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A feasibility and cost benefit prospection of grid connected hybrid power system (wind–photovoltaic) – Case study: An Algerian coastal site

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ABSTRACT

This paper presents the feasibility and cost benefit analysis of wind and photovoltaic power systems connected to a conventional grid. The main interest in such systems is on-site consumption of the produced energy, system hybridization, pooling of resources and contribution to the environment protection. To ensure a better management of system energy, models have been developed for determining the power that the constituting subsystems can deliver under specific weather conditions. Simulation is performed using MATLAB-SIMULINK, while the economic and environmental study is performed using HOMER software.

Results show that from the analyzed solutions for this case, for 24% of the renewable energy fraction, the set of PV(3 MW) and wind (1.98 MW) is the best one, since it presents the least cost of energy, the smallest initial capital and the highest Net Present Cost. The sensitivity analysis derive that these results are obtained if the grid electricity price is equal to $3/kW h.

From an economic point of view, this study shows that the renewable energy will not be immediately economically viable, even with generous feed-in tariff schemes. In these cases, it is preferable that the grid operator himself makes the investments in the renewable production. To improve the system energy performance, the options should not be focused on the production of renewable electricity, but rather on energy efficiency measures.

Contents

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1. Introduction

Authorities around the world are placing considerable conviction in renewable energy as important technologies for reducing energy related environmental problems, particularly CO_2 emissions. Recently, a growing number of organizations have begun to consider renewable energy and industries related to their production, distribution and services as opportunities to take rather than regulations [1–6]. Several factors including Kyoto Protocol, alarming reports from the Intergovernmental Panel on Climate Change (IPCC) and Copenhagen climate change conference (COP15) have contributed to this change in opinion, and many countries believe that the trend will continue such that it is very important for them to immediately prepare for the "green race". North African country Algeria is upping the ante in the renewable energy game. According to a recent PV-Tech [7] article, the country hopes to have 22 gigawatts (GW) of renewable energy online by the year 2030, with a good part being exported on the international market. State-owned utility Sonelgaz is expected to build 4.2 GW of renewables itself, providing underlying support toward Algeria's goal. Next year will see the first phase of the ambitious project, which will eventually include solar photovoltaic energy, concentrated solar power, and wind energy. As noted by PV Tech [7]: the first phase, which is expected to start in 2013, will include 1228 MW from PV power plants, followed by 2475 MW of concentrated solar (CSP) and 516 MW of wind energy by 2022. Besides Sonelgaz's commitment to wind and solar, the utility also has a deal with the Desertec CHP project, to look at possibly exporting 1 GW to European countries. With lots of sun to harness, Algeria, if it succeeds, could be a renewable energy market to watch out for in the years to come [8].

Some of the renewable energy systems are used to produce the heat such as solar water heating systems and ground-source heat pumps (GSHP) systems, while some other ones are used to produce electricity such as wind and photovoltaic systems as described in the following.

Systems leading converting renewable energy into heat are solar water heating systems used for the domestic, for the industrial water heating and used also in building air conditioning [9–11].

Ground source heat pump (GSHP) systems which use the ground-source and take a low-level heat occurs naturally underground and convert it to high-grade heat by using an electrically-driven or gas-powered heat pump. This heat can then be used to provide space heating for a building or can also be driven in reverse to provide comfort cooling [11–17].

The wind and the photovoltaic systems can be set up as autonomous or stand-alone, as hybrid systems (supplemented with other power sources) or tied into the utility grid as described below.

For a stand-alone installation, the energy produced employing photovoltaic solar panels or wind generators is either immediately consumed (pumping, ventilation, lighting, refrigerator, etc.) or stored in batteries for a later use. The produced current is either directly fed to the consuming equipment or converted using an inverter to supply devices that require AC power [18,19]. These systems supply electricity that is often used at remote sites and are built coupling different sources of production of electrical energy such as wind, solar and others. They also allow a more reliable supply of electricity. Nearly two billion people are not connected to the utility grid (44% of the world population). Thus, the development of hybrid systems for renewable energy conversion will undoubtedly help to solve many social problems, especially in poor countries, and open up vast commercial markets [18,20–23].

These are usually medium and large systems which are grid connected [24–27] and which, in general, produce electrical energy amounts depending on sunshine and wind conditions.

While many configurations of renewable energy systems exist, this case study examines the electrical energy generation from wind and PV sources which is considered as being the most promising renewable energy and is, therefore, to be developed to replace coal, oil, gas and even nuclear-based production. However, any process of transforming energy from one form into another usable form is complex and naturally includes certain number of economic and environmental features of different kinds (operation of large-scale renewable energy requires space where the resource is available that requires a "good" management planning and the electrical networks will also be adapted and managed so as to promote decentralized production). The obtained results of feasibility and cost benefit analysis allow reaching an objective judgment regarding the studied system.

2. Renewable energy resources availability

The availability of measured data is of considerable importance in the design of systems of energy production from renewable resources. The use of measured data will allow researchers to improve accuracy and the efficiency of energy production in the local climate. Designers will be able to choose the optimal orientation, the most adequate and accurate generator, products and materials to be used.

However, to make this study, the needed data are obtained from Bouzareah station in Algiers, which is considered as the main station where solar radiation and weather data are recorded for the last 10 years.

The measured data are available in real time (updated every 5 min), and made available through the Web site portal of Algerian Renewable Energy. The Center of Development of Renewable Energy offers through its website, a user interface to access and download freely the measured data for scientific and technical applications.

The actual station is a professional station which includes three pyranometers, a pyrheliometer, a sun tracker, several sensors for measuring temperature, humidity, rainfall, pressure and duration of sunshine, an ultrasonic sensor for measuring the speed and direction of wind at 10 m and a data logger type CR1000 Campbell scientific (see Figs. 1–3).

3. Site characteristics

The Bouzareah site is a coastal site and according to the *Köppen*-Geiger climate classification [28] it can be considered as a temperate