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Viability analysis of PV power plants in Egypt

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ABSTRACT

This paper investigates, from techno-economical and environmental points of view, the feasible sites in Egypt to build a 10 MW PV-grid connected power plant. Available PV-modules are assessed and a module is selected for this study. The long-term meteorological parameters for each of the 29 considered sites in Egypt from NASA renewable energy resource website (Surface meteorology and Solar Energy) are collected and analyzed in order to study the behaviors of solar radiations, sunshine duration, air temperature, and humidity over Egypt, and also to determine the compatibility of the meteorological parameters in Egypt with the safety operating conditions (SOC) of PV-modules. The project viability analysis is performed using RETScreen version 4.0 software through electric energy production analysis, financial analysis, and GHG emission analysis. The study show that placement of the proposed 10 MW PV-grid connected power plant at Wahat Kharga site offers the highest profitability, energy production, and GHG emission reduction. The lowest profitability and energy production values are offered at Safaga site. Therefore, it is recommended to start building large-scale PV power plants projects at Wahat Kharga site.

1. Introduction

Recently, the cost associated with electric energy derived from fossil and nuclear fuel, and the increases in environmental regulations continue to constrain the planning and operation of electric utilities. Furthermore, the global economic and political conditions that tend to make countries more dependent on their own energy resources have caused growing interest in the development and use of renewable energy [1]. In terms of its environmental advantages, renewables generate electricity with insignificant contribution of carbon dioxide (CO_2) or other greenhouse gases (GHG) to the atmosphere and they produce no pollutant discharge on water or soil.

In the Mediterranean Sea Area (MA) [2], more than 386 million people live in approximately 9 million km^2. Sixty-five percent of them live in the northern 30% of this total area, where economic strength and energy consumption are also concentrated. The northern MA produces 91% of the gross national product (GNP) and requires 85% of the entire primary energy consumption, or 7700 TWh/year. Over 90% of the MA's imported energy also goes to the north. MA installed power plant capacity amounts to 266,000 MW (1992), generating approximately 1000 TWh of electricity per year (90% in the northern MA). This total capacity can be broken down into 30% hydropower plants, 22% nuclear, 18% coal-fired power, 15% oil-fired, 11% gas-fired and a small contribution from geothermal and renewable plants. The need to replace old fossil-fired power stations, especially in the North, and the Southern demand for new capacity to fulfill the requirements of a rapidly growing population and essential economic growth, will shape future power plant planning [2].

Grid extension, replacement of old plants and implementation of new power plants to cover the growth of electricity demand is the main objectives of Egypt's electricity sector in the upcoming decade. The Egyptian grid extends north and south, parallel to the Nile River and the Red Sea, providing it with the unique North African situation in which both abundant cooling water and sunlight are available. The Egyptian Electricity Authority (EEA) predicts, in 1996, that the 1995 electricity production will double from about 50 to 100 TWh/year by 2010, requiring almost a 50% increase in generating capacity from about 13 GW in 1996 to almost 18 GW in 2010 [2]. The Egyptian total installed capacity in the year 2005/2006 is 20.4522 GW, with a rate of increase of 8.9% compared with the previous year; this installed capacity in 2006 is above the capacity prediction value done in 1996 for 2010. The generated energy in Egypt in the year 2005/2006 is 108,368 GWh can be broken down into 75.2% conventional thermal, 11.7% hydropower, 0.5% wind, 12.6% purchased [3].

In the early 1980s the Egyptian government recognized the fact that the traditional energy resources would be inadequate to meet future needs. Consequently a national strategy for the development of energy conservation measures and renewable energy applications was formulated in 1982 as an integral element of the national

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energy planning. The new and renewable energy Authority was established in 1986 to be a focal point for renewable energy activities in Egypt. The targets are to supply 3% of the electricity production from renewable resources by the year 2010 [3,4]. It is obvious that the implementation of such strategy will be an essential element of the national plans for achieving sustainable development and protection of the environment via upgrading energy efficiency and replacing conventional polluting resources by renewable resources.

Egypt is endowed with large wind energy resources that could reach approximately 20,000 MW in the Red Sea region, in addition to other contribution from the application of solar energy and solar thermal energy. The expansion plan of the new and renewable energy in Egypt is divided into two parts. First, wind power generation which is of 225 MW capacity in 2006 is being planned to be increased to 845 MW capacity in 2010. Second, implementation procedures are undergoing for the execution of the 150-MW thermal solar power plant, of which, 30 MW is the capacity of the solar component, in Kuriemat area. This is carried out in cooperation with the Global Environment Facility and the World Bank. Implementation and operation of the project are scheduled during mid year 2010 and the estimated generated energy will be 985 GWh/year [3].

Egypt has capable groups in the different aspects related to the implementation of PV projects. Theses can be utilized directly or through partnership or subcontracting arrangements with the key organization, which will be involved in any project. The main barriers of spreading-out the use of PV applications in Egypt can be broken into four causes: financial/economic barriers, technical and awareness/information barriers, policy and institutional barriers, and market barriers [4].

Just as the fossil fuel based energy industry relies on exploration and proven reserves for discovery and economic support of energy markets, the renewable energy sector depends upon the assessment of resources for planning and selling their energy production technology. For solar-based renewable energy technologies such as solar thermal or photovoltaic conversion systems, the basic resource or fuel available is solar radiation. Assessment of the solar resource for these technologies is based upon measured data, where available [5].

The monthly variation of global solar radiation and different meteorological parameters such as sunshine duration, relative humidity as a percentage, maximum temperature, water vapor pressure, mean sea level and the ratio of MSL to water vapor pressure was presented and analyzed for five locations in Egypt [6]. The long-term values of various meteorological parameters are available at the NASA renewable energy resource website (Surface meteorology and Solar Energy) [7], these data are available in table forms and/or plots for any location/region all over the globe. Both ground measurements and SSE data are available. Therefore, the NASA Surface meteorology and Solar Energy database is the main source of meteorological data used in this paper.

Although ground measurement data has been used successfully in the past for implementing renewable energy technology (RET) projects, there are inherent problems in using them for resource assessment. Ground measurement stations are located throughout the world, but they are situated mainly in populated regions. In remote areas (where many RETs are implemented) measurement stations are limited. Also, at any particular station, data recording can be sporadic leading to incomplete climatological profiles; and, data inconsistencies can occur within a station and from one station to another. In contrast to ground measurements, the Surface meteorology and Solar Energy (SSE) data set is a continuous and consistent 10-year global climatology of insolation and meteorology data on a $1^\circ \times 1^\circ$ grid system. Although the SSE data within a particular grid cell are not necessarily representative of a particular microclimate, or point, within the cell, the data are considered to be the average over the entire area of the cell [7].

Of the available software for analysis of RETs, the powerful freeware RETScreen Clean Energy Project Analysis version 4.0 software [8], which has been developed specifically to facilitate the identification and tabulation of all costs and to perform the lifecycle analysis of RETs is used in this paper to perform energy production analysis, financial analysis, and GHG emission analysis for a proposed PV-grid connected power plant at candidate sites in Egypt.

RETScreen software is capable of assessing RETs viability factors such as, energy resource available at project site, equipment performance, initial project costs, "base case" credits (e.g., diesel generators for remote sites), on-going and periodic project costs, avoided cost of energy, financing, taxes on equipment and income (or savings), environmental characteristics of energy displaced, environmental credits and/or subsidies, decision-maker's definition of cost-effective [8].

The RETScreen software integrates a series of databases to help overcome the costs and difficulties associated with gathering meteorological data, product performance data …etc. Worldwide meteorological data has been incorporated directly into the RETScreen software. This meteorological database includes both the ground-based meteorological data and NASA's satellite-derived meteorological data sets.

This paper investigates, from techno-economical and environmental points of view, the feasible sites in Egypt to build a 10 MW PV-grid connected power plant. Available PV-modules are assessed and a module is selected for this study. The long-term meteorological parameters for each of the 29 considered sites in Egypt from NASA renewable energy resource website (Surface meteorology and Solar Energy) [7] are collected and analyzed in order to study the behaviors of solar radiations, sunshine duration, air temperature, and humidity over Egypt, and also to determine the compatibility of the meteorological parameters in Egypt with the safety operating conditions (SOC) of PV-modules. The project viability analysis is performed using RETScreen version 4.0 software through electric energy production analysis, financial analysis, and GHG emission analysis.

2. Selection of a PV-module

Large number of PV-modules with widely different characteristics is available in the market. Therefore, a selection criterion is needed to select a specified PV-module to be used in a specific project. A survey of the characteristics of most of the available PV-modules from different manufactures is done. PV-modules with efficiency less than 15% are not selected in this study. Hence, candidate modules list is formed. The selection of a specific module from the candidate module list is then based on the value of ratio of the module capacity and its frame area (Capacity/Area criteria). The selected PV-module attains the maximum Capacity/Area. It is important to note that the selected PV-module may be not the global best fit for the selection criteria, but it fulfills the selection criteria among the surveyed PV-modules.

Based on the stated selection criteria, the mono-Si-HIP-205BA3 PV-module from Sanyo with 205 W peak capacity comprised of Hetero-junction with Intrinsic Thin-layer (HIP) PV cells is selected in this study. The selected module specifications [9] are summarized in Table 1. The rest of the PV-module specifications are available at [9].

3. PV study system description

This paper investigates, from techno-economical and environmental points of view, the feasible sites in Egypt to build a 10 MW