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DATA ACQUIREMENT FOR SUPPORTING A MICROGRID SYSTEM FOR A UNIVERSITY HOSPITAL: A CASE STUDY

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Abstract. *Microgrid systems represent an efficient solution for electricity generation where distributed energy applications are used. This work focuses on the data acquirement for the assessment of a microgrid system in the university hospital at Federal University of Santa Catarina. Description of the procedure used for data gathering and processing in order to infer the thermal and electrical demands of the hospital is presented, and the obtained results are contrasted with previous cases found in technical references. Energy balances on current supply equipment is carried out based on hourly measurements in order to obtain detailed profiles of steam and hot water for a winter, autumn and summer day, while electrical hourly demand profiles data were obtained from records of the electricity concessionary. Evidently, besides of properly taken measurements, it is necessary to identify correctly the operation schedules and different hospital activities in order to obtain a reasonable microgrid system specification. Finally, the information condensed in this work will serve as a source of technical information for further energy efficiency and microgrid studies focused on this type of applications.*

Keywords: *Electrical demand, Thermal demand, Microgrid systems, Hospital.*

1. INTRODUCTION

The growing use of renewable energy sources, as well as concerns about tariffs and energy quality have motivated the development of efficient solutions for the production, distribution and consumption of electricity. In consequence, in the last two decades, the Smart Grid systems have been employed as an efficient solution for electricity management. Smart grids incorporate innovative technologies for allowing two-way communication between the utility and its customers/users. As a result, the supervising capabilities along the transmission lines and the monitoring of the customer demands is what makes the grid “smart” (Kolokotsa, 2016). In that sense, when distributed energy applications are considered, the concept of microgrids is adopted.

A microgrid system is composed by distributed power resources and electrical and/or thermal loads, and can operate as an autonomous grid in parallel or islanded of the existing electricity grid. The microgrid system integrates and manages all generation sources, storage units and end users, being a complete and optimized solution for the integration, management and control of energy resources. The advantages of a microgrid system are the renewable energy integration, energy reliability, system efficiency and cost reduction. The microgrid supplies a range of customers, such as residential buildings, commercial entities, industrial parks and non-interconnected zones (Gaona et al., 2015; Mariam et al., 2013). Distributed generation encompasses a wide range of technologies, such as internal combustion engines, gas turbines, microturbines, photovoltaic, fuel cells and wind-power. These emerging technologies have lower emissions and the potential to have lower cost negating traditional economies of scale (Lasseter and Piagi, 2004).

The assessment of a microgrid system requires the characterization of the electrical and thermal loads of the building or zone where the microgrid will operate. Moreover, the correct specification of a microgrid depends directly on the quality of the gathered information concerning the energy use in the building application. Taking into account the relevance of the measurement method on the quality of the data, this work describes the procedures and the data processing for inferring the energy load profiles of a university hospital building at Federal University of Santa Catarina

(UFSC). This case study aims to provide significant information to the subsequent implementing of a microgrid system for this hospital.

2. CASE STUDY

The case study corresponds to the university hospital Polydoro Ernani de São Thiago at Federal University of Santa Catarina, located in the city of Florianópolis-Brazil. The university hospital has 205 beds and 32000 m² of total area, being classified as a large-size hospital (more 150 beds) according to Ministério da Saúde (1977). The hospital has thermal demands (steam, hot water, and cold water) to supply services such as laundry, cooking, air conditioning and other hospital applications. Additionally, the electrical demand is also a priority, considering the essential services and that some hospital equipment require safe and reliable electricity supply for their operation.

Currently, a boiler fueled with diesel oil is used to produce the steam employed for the laundry, cooking services and heating of water as represented in Fig. 1. The air conditioning system is constituted by three compression chillers (310 TR) that provide cold water through a closed hydraulic circuit and 290 split units of direct expansion refrigeration (400 TR). The boiler only operates on daytime, consequently, the water heating is performed with electrical heaters during the night period.

Regarding the electrical demand, a limit of 1350 kW is set by contract (higher demands cause fine) and during 2018, an average monthly consumption of 477 MWh was reported. In addition, new electricity demands will be required to supply air conditioning in a clinical area and to operate new equipment recently installed in some laboratories.

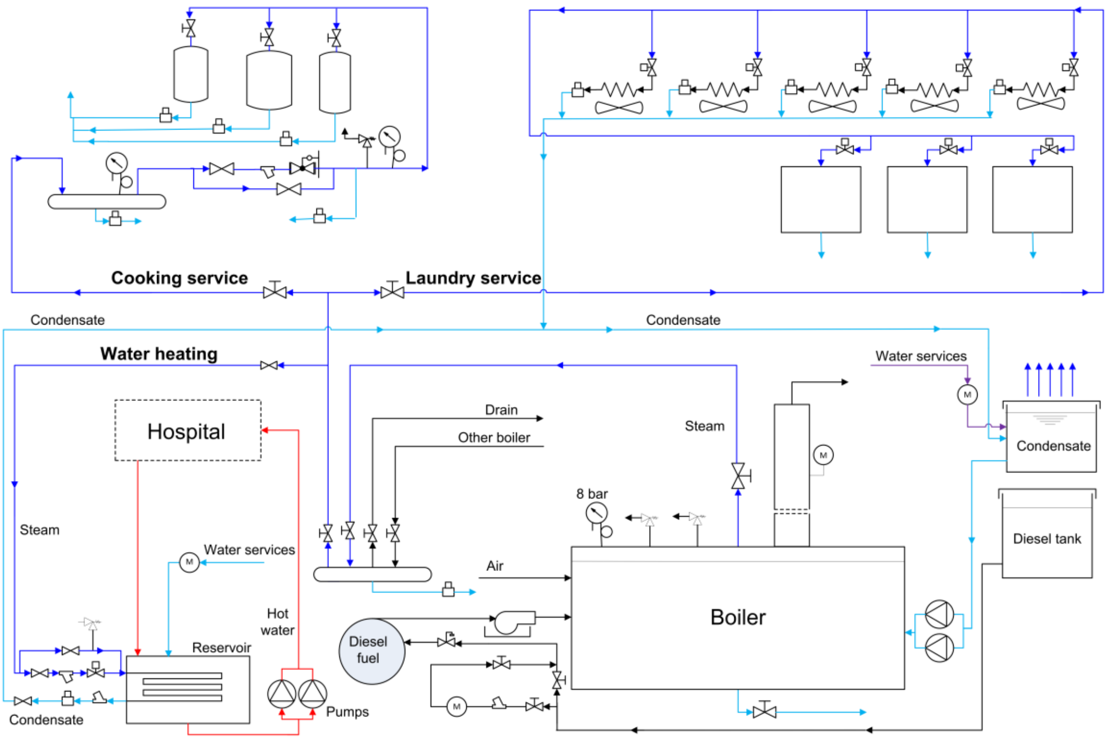

Figure 1. Steam system of the university hospital Polydoro Ernani de São Thiago.

3. METHODOLOGY

The main focus of this work consists in the characterization of the energy demand of the hospital. This aspect involves the recompilation of significant information about general data concerning the numbers of beds, hospital area, and uses for the electricity and determining of the energy demand profiles. Firstly, temperatures, pressures and other parameters are properly measured in order to perform the energy balances on the utilities production equipment (boiler, chillers, heaters, reservoirs, etc.). On the other hand, the consumption of thermal services was determined through careful measurements of hot water consumption, fuel consumption and emission gases in the boiler. For these measurements, volumetric flow meters installed at the facilities of the hospital were used to measure the hot water consumption and the fuel consumption of the boiler.

The hourly electrical demand profiles were obtained from the local concessionary of electric energy.

3.1 Steam production profile

The steam production was determined from the global thermal efficiency of the boiler and the measurements of the fuel consumption.

The global thermal efficiency of the boiler corresponds to a representative efficiency of the daily boiler operation, considering its dynamic performance due to the changes in the steam and hot water demands during the day. The boiler control system is based on the steam pressure value and, acts regulating the fuel quantity supplied into the boiler what represents boiler operating at low or high load conditions. For determining this global thermal efficiency of the boiler, measurements of concentrations and temperature of the exhaust gases were carried out for intervals of twenty minutes for two days. The concentrations of the exhaust gases (CO_2 and O_2) were measured with the OPTIMA7 portable gas analyzer, whose probe was installed in the exhaust flue stack of the boiler. Simultaneously, the exhaust gases temperature was measured using a type K thermocouple probe. Thermodynamic analysis was performed to calculate the energy loss in the exhaust gases. It was considered 1.5 % of energy loss to environmental and 0.5 % of energy loss by purging of the boiler, according to Bazzo (1995). From these considerations, the thermal efficiency of the boiler was calculated for each interval analyzed using the following expression,

$$\eta = 1 - \sum \text{Energy loss} \tag{1}$$

The global thermal efficiency was calculated as the weighted arithmetic mean of the values of thermal efficiency obtained for each interval time.

In relation to fuel consumption, measurements were carried out for two weeks in summer, autumn and winter. The days were classified as hot, warm and cold days, according to temperature mean registered on the day. Thus, it was possible to obtain representative measurements for all year, considering the warm days as the autumn and spring seasons, the hot days as summer and the cold days as winter. The limit values of daily temperature mean T_{env} that define this classification were obtained from the statistical distribution of daily temperature mean in Florianópolis registered for a period of two years. These limits are shown in Tab. 1.

Table 1. Interval of daily temperature mean for the day classification.

Daily temperature mean T_{env} (°C)	Day classification
$T_{env} < 19$	Cold
$19 \leq T_{env} \leq 23$	Warm
$T_{env} > 23$	Hot

For each set of data corresponding to the three periods of the classification, it was calculated the daily mean curve of fuel consumption. From this curve and the global thermal efficiency of the boiler, it was obtained the representative profile of daily steam production for each season.

3.2 Hot water demand profile

Similarly to the measurements of fuel consumption, measurements of hot water consumption were carried out for two weeks in summer, autumn and winter. According to the day classification presented in Tab. 1, the measurements were separated in three groups and mean values were obtained for a typical day of each season, representing the hot water demand profiles. The hot water system is shown in Fig. 2. On daytime, the water is heated using steam produced in the boiler. Steam saturated enters in the reservoir at 4 bar, circulates through a heat exchanger and condensates. The heat released because the steam condensation heats the water. The hot water consumption corresponds to the water supplied by the local concessionary of water services. A flow meter is installed in this line (indicated by letter M in Fig. 2). The hot water is pumped through the hospital to a volumetric flow rate of 11 m³/h and, the hot water that is not consumed returns to the reservoir. The steam mass flow required to heat the water and the corresponding thermal demand were calculated from the energy and mass balances of the reservoir. Then,

$$\dot{m}_3 = \dot{m}_1 + \dot{m}_2 \tag{2}$$

$$\dot{m}_4 = \dot{m}_5 \tag{3}$$

$$\dot{m}_3 h_3 + q = \dot{m}_1 h_1 + \dot{m}_2 h_2 \tag{4}$$

$$q = \dot{m}_4 h_{lv} \tag{5}$$

where the subscript numbers correspond to the respective flows as indicated in Fig. 2, h_{lv} is the enthalpy of vaporization of the steam at 4 bar and q is the thermal demand for the water heating. The steam mass flow required to heat the water corresponds to $\dot{m}_4$.

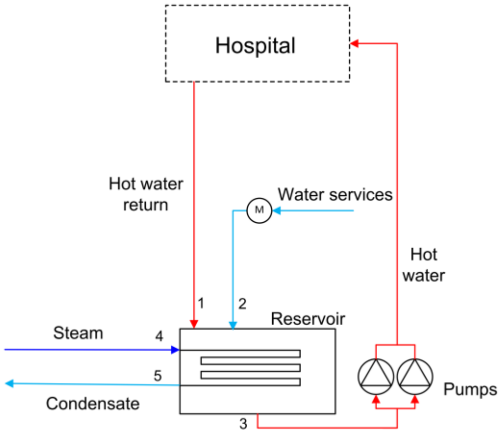

Figure 2. Water heating system of the university hospital Polydoro Ernani de São Thiago.

The water heating system has a control system that regulates the entry of the steam, acting a solenoid valve according to the set point of heating temperature. The heating temperature is set as a function of environmental temperature. Table 2 presents the values of set point of the heating temperature for each day classification as well as the temperature variation of the hot water after circulating for the hospital.

Table 2. Interval of daily temperature mean for the day classification.

Day classification	Set point of heating temperature (°C)	Temperature variation
Cold	60	5
Warm	52	4
Hot	45	3

4. RESULTS

Average energy indicators, as well as the electrical and thermal demand profiles for a day in each season are presented. The global thermal efficiency of the boiler is 0.873 and was calculated as described in section 3.1. This value was used to obtain the steam production profiles.

4.1 Energy indicators

Hospital general information concerning to the total beds, lighting power, total area, air conditioning power was collected. Energy indicators were calculated in order to describe the energy behavior of the hospital. These energy indicators such as total monthly electrical energy intensity, lighting, air conditioning, hot water and steam saturated consumption are shown in Tab. 3.

Average energy indicators for Brazilian hospitals are found in the technical literature (Szklo et al., 2004). For the classification as large hospitals, the bed density is comparable, but the lighting and air conditioning are higher which can be related with the function as university hospital. On the other hand, the monthly hot water consumption per bed is higher about three times than other large hospitals.

Observing the indicators obtained for each day classification, the lowest total monthly electrical energy is presented for cold days, increasing for warm days (19 %) and hot days (22.6 %). Concerning hot water, the consumption increases 27.3 % and 2 % for cold and warm days, respectively, when compared to hot days. In the case of the steam saturated consumption, the increase in relation to hot days is 20 % and 9.4 % for cold and warm days, respectively.

Table 3. Energy indicators for the university hospital Polydoro Ernani de São Thiago at UFSC.

Indicators			
Beds	205		
Total area (m²)	32000		
Bed density (beds/m²)	0.0064		
Lighting (W/m²)	9.56		
Air conditioning (TR/100 m²)	2.22		
	Cold days	Warm days	Hot days
Total monthly electrical energy intensity (kWh/bed)	2023	2405	2480
Hot water (m³/bed/month)	7.55	6.05	5.93
Steam saturated (kg/bed/month)	1478	1348	1232

4.2 Thermal and electrical demands

Regarding the classification day, it was made the relation with the seasons, corresponding the hot days for summer, cold days for winter and warm days for spring and autumn. Hot water consumption hourly for a representative day in each season is shown in Fig. 3. For all seasons, the consumption presents a similar behavior with the highest hot water consumptions at 9:00 h and 13:00 h, which is related to the schedules of the services in the hospital. The highest hot water consumption is presented in the winter period.

Figure 4 shows the thermal demand of water heating for a representative day in each season. One observes a similar behavior for each season with the highest thermal demand for winter and the lowest for summer. This result is consistent with the highest hot water consumption, set point of heating temperature and temperature variation (see Tab. 2) for winter. This thermal demand is supplied by the steam produced in the boiler on daytime and by electrical heaters during the night period.

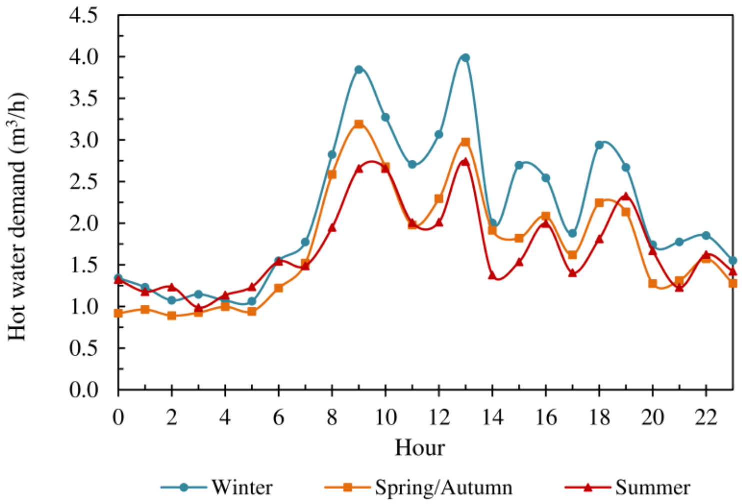

Figure 3. Hot water demand for a representative day in each season.

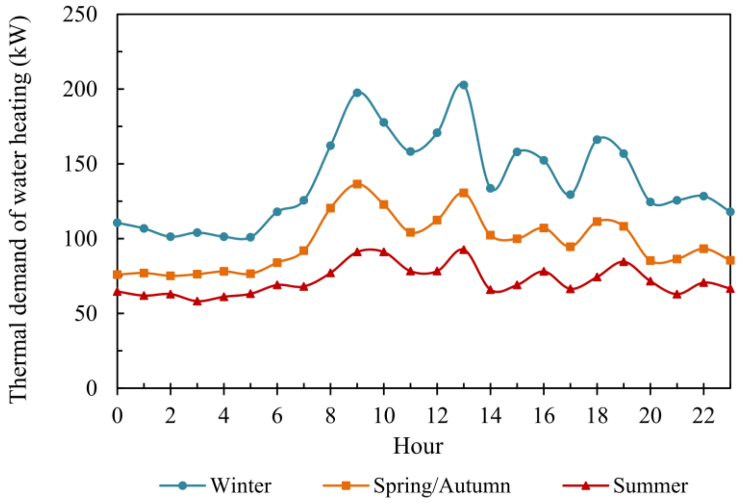

Figure 4. Thermal demand of water heating for a representative day in each season.

Figure 5 presents the steam production behavior for a typical day in each season. At 8:00 h, the high steam production corresponds to the initial activity in the laundry and the heating of the all pipes of the steam system. The highest steam production is presented in winter, which is in concordance with the highest thermal demand for water heating. The respective values of thermal power of the steam produced are shown in Fig. 6. Considering the daytime period, the difference between the thermal power of the steam produced and the thermal demand of water heating represents the thermal demand for other services such as laundry and cooking. These results are presented in Fig. 7, evidencing a similar behavior of the thermal demand for laundry and cooking services for each season, and the effect of the environmental temperature, which represents higher thermal demand in winter for the steam system heating at starting operation.

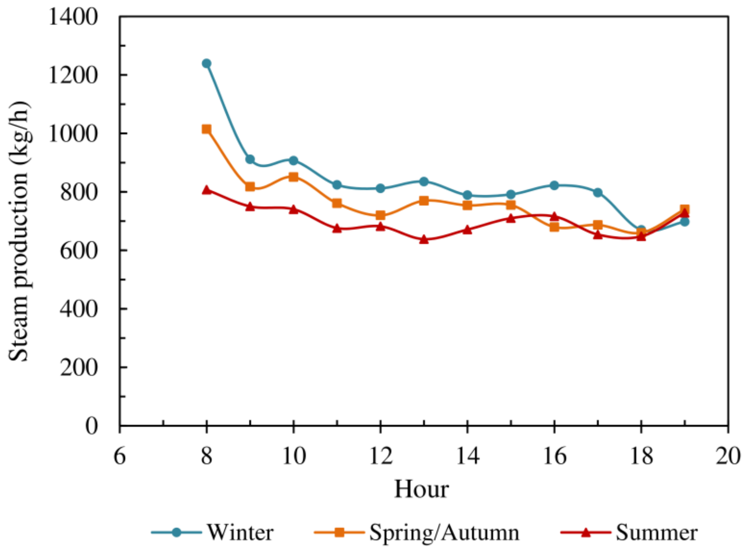

Figure 5. Steam production for a representative day in each season.

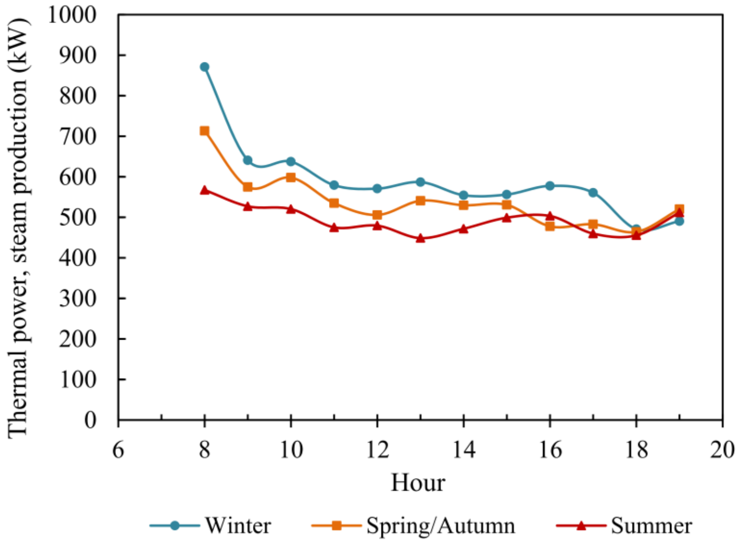

Figure 6. Thermal power related to steam production for a representative day in each season.

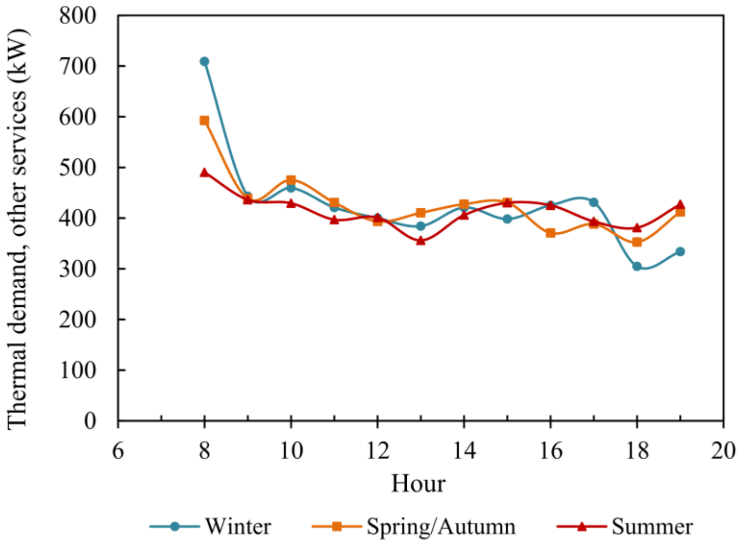

Figure 7. Thermal demand for laundry and cooking services for a representative day in each season.

The electrical demand for a representative day in each season is shown in Fig. 8. A significant increase is observed in the electrical demand in the summer days due to the air conditioning system, reaching values close to electrical contracted demand of 1350 kW, what represents a risk of fine. In relation to electrical demand for water heating during the night period, it represents approximately, 10 %, 15 % and 25 % of the total electrical demand for summer, sprig/autumn and winter, respectively.

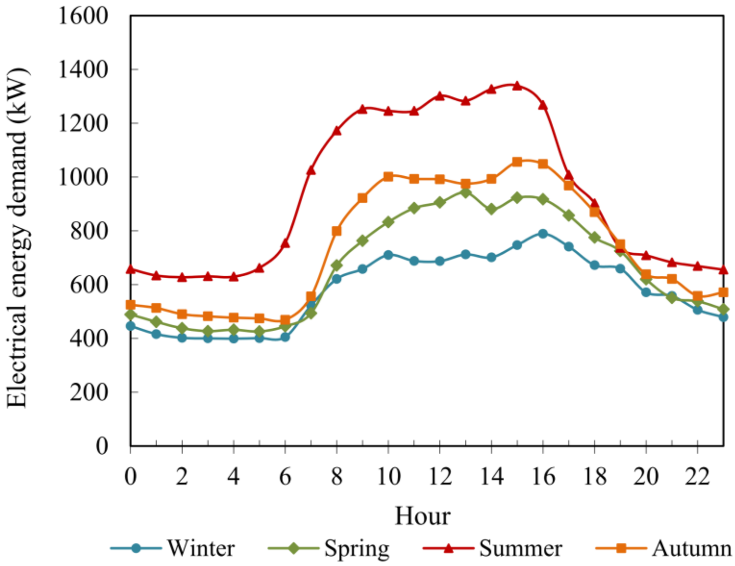

Figure 8. Electrical demand for a representative day in each season.

5. CONCLUSIONS

Data acquirement for assessment of a microgrid system at hospital of the Federal University of Santa Catarina was presented. The electrical and thermal profiles regarding a typical day for each season allow determining the interval of high energy demands to be supplied. Additionally, the energy profile has been characterized, providing relevant information for comparison with similar cases and further use in energy efficiency projects.

6. ACKNOWLEDGMENTS

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