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Integration of renewable power systems in an Antarctic Research Station

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ABSTRACT

The paper describes the design process of a photovoltaic (PV)-wind power system to be installed in the very challenging ambient conditions of the French-Italian Antarctic Base. Concordia Base has been built with the collaboration of Italian consortium PRNA, French Polar Institute IPEV and European Space Agency ESA. It is one of the three bases not located on the coast and is open all the year. The electrical load of the base, presently supplied by three diesel generators, has been previously characterised measuring the relevant quantities during a period of one year. During the same year an experimental campaign has been conducted to collect the necessary solar irradiance and wind data of the site. Models of the PV panels and of the wind turbine, previously set up and validated, have been used to simulate the plant behaviour and to estimate the possible contribution of renewable energies to the Concordia Antarctic Base supply in the different seasons. Finally, some economical aspects are discussed and the payback period is calculated.

1. Introduction

Renewable energy sources (RES) are nowadays considered as the best candidates to solve most of the challenging problems related to an ever increasing energy use, like the depletion of conventional resources and the environmental concerns. Powering remote equipment using RES, when the connection to the grid is not possible, can be really advantageous from the point of view not only of the environmental impact but also of the costs [1]. Of course, the use of non-polluting energy sources is especially desired in case the natural equilibrium of the site is particularly fragile, like for instance in the Antarctic area [2]. The contamination by pollutants is not only detrimental for the health of an ecosystem which is heritage of the humanity, but can also affect the important research activities that are being performed in that region [3,4]. There are no alternatives to stand-alone power systems, and they must operate in very challenging conditions. At the same time, because of the particular logistics, the transportation and handling costs of conventional fuels are very high [2]. RES-based supply systems (in particular PV and wind systems) seem to be a quite logical design option, however, they must be carefully designed to be suitable to the particular site features [5]. In fact, the latter are quite similar to those of both terrestrial remote plants and spatial applications. During the year, the temperatures vary from −20 °C to less than −80 °C, with an average value of −50 °C. Only two seasons are considered: summer (from November to January) and winter (from February to October). At the Italian-French Concordia Base, located 75°06′S and 123°21′E, there is light during all the summer months, and dark from mid May to mid August. In the remaining months there is a variable duration of the light/dark cycles (Fig. 1). The winds are quite strong, especially at the heights typical of wind turbine towers. To evaluate the possibility to supply the Concordia Base by a RES-based system in these particular conditions, the solar irradiance and the wind speed and direction at three different heights (3, 15 and 30 m), together with the temperature and the atmospheric pressure, have been measured during one year. Also weather data previously collected by NASA have been examined. The maximum value of solar irradiance, a little above 800 W/m^2, is attained in the second half of December. The maximum values of wind speed were 26.01, 23.47 and 21.36 m/s at 30, 15 and 3 m, respectively. The electrical load of the Base has been measured during the same period of time and this information, together with the solar and wind data, allowed to design a RES-based plant to be installed in the site.

2. Characterisation of the loads

The Concordia power station is made up of three 170 kVA Diesel generators, adapted to the particular conditions of the inlet air, which run two at a time. For safety reasons, there is also an

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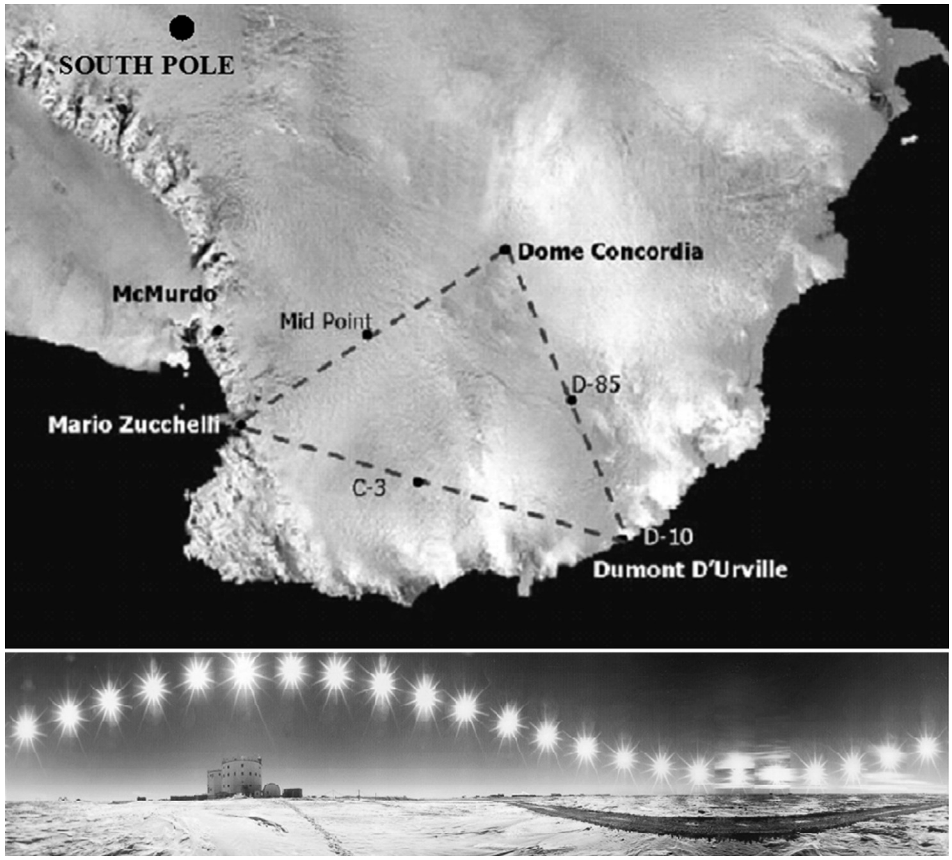

Fig. 1. Geographical position of Concordia Base and sun cycle during a day of December at Concordia Base.

emergency Diesel generator inside the noisy building [6,7]. The distribution system is an IT radial system at 400 V.

The devices to be supplied are electric motors (hydraulic pumps), resistors (heaters to melt the snow, to keep the fluids above the freezing point and to heat the buildings), information technology devices (computers, servers, PBX, power amplifiers, UPS, satellite systems and other lab devices).

The total installed load has been estimated in about 250 kW. The actual load has been analysed during one sun year, sampling currents, voltages, active and reactive power flows, power factor, and also the total harmonic distortion (THD), which is particularly important in terms of power quality because of the many computers to be supplied. The block diagram of the power station and the electrical panels, with the position of the data acquisition system, is shown in Fig. 2. Since the system is three-phase with neutral wire, the power of each phase has been measured.

The data acquisition system was based on a grid analyser connected to the output conductors of the generators through current and voltage probes. A PC provided the collection and display of data from the sampling device (model GSC 57 manufactured by HT ITALIA).

The measurement equipment allowed a data integration period varying from 5 s to 1 h. Since the aim was the acquisition of hourly data during one sun year, samples acquired each 5 s within 1 h have been averaged, obtaining a total of 8760 samples. In the same time period the maximum and minimum value of each quantity has been stored.

The data analysis put in evidence a substantial equilibrium of the phases, with the phase voltage within ±5% of the nominal value. The active power has maximum and minimum values of 157 kW and 22 kW, respectively (Fig. 3), with a coefficient of simultaneity, estimated considering an installed load of 250 kW, equal to 0.63. The reactive power varies between a minimum of 16 kVAR and a maximum of 85 kVAR, while the power factor never goes below 0.85.

As to grid distortions, the voltage has a mean harmonic distortion of 11%, while the value for current can be higher than 30%, both with a spectrum within 550 Hz (eleventh harmonic).

3. Acquisition of the solar irradiance data

The photometric analysis of the site has been performed through direct measurements with portable equipment by MAC-SOLAR, model SLM018C-2. The acquired data have been compared with official weather data from NASA available on the website. Based on these information, the hypothesis that there are no days in which the sunlight is filtered by fog, clouds, and other atmospheric agents, has been assumed. In fact, the atmospheric conditions in the site where the Base is located are of low pressure and bright sky, with very rare exceptions. Therefore, it was possible

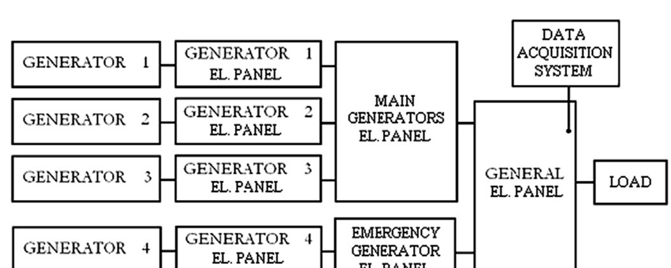

Fig. 2. Block diagram of the power station and the relevant electrical panels with the position of the data acquisition system.