Efficient Energy Management System for Integrated Renewable Power Generation Systems

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This paper presents viability study of integrated renewable power system for telecommunication applications. Rapid depletion of fossil fuel resources necessitated research on alternative energy sources. A wind solar integrated system is a reliable alternative energy source because it uses solar energy combined with wind energy to create a stand-alone power system. Incremental Conductance and Fuzzy Logic Maximum Power Point Tracking is proposed in this paper for solar and wind power system to provide a constant voltage with the help of DC-DC Single-Ended Primary-Inductance Converter. Main objective of this paper is to supply uninterruptible power for telecommunication loads from standalone solar-wind-Diesel integrated power system with efficient energy storage system. Embedded based Effective Energy Management Controller is proposed to monitor the power from all resources and load demand continuously and to control whole integrated power system. It provides uninterrupted power, effective utilization of sources, improves life time of battery and minimized usage of diesel. The whole system is analysed with telecom tower load demand and real weather data using MATLAB/simulink.

Keywords: Integrated power system (IPS), Single-Ended Primary-Inductance Converter (SEPIC), Energy Management Controller (EMC)

Introduction

Solar energy and wind energy have been deemed clean, inexhaustible, unlimited, and environmental friendly. The Indian telecommunications industry is one of the fastest growing in the world. India is currently adding 8-10 million mobile subscribers every month. Presently 40% power requirements are met by grid electricity and 60% by diesel generators. For every kWh of grid electricity consumed 0.84 Kg of CO2 is emitted. Total CO2 emission is around 5 million tons of CO2 due to diesel consumption and around 8 million tons due to power grid per annum. The move from diesel to solar, wind and other alternate renewable sources of energy will result in a reduction of 5 million tons of CO2 emissions. Integrated energy systems have proven to be advantageous1 for decreasing the depletion rate of fossil fuels, as well as supplying energy to remote rural areas, without harming the environment.

Proposed Integrated power system

In an integrated power system renewable energy sources like wind and solar are connected with conventional backup system. A stand-alone wind system with solar photovoltaic system is the best integrated combination2-4, of all renewable energy systems and is suitable for most of the applications, taking care of seasonal changes. In this paper the IPS consists of wind, solar, energy storage (Battery bank) unit and diesel generator. Energy storage system is providing a constant and continuous power to the load. Generally dump load option is introduced in renewable power generation system to protect the system during excess power generation especially peak season. Dump load is connected to the grid to act as a load when the energy production is excess than load and state of battery is fully charged. The standby power system is also required for renewable based power generation systems. In this paper diesel run generator is used as a standby power system. DG is switched ON only when all the sources are individually or in integrated mode are not able to meet the load demands then controller activate the diesel source selector switch automatically. The whole system is monitored and controlled by Energy Management Controller. Block diagram of Solar wind Integrated system with energy management controller is shown in Fig 1.
Wind Power System

Viability of wind power generation is dependent on the duration of useful wind speed and quality of wind. Wind speed and quality varies throughout the day/year from site to site.

The amount of power which is produced by the wind machine \( P_w \) is expressed as

\[
P_w = 0.5 \rho AV^3 \quad \cdots (1)
\]

Where \( \rho \) is the air density, \( A \) is the cross sectional area of the turbine is the wind velocity. Power generation is depends on cube of the wind velocity. Wind turbine characteristics are unknown, the controller algorithm brings the operating point towards by stepwise increases or decreases in the rotational speed of the wind turbine. Generally, MPPT is achieved using intelligent control methods.

Solar Power System

India receives abundant sunshine for around 300-320 days a year. Monocrystalline solar cells, Polycrystalline solar cells and thin-film solar cells are mostly used type of solar cells. The type of PV cell is selected based on the application in terms of cost, cell design, size and efficiency. Tracking of maximum power point (MPP) of a PV array is usually an essential part of PV system. Generally conversion efficiency of PV system is low (Less than 17 %) and the amount of electric power generated by solar arrays changes continuously with weather conditions. The location of MPP can be located, either through calculation models or by search algorithms. There are many MPPT algorithms utilized for PV array such as Hill climbing/P&O, Incremental Conductance (Inc Cond)\(^{13}\), Fuzzy MPPT\(^ {12}\), Neuro- Fuzzy MPPT etc., in this paper incremental conductance method (Inc Cond) of MPPT is proposed. In this method the array terminal voltage is always adjusted according to the MPP voltage. PV array voltage and current are continuously monitored in this controller.

SEPIC DC-DC Converter

Power converters play a vital role in renewable based power generation systems to obtain constant voltage. When the input of the system is not constant, output of the system is also fluctuating. Telecom tower (BTS) equipments require a constant DC voltage, it is obtained by DC-DC single-ended primary-inductance converter (SEPIC) that provides a
positive regulated output voltage. This type of converter is the optimum converter for renewable energy sources since source voltage fluctuates above and below the output voltage. Unlike Cuk converter, it produces output as in the same polarity of input. Assuming 100% efficiency, the duty cycle, D, for a SEpic converter operating in Continuous Conduction Mode and or Discontinuous Conduction mode. In a wind source and diesel source SEpic converter acts as a buck converter. In a solar power plant SEpic converter acts as a boost converter.

**Energy Management Controller (EMC)**

Single source system gives power to the load directly. When more than one source is introduced, the generated power from sources should be regularised. The main problems of the integrated power systems are related to the control and supervision of the power system. An overall energy management strategy is designed for the proposed system to manage power flows among the different energy sources and the backup system. Embedded Energy Management Controller (EEMC) monitors the status of load, power generated by wind source and PV system, SOC of the battery and Dump load battery. All the sources are connected with DC bus through source selector (MOSFET) switches. Each switches are activated by control signal generated by EMC. The power balance equation for the proposed system can be written as

\[
P_{\text{net}} = P_s + P_w + P_B \quad \text{and} \quad P_{\text{net}} = P_B + P_{\text{net}} = P_{DL} \quad \text{and} \quad P_{\text{net}} = P_{DG} = P_{\text{Load}}
\]  

Equation (2) shows the total power of the IPS of different operating conditions.

**Simulation Results and Discussion**

In order to verify the system performance under different conditions, simulation studies have been carried out using Base Transceiver Station (BTS) load demand and real weather data. The weather data’s (solar radiation, wind speed, sunshine hours and air temperature) are obtained from the online records of the weather station established by Tamil Nadu Agricultural Weather Network (TNAWN) at Tamil Nadu Agricultural University (http://www.tnau.ac.in), Coimbatore. Simulation model of IPS with energy management controller is developed using MATLAB/simulink R2011b. Rating of the proposed model is given below

Wind power plant : 1.5 kW
Solar power plant : 1.5 kW (10 No X 300w X 24V)
Battery Bank : 2.5 kW
Dump load Battery : 1.5kW
Diesel Generator : 3 kVA to 12 kVA
Load (DC) : 1kW, -48 V, (1.5 kW to 3kW)
Load (AC) : 0.5kW (For lighting load), 440 V, 50Hz, 3 Phase

Since telecom tower (BTS) equipments works in -48V DC. The negative supply system will give noiseless signal and minimize the filter circuit than positive supply system. Three phase AC power is provided for other usage like light loads, Air Conditioner, & cooling fan etc., used in BTS. Three phase AC supply is obtained from MOSFET based Hex bridge inverter, which is connected with DC bus and controlled by pulse width modulation technique and given to the AC load. The simulation working model is designed with, wind power generation is starts at 4 m/s and in case of high wind speed >25 m/s wind generator is turned off. The solar PV system starts generation at 100 W/m$^2$ up to 1000 W/m$^2$. SOC of battery is maintained between 20% to 100%. All the sources are connected with DC bus through source selector (MOSFET) switches, which are activated by control signal generated by EMC. Simulation model of the proposed system with EEMC is shown in Fig. 2. Some expected special cases are discussed in the following section

Case 1: It is the state when any one source is sufficient to run the load. Consider if solar alone is sufficient to run the load solar selector switch (S2) is activated and remaining selector switches are turned off. Battery charging controller (S5) is activated.

Case 2: It is the state when any one of the renewable source and battery are sufficient to run the load. Consider solar and battery are sufficient to meet the load. Solar and battery selector switch (S2&S4) are activated and remaining selector switches are turned off.

Case 3: It is the state when both renewable sources are sufficient to run the load. Solar and wind selector switch (S1, S2) is activated and remaining selector switches are turned off. Battery charging controller is activated and if battery is in fully charged state (SOC > 95%) then the excess power is stored in dump load battery.

Case 4: It is the state when both sources are not sufficient (less than minimum set power) to run the load and battery alone is sufficient to run the load.
Consider if battery alone is sufficient to run the load, battery discharging selector switch (S4) is activated and remaining selector switches are turned off.

Case 5: It is the state when battery, Dump load battery and both renewable sources are not sufficient (lesser than minimum set power) to run the load, Diesel generator selector switch (S3) is activated and remaining selector switches are turned off. Battery charging controller (S5) is activated.

Similar to above, many cases are programmed in embedded system (not discussed in this paper). Embedded based Energy Management Controller is control the overall system effectively. Other than embedded controller, we can use mechanical switches (relays) and Fuzzy Logic Energy Management Controller (FLEMC) for overall control strategy.

Conclusion
The wind and solar integrated power system is simulated using MATLAB. From the simulation it is proved that the integrated system supplies uninterrupted power to the load. MPPT algorithms applied in wind and solar sources make the system efficient. Integrated power system supplies AC and DC load so it is suitable for all applications like remote areas, villages and hill stations. Embedded based Effective Energy Management Controller controls integrated power system to provide uninterrupted power, minimizing usage of diesel, effective utilization of sources and improves life time of battery. Since the usage of diesel generator is minimized emission of harmful gases from it is minimized. So it is a pollution free green energy system. This proposed system is optimally suitable for Telecommunication load in off grid areas, where constant voltage and continuous power is required. By suitable modification of power control strategies presented in this paper such as MPPT technique and the different energy management controller, the same system with different ratings can be developed to power up any kind of loads.

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