Design & Development of Micro Biomass-Wind-Solar Hybrid System for Remote Village Electrification

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Abstract- *The main objective of this paper is to report and present design of a 22 kW Biomass-wind-solar hybrid power station (22kW generation has been divided into 10kW biomass generator, 10kW energy generation from wind & 2kW energy generation from solar power) and associated wireless sensor and Labview based monitoring instrumentation system for information & development of renewable & non-conventional modes of energy. The hybrid unit contains three complete generating plants, a wind turbine system, a PV solar cell plant & a biomass generating system. These are connected & synchronised in parallel to the power grid. Since solar energy resources are high in summer, this will provide an excellent complement to the load demand when summers are not windy, moreover for the support during the unavailability of both wind & solar biomass will provide a perfect support.*

Keywords- Indian power sector, smart grid technologies in India, challenges

I. INTRODUCTION

Energy is available in two different alternatives: non-renewable (coal, fuel, natural gas) & renewable energy (solar, wind, biomass, hydro, tidal etc.) sources. After industrial revolution in 19th century, first coal & then fossil fuel are used as primary sources but from the end of 20th century & beginning of 21st century wind power generation was welcomed as an alternative. After 1973 oil crisis, the dependency on renewable energy increases & new modes of eco-friendly energy generation concepts were brought into play. Atmospheric environment is polluted due to thermo-electric power plants & petroleum materials these pollution materials are acting as catalysts for the search of development of renewable energy sources. Moreover, completely depending on one renewable energy source for energy generation is not that beneficial, so the concept of Hybrid-renewable-energy-system(HRES) are becoming popular for remote area power generation applications. Economic aspects of these technologies are sufficiently promising to consider them for developing power generation capacity in developing & remote areas. This paper describes methodologies to model HRES components, HRES designs & evaluation. The trends in HRES designs show that the hybrid biomass/PV/wind energy system are considered as they are non-exhaustive, site-dependent, non-polluting & potential sources of alternative energy. However, there are certain common drawbacks of solar & wind energy. One of them is their unpredictable nature, standalone photo voltaic (PV) or wind energy system do not produce usable energy for considerable portion of time during the year. So, to overcome this, biomass power/energy generation is considered power generation for constant dependency.

The drawback in case of PV energy generation is mainly due to dependence on sunshine hours, which are variable in former case& on relatively high cut-in wind speeds, which range from 3.5 to 4.5 m/s, in the latter case resulting in underutilization of capacity [1]. The independent use of all the systems results in considerable over-sizing for system reliability, which in turn makes the design costly [2].

II. HYBRID RENEWABLE SYSTEM COMPONENTS MODELLING

General methodology for HRES components like biomass, wind, PV & battery is described here. [3] Hybrid biomass/photovoltaic/wind energy systems rely on highly transient energy sources & exhibit storing short-term & seasonal variations in their energy output. Thus, the energy produced in periods of load demands needs to be stored in order to stabilize the output, when the demand is high. While batteries are most commonly used for this purpose, they lose 1-5% of their energy content per hour & thus can store energy for short periods of time. There are presently no practical means available for long term storage of excess electrical energy produced. Though it is not necessary, but still, for emergency usage of energy, the energy generated from biomass plant is also stored in the battery, as it needs more cost to start up a plant each time. So energy storing will be a cost saving scheme. Standalone commercial PV or wind does not produce usable energy for considerable portion of time during the year. So, combination of these three energy sources into a hybrid energy system reduces the battery bank & diesel requirements. Feasibility of PV & wind energy system strongly depends on solar radiation & wind energy potential available at the site [1,4,7]. Area of PV array, number of wind machines & battery storage capacity play an important role in operation of this hybrid system. Most biomass power plants use direct-fired combustion systems. They burn biomass directly to produce high-pressure steam that drives a turbine-generator to produce electricity. In some biomass industries, the extracted or spent steam from the power plant is also used for manufacturing processes. These combined heat & power systems (CHP) greatly increase overall energy efficiency to approximately 80% from the standard biomass [2*] system with efficiencies of approximately 20%. A simple biomass electric generating system is made-up of several key components. For a steam cycle, this includes some combination of (i) equipment for fuel storage& handling (ii) furnace (iii) boiler (iv) pumps (v) fans (vi) steam turbine (vii) generator (viii) condenser (ix) cooling tower (x) system control. The output [1*] can be directly distributed or can also be stored in a battery.

For continuous monitoring of the complete hybrid system few technologies needed to be implemented like (i) computer modeling approach for evaluating the general performance of a hybrid system [8] (ii) evaluation of performance of hybrid energy system using synthetically generated weather data [9] (iii) elaborate discussion of analytical model for predicting the performance of hybrid system with hydrogen energy storage for long-term utilization [10].

Optimum size specifically of the PV & Wind energy system can be calculated on an hourly basis & of daily average power per month, the day of min PV power/month & the day of min wind power/month, [11] which is presented by a method for optimum size of hybrid PV/wind energy system. For more perfection, various optimization techniques are used to design a hybrid energy system in most cost effective way & they are (i) linear programming [12]: (ii) probabilistic approach [13]; (iii) Dynamic programming [14]; (iv) Multi-objective [15]. In order to calculate reliability/cost implications of hybrid energy system [16] there is a Monte-Carlo simulation approach; there are comparisons of results of two optimization techniques based on simplex & other algorithm for hybrid energy system [17].

Hybrid energy systems are also designed not only for meeting electricity requirements but also for meeting fresh water requirements through desalination [18]. There are many attempts made towards improving the prospects for utilizing renewable energies in combination with energy supply system, for the power & heating requirements of a residential complex. The earlier studies reveal that hybrid energy systems are providing to be promising worldwide, in view of cost, maintenance, power independency etc.

III. AN OVERVIEW OF THE PROJECT

The mentioned hybrid energy system project proposes construction of a 220kV Biomass-Wind-Solar power & instrumentation system where a 10kW Bergey excel-S wind turbine with a power sink II utility intertie module (208V/240V Vac, 60Hz). The BWC Excel 10 is a modern 7m (23 feet) diameter, 10kW wind turbine designed for high reliability, low maintenance & automatic operation in adverse weather condition widely used in urban setup [American Wind Energy Association(AWEA) rated power is 8.9kW at 11 m/s (24.6 mph)]. With this we also need eight BPS x 175B, 175 W solar photo-voltaic panels, enough biomass resources & life stocks for energy generation in biomass plant & related power instrumentation /data acquisition hardware. A 100’ long wind tower for new wind turbine, on the other hand using bio-fuel that are the liquid or gaseous fuels produced from biomass, most commonly ethanol & biodiesel which are produced after physical processing like re-radiation or evaporation techniques. The whole plant or system is been mentioned through wireless sensors, Labview software & N1FPGA data acquisition model. Rectifiers are been used for the electricity conversion from ac to dc & vice versa.

IV. ESTABLISHMENT OF THE HYBRID UNIT

The hybrid unit contains three complete generating plants, a wind-turbine system, a PV solar cell plant & a biomass plant. These sources are connected & synchronized in parallel to the power grid often the process is called as grid-tie interactions.

The overall project block diagram is presented in Fig.1.

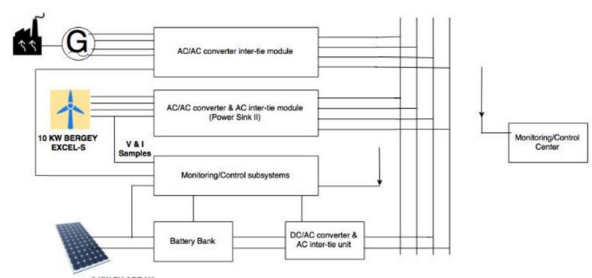

Figure 1. Proposed 22kW biomass-wind- solar power system

All the implementations are already mentioned for this hybrid energy system; a 10kW wind turbine was chosen for its low maintenance & many safety features. One of the low maintenance feature is the turbine’s permanent magnet generator & internal governor. The turbine generates 10kW when running at its rated speed of 13m/sec (29 mph). Turbine’s blades are made of fiber glass (3 blades for each turbine). Another feature of the wind turbine is a sophisticated internal regulator that periodically checks the line voltage & corrects for low voltage conditions. The PV solar panels are 24V dc units & are chosen for their ultra-clear tempered glass that is manufactured for long term durability. As widely known, one of the largest problems in power flow is power quality as they are unable to provide a good sinusoidal waveform output & causes problems such as harmonic contamination & poor voltage regulation (a maximum limit of 3 to 4% total harmonic distortion may be allowed from inverter output). The inverter used in solar PV system has a power rating of a 2.5 kVA containing 12 deep-cycle lead-acid batteries connected in necessary series/parallel combinations. The biomass power plant has a specification to generate 10kW of energy & many processes are also introduced like Combined Heat & Power system (CHP) to increase the efficiency to approximately 80% from the standard biomass system.

To monitor & store the voltage, current, power & harmonic contamination data, two fluke power quality analyzer are used in the system. In addition, permanently mounted ac/dc digital panel meters from part of the systems instrumentation.

Fig2. shows the functional block diagram of 1.5kW biomass-wind-PV hybrid power system. We can get much larger output (wind power specially) if we use wireless sensor & wireless communication among wind turbines, PV modules & the main computer. Vibration monitoring using N±9234 sensor module that includes monitor vibrations on the turbine structure at the base & on the nacelle. Yearly wind speed, direction, temperature monitoring & data storage strain monitoring which is a common technique for determining structural health. Using OREOA wind assessment study, wind turbine noise impact measurement using NI sound and vibration analysis software. Adding biomass & solar power into a wind system will increase the reliability of the overall system for every seasons of a year.

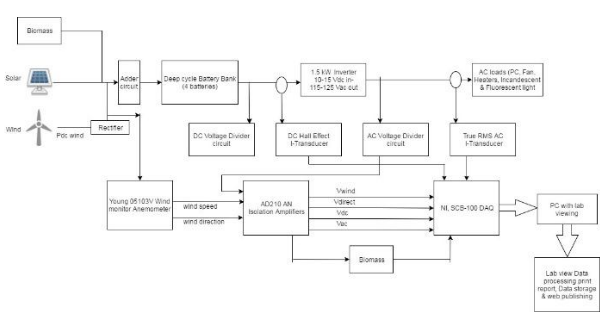

Figure 2. Instrumentation & data acquisition functional block diagram.

The electricity generated by the power station will be used as renewable energy input for the smart grid named as Phase II. Thus in Phase II stage of the project the following electronic/electrical materials will be required to set up seamless interface between the hybrid power (system) station & smart grid based smart city: COTS, actuator, power & energy meters, cabling, conduits, junction boxes, CBs, switches, frames, digital displays, power supplies, sensors (temperature, humidity, vibration, solar radiation, airflow), AD/DA converters, microprocessor development kit & other miscellaneous materials needed or intelligent circuitry, measurement, data acquisition & monitoring.

V. CONCLUSION

A complete 22kW biomass-wind-solar power & instrumentation/data acquisition system will be completed & synchronized with the ac power grid providing supply to the smart city. The components for maintaining the hybrid plant & also studying it needs statistical analysis, computer programming, electrical circuits, analogue devices, digital electronic, programmable logic controllers (PLCs), electromachines, power system interactions& instrumentation/interface using wired/wireless sensors & networks. The wireless sensors collect data on wind, temperature, vibration, sound, voltage, current, power, load charges at all the 3 power system & communicates with NI data acquisition hardware & the main computer. By applying Labview based instrumentation & data acquisition can provide a remote access to the biomass-wind-solar power system. This project concept will be helpful because of its grid-tied biomass-wind-solar power system. The places having solar resources higher in summer this project will provide an excellent complement to the load demand when summers are not windy & as a secondary Biomass energy generation which is completely independent form the nature. Further this model is helpful for remote village electrification, particularly for less populated villages where load requirement is low.

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