CONTROL OF INDOOR SWIMMING POOLS WITH POTENTIAL FOR DEMAND RESPONSE

E. Ribeiro[1,4], H. M. Jorge[2,4] and D. A. Quintela[3,5]
[1]*School of Technology and Management, Polytechnic Institute of Leiria, Leiria, Portugal*
[2]*Department of Electrical Engineering and Computers, University of Coimbra, Coimbra, Portugal*
[3]*Department of Mechanical Engineering, University of Coimbra, Coimbra, Portugal*
[4]*Institute for Systems and Computers Engineering of Coimbra (INESCC), Coimbra, Portugal*
[5]*Association for the Development of Industrial Aerodynamics (ADAI), Coimbra, Portugal*

Keywords: Indoor Swimming Pools, Building Energy Management System, Smart Grid, Demand Response.

Abstract: Buildings with indoor swimming pools are recognised as very high-energy consumers and present a great potential for electrical and thermal energy savings. A building energy management system (BEMS) could be conceived in order to optimize the building energy demand and with smart grid interaction. This paper presents the condition and potential contract-based demand side response in indoor swimming pools context. The BEMS designed by the authors implements control strategies for HAVAC and pumping system in order to reduce the electricity demand during peak hours or in response to a emergency signal from the system operator in critical times. These strategies can carry out a significant reduction on power demand both in HVAC and pumping systems.

1 INTRODUCTION

In Portugal, the number of sport complexes with Indoor Swimming Pools (ISP), with an intensive use, has increased significantly during the last decades. The growing of such facilities has shown the necessity to promote the evaluation and control of the indoor environment variables in order to minimise the energy consumption, according to the measures proposed by the European Community Directive 2006/32/EC (EC, 2006). By this directive, all buildings must be classified from an energy point of view, using de Energy Efficiency Index (EEI), have to implement measures leading to the Rational Use of Energy (RUE), and install a Building Energy Management System (BEMS).

A BEMS was designed integrating some control strategies in order to optimize the building energy demand, being able to reduce electric energy consumption during peak periods or in response to an emergence signal send by the utility requesting power demand reduction.

There are some roles and responsibilities of actors involved in the Smart Grids (SG) deployment, defined by the European Community task force for SG (EC, 2011). The focus of these roles is the Demand Response (DR). Developments in DR vary substantially across Europe reflecting national conditions and are triggered by different sets of policies, programmes and implementation schemes (Jacopo *et all*, 2009). Currently in Portugal the electric pricing relies on time of use (ToU) tariffs that penalize the consumption of electricity in the peak periods.

In addition to control strategies for reducing power demand the full study also deals with the optimization use of energy in all main ISP process: Heating, Ventilation and Air Conditioning system (HVAC), Pumping System (PS), Water heating for baths, Lighting (Lig).

2 METHODOLOGY

The DR essence is to manage customer electricity consumption in response to supply conditions, for example: reduce consumption at critical times (CT) or in response to market prices (RMP).

The first topic (CT) normally occurs in shorts periods of time when it is necessary flexibility of power consumption at the client's side to allow supplier selection. For this situation it is required

Ribeiro E., M. Jorge H. and A. Quintela D..
CONTROL OF INDOOR SWIMMING POOLS WITH POTENTIAL FOR DEMAND RESPONSE.
DOI: 10.5220/0003952301450148
In *Proceedings of the 1st International Conference on Smart Grids and Green IT Systems* (SMARTGREENS-2012), pages 145-148
ISBN: 978-989-8565-09-9
Copyright © 2012 SCITEPRESS (Science and Technology Publications, Lda.)

that the supply contract allows the reduction of energy consumption to the consumer.

The second topic (RMP) is used in longer periods of time, during the peak hours where the price of energy is higher. In the near future the utilities will offer real time pricing tariffs, where the peak hours are dynamic, not fixed.

Subsequently are defined the conditions that the consumer can reduce energy bills, but for that he should have capacity to reduce power demand in the process without exceeding the minimum threshold of safety or comfort.

In ISP can by identify three main energy process (Rodrigues, 2007) that are responsible for almost 90% of the overall electric energy consumption (Figure 1).

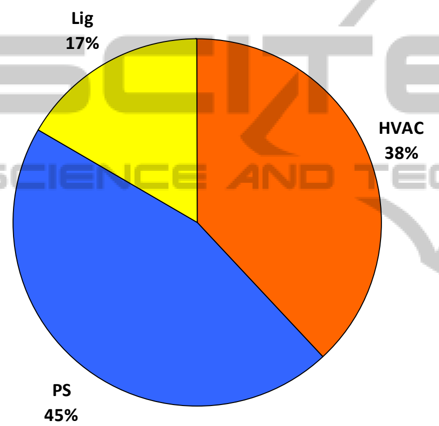

Figure 1: Electric Energy consumption by topic.

The HVAC and PS could have greater potential to reduce electricity consumption, but it must be guaranteed certain conditions related to the level of water quality and comfort.

For HVAC the environmental conditions of ISP are regulated by the standard NP EN 15288-1(IPQ, 2009), where it is defined besides other parameters that relative humidity (RH) could change between 40% and 80%, preferably less than 60%.

In CT case, the environmental variables threshold for RH could be adjusted to achieve 80% for a maximum period of 30 minutes so that to have no excessive degradation of the environmental conditions. After period of control the environmental thresold must be go back to the normal value.

In RMP case, the environmental thresold should be adjusted with RH to reach 60% as long as we want.

In the PS the control conditions are strongly dependent of the quality of water determined by determining Langelier Index (Langelier, 1936), (Perkins, 2000) also known as Saturation Index (SI). In these case the SI is considered satisfactory when it remains between -0.5 and +0.5 (DHHS, 2005).

During the CT case, the flow rate could be reduced to $1/3$ of the nominal flow until $|SI| > 0.5$. When $|SI|> 0.5$thenthe flow rate must return to the nominal value.

In RMP case, the flow rate could be reduced to $1/2$ of the nominal flow, and checked the IS in regular periods of 15 minutes. If $|SI| > 0.5$ we must increase the flow rate by 10% until the nominal flow is reached, or otherwise reduce the flow by the same value.

A BEMS, using a network of direct digital controllers, controls all process presented with specific control strategies described below. In the HVAC system the control model proposed is based on real time determination of the environmental variables that optimize the energy consumption, bearing in mind the regulation and the aim. In the PS an expedite approach to the control model was elaborated using variable flow rate operation.

SCITEPRESS SCIENCE AND TECHNOLOGY PUBLICATIONS

3 CHARACTERIZATION OF CASE STUDY

According to a case study analysis of energy consumption during the year 2006, the total of electrical energy was 1580 MWh/year and natural gas was 223799 m^3 (Rodrigues, 2007). The HVAC system and PS can be estimated an average electric power of 58kW and 69kW, respectively, corresponding to 70% of electricity consumption.

The building under analysis is a sports complex with 15200 m^2 which incorporates an Olympic Pool (OP) of 50x25 m^2, a Children Pool (CP) of 25x12.5m^2 and a multi-sports pavilion of 30x50m^2.

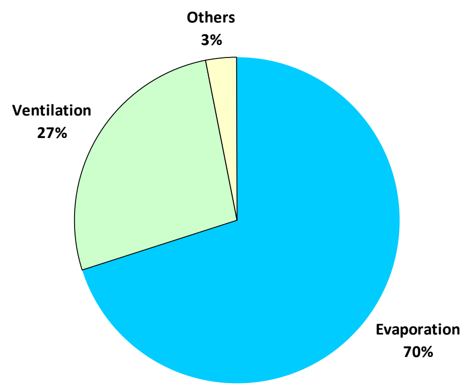

Figure 2: ISP HVAC energy balance.

The HVAC at pool level is ensured by Air Handling Units (AHU) with dehumidifying and heating capacities in continues work. The use of the AHU is necessary to maintain de air quality and the comfort conditions. The most important objective of control is to minimise the high evaporation rates which asks for electric energy for dehumidifying, and which are the largest source of energy losses (Figure 2).

In this case the latent energy associated to the pool evaporation is the must important variable of the control process (USDE, 2009). Recent studies (Shah, 2003) identify an empirical formula to determine the pool evaporation and that takes into consideration the environmental variables and the influence of users.

Taking into account the complexity of the parameters involved in HVAC system, the choice of energy simulation programs is actually the better way, to quantify the benefits that can be achieved by different control strategies (Pedrini, 2003).

A rigorous choice of environmental variables (t_a - air temperature and RH) reduce the evaporation of pool and decrease energy consumption (Ribeiro, 2011). The ESP-r program was used throughout the present work, and the simulation gives the latent energy (P_{lat}) needed to maintain the ϕ level. We can determine the electric power (P_{ep_lat}) spend knowing the HVAC coefficient of performance (COP) by:

$$P_{ep\_lat} = \frac{P_{lat}}{COP} \qquad (1)$$

The OP and CP PS are composed by five and three centrifugal pumps in parallel with nominal water flow rate of have 650 m^3/h and 188 m^3/h respectively, and pool water treatment equipments.

The introduction of variable-speed drive in hydraulic systems is current practice in systems with variable flow rate promoting significant reductions in energy consumption (Akayleh *at all*, 2009).

With water quality monitoring, it is possible to identify operation patterns at variable flow rate, that are depending on the number of pumps in use on the system (n) and the number of pumps with variable speed (f), which provide significant electricity savings (Ribeiro, 2010).

4 RESULTS

In the HVAC the electric power used to reduce the latent load of the building is quantified by simulation. Three simulations (Real, CT and RMP case) were performed considering the respective environmental variables (Table 1).

Table 1: HVAC environmental variable.

Variable	OP			CP		
	Real	CT	RMP	Real	CT	RMP
t_a (ºC)	28.3	23.5	26.7	30.5	25.5	28.9
RH (%)	52.3	80	60	52.7	80	60
$\overline{P_{ep\_lat}}$ (kW)	22.2	10.08	18.38	3.84	1.83	3.6

For the PS the conditions are strongly dependent on the quality of water determined by the SI, but in this case assuming that $|SI|$ is always less then 0.5. Applying the expedite formula developed by the author is possible to determine the (n, f) which minimizes the installation electric power (Figure 3 to 6) with the flow rate considered (Table 2).

Table 2: PS´s flow rate and electric power demand.

	OP		CP	
	m^3/h	kW	m^3/h	kW
Real	650	46.40	188	9.96
CT	216	22.05	62	4.90
RMP	325	33.15	94	8.90

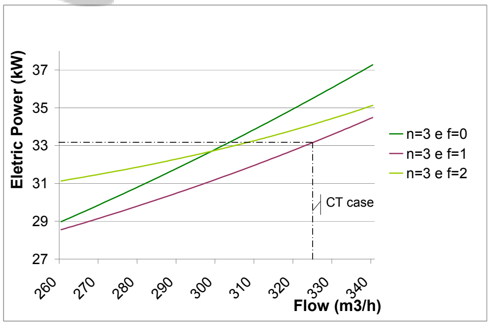

Figure 3: OP – CT case.

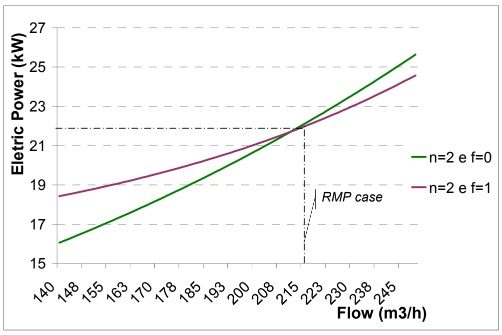

Figure 4: OP – RMP case.

SCITEPRESS SCIENCE AND TECHNOLOGY PUBLICATIONS

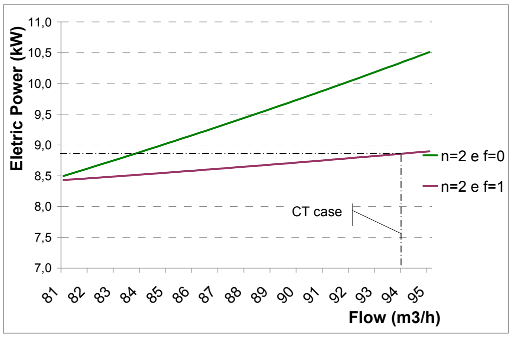

Figure 5: CP – CT case.

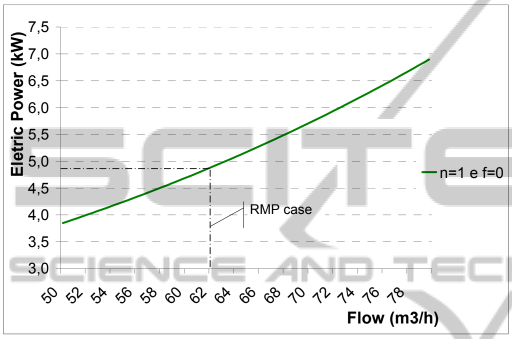

Figure 6: CP – RMP case.

For HVAC and PS the results for the power reduction potentials are determined and presented in Table 3.

Table 3: Potential power reduction (kW).

	HVAC		PS	
CT	14.13	24.5%	29.41	42.9%
RMP	4.06	7.0%	14.3	20.9%

It is remarkable the enormous reduction of power demand in the case of PS and the substantial decrease in HVAC.

5 CONCLUSIONS

According to the present results the potential for application of DR concept in this pool is important.

The BEMS designed by the author's implements some control strategies applied to HAVC system and PS to reduce electricity demand during peak hours, which represents a significant reduction in the power demand of 7.0 % and 20.9% in the HVAC system and the PS system, respectively. In a situation of emergency to the grid, the maximum reduction in power demand that can be obtained is 24.5 % and 42.9% in HVAC and PS, respectively.

It is expected a promising future for DR in these kinds of buildings taking into account the large number of such sport complexes in Portugal.

The authors believe that the present contribution underlines the importance of sport complexes with Indoor Swimming Pools for contract-based DR, of using adapted Building Energy Management System.

This work has been partially supported by FCT under project grant PEst-C/EEI/UI0308/2011.

REFERENCES

Akayleh A., Mohammed A., Essam A., Salah A., 2009, *Water Pumping System with PLC and Frequency Control*, Journal of Mechanical and Industrial Engineering, Pages 216 – 221,.

DHHS - Department of Health and Human Services, 2005, *Swimming pool and spa manual and operator's course*, Nebraska Government.

EC - European Community, 2006, *DIRECTIVE 2006/32/EC - Energy end-use efficiency and energy services*, Official Journal of the European Union.

EC - European Community, 2011, *Smart Grids Task force - Expert Group 3: Roles and Responsibilities of Actors involved in the Smart Grids Deployment*.

IPQ - Instituto Português da Qualidade, 2009, *NP EN 15288-1:2009 - Piscinas Parte 1: Requisitos de segurança para a concepção*.

Jacopo, T., Mohamed, G., Matthew, L., 2009, *Demand response experience in Europe: Policies, programmes and implementation*, Energy doi:10.1016/j.energy.2009.05.021.

Langelier, W., 1936, *The analytical control of anti-corrosion water treatment*, Journal AWWA.

Pedrini, A., 2003, *Integration of low energy strategies to the early stages of design process of office buildings in warm climate*, Universidad de Queensland, Australia.

Perkins, P., 2000, *Swimming Pools*, Taylor & Francis e-Library.

Ribeiro, E., Jorge, H., Quintela, D., 2010, *A introdução de VEV's no sistema de bombagem de piscinas interiores, em piscinas interiores*, PCEEE - Portugal em Conferência para uma Economia Energeticamente Eficiente.

Ribeiro, E., Jorge, H., Quintela, D., 2011, *HVAC system energy optimization in indoor swimming pools*, 3rd International Youth Conference on Energetic,

Rodrigues, P., 2007, *Climatização de Recintos com Piscinas Interiores – Eficiência Energética*, Technical Report.

Shah, M., 2003, *Prediction of evaporation from occupied indoor swimming pools*, Energy and Buildings 35, pages 707–713.

USDE – US Department of Energy, The Office of Energy Efficiency and Renewable Energy, 2009, *Swimming Pool Cover*.

SCITEPRESS
SCIENCE AND TECHNOLOGY PUBLICATIONS