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Study of An Autonomous Hybrid Renewable Energy System

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Abstract— *This paper study of an autonomous hybrid renewable energy system. Mainly, hybrid systems are divided into two categories as stand-alone and grid-connected systems. Since wind and solar energies are complementary in electric power generation from the complementarity of time and region; in stand-alone systems, energy provides by wind turbine and PV are the major renewable energy resources. Moreover, storage resources such as diesel generator (DG), battery, super capacitor bank, super conducting magnetic energy storage (SMES), and fuel cell-electrolyzer are used to overcome the intermittent nature of wind and solar energies. Stand-alone systems are the most promising technologies for supplying load in remote and rural areas. They provide greater reliability, higher efficiency and lower cost in comparison with using single resources technologies*.

Keywords— diesel generator; photovoltaic; wind turbines; super conducting magnetic energy storage, hybrid renewable energy systems

1. INTRODUCTION

Nowadays renewable energy resources are one of the promising ways to address many problems encountered since 1970 when the world major industries faced the shortage of Petroleum and worst energy crises. Climate change, desertification, greenhouse effect, etc., lead the world towards sustainable energy era. Using natural and renewable resources such as wind, solar, geothermal, tidal, wave and hydroelectric offer clean alternatives for fossil fuel; in which they are omnipresent, abundant, free, clean and easily accessible even in isolated and undeveloped places.

Design a renewable energy system with the low adverse socio-economic and environmental impacts, are one of the challenges for its developments. Renewable energy systems need to be adequately informed and assessed at initial stages. Unpredictable nature of these resources is one of the drawbacks for their development, especially when having a reliable source of energy to match the time distribution of load demand is essential. This drawback together with high initial cost, and dependency on weather conditions lead to combine different renewable resources to form a Hybrid system which can be flexible, cost effective, reliable and efficient. However, careful planning and assessment is required to ensure the successful implementation of a hybrid power system. Training of operators, involving local community on electrification programs, overseeing installation and commissioning, maintenance procedures, system monitoring and reporting are all part of the successful hybrid power system implementation process.

Since wind and solar energies are complementary in electric power generation from the complementarity of time and region; in stand-alone systems, energy provided by wind turbine and PV are the major renewable energy resources [1]. Moreover, storage resources such as diesel generator (DG), battery, super capacitor bank, super conducting magnetic energy storage (SMES), and fuel cell-electrolyzer are used to overcome the intermittent nature of wind and solar energies [2].

Since the combination of PV and wind are the most common sources of renewable energies in stand-alone systems, in this project, optimization of hybrid systems which include PV and wind as the sources of energy generations combined with battery and diesel will be investigated.

Component models of renewable resources are summarized in the following section and later the arrangement of sources and connections of hybrid systems will be discussed to predict the hybrid renewable energy systems (HRES's) performance.

2. PROBLEM STATEMENT

Renewable sources such as wind, solar, and hydro power, which offer clean alternatives for fossil fuel, are omnipresent, abundant, free, clean and easily accessible even in isolated and undeveloped places in the form of stand-alone hybrid systems. These systems are mainly used in remote area communities to generate electricity. However unpredictable nature of these resources is one of the drawbacks for their development, especially when having a reliable source of energy to match the time distribution of load demand is essential.

This drawback together with high initial cost, and dependency on weather conditions result in combining different renewable resources to form a Hybrid system which can be flexible, cost effective, reliable and efficient. However, hybrid systems need to be adequately informed and assessed at initial stages. Design a renewable energy system with the low adverse socio-economic and environmental impacts, are one of the challenges for hybrid renewable energy developments. Thereby, knowledge of all factors which influence the performance of the system and accurate modeling for each component are prerequisites for designing an accurate model of the HRES. In recent years, there are a number of studies conducted on different aspects of stand-alone hybrid systems in terms of component or configuration to optimize the stand-alone systems. Therefore, finding the best suited model for a particular region would be the basic need of any study..

3. MODELING

Mainly, hybrid systems are divided into two categories as stand-alone and grid-connected systems. Since wind and solar energies are complementary in electric power generation from the complementarity of time and region; in stand-alone systems, energy provides by wind turbine and PV are the major renewable energy resources [1,3]. Moreover, storage resources such as diesel generator (DG), battery, super capacitor bank, super conducting magnetic energy storage (SMES), and fuel cell-electrolyzer are used to overcome the intermittent nature of wind and solar energies [2,4].

Stand-alone systems are the most promising technologies for supplying load in remote and rural areas. They provide greater reliability, higher efficiency and lower cost in comparison with using single resources technologies.

Since the combination of PV and wind are the most common sources of renewable energies in stand-alone systems, in this study of optimization of hybrid systems which include PV and wind as the sources of energy generations combined with battery and diesel will be investigated. Component models of renewable resources are summarized in the following section and later the arrangement of sources and connections of hybrid systems will be discussed to predict the hybrid renewable energy systems (HRES's) performance.

3.1 Photovoltaic (PV) Technology

Photovoltaic systems are classified into two categories of grid-connected and stand –alone systems which are known as Remote area power supply (RAPS) systems [5]. Fig.1 illustrates the classification of PV stand-alone systems.

All technologies related to capturing sunlight or artificial light and convert it into the electricity are known as photovoltaic (PV), which are classified into crystalline, thin film, compound semiconductor and nanotechnology. Technological development in PV technology would lead to the more promising and demanding projects in rural electrification [6].

Crystalline silicon solar cell was developed in 1950's [7]. Considering its head start, reliability and material availability, it has always been the most widely used solar cell which has lead the global PV market.

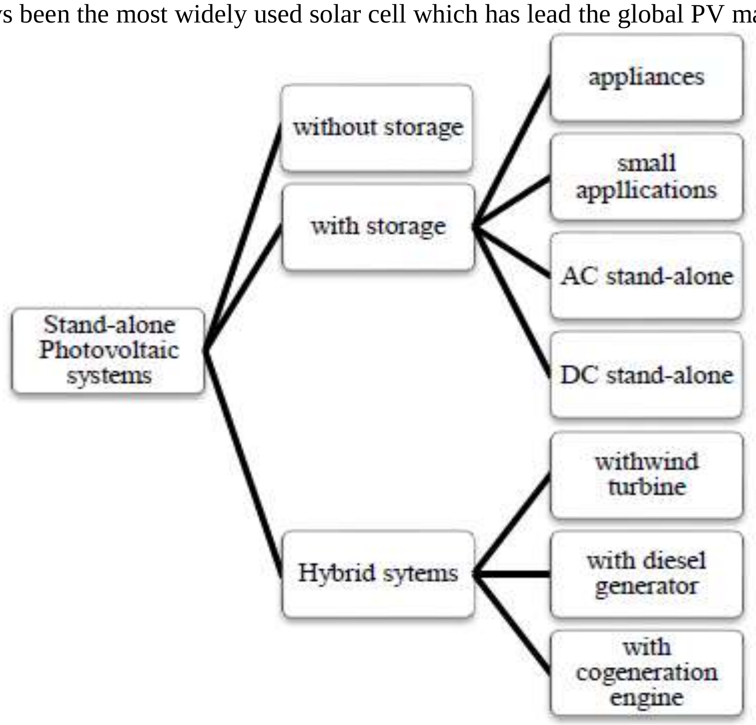

Fig.1. Classification of PV systems

3.2. Wind turbine technology

Wind turbines harness the power of the wind and convert it into electricity energy. Being low-cost, easily available and environmentally friendly, it continues to be the fastest growing electricity generator technology in the world [8]. Wind turbines can be classified based on the orientation of the axis of the rotor with respect to the Ground: those whose rotor rotates around a horizontal axis, and those whose rotor shaft rotates around a vertical axis. Horizontal axes wind turbines are more common and generally are used for large scale electrical grid-connected power plants.The vertical axis wind turbine is an eggbeater-shape and often known as Darrieus rotor after its inventor. Despite a few problems with the vertical-axis, its advantages outweigh disadvantages in several aspects: Unlike horizontal-axis wind turbines (HAWT), they can accept wind from any direction. The speed increaser and generator can be installed at ground level that makes it accessible and it doesn't need over-speed protection. They are applicable in low-wind speed and since they don't require tower, the capital cost for vertical-axis wind turbines (VAWT) is lower [9]. However, the problem is that the rotor is closer to the ground and cycling variation of power will happen on each rotor revolution.

Small wind turbines can provide enough electricity and be cost effective if the following rules are considered: the average of low wind speed month become 3-4m/s, wind tower located away from buildings and trees [10], it is installed not too far away from the load due to more losses and cost of wiring, considering DC having more losses from wind turbine to the load rather than AC.

3.3. Battery technology

The battery storage is usually used as a backup for the hybrid stand-alone systems to increase its availability, and provide load leveling for short-term fluctuations. As given in the literature, there are various methods for storing the renewable energy. A study on using super capacitor is conducted in [11]. The results show that battery life time increased by relieving the battery of narrow and repeated transient charging and discharging. Lead-acid batteries have been the most commonly used energy storage units in hybrid systems by delivering electricity in range of 5 V to 24 V DC. They are of low cost, readily available, and highly efficient. Capacity of lead-acid batteries is ranging from 10Ah up to 1000Ah. There are some limitations in using lead-acid batteries as they are subject to frequent maintenance and sensitivity to harsh temperatures [12].

Modeling of the batteries is a key issue of hybrid power system, due to the life cycle cost of the batteries as one of the major expenses for the systems. Defining a general model for the battery, which covers all the factors, is quite difficult. Accordingly, depending on the application of the model, different approaches have been applied. Modeling of the batteries is classified into three categories i.e. Chemical Model, Electrical Models, charge accumulation and empirical models [13]. Most of modeling focus on three different characteristics: performance or a charge model, voltage model, and the lifetime model.

In Fig.2 depicts Block diagram of a hybrid wind/photovoltaic generation unit.

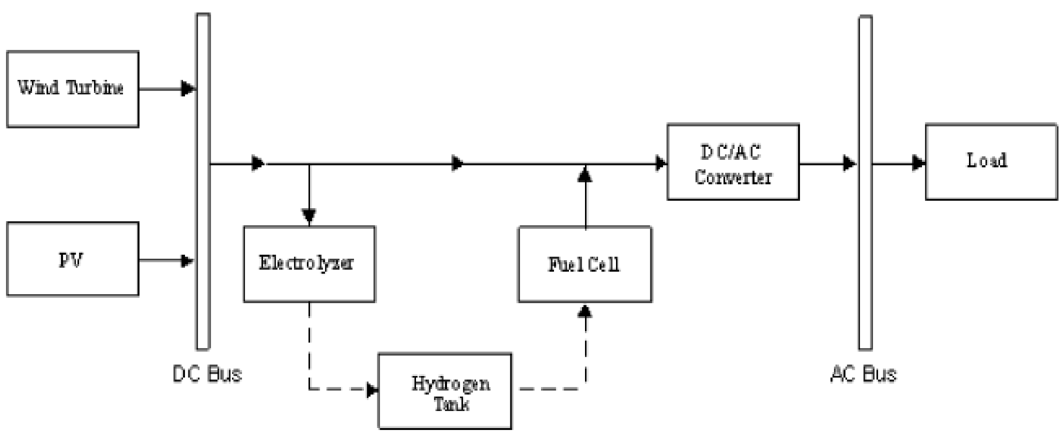

Fig.2 Block diagram of a hybrid wind/photovoltaic generation unit.

4. CONCULISION

The unpredictable nature of renewable energy resources, high initial cost, and dependency on weather conditions result in combining different renewable resources to form a Hybrid system which can be flexible, cost effective, reliable and efficient. Techno-economic analysis of hybrid systems ensures that a right combination is chosen. In the present study, the design and techno-economic evaluation of stand-alone hybrid renewable energy systems are reviewed. The existing technologies for photovoltaic solar cells, wind turbines, batteries and diesel generators, as the storage and backup systems, are investigated. To come up with a cost and energy efficient hybrid renewable energy system, the economic and technical criteria to optimize the systems are studied.

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