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Energy Management for on-Grid and Off-Grid Systems Using Hybrid Energy Sources

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Abstract

Renewable energy systems such as photovoltaic (PV) and wind energy systems are widely designed grid connected or autonomous mode. This is a problem especially in small powerful system due to the restriction on the converter markets. Converters which are utilized in these kinds of energy systems operate on grid or off grid. In this project, an optimal power management strategy has been developed by designing a wind-PV hybrid system to operate both as an autonomous system and as a grid-connected system. The converter used in this study has been designed to operate both on-grid and off-grid. Due to the continuous demand for energy, gel batteries can be used in the hybrid system to store the energy in an efficient manner. The designed control Unit performs energy management for on grid and off grid wind/PV and battery hybrid systems by providing an effective energy transfer to batteries, loads and grid. So the designed control unit provided the opportunity to work more efficiently.

Keywords: Energy management system, Renewable energy sources, Hybrid energy system, Micro grids, Optimization techniques.

INTRODUCTION

Energy management is necessary in this present scenario. Energy management helps in not only saving the energy but also in utilization of electrical energy in the efficient manner. So this project mainly focuses on Energy management of hybrid sources. The main purpose to focus on energy management system is due to the present energy scenario where the demand for energy is increasing rapidly. The use of renewable energy sources is rapidly increasing all over the world. \

RENEWABLE ENERGY SCENARIO IN INDIA

The use of renewable energy sources is rapidly increasing all over the world. New investments in renewable energy have reached 260 billion dollars world. Even though the world economic crisis has been affecting the world economy since 2008, significant investments in renewable energy have continued. When new investments are evaluated on a sartorial basis, it is seen that investments in the field of wind and solar systems have been in the forefront. Today, more than half of the world population has been living in urban areas. Due to the large population densities in urban areas, world energy sources are consumed in these densely populated areas as expected. By the reason of 60–80% of world energy has been consumed in urban areas, 75% of CO2 emission occurs through these areas. Due to the population density in urban areas has been rapidly increasing, It is estimated that by the year 2050, 70% of overall population is going to be living in urban areas and as a result of this, the energy consumption rate is expected to be increased 80% more. Therefore, promoting the usage of small wind-solar system in urban areas has a significant importance.

WIND/PV SYTEM TOPOLOGY

In this project, the PV panel and wind turbine generators are used as the main power generator in the system. Due to the continuous demand for energy, energy storage devices are required. Therefore, gel batteries can be used in the hybrid system. In order to operate hybrid system on grid and off grid the control unit was developed. With this control unit, the system can operate both on grid and off grid. By this means, the hybrid system could work more efficiently.

A. PV Panel

The PV cell is formed by combining p and n type semiconductor material in a thin layer. Therefore, they are similar to diode in structure. The PV cell coverts the solar radiation into electricity energy. Meanwhile, they fairly generate very low voltage in the high current density. Therefore, a PV cell shows a character of current source. In order to determine the behaviour of PV cell, many equivalent circuit structures are presented in the literature. The most commonly used is the one diode equivalent circuit. A crystalline silicon PV cell's electrical equivalent circuit is shown at Fig 1.

The mathematical relationship between the ideal PV cell and current-voltage can be expressed, by using the Semiconductor theory, currents and voltages laws of Kirchhoff's at equivalent circuit of PV module [6].

$$I = I_{PV} - I_0\left(\exp\left(\frac{q \cdot V}{akT}\right) - 1\right) \quad (1)$$

I_{PV} is the current generated by light on the cell, I0 is the diode reverse saturation or leakage current, q (1.60217646 × 10^{-19} C) is the electron charge, k is Boltzmann constant (1.3806503 × 10−23J/K), T p-n is the temperature of junction surface (in Kelvin), a is the diode ideal constant. The current-voltage characteristics cannot be determined by using only at the real PV panels. The reason for this is being losses. The relationship between the PV Panel outputs current is expressed by while considering the losses shown as resistor in Fig 1.

$$I = I_{PV} - I_0\left[\exp\left(\frac{V + I \cdot R_s}{V_t \cdot a}\right) - 1\right] - \frac{V + I \cdot R_s}{R_P} \quad (2)$$

V_t is the thermal voltage of panel formed by Ns cells connected in series and it is calculated with ,

$$V_t = N_s kT / q \quad (3)$$

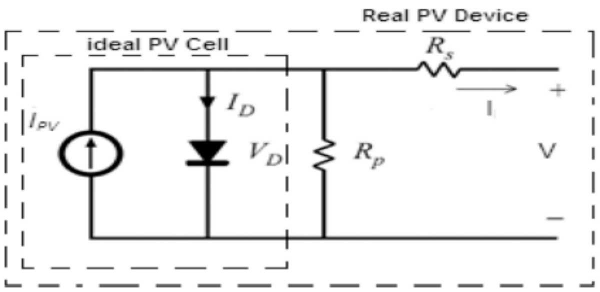

Figure 1. Equivalent circuit of PV cell

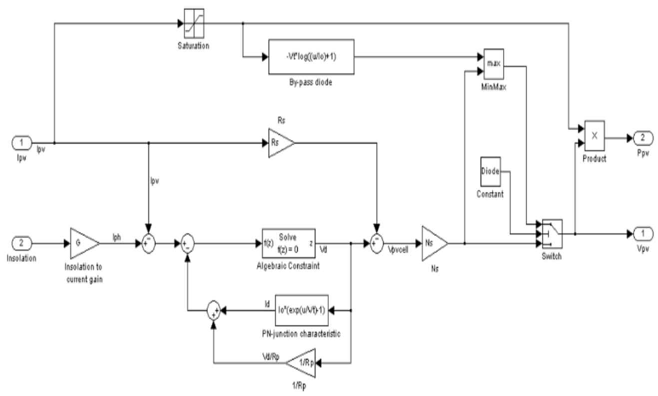

Figure 2. PV module’s model in MATLAB/Simulink

PV module’s model was prepared by using this equation and this model is shown in fig 2. Simulation of the PV cell to perform the desired properties, PV cell's maximum current, maximum voltage, maximum power, short circuit current and open circuit voltage must be entered into the model. The current voltage characteristic is shown which is based on the amount of the radiation of PV panels used in this study.

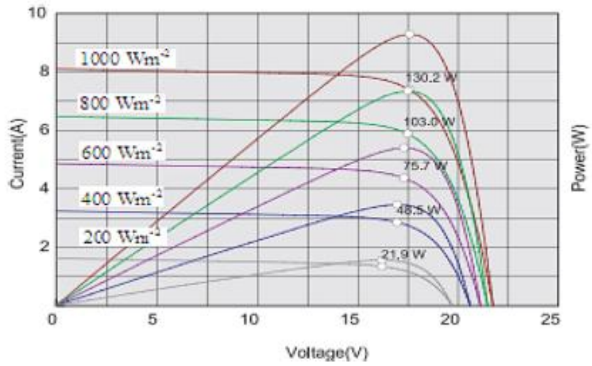

Figure 3. I-V and P-V characteristics of PV module

As it is shown in fig 3, while the radiation is increasing, the current and power values obtained from PV panel are increasing. Similarly, these values decrease depending on the decrease of radiation amount.

B. Wind Turbine

Wind turbines use the kinetic energy of wind depending on the swept area of blades. The kinetic energy causes rotation is given as,

$$E = \frac{1}{2}\rho_a \cdot v \cdot V^2 \quad (4)$$

ρ_a is air density and v is the speed of airflow obtained from the rotor. When blade swept area is AT and wind velocity V, the theoretical power can be obtained from the wind is calculated by eqn 5.

As it is seen, power in wind flow depends on blade area and wind speed. Although these parameters effect the power obtained from the wind spectrum, the most important parameter is the wind speed.

$$P = \frac{1}{2}\rho A_T V^3 \ (W) \quad (5)$$

These theoretical calculations indicate an isolated system without any external factors. As expected, there is always an energy loss in physical systems and here, due to this energy loss, it is impossible to obtain the full power calculated. Maximum power that can be obtained from a wind turbine depends on turbine efficiencies (Cp), efficiency of gear mechanism (if there is any), efficiency of mechanical coupling and efficiency of generator, and especially depends on the value Cp. Cp refers to amount of energy converted from wind energy to electrical energy. Accordingly, Cp is calculated by,

$$C_p = \frac{\text{Türbin tarafından üretilen güç}}{\text{Rüzgardan elde edilebilecek toplam güç}} = \frac{P_r}{P_w} \quad (6)$$

The whole wind, which is slammed opposite from the turbine wings, cannot be stopped at the horizontal-axis wind turbines.

The wind, which flaps the turbine blades, returns the blades and during this time, the slower wind continues its road by spreading behindthe blades. The powerequation which is placed in front of the turbine blades is calculated by,

$$P_m = \frac{1}{2}\rho\left(\frac{16}{27}A_2 v_1^3\right) \text{ W}$$

16/27 = 0.593 is stated as Betz Limit, and it is expressed that the turbine cannot receive more than 59.3% of wind power. In accordance with the explanations mentioned above, the power which can be obtained from a wind turbine can be expressed by,

$$P_m = C_p\left(\frac{1}{2}\rho A v^3\right) \tag{7}$$

The output voltage generated by wind turbine, which is based on the wind speed used in this project is shown in below fig 4.

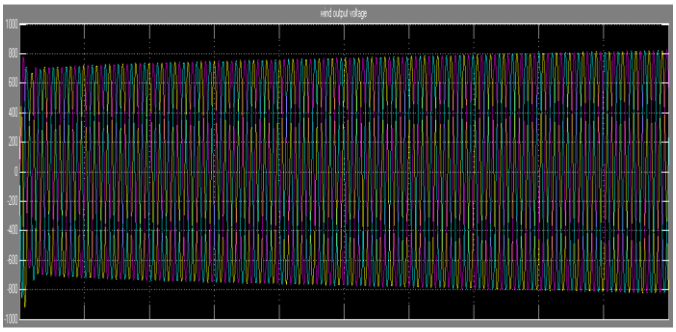

Figure 4. Wind output Voltage

C. Battery Model

The batteries are used in small power renewable energy systems in order to store electricity energy wherefore solar power and wind power is not compliance with the energy usage of a temporal. In this way, the energy continuity of autonomous loads is provided in the energy-producing systems in accordance with the meteorological conditions, day/night differences and seasonal changes. Storage in renewable energy systems, particularly suitable price/performance ratio and high environmental optimum results in terms of recycling are provided with lead-acid batteries[11].

Considering the lack or being sufficient of wind or solar energy, battery pack capacity of wind-photovoltaic hybrid power system, allows the loads of energy so as to provide at least three days is determined. The presence of such storage prevents the power outage in case of maintenance or in fault.The most common of these batteries are Lead acid, Lithium-ion, Nickel–cadmium, Sodium–sulphur,anadium redox and Zinc–bromine. Due to the low initial costs and availability, lead-acid batteries are widely preferred in renewable energy appcation. However, these kinds of batteries have short life time cycle. There are also various storage systems apart from chemical batteries. All these storage systems have several advantage and disadvantages whit respect to each other. Batteries have three main working conditions; discharge, state of charge and float charge.

In case discharge, the batteries transfer energy to loads or grid by converting chemical energy into electricity energy. In the case of charge, the electric energy is converted into chemical energy. Float charge status is the required study of battery in order to provide certain amount of storage. In the lead acid batteries, primarily current-limiting charging method is selected in order to provide water recycling. In this study, two 12 V 200 Ah capacity batteries are used. In the figure, charge and discharge curves of batteries are shown.

Value of the battery charge and discharge, show differences based on excess or shortage power consumption. Therefore, to protect and to ensure the efficient operation of the battery, the battery charge controller is used in order to limit the discharge and charge current in maximum rate. Battery current can be calculated by.

$$I_{bat} = \frac{P_{PV}\eta_{reg1} + P_{wind}\eta_{reg2} - P_{dem}/\eta_{inv}}{V_{bat}} \tag{8}$$

In the formula; P_{pv}: PV output power, P_{wind}: wind turbine output power, η_{reg1} : Regulator efficiency of the PV panel, η_{reg2}:Regulator efficiency of the wind turbine, P_{dem}: power demand, η_{inv}: Inverter efficiency, V_{bat}: Battery voltage.

SYSTEM MANAGEMENT & CONTROL

In renewable energy power systems, central control unit (supervisory controller), control the operation mode of the system and the flow of power also provides the optimum operation of control units which belongs to each energy source. Main decision factors for power management strategy is power level supplied by wind turbines and solar panels and the battery power level of the state of charge. Supervisory controller must balance the power flow between system components. However, because power generation varies depending on atmospheric conditions, power management strategy can be very complex [7].

Control unit which is designed in this project, provides the operation of the hybrid system as autonomous and grid connected. The control unit's input terminals are output of PV panels, wind turbine output, battery, grid and autonomous loads. The output terminals are the switch between the DC/AC inverter and the grid, the DC/AC inverter and autonomous loads, grid and autonomous loads and the switch on the battery cable. PV generator is composed of fifty series cells and five parallel cells. PV array generates output voltage of 96.872v and wind power generates output voltage of 700v. DC/DC converter is used to stabilize the output voltage of solar and wind by using fuzzy logic controller. The FLC is designed with fuzzy logic toolbox in MATLAB.

A. Dc/Dc Converter

A **DC/DC converter** is a power converter with an output DC voltage greater or lower than its input DC voltage. In this project DC/DC converter is controlled by using fuzzy logic controller to obtain a stable single phase 230v as a output from the DC/DC converter.

The system components of DC/DC converter is described as follows, input voltage to the converter is from two sources (i.e.) solar and wind. Therefore total input voltage to the DC/DC converter will be around 500-700v. Since control unit is employed with fuzzy logic controller the output voltage of the converter is maintained to a constant voltage of 230v..which is shown in fig 6.

In order to cross check the efficiency of the fuzzy logic controller, the same simulation is carried out with different controller for control unit (i.e.) PI controller. Corresponding scope of PI controller is shown in the fig 5. It is observed that by using fuzzy logic controller the time taken to stabilize the voltage is very less when compared to the PI controller.

So DC/DC converter with fuzzy logic controller results in efficient output when compared to DC/DC converter with PI controller.

So this is efficient when compared the converter with PI controller.so in are they are adopting this controller, since it is more efficient.

B. PI output vs. FLC output

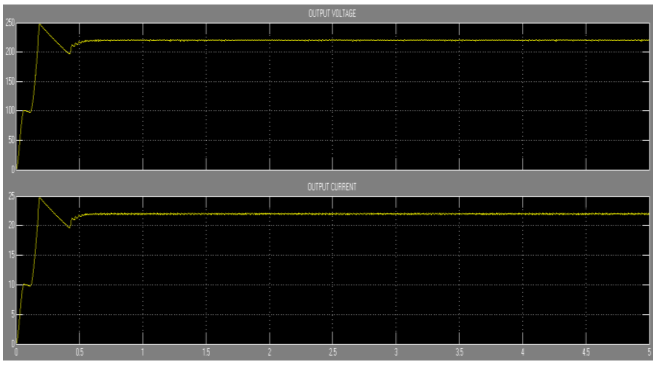

Figure 5. PI output

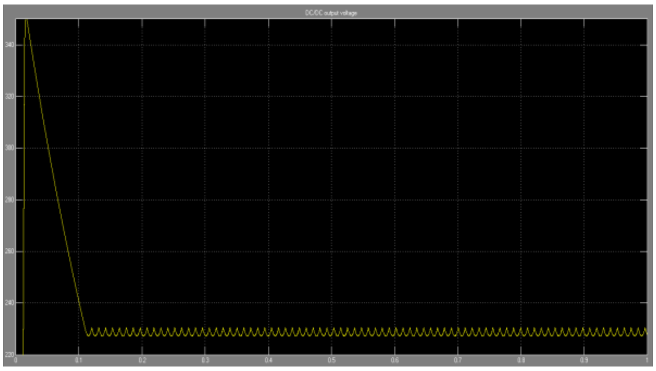

Figure 6. FLC output

SIMULATION MODEL

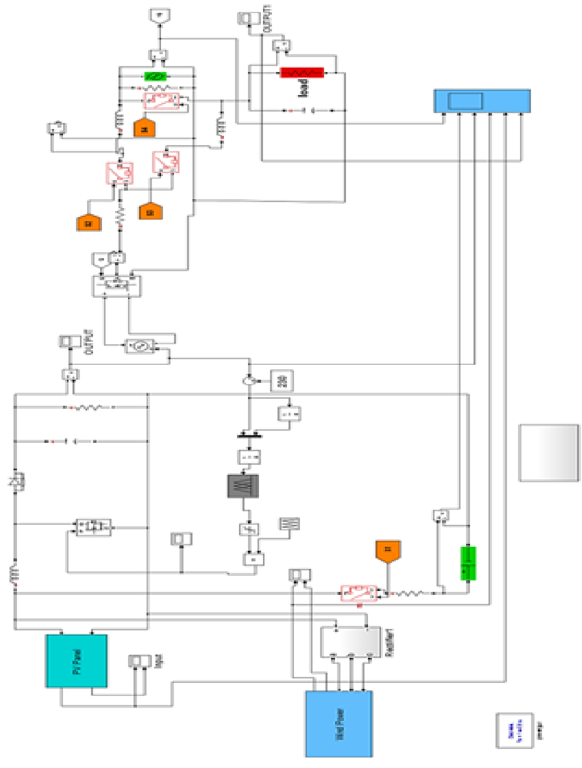

Figure 7. Simulation model

Simulation Output & Discussion

Modes of operation:

Table 1. Operating modes

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

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

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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.

A. Simulation Output for Mode 1 and Mode 2

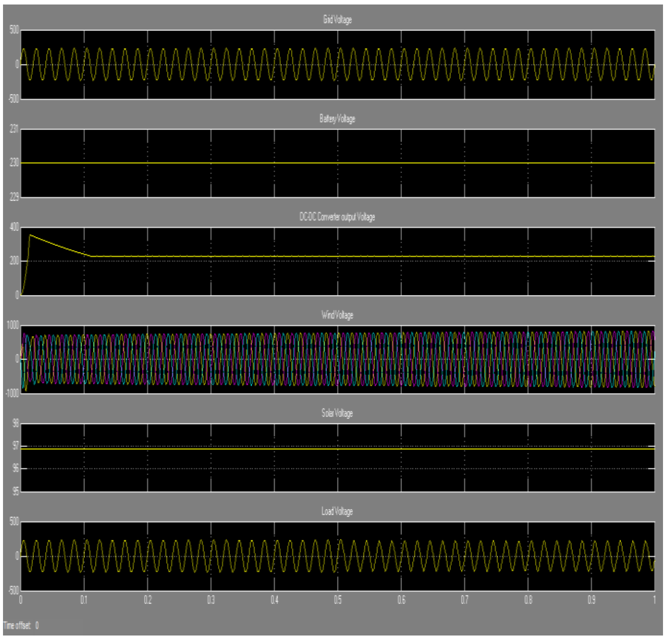

Figure 8. Mode 1/ Mode 2 output

B. Simulation Output For Mode 3

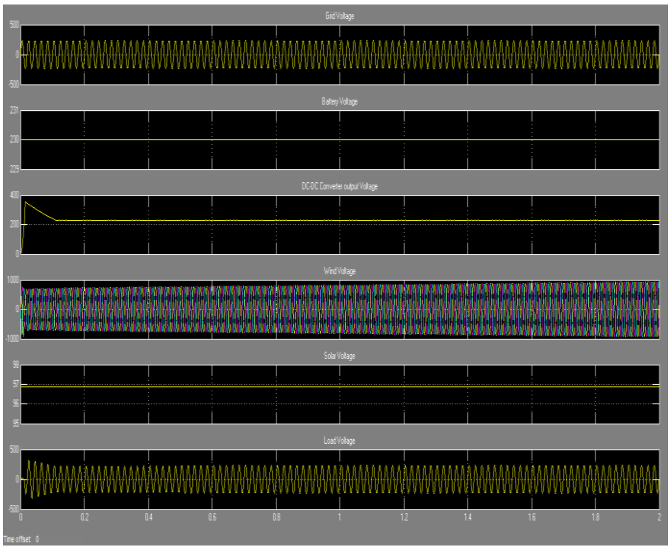

Figure 9. Mode 3 output

Thus it is observed from the below simulation output, continuous power supply to the load is guaranteed irrespective of any kind of disturbances that could occur in grid side. Because in all three modes the load voltage remains unchanged (i.e.) 230V. Even though when there is no grid power supply to load, hybrid sources come into the act to ensure the continuous power supply which is observed in mode 3. This scenario ensures the stability in the power supply.

CONCLUSION

The proposed system is based on fuzzy logic controller is found to be more compact and less complex. Within the context of developed control unit application, when the developer control unit is used, the power transferred to grid, batteries and/or autonomous loads are averagely more than the present scenario according the control unit is not used. By adopting this proposed method the power oscillations are reduced and steady state is reached at much faster rate. Results show excellent performance with FLC when compared to PI controller.

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