Hydrogen energy system for cooling habitation located in Ghardaïa using TRNSYS 16

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Abstract - *Hydrogen system is mainly based on the Proton Exchange Membrane PEMFC technology (cogeneration), using hydrogen and air, respectively, as fuel and oxidant. The heat exhaust is evacuated to the Thermal Storage Tank (TST) which is using in LiBr/H_2O single effect absorption system for residential system cooling. Absorption system is based on evaporation of the refrigerant (water) in the evaporator in low pressure. Numerical simulation of the absorption cooling system using the thermal energy of the Proton Exchange Membrane Fuel Cell (PEMFC) for residential application situated in the Unit of Applied Research in Renewable Energy in Ghardaïa (southern Algeria) has been made and performances was analysed, we have determine the quantity of electrical and thermal energy generated by the PEMFC. TRNSYS 16 is used to plot initial and final residence temperatures before and after cooling. The results showed the feasibility of using PEMFC for cooling.*

Résumé - *Les systèmes à hydrogène basés sur la technologie pile à combustible PEMFC (cogénération), utilisent l'hydrogène et l'air comme carburant et comburant, respectivement. La chaleur générée est récupérée et stockée dans un réservoir de stockage thermique (TST) qui est utilisé comme générateur dans un système à absorption à simple effet LiBr/H_2O qui sert au refroidissement d'une habitation. Le système à absorption fonctionne en évaporant l'eau (réfrigérant) dans l'évaporateur à une basse pression. Une simulation numérique du système à absorption utilisant l'énergie thermique générée par une pile à combustible du type PEMFC appliquée à une habitation située à l'Unité de Recherche Appliquée en Energies Renouvelables – Ghardaïa (Sud Algérien) est élaborée et les performances ont été analysées. Nous avons déterminé la quantité d'énergie électrique et thermique générées par la PEMFC. Le logiciel TRNSYS 16 est utilisé pour tracer l'évolution des températures initiales et finales de l'habitat avant et après le refroidissement. Les résultats montrent la faisabilité d'utilisation des PEMFC pour le refroidissement.*

Keywords: Thermal storage tank - Absorption; cooling - TRNSYS 16.

1. INTRODUCTION

The residences represent one of the biggest parts of the world energy consumption. However, reducing their energy consumption became a priority only recently [1-3]. There are two ways to proceed: the first way consists in improving the architecture of the residence, in order to reduce the thermal losses and exploit the extern gains [4].

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The second way consists in producing properly the energy of the residence. These approaches are not contradictive, but complementary, and successive. Integrating renewable energies in a badly insulated residence is a complete mistake.

The integration of renewable energies in a residence leads to two problems: the design of the devices and their control [5]. The design is function of the autonomy degree planned for the residence. It sets the energy production potential of the devices.

The control optimises the operation of the devices, minimizes the losses and guarantees the comfort of the occupants [6-10].

Numeric models represent a powerful tool, which allows testing quickly a large number of devices and controlling systems in many situations.

This paper describes the first step of this work: the choice of a dwelling model and its energy systems, and the analysis of its processing using simple control methods.

TRNSYS 16 is the software used to simulate the evolution of the residence and its components; the study is based it in the city of Ghardaïa, Algeria.

2. DESCRIPTION OF THE MODEL

2.1 Description of the building

The numerical simulation environment used for this work is TRNSYS 16. The residence is a single family house with a surface of 60 m². This house is situated in the Unit of Applied Research in Renewable Energy (URAER) Ghardaïa, in the latitude of 32° 36’ N and longitude 3°81’E in Algeria.

It is modelled with the type 56 and the TRNBUILD interface. We have modifier some characteristic of the residence as follow; it is a well-insulated building, although it is possible to get better performances. Windows are double-glazing, modelled with type 2001 from the TRNBUILD library.

Table 1: Windows surface

Walls orientation	North	South	East	West
Windows surface, m^2	3	12	4	4

Table 2: Walls description

Wall type	Orientation	Surface, m^2	Conductance
External Wall	North	50	0.342
External wall	South	50	0.342
External Wall	West	40.5	0.342
External Wall	East	40.5	0.342
Roof	North	61.4	0.227
Ground	Horizontal	70	0.196
Internal Wall		200	2.686

2.2 Description of the energy production storage and cooling systems

For the cooling space, several subsystems are integrated in the residence. The PEMFC supplied by hydrogen and oxygen, a Thermal Storage Tank (TST), a single effect H_2O/LiBr absorption cooling system. Thermal compressor consists of an absorber, a generator, a pump, and a throttling device, and replaces the mechanical vapor compressor. Absorption chillers have a low coefficient of performance.

However, absorption chillers can substantially reduce operating costs because they are powered by low-grade waste heat. Vapor compression chillers, by contrast, must be motor or engine driven.

A single-effect absorption system means all condensing heat cools and condenses in the condenser [11-13].

Fig. 1 shows the schematic diagram of the PEMFC energy system. The PEMFC and the thermal storage tank (TST) are connected by heat exchanger. This tank is a cylinder tank; it is 1.7 m high with a volume of 0.5 m^3.

The PEMFC heats the tank in priority. Its pump is activated as soon as the temperature of the fluid exiting the PEMFC is 5 °C higher than the tank's bottom's temperature. The tank also heats domestic heat water.

Vapor is generated by the desorber (TST generator) through heat supply from the exhaust heat of the PEMFC [14], and then condensed in the condenser. Cooling is provided by evaporation of the liquid condensate from the condenser.

The heat of absorption must be removed from the absorber by cooling water. As for the LiBr solution circulation, the weak solution is pumped by the solution pump and pre-heated in the solution heat exchanger, while the strong solution emerging from the generator is cooled there and throttled to the absorber afterward.

The chiller is operated under two different pressure stages. The desorber and condenser operate under the high pressure, and the absorber and evaporator operate under the low pressure.

Both pressures are determined by the vapor pressure of the pure refrigerant and the saturation pressure of the solution [15].

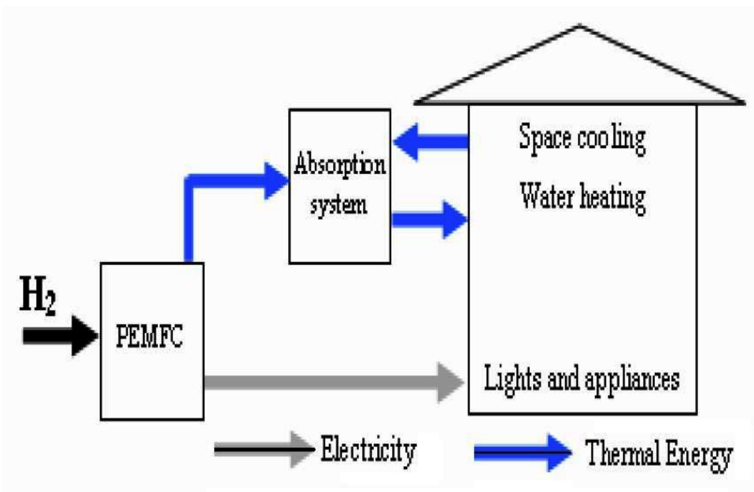

Fig. 1: Schematic description of the PEMFC energy system

Table 3: TRNSYS types used for the thermal simulation

System	Type	Details
Meteorological data	Type 9	TRNSYS library
PEMFC	Type 170	TRNSYS library
Absorption system	Type 107	TRNSYS library
Thermal storage tank	Type 4	

2.3 Description of the electrical loads

The figure 2 shows the electrical loads variation and the (Part load Ratio) PLR according to the time.

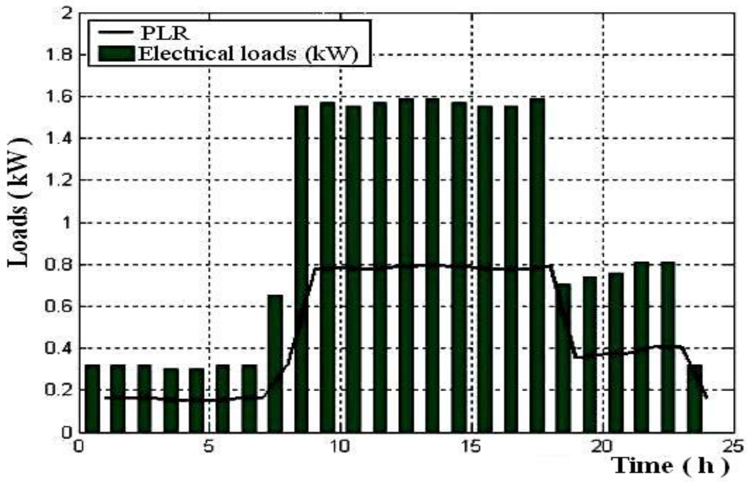

Fig. 2: Evolution of the electrical loads and the PLR according to the time

The electrical loads variation show the pick demand on electrical energy is from 9:00 am until 6:00 pm that corresponds to the high values of the ambient temperature in this time.

3. SIMULATION RESULTS

Since no heating device is used, the study of the dwelling is studying during a summer day. The simulation time step is 1 hours. The study is focused on two phenomena.

First, the evolution of the temperature of the dwelling before and after cooling. The second phenomenon is the evolution of the average temperature of the storage tank.

Figure 3 shows the lists of parameters, inputs, outputs, derivatives, special cards, external files and comments associated with a component model.

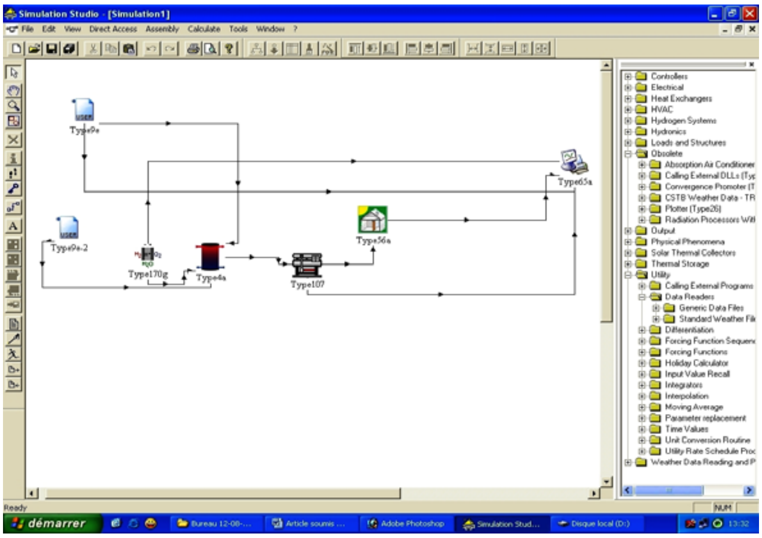

Fig. 3: PEMFC energy system Assembly Panel in TRNSYS simulation studio

As it can be seen, in figure 4, the TST temperature witch correspond to generator temperature has a constant value of about 70 °C, the difference between the initial inlet temperature (ambient) and the final inlet temperature of the habitation is very important.

The initial inlet temperature is between 27 and 32 °C, after cooling we can see the inlet temperature is between 20 et 27 °C.

We can say that cooling by the LiBr/H2O single effect absorption system is very efficient.

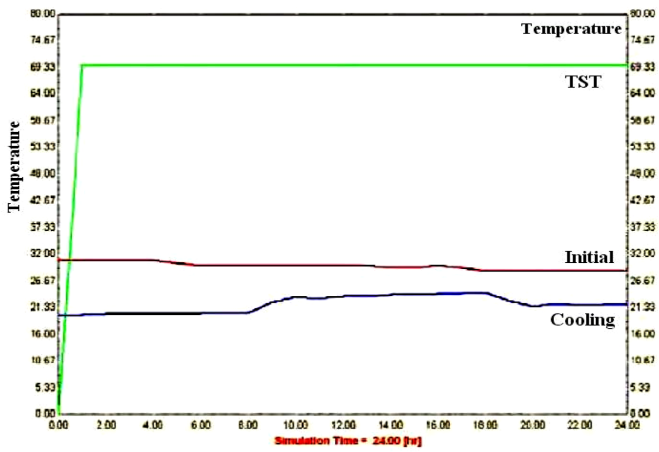

Fig. 4: Temperature of TST, of the ambient temperature and the residence

It can be noted on the figure 4 the capacity of the storage tank: when it is heated until 70 °C, it contains enough energy to provide the residence with domestic hot water. It is also noted that it takes about four hours for the boiler to recharge the storage tank.

Figure 5 show the coefficient of performance of the absorption system according to the time. As can be observed the COP reaches its maximum 0.61.

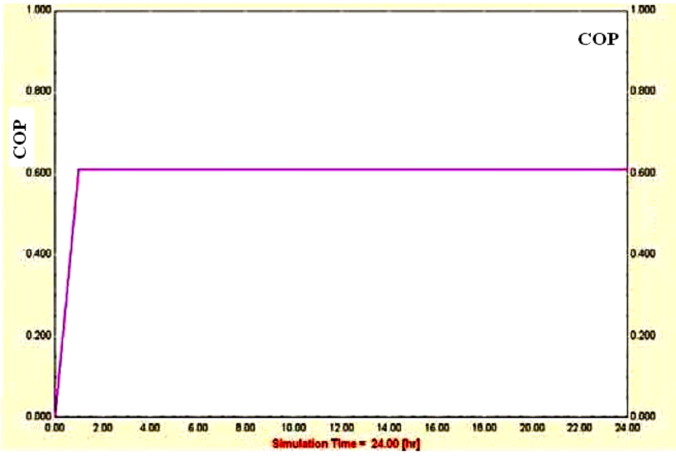

Fig. 5: Coefficient of performance of the absorption system

The maximum value for the COP (0.62) corresponds to a generation temperature of 70 °C. However, it can substantially reduce operating costs because it is powered by low grade waste heat.

4. CONCLUSION

In this paper, hydrogen energy system integrating the PEMFC sub-system and the absorption sub-system has been simulated by TRNSYS 16 and by using URAER residence data. Obtained results show that the best COP of absorption sub-system is about 0.62 which corresponds to a generation temperature of 70 °C.

The demonstration was made that there is a huge energy saving potential in this residence. We can suggest many leads to increase the part of PEMFC and thermal storage tank in the residence. We can improve the system with increase in the volume of the tank. This will probably be done in future studies.

The evolution of the temperature in the residence has been monitored. The temperature of the residence is between 20 and 27 °C witch is a great improvement in the summer day.

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