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A review on Integrated Renewable Energy System based power generation for stand-alone applications: Configurations, storage options, sizing methodologies and control

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ABSTRACT

Uneconomical extension of the grid has led to generation of electric power at the end user facility and has been proved to be cost effective and to an extent efficient. With augmented significance on eco-friendly technologies the use of renewable energy sources such as micro-hydro, wind, solar, biomass and biogas is being explored. This paper presents an extensive review on various issues related to Integrated Renewable Energy System (IRES) based power generation. Issues related to integration configurations, storage options, sizing methodologies and system control for energy flow management are discussed in detail. For stand-alone applications integration of renewable energy sources, performed through DC coupled, AC coupled or hybrid DC–AC coupled configurations, are studied in detail. Based on the requirement of storage duration in isolated areas, storage technology options can be selected for integrated systems. Uncertainties involved in designing an effective IRES based power generation system for isolated areas is accounted due to highly dynamic nature of availability of sources and the demand at site. Different methodologies adopted and reported in literature for sizing of the system components are presented. Distributed control, centralized and hybrid control schemes for energy flow management in IRES have also been discussed.

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1. Introduction

Requirement of energy in its most suitable form is the need of millions of people throughout the globe. It can be fuel, used in transportation, electrical energy for lighting loads, etc. With the beginning of 21st century, industrialization has raised many folds compared to 18th century; this has resulted in a massive scale extraction of fossil fuels at an alarming pace globally. The global climate change has added to the problem of scarcity of fossil fuels. Now it is time to look into the solution of energy crisis, created by the reduction of fossil fuels without altering the climate behavior. In stand-alone mode, transportation of conventional energy sources (like coal, oil, and natural gas) is quite difficult and grid extension is also not cost effective due to remoteness and difficult terrain. Renewable energy is the most appropriate solution to supply energy in isolated areas. Utilization of locally available resources is the best possible option to meet the energy requirement. Depending on the site conditions, single technology or aggregated technology would be selected in stand-alone mode.

Single technology based system (solar photovoltaic/wind/small hydro) is a viable option to supply energy in isolated areas. Un-electrified rural areas like village hamlets or small villages that are far away from the utility grid can be electrified by single technology. In plane remote areas, possible schemes are solar photovoltaic based system, wind energy system etc. Biomass gasifier/biogas based system are suitable for forest remote areas and Micro Hydro Power (MHP) based scheme is appropriate for remote hilly regions. Presently, rooftop solar photovoltaic systems are popular in urban areas to meet out energy demand of a building. Renewable energy resources are highly site-specific and intermittent in nature as some of the energy sources are available in abundance during winter and others during summer. Therefore, as demand increases in stand-alone mode, single technology based system are associated with high system cost and low reliability. In order to deal with such limitations of single technology based system, the concept of Integrated Renewable Energy System (IRES) has been evolved for power generation in stand-alone applications [1].

Integrated Renewable Energy System (IRES) has been proposed by various researchers to electrify remote areas [2–6]. In IRES, energy demand of a remote area is met by using energy potential of locally available renewable energy sources. In this technology, renewable energy sources like solar, wind, Micro Hydro Power (MHP), biomass, biogas etc. can be considered for power generation. IRES have the potential to aggregate benefits such as energy efficiency and energy conservation, resulting from the combination of renewable energy sources. Integrated use of different renewable energy resources minimizes energy storage requirement, increases reliability of power supply and quality of power. For stand-alone applications, these systems are always incorporated with storage devices in order to manage the stochastic behavior of renewable energy sources like solar and wind. Wind–solar–MHP based integrated system is shown in Fig. 1. Control system is the heart of IRES that provides the information and communication among various components of system. Control system regulates the output of renewable energy sources and also, generates the signals for scheduling of storage subsystem and dump load. It protects the storage system from overcharging and it help to operate the storage system in prescribed limit. Whenever surplus energy is available, it is sent to storage subsystem to store the surplus energy and if storage system if fully charged, it is wasted in dump load that can be utilized in cooking, water heating, baking etc. Under condition when demand exceeds generation, stored energy is used in order to fulfill deficit load demand.

Some remote places have not sufficient availability of renewable energy resources, under such conditions it is required to add some conventional option like diesel/petrol/gasoline based generator, along with renewable energy resources to fulfill load demand. As diesel generator based integrated system pollutes the environment, it is therefore analysis of green house gas emission level must be carried out. This scheme is not appropriate for hilly terrain and remote areas as problems associated with transportation of fuel.

This paper presents an extensive review on various issues related to IRES in stand-alone mode, like integration configurations, storage options, sizing methodologies and system control of IRES. Various integration configurations for integrating renewable energy sources are given in Section 2. Section 3 deals with the storage technology options for integrated system. Mathematical model for energy conversion of renewable energy sources is given in Section 4. Criteria for sizing of system components and various sizing methodologies are discussed in detail in Section 5. System control schemes of IRES for energy flow management are given in Section 6. Discussions and findings of review work of IRES is