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Hybrid renewable energy systems for off-grid electric power: Review of substantial issues

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ABSTRACT

A hybrid power system is an emerging power generation technique which involves a combination of different energy systems, mostly renewables for optimal output configuration. In modern pursuit for renewable energy (RE) development, optimum conditions for the production and utilization of energy system are considered to be an indispensable feature for economic load dispatch. This is a rationalizing fact taking into consideration the rising price of energy for socio-economic development. Therefore, this paper reviews primary issues regarding the drivers and specific benefits of hybrid renewable energy systems (HRES). Moreover, this paper presents discussions on the various renewable energy sources which can be explored for HRES implementation. Finally, the framework unfolds a vivid review on factors to be considered for designing and implementation of HRES in general including simulation and optimization software packages for making such analyses.

Contents

1. Introduction . . . 528
2. Literature review . . . 529
3. Drivers for hybrid renewable energy systems development . . . 529
   3.1. Economic factor . . . 529
   3.2. Shortage of electric power supply . . . 530
   3.3. Environmental perspective . . . 530
   3.4. Socio-political demand . . . 530
   3.5. Increasing renewable energy subsidies . . . 530
   3.6. Availability of renewable energy resources . . . 530
   3.7. Renewable energy policy . . . 530
   3.8. Utilization of energy storage systems . . . 531
4. Benefits of hybrid power system . . . 531
   4.1. Boasting power system integration methods . . . 531
   4.2. Increase in the reliability of RE exploitation . . . 531
   4.3. Viable rural electrification option . . . 531
   4.4. Influencing the development of advanced power electronics interface technology for harvesting energy . . . 531
   4.5. Resolution of RE intermittency . . . 531
5. Sources of RE with potential for hybrid power system utilization . . . 533
   5.1. Biomass . . . 533
   5.2. Solar energy . . . 534
   5.3. Wind energy . . . 534
   5.4. Hydropower . . . 535
6. Important issues in hybrid electric power systems design . . . 535

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6.1. System sizing and optimal configuration . . . 535
6.2. Load profile study . . . 536
6.3. Software application for simulation and optimization of hybrid systems. . . . 536
7. Conclusion . . . 536
References . . . 537

1. Introduction

Currently, global energy consumption at all level of society development has considerably increased in the last few decades. However, several interesting numbers of contemporary literatures have confirmed scenarios of continuous increase in energy demand based on the progression of socio-economic activities. This step up in demand for energy may possibly be attributed to increasing quest for socio-economic sustainability in developed regions and industrialization in developing countries. Electricity is one of the core factors to all forms of development in the present day. For instance, a micro-economic activity at rural level such as small scale agricultural production is convincingly and progressively in need of modern energy for continued existence in line with modernization tendencies. Thus, in most rural areas of developing countries, grid connected electric power supply is economically not realistic due to high cost of paying for the energy amid constricted energy potential of the inhabitants. Supply of electricity with diesel based fuel becomes very much expensive while hybrid/photovoltaic/wind generation becomes competitive with diesel only generation [1–3].

Technologies utilizing single energy generation systems such as solar, wind, biomass, geothermal, hydropower and diesel only have well-known history in the context of global energy development. Without doubt, electric power generation evolved from the utilization of single energy system. Varieties of energy production systems comprising of a single source of heat energy scheme have been studied in the research works [4–7]. In [8–12], solar based energy generation using vacuum-tube collectors, solar storage system and solar water heating systems have been reported. Some other literature sources based on solar energy [13–16] applications have confirmed the usefulness and viability of the technique for electricity generation. Barry and Attilio published a research article on the application of biomass gasification only for electrification in Vanuatu [17] and the Malaysian case studies using biomass residue from oil palm [18] and banana [19]. In India, Purohit [20] presented a study on the economic potential of biomass power project using gasification under a clean development mechanism of the Kyoto protocol. Off-grid and grid-connected energy systems using wind power turbines alone have been exploited by research and development [21–26]. In a similar technique of single energy system utilization, hydropower [27–32] is as well being used single-handedly for electricity generation. Emerging technologies of electric power generation is essentially advocating for combinations of different resources for efficient and quality power delivery especially on the utilization of different kinds of renewable sources thereby causing some paradigm shift of attentions from single energy system application for electricity generation to combinations of energy systems called hybrid power technologies. Hikmet et al. [33] reported an experimental evaluation of using different kinds of renewable energy sources for heat energy production. In most cases, the end product of a hybrid energy system can be heat, electricity or heat-electricity using a combined facility known as cogeneration. Hybrid electric power systems is a mechanism that explore multiple sources of energy connected together to achieve synchronized power output. Nowadays, the uses of hybrid energy system are tremendously working in favor of renewable energy system exploitation. Notably, a HRES has enormous potential to provide quality, secured and reliable electricity to the consumers especially on micro-grid operations for remote locations.

Various research works [34–36] have confirmed that HRES in off-grid applications are economically workable, mainly in remote locations. In some cases, rather than being on economically competing track with a diesel based power supply system, a combination of different systems to form a hybrid system is more reliable in producing electricity, and often presents the best solution for electrifying remote areas [3]. Fig. 1 presents an

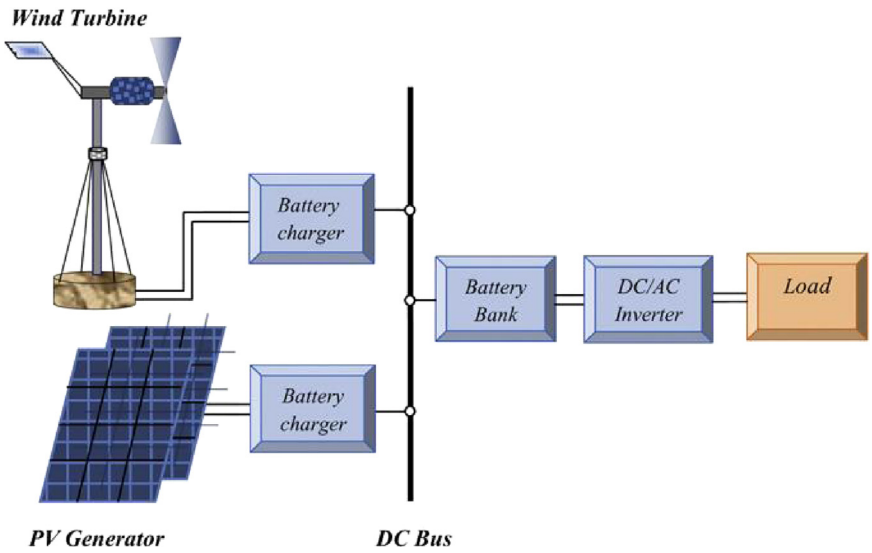

Fig. 1. Block diagram of a hybrid PV/wind system [38].