement
3. Economies of scale

Micro grids include multiple load and distributed energy sources that can be operated in parallel with the utility grid or small independent power system. It increases reliability with renewable distributed energy generation, micro grid system. It increases the efficiency with reduced transmission lines and by integration of alternative energy sources. [7]

Hybrid Renewable Energy System (HRES) combines two or more renewable energy resources with storage, in order to fulfil the demand of an area.[3] Using a singular form of renewable energy, such as solar PV, to supply a rural area is possible, however no electricity will be generated when sunlight is not available and therefore no electricity will be supplied during that time. To make the system further reliable, energy storage must be added to the system to store energy in times of excess generation and supply energy in times of a lack of generation. The term hybrid power system is used to describe any power system combine two or more energy conversion device, or two or more fuel for the same device. Although the energy produced by wind during night can be used directly without storage. Battery is needed to store solar and wind energy produced during the day.

*A. Topologies used*

HRESs present a common DC bus to which all the energy sources are connected. The most used topologies are the parallel hybrid and series hybrid. In the parallel hybrid topology, all the energy sources are connected to the common DC bus through DC-DC power converters, whereas, in the series hybrid topology, some energy source (commonly some energy storage device) is directly connected to the common DC bus without DC-DC power converter. An energy efficiency analysis of the commonly used series and parallel hybrid topologies in hybrid power systems

*B. Configuration with hydrogen support*

Using unidirectional dc dc boost electrolyzer which convert 24v to 48v.

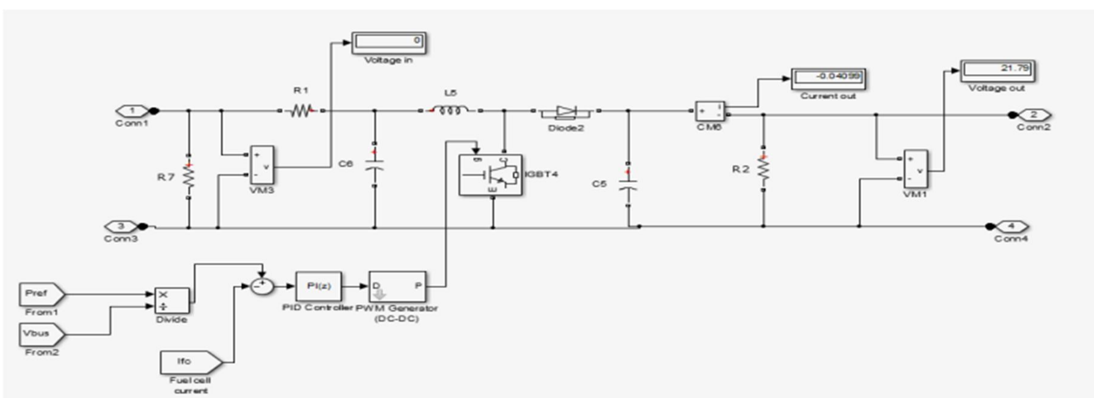


Fig 1. Configuration with hydrogen support

II. PROPOSED WORK DESCRIPTION

HRES is the combination of two or more renewable energy systems here the Hybrid system consists of a photovoltaic panel, wind turbine, proton exchange membrane fuel cell (PEMFC), electrolyzer, power convertor and a three-phase variation load. The load supplied is based on the photovoltaic panel and wind turbine, while the fuel cells are back-up for compensating possible power load shortage.

The surplus of power produced will be stored in a hydrogen tank by an electrolyzer system when the PV panel and wind turbine produce more power than required. Photovoltaic panels are used as popular renewable energy sources, two major problems they encounter depending on power production are with solar irradiation and surplus energy storage.

Renewable energy sources are known to support system hydrogen generation.[1] Therefore, the newly developed idea is the ability to supply the load without any compensation by the wind turbine or PV panels solutions in offing. Although photovoltaic panels are used as popular renewable energy sources, two major problems they encounter depending on power production are with solar irradiation and surplus energy storage. These problems can be solved by using other renewable energy sources and storage systems such as electrolyzer, hydrogen storage tank, fuel cell and battery. Due to high efficiency, fast response, flexibility and modular structures, a combination of electrolyzer, hydrogen tank with fuel cell is the best choice for a hybrid system that uses photovoltaic panels and wind turbine system [14].

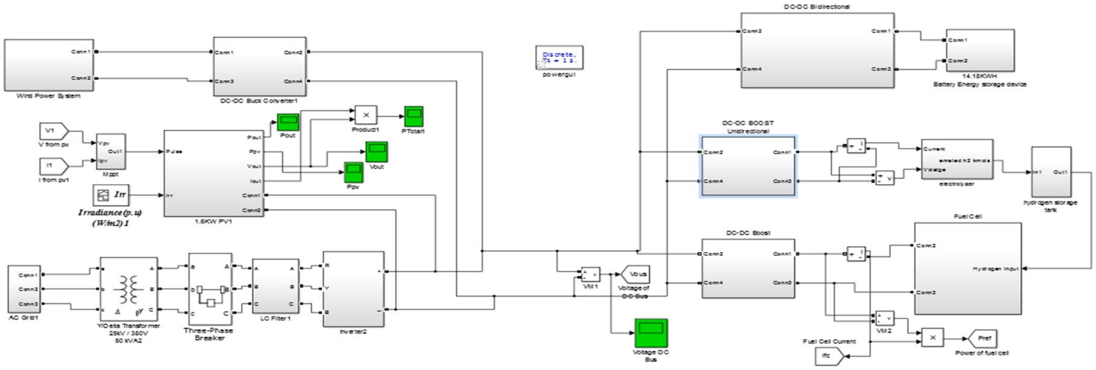

Fig.2: Block diagram of the proposed hybrid system

*A. Source Modelling*

*A.1 DC-DC converters*

DC-DC power converters are employed in order to transform an unregulated DC voltage input (i.e. a voltage that possibly contains disturbances) in a regulated output voltage and connected to each energy source allow controlling the energy flow between the sources adapting their variable voltages of the constant DC bus voltage of the HRES. The present work deals with the design and control implementation of a Buck-Boost DC-DC power converter.

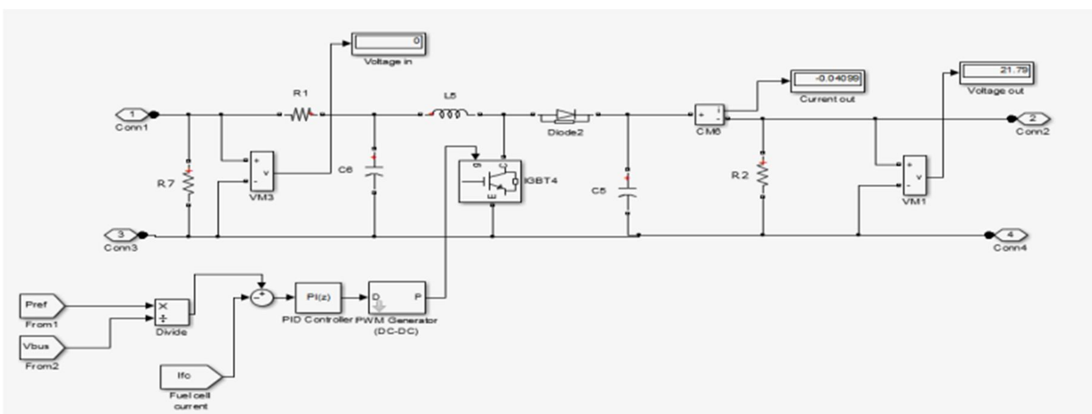


Fig 3 Circuit of dc-dc boost converter

The DC/DC converter regulates unregulated DC voltage obtained by PV arrays and wind system.
The design of DC-DC boost converter is based on the equations 1-4.

$D = 1 - \frac{V_{in}}{V_{out}}$..................(1) , $R = \frac{V_{out}^2}{P_{in}}$........................(2) ,$L = \frac{D(1-D)^2 R}{2 * f_s}$....................(3)

$C \geq = \frac{V_{out *} \; D}{R * f_s \;\; * \Delta V_{out}}$....................(4)

Where, D is the duty cycle, Vin is the input voltage, Vout is the output voltage, R is the load resistance and fs is the switching frequency. PI controller is used to get regulated output voltage from the boost converter. The present work deals with the design and control implementation of a Buck and Boost DC-DC power converters.[8]

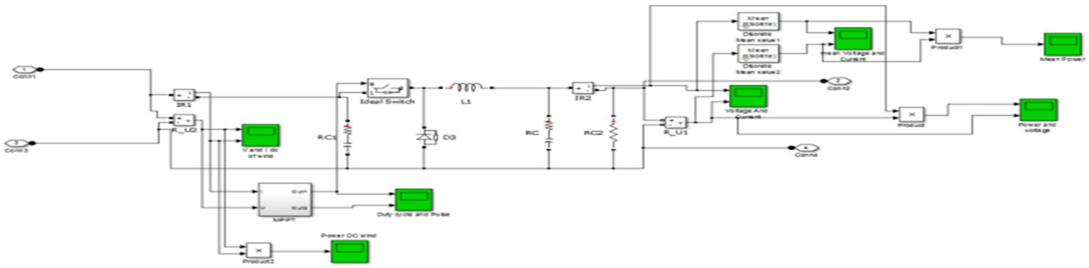

Fig 4. Circuit of dc-dc buck converter

The DC/DC converter regulates unregulated DC voltage obtained by PV arrays and wind system.
The DC-DC buck converter is based on the following equations.
The duty cycle is always positive and less than 1.

$$D_{buck} = \frac{Vout\ \eta}{V_{in}max} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. (5)$$

For buck mode the following equation is a good estimate for the right inductance:

$$L > \frac{V_{out} \times V_{in\ max} - V_{out}}{K_{ind} \times F_{sw} \times I_{out} \times V_{in\ max}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots. (6)$$

Where:

$V_{in\ max}$ = maximum input voltage
$V_{out}$ = desired output voltage , $I_{out}$ = desired maximum output current
$F_{sw}$ = switching frequency of the converter
$K_{ind}$ = estimated coefficient that represents the amount of inductor ripple current relative to the maximum output current. A good estimation for the inductor ripple current is 20% to 40% of the output current, or 0.2 < Kind < 0.4.

The CUK converter can step the voltage either up or down, depending on the duty cycle. The CUK converter contain the series inductors at both input and output, hence it has much lower current ripple in both circuits. The average output voltage can be calculated in term of the switch duty cycle. D = on time duration of switch/ total switching time period

$$\text{Duty cycle} = \frac{V_o}{V_{s-}V_o} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

$$\text{Output voltage } (V_o) = V_s \left[\frac{D}{1-D}\right] \ldots\ldots\ldots\ldots\ldots\ldots\ldots (8)$$

The equation used in dc-dc CUK converters is

$$V_o = \frac{D\ V_{in}}{(1-D)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots...... (9)$$

Where, f = switching frequency
ΔI = peak to peak ripple current I (assuming 10% of I),ΔI = peak to peak ripple current I (assuming 10% of I)
ΔV= voltage ripple (assuming 5% of V) ,D = duty cycle.

*A.2 Maximum Power Point Tracking (MPPT)*

The PV array must operate electrically at a certain voltage which corresponds to the maximum power point under the given operating conditions. To do this, a maximum power point tracking (MPPT) technique should be applied. Various MPPT techniques like look-up table methods, perturbation and observation (P&O) methods and computational methods have been proposed in the literature.[13] . To both increase the capacity of PV arrays and maintains power quality, it’s necessary to comply with the technique requirements of the PV system, such as fault-ride-through capability and harmonic current regulation. Especially when a large scale PV module is connected to the grid, the effects on the grid may be quite severe.hence, the system operation and system stability under fault conditions should be examined when PV modules are interface with power grid. Increasing use of static power converters like rectifiers and switched mode power supplies causes injection of harmonic currents into the distribution system. Current harmonics produce voltage distortions, current distortions, and unsatisfactory operation of power systems.

*A.3 Electrolyzer Model*

An electrolyzer is a well-known electrochemical device utilizing electrical current to decompose water into hydrogen and oxygen. It consists of several electrolyzer cells connected in series. The current in comparison to voltage feature of an electrolyzer depends on its working temperature according to Faraday's law, the production rate of hydrogen in an electrolyzer cell is directly proportional to the transfer rate of electrons at the electrodes, which in turn is equivalent to the electrical current in the circuit.

Expressed in the following equation,

$$nH_2 = \frac{\eta F . n_n . ie}{2F} \quad \text{……………………………….(10)}$$

$nH_2$= Hydrogen production rate, mol s-1,

$\eta F$ = Faraday's efficiency,$n_c$ = the number of electrolyzer cells in series ,$i_e$ = electrolyzer current [A], F = Faraday constant [C kmol−1]

The ratio between the actual and the theoretical maximum amount of hydrogen produced in the electrolyzer is known as Faraday efficiency. Assuming that the working temperature of the electrolyzer is 40 °C, Faraday efficiency is expressed by

$$\eta F = 96.5 \times e^{\frac{0.09}{i_e} - \frac{75.5}{i_e^2}} \quad \text{……………………………………….(11)}$$

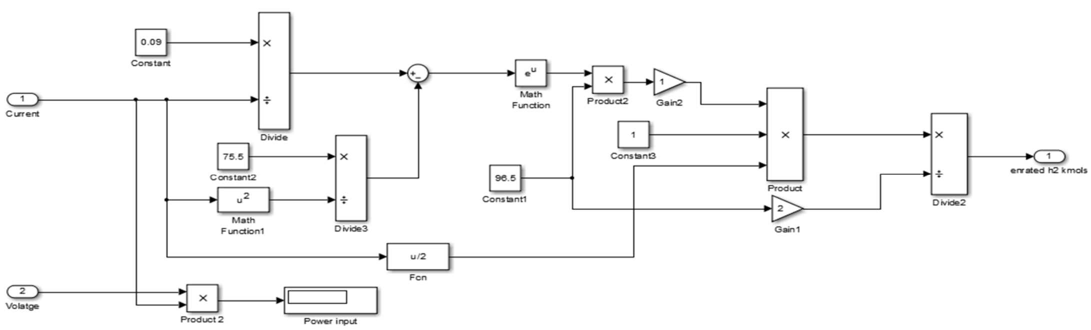


Fig 5. Electrolyzer Model

III. SIMULATION RESULT AND DISCUSSION

The main objective of the control scheme is to supply constant power to grid and gird connected load. It is done by using different power converter which converts unregulated supply into regulated supply. In simulation model there is use of buck as well as boost converter. The power obtained from wind turbine system is of large amount and unregulated so maintaining it constant we used the dc-dc buck converter which step down voltage level and maintained the constant voltage at the dc bus and power obtained from PV panel is less so there is used of dc-dc boost converter which step up the voltage level and maintain the constant voltage level.

The inverter model has been used to convert dc supply into ac supply. In order to minimize the current converter error, conventional PI controllers are tuned by PSO. Throughout this simulation, the dynamic response of the inverter studied under two different operating conditions. Thus, the HRES are simulating under several changes (by step and slope) in the reference of active and reactive power injected into the grid, and grid voltage sag considered. In both cases, as it will be shown below, the EMS is responsible for overseeing the HRES, controlling the system devices in order to produce the power demanded by the grid. All the results have been validated in several simulations.

In simulation modelling there is use of buck, boost converter for controlling the unregulated power and converting it into regulated power supply and then compare it with CUK converter and found that CUK converter has continuous input and out pit current. Voltage and Current changes in the low frequency domain better performances than other current mode control techniques, Such as the hysteretic or the peak current-mode control. Output voltage can be either greater or less than input voltage. It reduces the overshoot of a converter and settling time.

## IV. Simulation Results

### *A. With buck and boost converter*

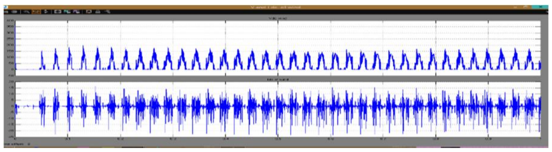

Fig.6 Output voltage and current of wind power system

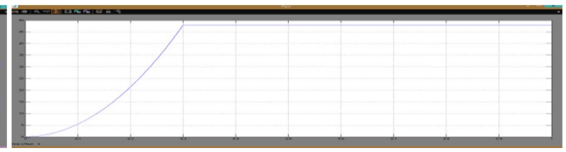

Fig.8 Output power of PV panel

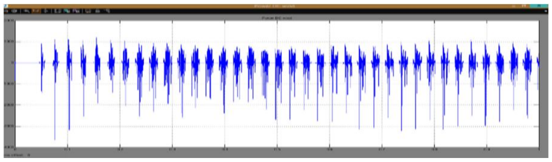

Fig.7 Power output of wind power system

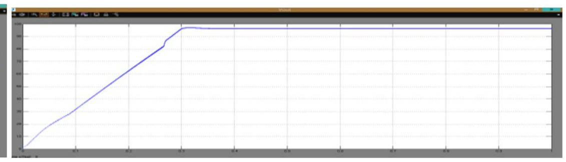

Fig.9 Solar output voltage

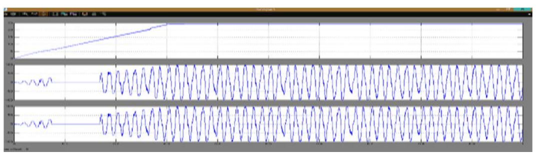

Fig.10 Voltage at Dc bus, inverter and at load

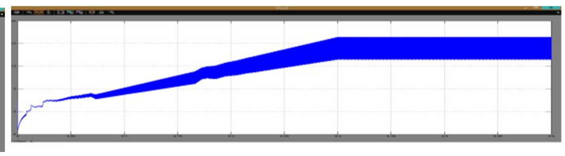

Fig.15 Power output of solar system

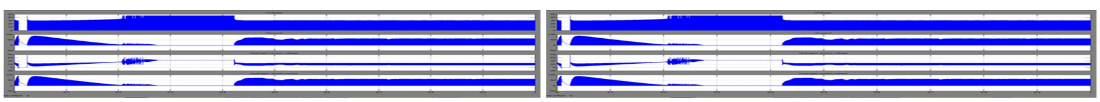

Fig.11 Hydrogen System Output

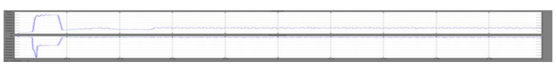

Fig.12 PQ at grid side

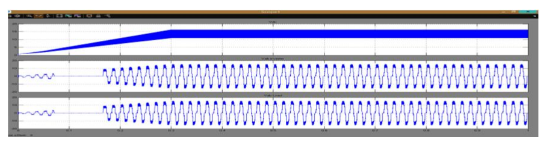

Fig.16 Voltage at DC bus ,inverter and at load

### *B. With CUK converter*

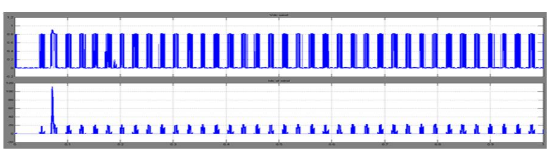

Fig.13 Voltage and current output of wind power system

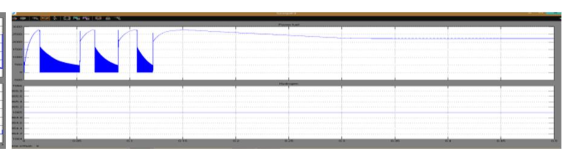

Fig.17 Hydrogen system output

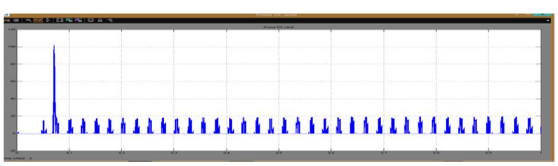

Fig.14 Output power of wind power system

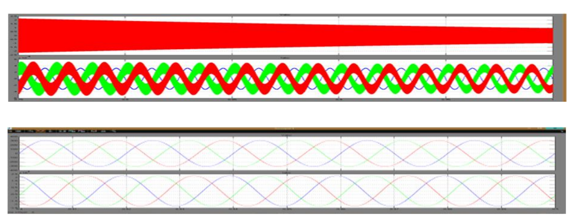

Fig.18 VI measure at grid

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