CHEMICAL ENGINEERING TRANSACTIONS

VOL. 29, 2012

A publication of AIDIC
The Italian Association of Chemical Engineering
Online at: www.aidic.it/cet

Guest Editors: Petar Sabev Varbanov, Hon Loong Lam, Jiří Jaromír Klemeš

ISBN 978-88-95608-20-4; **ISSN** 1974-9791 DOI: 10.3303/CET1229209

Integrating Renewable Energy to Power, Heat and Water Systems

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Recently, the use of renewable energy has made a significant contribution on many areas of sustainable development. For instance, renewable energy has an important role in providing energy access to households and small industries. The integration of renewable energies in small industries can be a complicated task due to differences in the process conditions inside of them. Therefore, it is important to consider the process integration techniques.
Among the main inputs of most industries are: water, heat and power. These are generally handled separately in networks and systems which are intimately related so that any change in one of them has an effect upon the other.
This paper presents the integration of renewable energy in the form of photovoltaic power for running a heat and water system. More specifically it looks at the effect of power quality upon the efficiency of the pumping system. From the electrical point of view, there are various factors that determine the quality of power; failure to recognise them may result in adverse thermal and throughput effects. This situation is analysed in this first paper of a series of them by means of a case study. In a subsequent paper, we will show the way these adverse effects are mitigated and the type of hardware used to this end.

1. Introduction

Renewable energy is continually finding new areas of implementation in the different fields where energy consumption takes place (Pantic, 2010); such is the case with industrial processes where important amounts of both thermal and electric energy is needed, even when industrial processes often have strict parameters for its variables and goals (Betka and Moussi, 2004, 2006, Eskander and Aziza 1997).
For the specifics of this article, the implementation of renewable energies will be presented as a feasible option from the energetic standpoint, regardless of the economic, but emphasizing the demands of the PMHI system. We must remember that the PMHI systems are themselves composed of different elements: power, mass (water) and heat. If renewable energies were to be implemented for industrial processes, each and every condition of the very process should be thoroughly taken care of, *so that the system does not resent from the change of supplied energy*.

2. Power, Heat and Water Systems

Some articles present a detailed implementation of the use of power, water and heat, as in the case of Martinez-Patiño et al. (2010). These very specific types of systems are complex, as different variables

Please cite this article as: Martinez-Patiño J., Picón-Núñez M., Hernández-Figueroa M. A. and Estrada-García H. J., (2012), Integrating renewable energy to power, heat and water systems, Chemical Engineering Transactions, 29, 1249-1254

and goals are involved and must be linked for the proper operation of the intended process; for example, voltage, frequency and other parameters must be met for electric energy; in the case of thermal energy, variables such as temperature and pressure, etc.; and for water, flow and velocity parameters, among others. Even after taking into account how complex it is to implement these variables in power, mass and heat systems (PMHI), they are harmonized by using different process-implementation techniques. A PMHI system is basically constituted of: a pumping system (power), a heat exchange system (heat) and a heat and mass exchange system (water), as illustrated in Figure 1.

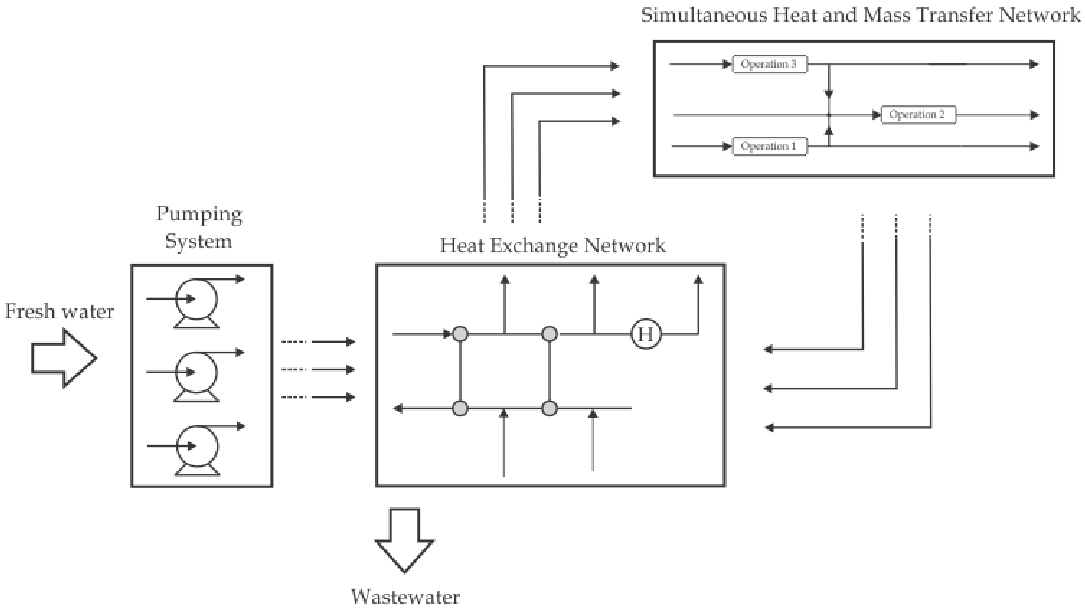


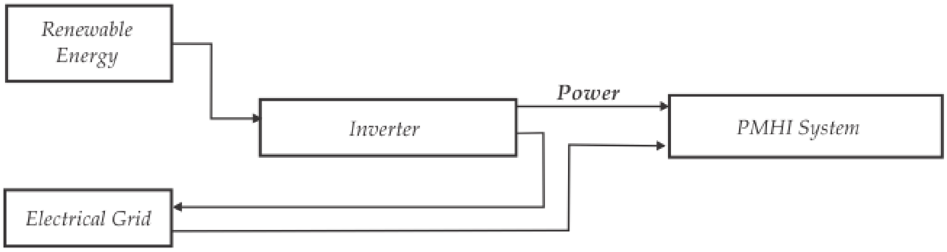
Figure 1. Power, mass and heat integration system (PMHI)

3. Electric Parameters for the Implementation of Renewable Energies

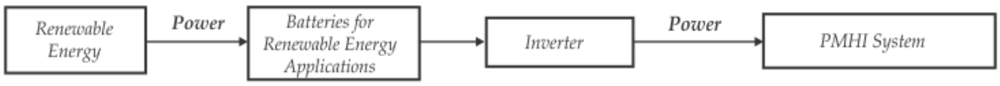
All PMHI systems consume energy, either in the form of electrical power, heat, or both of them. In this paper we look at the implementation of power by means of renewable energies using a photovoltaic system. Due to power having different parameters in different regions of the world, it is essential to know and understand the parameters to be met in the given PMHI system. The most important are voltage and frequency and the amount of power to be used in the system.

/The implementation of renewable energy in PMHI systems can differ regarding the various sources available, namely: wind power, small hydro power, photovoltaic, etc., but it will always be essential to comply with the required electrical parameters and with regard to the intermittency of its use throughout the day.

In order to further illustrate this situation, Figure 2 is shown. In part (a) of Figure 2, power is generated by renewable energy and is supplied to the process; also electric energy from the grid is used for cases where renewable energy is not enough. In part (b), power is generated by renewable energy and is directly supplied to a set of batteries which in turn supply power to the process.



a)



b)

Figure 2. a) Power generated by renewable energy along with supply from the electric grid; b) power is generated by renewable energy and a set of batteries supply the power to the PMHI system.

4. Case Study

The case study to be presented here corresponds to the case of a standalone photovoltaic system to supply the power to run a 1 Hp water pump in the city of Salamanca, Guanajuato (Mexico).In the city of Salamanca, the average annual solar radiation is 5.5 kWh/d. A mono-crystalline 140 Wp solar panel with nominal voltage of 18 V, and a 12 V deep cycle battery with 104 A·h capacity was used for the test (Figure 3). The solar panel has a capacity to supply 810 Wh/d (Figure 4). The maximum battery supply capacity is calculated form:

$$E = C * V \tag{1}$$

Where:
E = Energy expressed in Wh
C = Load capacity expressed in Ah by the manufacturer
V = Accumulator Voltage

After substitution we get that E = 1,248 Wh. Given that the solar panel supplies energy for 810 Wh a day and the battery has capacity for 1,248 Wh, the capacity of the battery will only be at 65.
Once the battery is fully charged, it was used to pump 450 L of water to a tank. Measurements of the adverse effects of the use of a solar power panel are determined by comparing it with the operation of the system using power directly from the grid. The two parameters measured were: temperature rise of the pumped water and time used to accomplish the task. These results are displayed in Table 1.
Figure 5 shows the wave form supplied from the photovoltaic system and the electrical grid. The photovoltaic system uses a hardware called inverter which is supposed to provide the power at the required parameters. Figure 5 shows the way the electric wave is deformed in the case of a photovoltaic system as its operation necessarily required the application of an additional piece of equipment called inverter. This deformation has an adverse effect upon the performance of the pumping system as revealed in Table 1 where water experiences a temperature rise of 2.4 °C and the time required to transfer 450 L is increased from 421 to 463 s. In a real application, the temperature rise and the time consumed for pumping will affect the target temperatures and the plant throughput. It is important to note that the temperature rise of the water with be a function of the temperature at which water enter the pumping system.

Figure 3: Mono-crystalline Solar Panel.

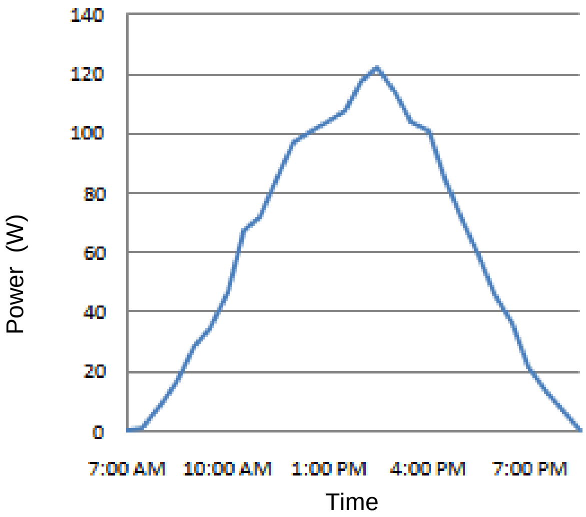
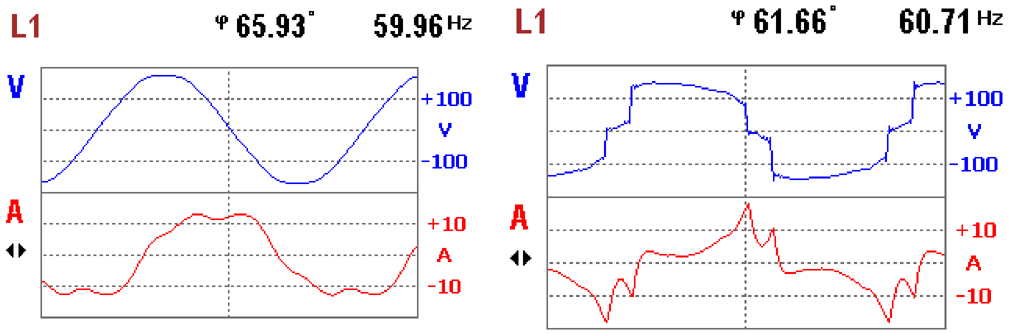


Figure 4: Power Generation Curve of PV system.

Table 1: Comparison of operating parameters.

Power	Inlet Temperature (°C)	Outlet Temperature (°C)	Pumping Time (s)
Electric Grid	44	44	421
PV System	44	46.4	463
Difference	**0**	**2.4**	**42**



a) Electrical Grid b) PV system (Inverter)

Figure 5: (a) Wave form obtained from the grid and (b) from a photovoltaic system.

5. Conclusions

The work described in this paper has implications when it is put in the context of industrial processes. It was demonstrated that when a photovoltaic system is employed to pump water, two essential variables are altered when compared to the use of a traditional system (electric power from the grid): temperature and pumping time.
Both variables affect directly the process. The question then arises: Why are these two variables altered? The answer to this question is that the power inverter equipment that accompanies the photovoltaic system does not provide the quality power required by pump, thus modifying operation. This modification is the result of frequency variation and poor quality energy.
Both factors contribute to the heating of the electric machinery, bringing about an increment in temperature and extending the pumping time. Having said this, an important point to be made is that in order to implement the use of renewable energies, it is essential to ensure that the electric parameters to be delivered are verified for the system to remain at operable conditions.

Acknowledgement

This study is included in a greater project financed by SEP (Secretaría de Educación Pública), PROMEP IDCA 9395.

References

Betka, A., A. Moussi, 2006. Optimized Solar Water Pumping System Based on an Induction Motor Driving a Centrifugal Pump, Colloque National sur l'Energie Solaire, Proceeding, 107 – 112.

Betka, A., Moussi, A., 2004. Performance optimization of a photovoltaic induction motor pumping system. Renewable Energy, 29, 2167–2181.

Eskander M.N., Aziza M.Z., 1997, A Maximum Efficiency-Photovoltaic- Induction motor pump system, Renewable Energy, 10(1) 53–60.

Martínez-Patiño J., Picón-Núnez M., Hernández-Figueroa M. A., Verda V., Serra L. M., 2010. On the integration of power, heat and water in industrial processes. Chemical Engineering Transactions 21, 253-258.

Pantic S., Candanedoa L., Athienitisa K., 2010. Modeling of energy performance of a house with three configurations of building-integrated photovoltaic/thermal systems. Energy and Buildings, Volume 42 (10) 1779-1789.