ENERGY GENERATION AND MANAGEMNET CONCEPT FOR THE NEW BUILDINGS OF THE COMANDANTE FERRAZ ANTARCTIC STATION

Tiago Malavazi de Christo*, Jussara Farias Fardin,
Domingos Sávio Lyrio Simonetti & Cristina Engel de Alvarez

UFES - Universidade Federal do Espírito Santo
Av. Fernando Ferrari, 514, Goiabeiras, Vitória – ES, Brazil, Zip Code: 29075-910

*e-mail: tmalavazi@ufes.edu.br

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Abstract: *This paper explores the main investigations related to the power plant concept proposed for the new buildings of the Comandante Ferraz Antarctic Station. Energy planning for the new buildings was made based on detailed studies of energy conservation, renewable energy integration, heat recovery and state-of-the-art energy management techniques. The investigations justify the choice for a hybrid power plant for the new buildings, integrating wind and solar renewable sources, a redundant combined heat and power generation system, and a management system operating on the Smart Grid concept. The expected fuel savings and the reduction of emissions resulting from the adoption of these concepts is about 40% compared to a traditional plant.*

Keywords: Energy Planning, Renewable Energy, Smart Grid, Antarctica.

Introduction

In general, Antarctic stations resemble small isolated villages that need drinking water, heating, waste disposal and power generation to ensure the survival of its inhabitants and the continuity of researches (Alvarez, 1996).

In this scenario, one of the most worrying elements when aiming to reduce the environmental impact caused by human activities in Antarctica consists in the use of fossil fuels to produce electricity or thermal energy. In general, the production of energy by oil powered generators is regarded as a more reliable and cheap solution compared to renewable energy sources. However, in Antarctica, the logistic difficulty, the risks of oil spill and the influence of the emissions on the local nature and local researches make the use of fuels even more undesirable (Christo, 2012).

Considering the possibility of reconstructing the Comandante Ferraz Brazilian Antarctic Station (EACF) with a more safe, efficient and clean power plant, this work investigates feasible criteria to be adopted in the Reference Term to the EACF's new buildings (Instituto dos Arquitetos do Brasil, 2013).

Materials and Methods

In order to identify the energy consumption profile and the possibilities of improvement of the former EACF, the energy audit of the Station conducted in 2011 was assessed (Christo, 2012). The possibility of heat recovery in generators and management of electrical and thermal loads are analyzed.

The investigation of feasible technologies for electricity and heat production in Antarctica was made based on technical papers of the most modern and efficient Stations. These Stations are the Belgium Princess Elisabeth, the Australian Mawson Station, the United States McMurdo Station and New Zealand Scott Station. Issues such as security, reliability, complexity of logistics, installation and maintenance, life cycle, and local environmental impacts were considered (Christo, 2012).

Criteria related to the use of renewable sources are based on the research conducted by Christo (2012) and they considered INPE (Brazilian National Institute of Spatial Researches) measurements made on EACF site, from 1986

to 2010, and solar data from NASA Surface and Solar Energy program from 1983 to 2005. The robustness for climate, installation and maintenance complexity, efficiency, capacity factor, positioning and minimal use of batteries was also considered. Regarding the Combined Heat and Power (CHP) generators, issues such as redundancy, efficiency curve, optimum work point and noise isolation were also considered (Lora & Nascimento, 2004).

Criteria for energy management, possible techniques for demand and power generation control were researched considering the limitations imposed by climate extremes, logistics, environmental impact, human survival and continuity of research. The characterization of the intelligent power grid was based on features described by the Department of Energy of the United States (DOE, 2012).

Results

The investigation carried out by Christo (2012) demonstrated that the adoption of a hybrid energy system for the former buildings of the EACF was feasible and could improve the annual fuel autonomy and also reduce emissions in about 40%. The adoption of a hybrid energy micro grid with Diesel CHP generators, 4 wind turbines of 15 kWp each and 45 solar panels of 327 Wp each would make the former EACF reach 37% of savings in the annual fuel consumption, a reduction of about 350 tons in CO₂ emission per year and 20 trips with vessels of oil could be avoided each year. Regarding the wind power, a turbine of 15 kWp would be capable of promoting a reduction of approximately 14,500 litres/year of diesel oil. For the photovoltaic panels, 1 kWp installed would provide a reduction of 354 litres/year. These are the initial rates of annual fuel savings per installed power plant, which decrease on a nonlinear way with the increment of number of turbines and solar panels (Christo, 2012).

Among other Antarctic station power plants, the energy solution adopted by the Princess Elisabeth Station is the one that is more different in concept, efficiency and complexity. This station features a hybrid energy plant, Diesel-Wind-Solar system, and stands out by the application of advanced materials and construction techniques, optimum positioning of windows, solar panels and collectors, the choice of wind turbines with simple building and high performance, able to withstand winds of 250 km/h. Combined with these

solutions, a complex Smart Grid system able to manage 35,000 variables was also implemented (Rattinghe, 2008). According to the study presented by the Polar Foundation (2009), the fraction of energy from renewable sources was 95% and diesel consumption was less than 2,500 liters in the evaluated period.

Australian stations differ by the use of integrated designs of a Diesel-Wind hybrid plant, using two 330 kW wind turbines modified to withstand extreme conditions and an energy storage project with liquid hydrogen in portable cylinders for provision of energy in remote areas. For damping power flows of the wind plant, a system integrated to the electric boilers was developed. Its two wind turbines are capable of supplying up to 95% of the energy consumption and the fuel economy has been as high as 58% compared to the corresponding months of 2002 (AAD, 2011).

Similarly, McMurdo and Scott stations operated by the United States and New Zealand, respectively, jointly developed a Diesel-Wind energy matrix, with 1 MW of installed wind power, making it the largest wind plant of Antarctica. The aim is to reduce diesel consumption in about 463,000 liters per year, 11% of the total, and an annual reduction of 1,242 tons of CO₂. For the purpose of damping power flows of the wind plant, a flywheel able to provide up to 500 kW during a time of up to 30 seconds was installed (GESDB, 2013; NREL, 2012).

Thus, a hybrid energy system was proposed to the new buildings. For the criteria concerning the main thermoelectric generation, the use of generators with heat recovery, an emergency generator and adoption of at least 100% redundancy have been proposed. Considering the availability of wind and solar resources, space for installation and the technologies also tested in Antarctica, the integration of renewable sources on the EACF's power plant was proposed as a way to reduce the fuel consumption, emission of pollutants and the logistic effort with fuel transportation. In order to facilitate maintenance and minimize the risks in case of electromechanical failures or fires, the compositions of the plant systems must be established in such a way as to enable modular structures and parallel and individual operation. The selection of equipment and components must take into account the logistical limitations and environmental specificities,

Figure 1. Conceptual topology of the system of generation of electrical and thermal energy designed for the new Brazilian Antarctic Station. Adapted from Estúdio41 (2013).

giving preference to the more compact equipment, with simple mounting, and whose maintenance, especially in external areas, is possible to be carried out quickly and safely (Instituto dos Arquitetos do Brasil, 2013).

As a result, and in accordance with the criteria established, the conceptual design winner of the contest for reconstruction of the EACF presented an exciting proposal of a hybrid MicroGrid. The proposal is illustrated in Figure 1. The matrix is composed of CHP generators, wind turbines and photovoltaic panels. For integration of sources, multiple interconnected converters, supervised and controlled by a SCADA system, are proposed (Estúdio41, 2013).

It was defined that the hybrid power plant proposed for the new EACF must operate as a Smart Micro Grid, dealing with intermittent production of energy from various sources, such as wind, solar and thermal power generation. To manage the thermal and electrical demands, CHP generations, boilers and energy storage systems, it was proposed to implement a smart Supervisory Control and Data Acquisition (SCADA), ensuring greater efficiency, reliability and security. However, for safety reasons, there

must always be redundancy and the possibility of manual operation (Instituto dos Arquitetos do Brasil, 2013).

Discussion and Conclusion

The incorporation of cogeneration technologies, wind and solar generation into energy plants of the Antarctic stations has been proven to be feasible and desirable for seeking greater autonomy and reduction of environmental impacts. The expected fuel savings and the reduction of emissions resulting from the adoption of these concepts is about 40% compared to a traditional plant. However, the choice of the most appropriate technologies for each region, their respective sizing and management are essential for the efficient and safe functioning.

The energy planning for the new buildings was made based on detailed studies of energy conservation, renewable energy integration, heat recovery and state-of-the-art energy management techniques. The investigations justify the choice for a hybrid power plant to the new buildings, integrating wind and solar renewables sources, a redundant combined heat and power generation system, and a management system operating on the Smart Grid concept.

However, the real possibility of reducing fuel consumption in the new buildings of EACF depends on the management system program.

Despite the real possibility of reducing fuel consumption in the new buildings of EACF, this will also require the deployment of a complex management program. For this purpose, aspects such as demand and energy dispatch management, in several critical cases, should be assessed. Therefore, monitoring and characterizing renewable resources in the region, energy audits and techniques for energy management of the EACF plant must be continuously investigated to ensure an efficient and safe operation of the Station.

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References

- Alvarez, C. E. D. *Arquitetura na Antártica: ênfase nas edificações brasileiras em madeira*. (Dissertação de mestrado em arquitetura e urbanismo). Universidade de São Paulo, 1996.
- Australian Antarctic Division – AAD. (2011). *Australia's Antarctic Stations*. Retrieved in February 2011, from <http://www.antarctica.gov.au/living-and-working/stations>
- Christo, T. M. *Uma proposta de matriz energética para a Estação Antártica Comandante Ferraz: uma experiência aplicável a novas edificações*. (Dissertação de mestrado em Engenharia Elétrica). Vitória: Universidade Federal do Espírito Santo, 2012.
- Estúdio41. (2013). *Estação Antártica Comandante Ferraz: Projetar e Construir para o Brasil na Antártica*. Retrieved in 28 May 2013, from <http://www.estudio41.com.br/?conteudo=projeto&id=54>
- Instituto dos Arquitetos do Brasil. (2013). *Termo de Referência: Concurso Estação Antártica Comandante Ferraz*. Retrieved in February 2013, from <http://concursoestacaoantartica.iab.org.br/>
- Lora, E. E., & Nascimento, M. A. (2004). *Geração termelétrica: planejamento, projeto e operação*. Rio de Janeiro: Interciência.
- National Renewable Energy Laboratory – NREL. (2012). *NREL Newsroom*. Retrieved in February 2013, from <http://www.nrel.gov/>
- Global Energy Storage Data Base - GESDB - DOE. (2013). *Antarctica NZ ABB PowerStore Flywheel*. Retrieved in May 2013, from <http://www.energystorageexchange.org/projects/758>
- Rattinghe, K. V. (2008). *Princess Elisabeth Research Station at Antarctica: renewable Energy Systems design, simulation and optimization*. (Dissertação de mestrado em Aerospace Engineering). Delft: Delft University of Technology. 129p.
- U.S. Department of Energy – DOE. (2012). *Smart Grid*. Retrieved in 2012, from <http://energy.gov/oe/technology-development/smart-grid>