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ENERGY MANAGEMENT OF HYBRID POWER SYSTEM PV WIND AND BATTERY BASED THREE LEVEL CONVERTER

M R Sreelakshmi
Research Scholar
Shri Jagadish Prasad Jhabarmal Technical University (JJTU)
Sreelakshmi.m.r.29@gmail.com

Dr. Anupama Deshpande
Associate Professor,
Internal Faculty
Shri Jagadish Prasad Jhabarmal Technical University (JJTU)
Mangala.d.2000@gmail.com

Dr. B Hari Krishna
Associate Professor
CMR College of engineering
Harikrishna07@gmail.com

ABSTRACT

Hybrid renewable electric energy generation system becomes essential to the most of electric networks and the stand-alone systems like the water pumping and telecommunication systems. The renewable sources usually required storage system due to change in the power outputs during the day. Due to increase in demand of using batteries, the charging process of battery system needed to be well managed through an adaptive controlled energy managing system. In this paper a standalone system using photovoltaic, wind generation, fuel cell and storage batteries are contributed in supplying the desired load and the charging balance of batteries is achieved by using AI techniques to enhance battery charging controller performance. The main goal of this paper is to design and implement an integrated smart artificial controller, this controller is responsible for controlling both the battery charge voltage using the boost converter and the other controller is to control the charging current of the battery through DC to DC converter using (ANFIS) and (GA) techniques. This study is implemented using MATLAB /Simulink and the results are presented to show the applicability and effieciency of the proposed technique.

1.0 INTRODUCTION

Since electric vehicles have been utilized in the 1990s, their dispersion into the vehicle market has not been up to the mark because of the reason that it is less cost effective and these vehicles need to recharge once in 60 to 70 km drive. The hybrid vehicles play a major role in the present market and it obtains their energy from the combustion engine. However, in order to alleviate the utilization of gasoline, the plug-in electric vehicles (PHEVs) [15] entered into the market and it takes the energy from the grid for driving. To increase the life of storage system, cost reduction, and the flexible grid connectivity, the PHEVs are still under research. Nowadays, the park stations, roadside units, and the standard home outlets are used to charge the battery packs of EVs. The storage system present in the EV takes a prolonged period for recharging the battery packs and it will vary depending upon the capacity.

A new charging method is introduced for recharging the EVs. The control system present in this mechanism automatically charges the battery packs without the contribution of the driver. The performance analysis has been done and the result is compared with other EVs. The plug-in EVs are used to reduce the greenhouse gas emissions. The high-frequency ac-dc converter is used to charge the traction battery packs and an electromagnetic interference (EMI) filter is connected with the high-frequency transformer to suppress the EMI [11] noise has been studied. A high sampling rate camera with a sensor is used to estimate the slip angle measurement of EV. The performance of this model based estimator has been studied by Yafei et al. with the help of multi-rate Kalman filtering.

An experimental setup has been implemented and electrifying the plugin EVs by parking garage standard outlet. A comparative analysis has been performed for SOC under different temperature conditions.

Hybrid renewable energy (RE) based power generation become popular because of anxiety over the atmosphere. To eliminate the transmission loss and grid connectivity problems, RE based power generation is carried out. The wind power generation system has a less harmful impact compared to fossil fuels [10].

2.0 EXISTING SYSTEM

Currently, the most frequent application of DC MGs is the electric powered energy furnish of remoted structures like vehicles, area crafts, statistics centers, telecom systems, whilst they have been proposed for rural areas and islands [2]-[4]. Nowadays, due to the increase of the usage of DC loads, DC MGs have been created due to their advantages in terms of low cost and efficiency" [5]–[7]. However, to decrease the quantity of a couple of conversion degrees "and to connect the AC and DC sources and loads in a efficient/economic way, AC/DC MGs have grow to be an best desire to connect the MGs" [8]. There are many challenges that face microgrids operation. The first challenge is to limit the operational value of the MG. Secondly, the "intermittency of RESs such as photovoltaic (PV) and wind turbine (WT) due to the fact of the climate version which may additionally reason energy imbalance and power-quality problems.

3.0 PROPOSED SYSTEM

The proposed small scale micro grid is worked as a smart framework by a energy management and control framework. A energy management algorithm, mulling over the accessible energy at the inexhaustible bases, micro grid control request [1] [8] are main condition of charge of the Super capacitor and battery, this work created a Small scale micro grid as a self-Sufficient framework. The power from micro grid will be effective guarantee of power exchange between the vitality sources to micro grid. Moreover, P1, B1,B2 and C1,C2 are the Switches Across the photo voltaic ,Battery and Super capacitor Respectively to performs Buck – Boost operation.

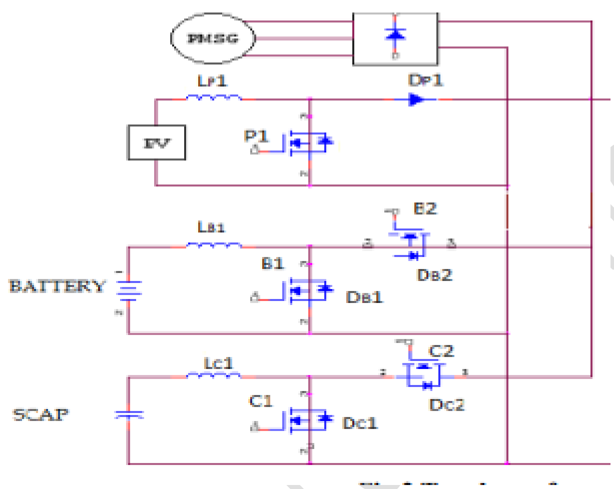

Figure Topology of converter circuit

The features of the proposed topology are:

1) the inherent nature of these two converters eliminates the need for separate input filters for PFC;

2) it can support step up/down operations[8] for each renewable source (can support wide ranges of PV and Wind input);

3) MPPT can be realized for each source;

4) Individual and simultaneous operation is supported.

4.0 TECHNIQUES USED

Wind generator system

The power transfer and control of a wind turbine system is based on PMSG [2] and connected to the three-phase grid using a back-to back converter. The machine side converter is controlled to extract the maximum power from wind using vector control. The grid side controller is designed to control the power flow using α–β reference frame [13]. The power transfer strategy is proposed to control the flow of the power between the WT and the grid. Measured wind speed (for example with anemometer) is used to get the optimum rotor speed required to achieve the maximum power from the wind turbine.

The speed of the rotor is measured in order to compensate for the error of the controller and the reference of the direct axis current is zero. The PIs of the d-axis and q-axis can be designed using a small-signal (average) model, and the d–q reference voltages are transformed using Clarke and Park transformations to form three-phase reference voltages [3] to command the switches of the converter using the sinusoidal pulse width modulation (SPWM) method. The DC-link voltage is controlled in a constant value by the grid side converter.

Grid side controller

The purpose of the grid side converter is to inject electrical power in the grid produced by the generator [11] with a good PQ. Moreover, the DC-link voltage control is also commanded by the grid side converter. The converter output current flows through the grid. Therefore, it is desirable that this current has a sinusoidal waveform [6]. The grid converter output current is controlled by the inner loop and has a faster response than the DC link loop. Therefore, the inner loop is considered unitary when the DC-link voltage control[7] is designed. The power calculation uses the active and reactive power references to produce the current references, which in turn will be multiplied by the DC-link controller output signal. Then the signal is used to command the inverter.

5.0 IMPLEMENTING METHODS

A simple approach is the direct DC coupling of two storages. Main advantage is the simplicity and cost-effectiveness. Moreover, the DC-bus voltage experiences only small variations. Main disadvantage is the lack of possibilities for power flow control and energy management and a resulting ineffective utilization of the storages (e.g. in a super cap/battery-HESS [3] with direct coupling only a small percentage of the super cap capacity can be utilized when operated within the narrow voltage band of the battery). The second energy storage coupling architecture in a HESS is via one bidirectional DC/DC converter [2] [16]. The converter can either be connected to the "high-power" or to the "high-energy" storage. In the latter case the "high-energy" storage can be protected against peak power and fast load fluctuations. The DC/DC converter [10] then operates in current-controlled mode. A drawback of this solution is the fluctuation of the DC-bus voltage, which is identical to the voltage of the "high-power" storage.

The third and most promising coupling architecture consists of two DC/DC-converters. Here the parallel converter topology is very common. The additional DC/DC-converter associated with the "high-power" storage is in charge of the voltage regulation of the DC-bus. It helps to operate the "high-power" storage in a broader voltage band, and hereby the available storage capacity is better utilized. Besides the parallel converter topology also a serial [7][14], cascade-type of converter topology is possible, which is generally more expensive and more difficult to be controlled. Disadvantages of the two converter coupling architecture are higher complexity and slightly higher costs. There are isolated and non-isolated DC/DC converter topologies available for HESS-applications [1] (e.g. buck/boost, half-bridge, full-bridge) with the trend to highly efficient and cost effective multi-port converters with a reduced number of conversion stages).

6.0 METHODOLOGY

The renewable charging station is constructed with the solar PV module of 10m×20m of SPM050-P and a vertical axis wind turbine (WKV-10000) with the rated wind speed of 12 m/h. The weather report has been analysed for the last five years (2012-2017) and the extracted statistical data shows that there are 276 sunny days are available during the year. The solar PV can generate full power during these days and it is very less in the remaining days, the power requirement can be managed by both the solar and wind power and the balance energy needed for charging EVs [11] can be taken from the grid. The total power generated by the charging station from the solar PV modules and the wind turbine has to be estimated. The generated power should be managed the daily power demand. So that a statistical analysis has to be performed for the average number of PEVs and EVs [2] charged per day around the vicinity of the charging station.

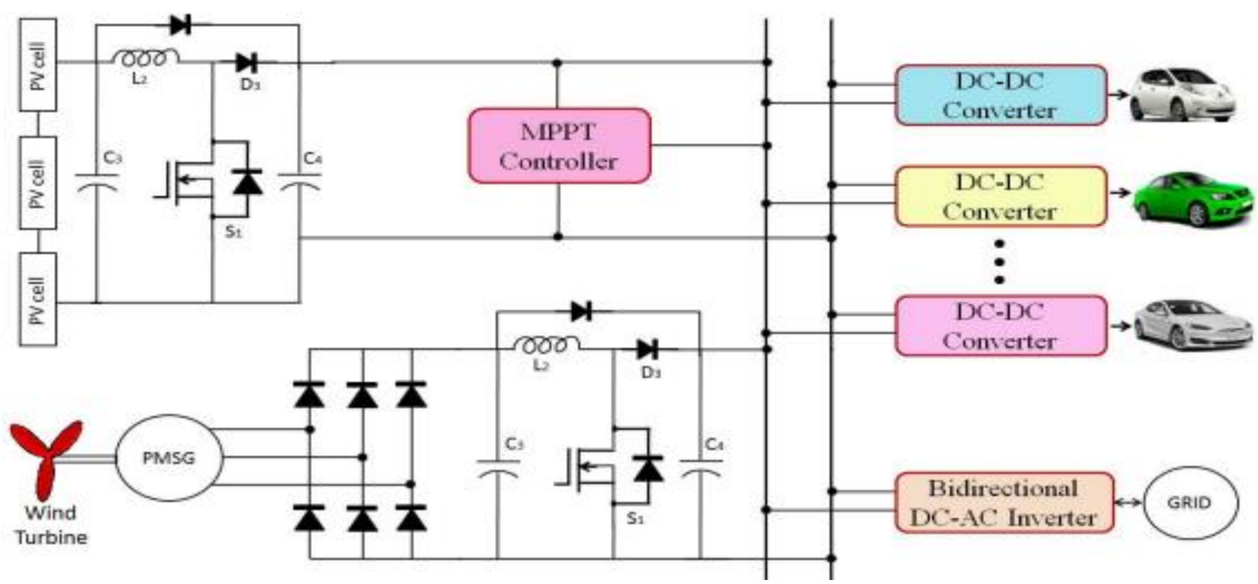

Figure Implementation of the proposed charging station for EVs

The number of EVs charging hour by hour per day is shown in Fig. The proposed SWCM consists of a wind energy conversion system, PV array, maximum

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power point tracking (MPPT) controller, unidirectional DC/DC converters for PV array, DC-AC inverter connected to grid, and bidirectional DC-DC converter for providing charging to EVs. In this study, the charging station is constructed in such a way that it can handle 10 EVs charging points. It is noted that the proposed charging stations can switch vehicle-to-grid (V2G) []15] connection. An automatic system is incorporated to manage the charging of EVs and discharge the electric energy through the grid when the load demand of the grid is high.

The wind energy conversion system and the solar modules have been connected through the two identical DC-DC converters to the DC bus, and the PV array [13] is continuously monitor and track by the controller and the DC-link voltage is taken as a reference for the controller. The implementation of the proposed charging mechanism for EVs is shown in Fig. It reveals that the SWCM provides balance between the load demand of the grid and energy [12] to charge EVs.

SOLAR AND WIND MODELLING

The hybrid renewable sources such as the wind and solar energy generation mechanism are used to generate electrical energy for recharging the battery packs of EVs. The characteristics (V-I and P-V) of solar module and the wind turbine performance [10] have been modelled. The stochastic behaviour of both the renewable sources can be done by probability distribution function (PDF) in a statistical manner.

1. Modelling of Wind Speed

The wind accumulates in the turbine depends on the present speed of the vehicle. The stochastic behaviour of the wind speed in a specific time duration 't' can be described using Weibull PDF by Khatod. The wind speed St for 't' segment can be expressed by Weibull distribution as:

$$f^t(P) = \frac{\beta^t}{\alpha^t}\left(\frac{P^t}{\alpha^t}\right)^{\beta^t-1} exp\left(-\left(\frac{P^t}{\alpha^t}\right)^{\beta^t-1}\right), for\ \alpha^t > 1; \beta^t > 1$$

Where βt and αt are the shape parameters and it can be calculated as follows:

$$\beta^t = \left(\frac{\sigma^t}{\mu_p^t}\right)^{-1.086}$$

$$\alpha^t = \frac{\mu_p^t}{\Gamma(1+1/\beta^t)}$$

Where க□ and கare the mean and standard deviation of wind speed at time segment 't'.

2. Wind turbine power generation model

The output power of the wind turbine depends on the speed of the vehicle. A specific time frame is divided into different states and the wind speed is within the specific limit [14]. The probability of wind

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speed □0 (□□ க) for 't' time segment can be expressed based on as:

$$P_s(K_n^t) = \begin{cases} \int_0^{(K_n^t+S_{n+1}^t)/2} f^t(K)\, dk \,, for\ n = 1 \\ \int_{(S_{k-1}^t+S_k^t)/2}^{K_n^t+K_{n+1}^t)/2} f^t(K)\, dk \,, for\ n = 2\ to\ Nw - \\ \int_{(K_{n-1}^t+K_n^t)/2}^{\infty} f^t(K)\, dk, for\ n = Nw \end{cases}$$

The power generation characteristics of the wind turbine are non-linear and it can be expressed for the average wind speed Savg at kth state based on as:

$$P_{WT} = \begin{cases} 0, for\ K_{avg} \le K_{cut} \\ a * K_{avg}^3 + b * P_{rated}\,,\ for\ K_{cut} \le K_{avg} \le K_N \\ P_{rated},\ for\ K_N \le K_{avg} \le K_{out} \end{cases}$$

where Kcut is the cut-in wind speed; Kout is the cut-out wind speed; Prated is the maximum generated by the wind turbine; KN is the nominal wind speed and the constants x and y can be obtained as:

$$a = \frac{P_{rated}}{K_N^3 - K_{cut}^3}$$

$$b = \frac{K_{cut}^3}{K_N^3 - K_{cut}^3}$$

Solar irradiance Model

The index terms Iph, Id, D, Rsh, and Rser represents the photocurrent, diode ideality factor, p-n junction of a solar cell, shunt resistance, and series resistance respectively.

7.0 RESULTS

The response of the system in the absence of source-1 is shown in Fig. Until time 2s, both the sources are generating the power by operating at their corresponding MPPT and charging the battery at constant magnitude of current, and the remaining power is being fed to the grid. At 2 s, source-1 is disconnected from the system. The charging current of the battery remains constant, while the injected power to the grid reduces. At instant 4 s, source-1 is brought back into the system. There is no change in the charging rate of the battery. The additional power is fed to the grid. The same results are obtained in the absence of source-2. Fig. shows the results in the absence of both PV and wind power, battery is charged from the grid.

The system presented in Figure has been partially verified experimentally with a single-phase 2 kVA prototype. The experiment uses the same parameters as in simulation. The experimental results presented in this section come from the flow chart presented in Figure. Figure presents the PCC voltage, BBS output current and the load current during transition from mode 2 to mode 1. Initially, the price of the energy is the one expected, and the BBS output current is sinusoidal and in phase related to the PCC voltage, which means that the BBS injects active power into the grid.

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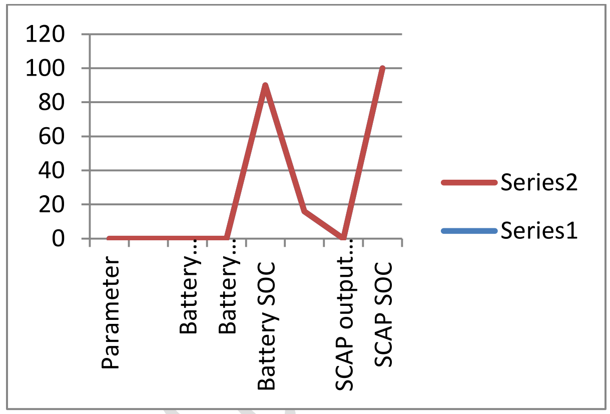
Table System Specification for DC/DC Converter

S.No	Parameter	Values	
		Charging	Discharging
1	Battery output voltage	13.1V	12.2V
2	Battery output current	1A	45A
3	Battery SOC	90	85
4	SCAP output voltage	16	5
5	SCAP output Current	1A	3000A
6	SCAP SOC	100	50

Later, the BBS begins to charge the batteries with the unity power factor from the grid's point of view. As a result, the BBS output current is 180° phase-shift related to the PCC voltage. The load current is kept unchanged. Figure presents the BBS terminal voltage and the cell output voltages during mode 2 in a steady-state condition. The terminal voltage has 19 levels, and it produces a sinusoidal waveform with a reduced output filter. The upper cell output voltage is a quasi-square wave form with 60 Hz frequency.



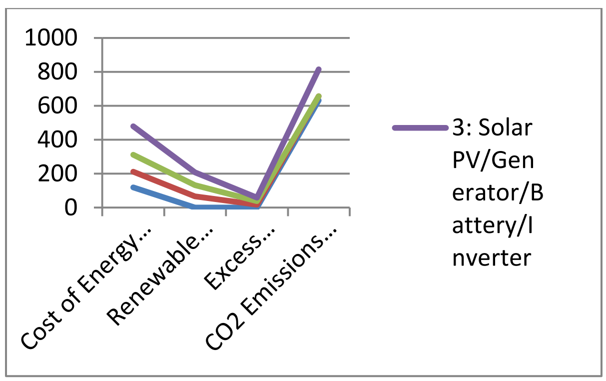
Graph System Specification for DC/DC Converter

For the energy storage, the nominal capacity is 1,068 kWh (string size of 4 and 267 strings in parallel). The energy in for the battery bank is 69,640 kWh/year and the energy out is 55,713 kWh/year. This represents 13,928 kWh/year of loss through the battery bank. The inverter capacity was 864 kW but the mean power output from the inverter was 263 kW. This represents a capacity factor of 30% for the 8,760 hours per year of operation. The energy in for the inverter is 2,385,728 kWh/year and the energy out is 2,299,899 kWh/year. The inverter power loss is 95,829 kWh/year.

The optimized hybrid Solar PV/Fuel Cell/Generator/Battery/Inverter power system produces 3,055.95 MWh/year. From the total energy produced from the hybrid system, 78.1 % is used to meet the AC primary load of the building, 18.2 % is the excess power (can be used to meet the thermal load of the building), 3.6% is the system losses in both the battery bank during charging and discharging process and the inverter (conversion form DC to AC power), and 0.08% is the unmet load. The renewable fraction of the hybrid power system (system 1) is 66.1%. Figure shows a comparison between the three systems of the total energy production from the solar PV, Fuel cell, and Diesel generator; the energy consumption (AC primary load of the building), the losses in the battery and inverter, the unmet load and the renewable fractions.

For the daily performance of the system, the results show that during the day most the energy is produced from the PV system where the solar irradiance is high and during the night most of the energy is produced from the fuel cell. A comparison study was performed concerning the performance and the cost of the hybrid power systems for the best three Systems. It is shown clearly from these results that system 1 with Solar PV/Fuel Cell/Generator/Battery offers the best option with respect to the cost of energy (92 $/MWh). The system offers a high renewable fraction (66.1%) and is the second rated with respect to the carbon dioxide emissions (24 kg CO2/MWh).

The system will meet all the energy demand for the building with 18.2 % excess electricity that can be used for the thermal load of the building. A summary of the capital, replacement, fuel, and operation and maintenance costs for the PV/Fuel Cell/Diesel Generator/Battery/Inverter hybrid power system was also determined. The initial total capital of the hybrid power system (system 1) is $1.54 Million ($1.23 Million for the PV system) with a payback period of 6.83 years. The cost of energy (COE) for the proposed system is 92 $/MWh.



Graph Hybrid power system performance comparison

Modes of operation:

Table operating modes

Number of modes	Timing in seconds	S1	S2	S3	S4
1	0 - 0.5	1	0	0	1

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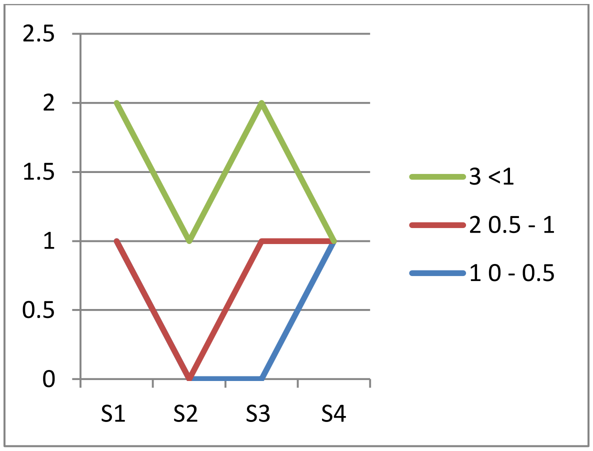
2	0.5 - 1	0	0	1	**0**
3	<1	1	1	1	0

Where, S1= Battery switch.,

S2= Renewable sources to Grid switch.,

S3= Renewable sources to load switch,

S4= Grid to load switch.



Graph Operating modes

A. Mode 1

In mode 1 of operation, normal power supply to load occurs (i.e.) from grid power to load. During this operation of mode, power supply is not obtained from hybrid sources. So during this mode the voltage from the solar and wind sources is stored in the battery. According to the simulation, this mode is in operation from 0 sec to 0.5 sec.

B. Mode 2

In mode 2 of operation, power supply for load is obtained from solar and wind sources (i.e.) from renewable sources to load. During this operation of mode, power supply is not obtained from grid sources and also voltage from the renewable sources is not stored in the battery. According to the simulation, this mode is in operation from 0.5sec to 1sec.

C. Mode 3

In mode 3 of operation, power supply for load and grid is obtained from hybrid sources (i.e.) from renewable sources plus battery to load and grid. During this operation of mode, stable power supply to load and grid is obtained from hybrid sources to overcome fluctuations if any. The voltage from the solar and wind sources is stored in the battery as well to maintain the battery voltage. According to the simulation, this mode is in operation after 1sec.

8.0 CONCLUSION

A Power Management Strategy for Hybrid Grid interconnected PV-Wind Energy system is proposed in this paper. In this, the proposed hybrid system is implemented using different MPPT controllers to provide the effective performance of the system. The proposed PSO and Cuckoo based MPPT calculations involves the system parts and furthermore balance the power stream. The accessible power from the PV item is profoundly dependent on solar radiation. The dynamic execution of the proposed energy the executives system dependent on MPPT with its control and correspondence system is tried tentatively and utilizing

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SIMULINK under genuine record of climate examples and load conditions. The near outcome for the proposed system with various MPPT controllers is appeared.

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