International Journal of Emerging Technology and Advanced Engineering

Volume 3, Special Issue 3: ICERTSD 2013, Feb 2013, pages 622-627

An ISO 9001:2008 certified Int. Journal, ISSN 2250-2459, available online at www.ijetae.com

HYBRID ENERGY SYSTEM SIMULATION FOR SUSTAINABLE ENERGY UTILIZATION

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ABSTRACT

Complex power generation scheduling, correlated uncertainties, environmental issues and hybrid energy system modeling have become very important research topics due to rapid growth of large-scale distributed renewable energy system, deregulated electric power markets and responsive demand. The intermittent nature of the primal energy sources (i.e. wind, sun, water) increases uncertainty as well as the complexity of the hybrid renewable energy systems. In hybrid energy system, different renewable sources of energy are integrated together to operate under changing natural conditions. Different types of hybrid power systems namely wind/FC/UC-based hybrid power generation system, solar cell/wind turbine/fuel cell hybrid power system, and solar cell (SC), wind turbine (WT), fuel cell (FC) and ultra capacitor (UC) systems, can be operated to achieve minimum or negligible fluctuation of power output from hybrid power system with respect to changes in load and environmental conditions. Simulation and optimization of hybrid renewable energy systems having different combination of energy sources have been carried out by several researchers. In the present paper, a study has been made for hybrid energy system simulation for sustainable energy utilization.

Keywords: Hybrid System, Renewable Energy, Simulation and Optimization

1. INTRODUCTION

Social, economic and industrial growths of any country require energy. But energy generation from fossil fuels has a detrimental effect on environment and climate. Renewable energy generation is the best option for protecting environment as well as solution towards the limited availability of fossil fuel. Renewable energy sources are biomass, wind, solar (thermal and photovoltaic), hydroelectric, marine, geothermal, tidal energy and nuclear fission. The challenges of renewable energy system are the fluctuations in output power due to changing environmental conditions, cost and load variation. Design and configuration of hybrid renewable energy based power system is essential to minimize the short-comings of single renewable energy system. So modeling and simulation for renewable energy system is necessary for designing and analyzing hybrid power system, performance evaluation of renewable energy system, analysis and control of renewable energy system and optimization of renewable energy system. The simulation of renewable energy system is mostly carried out using Matlab and Simulink software and optimization is done by fuzzy logic and genetic algorithm. Some dedicated software package for specific purpose is also used for simulation and optimization of renewable energy system. Modeling and simulation greatly helps to understand, evaluate and optimize the renewable energy system. In the present paper, a review of literature consisting modeling and simulation of renewable energy systems with its evaluation, control and optimization have been discussed.

2. HYBRID SYSTEM.

Hybrid system is an integrated system that utilizes different renewable energy sources such as solar energy, wind energy, or micro hydropower together to operate under changing natural conditions to provide a quality power supply to remote areas. The abundant energy available from renewable sources can be harnessed and converted to electricity in a sustainable way to supply the necessary power to the people without accessing the electricity grid. The advantages of the hybrid system in remote areas are such as the cost of transported fuel are avoided and that are reduced the concern on the issues of climate change and global warming. The disadvantage of standalone power systems using renewable energy is that the availability of renewable energy sources has daily and seasonal patterns which results in difficulties in regulating the output power based on the load demand.

Presented at International Conference on Energy Resources and Technologies for Sustainable Development, 07-09 February 2013, Howrah, India.

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ISSN 2250-2459, *Volume 3, Special Issue 3: ICERTSD 2013, Feb 2013, pages 622-627*

Combining the renewable energy generation with conventional power generation will enable the power generated from renewable energy sources to be more reliable and affordable in case of hybrid system. A schematic of a solar PV-Wind hybrid system is presented in Figure 1. The system has an ability to provide 24-hour grid quality electricity to the load providing a better efficiency, flexibility of planning and environmental benefits compared to the stand-alone system.

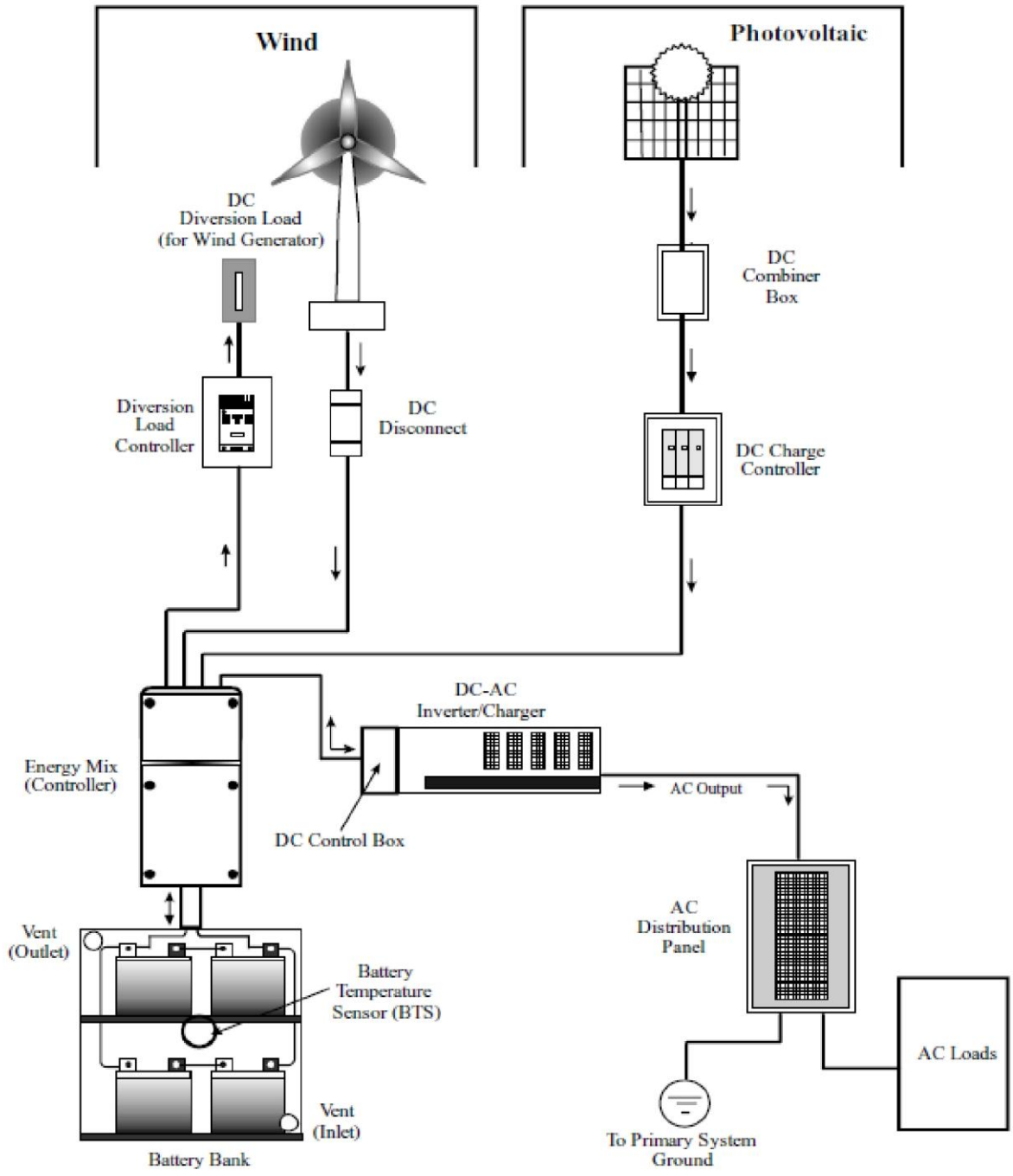

Fig.1. Schematic diagram of Solar PV-Wind Hybrid system. [1]

3. SIMULATION TOOLS FOR RENEWABLE ENERGY

Simulation is useful to understand a new system before implementation. Simulation for renewable energy is a potential research area to plan for enhancement of power quality, stability and reliability in a designed renewable energy system. *Polysun* is a well-known simulation tool used to simulate solar thermal systems, solar cooling, photovoltaic and heat pump systems. Lundh *et al.* [2] have generated hot water profile using simulation code in Matlab and compared that profile with standard hot water profiles

ISSN 2250-2459, *Volume 3, Special Issue 3: ICERTSD 2013, Feb 2013, pages 622-627*

by *Polysun* and *Winsun* simulation tools. Objective of their work was to show the resemblance between the shapes of standard profiles with their own generated profiles. They concluded that the hot water profiles used in solar heating simulation tools differs with the average hot water profile of their study. Ghorbani *et al*. [3] have developed Renewable Energy Vehicle Simulator (REVS) package in Matlab/Simulink simulation language and IDEAS package. REVS has been designed to simulate and analyze the hybrid electric vehicle design considering the parameters namely dynamics, energy management, fuel economy. Norman [4] has used Sandia's simulation software tool to simulate wireless sensor networks. Sandia's simulation software tool is already used for simulation of renewable energy sources for commercial needs. Parker [5] has developed dynamic model of wind energy converter (WECS) and micro-hydro converter (MHCS) using Mathworks Simulink package incorporating the Real-Time Workshop. The simulator is used to simulate aerodynamics and hydrodynamics of renewable energy sources. He has developed a novel solution for the problem of communication between the PC and the DC drive. The combination of ANSYS ASAS software and FLEX5 is used for simulation and analysis of offshore wind turbine, wave energy device, tidal energy device, wave energy mechanical energy coupling, random wave and survival wave condition.

4. SIMULATION OF HYBRID POWER SYSTEM

Different types of hybrid power systems namely wind/FC/UC-based hybrid power generation system, solar cell/wind turbine/fuel cell hybrid power system, and solar cell (SC), wind turbine (WT), fuel cell (FC) and ultra capacitor (UC) systems are modeled and simulated using SimPowerSystems and Matlab/Simulink software packages. The objective of these simulations is to achieve minimum or negligible fluctuation of power output from hybrid power system with respect to changes in load and environmental conditions [5-8]. An integrated hybrid power system consisting of a photovoltaic energy system and a wind power system was modeled along with an optimized digital control system design and rapid Field Programmable Gate Array (FPGA) prototyping with the digital controller. The above system was compared with a system already simulated using Matlab/Simulink software simulated three stand-alone solar photo-voltaic (SPV) hybrid power systems using different energy storage technologies i.e. SPV-Battery system, SPV-Fuel Cell (FC) system and SPV-FC-Battery system using HOMER software. The purpose of this simulation was to optimize, analyze and compare the effect of Maximum Power Point Tracker (MPPT) technology system on the three SPV systems using different storage technologies. It has been found from simulations that SPV-FC-Battery hybrid system has least system cost and best energy consumption pattern compared with the other two single storage systems [12]. Sousa et al. [13] have modeled and simulated systems of multiple sources of energy (SMSEs) using formalism Differential Hybrid Petri Nets. Petri Nets is used to describe large number of system models, analyze techniques and graphical representations considering local states and local actions with their mutual relationships. They modeled discrete events dynamic, continuous dynamics considering their mutual dependence and did formal verification. A simulation model of combined biogas, bio-ethanol and protein fodder co-production in organic farming has been developed to analyze the scope of renewable energy production in sustainable agriculture [14]. Site specific, load and resource dependent optimization of hybrid energy system, using LINDO software 6.10 version, reveals that stability and continuous power supply property of hybrid energy system is better than any single renewable energy system [15]. Gaunt *et al.* [16] have simulated a renewable energy based hybrid (wind and solar) power system model. They modeled the combined uncertainty in availability of energy, the load variation and compared the effects of different combinations of energy storage on load variation for adequate and reliable energy supply. A simulation model was developed to optimize the system design of a hybrid power system with HOMER software [17]. Different types of hybrid generating systems with storage technology, namely photovoltaic system with diesel generator, wind power solar PV/hydrogen fuel cell energy system and the grid-connected hybrid generation system consisting of fuel-fired generators (FFGs), wind turbine generators (WTGs), PV panels (PVs), and storage batteries (SBs) are simulated by time-series based optimized simulation, MATLAB software and multi-objective particle swarm optimization algorithm coded with C++ language for design optimization, cost optimization considering system constraints and performance prediction [18-20]. The transient analysis of integrated generation systems (IGSs) due to sudden changes of load, parallel operation of rotating machines and static converters having different characteristics is simulated using a simulation package called Combined Multiple Renewable Energy Sources System Simulator (CMRESSS) to calculate the electrical and mechanical parameters during normal or abnormal conditions. This simulation package which runs in MS-DOS environment has been developed and tested by performing several simulations [21]. A hybrid wind-dump load generation system under changing operating conditions and a wind-battery hybrid system is simulated and modeled by Takagi-Sugeno (TS) fuzzy model, linear quadratic regulator (LQR) and sliding mode nonlinear control design technique. The TS fuzzy based controller is compared with a proportional-integral (PI) controller and the simulation results show that the proposed controller provide less fluctuations in power output during wind speed and load variation disturbances than the PI controller in wind-hybrid power generation system. The results show that the output fluctuations are much less and performance behavior is more smooth for wind-battery

ISSN 2250-2459, *Volume 3, Special Issue 3: ICERTSD 2013, Feb 2013, pages 622-627*

hybrid system [22, 23]. An operation and control methodology of a three phase, four wire voltage source inverter (VSI) under unbalanced voltage conditions for a hybrid power system is modeled. The control techniques are applied by dividing the supply voltages and currents into positive, negative and homo-polar sequence components which are controlled independently using different synchronously rotating reference frame systems. So the output voltage is unaffected by load imbalances [24]. Aboul-Seoud *et al.* have simulated the effect of wind speed and tide variation on the output power of a grid connected wind/tidal hybrid system. They have simulated the system after incorporating a dynamic voltage regulator (DVR) controlled by a tri-loop dynamic error driven PI controller, compared the simulated results with that of the network without DVR and the power output and voltage variation reduced [25]. A stand alone renewable energy based power supply system consisting of aqua electrolyzers, fuel cell generators, wind turbine generators and diesel generators in isolated small islands is simulated. The total output power meets the total load demand, no separate batteries are required and the system efficiency is improved [26]. An object oriented simulation model using AnyLogic simulation software has been developed to design micro grid hybrid system. AnyLogic is a hybrid simulation software which integrates discrete event, system dynamics, and agent based models to model systems [27].

5.OPTIMIZATION OF RENEWABLE ENERGY SYSTEM

Simulation and modeling of existing wind-diesel power system and various configurations of hydrogen system using Simulink 5.0 of Matlab simulation tool evaluate optimum hydrogen integrated wind power system. It shows that the hydrogen integrated wind power system reduces the diesel fuel consumption. Development of simulation tools for performance evaluation and optimal integration of the renewable energy system in building design are significant to optimize the design of renewable energy system configuration [28,29]. Optimally configured renewable generating systems for residence is proposed using genetic algorithm to minimize total cost, which is sum of initial cost, operation cost and maintenance cost [30]. Stochastic bottom up electricity market model is used to optimize unit commitment considering the stochastic behavior of wind power generation [31]. The unit commitment problem is also solved by a genetic algorithm operated improved binary particle swarm optimization (PSO) algorithm. A refined algorithm, using multiple populations and some genetic algorithm concepts, is effectively used in various sized thermal power system with equivalent solar and wind energy system with high quality financial (minimized production cost) solutions [32]. A knowledge based design approach is used to configure integrated renewable energy systems (IRES) to minimize the total cost at pre-selected reliability level, which is quantified by the loss of power supply probability (LPSP) [33]. Energy flow management of integrated generation system (IGS), multi agent system (MAS) for distributed renewable energy (DRE) management of a set of eco-building units, and cost effective control structure of DC-grid for offshore wind farm HVDC connection are significant steps towards cost optimization of renewable energy systems [34-37].

6. CONCLUSIONS

The objectives of renewable energy system simulation are design and configuration of renewable power system comprising of renewable energy sources, cost optimization, minimization of carbon emission and other environmental hazards, uninterrupted power output maintaining standard stability criteria, and proper energy flow management. The modeling and simulation of renewable energy system are useful in configuration, analysis, performance verification and optimization of several renewable energy systems. So decision making regarding renewable energy system becomes easy and fruitful. It is obvious from several simulation methods and their results that more implementation of power electronics in renewable energy system is required. Realistic approach and consideration of large number of operational and environmental parameters are necessary for simulation of renewable energy system to get more effective application for sustainable energy utilization.

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