UNIVERSITY OF CORSICA - UMR CNRS 6134: RESEARCH ACTIVITIES IN RENEWABLE ENERGY FIELD

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Renewable Energy Team

Brief presentation

This research group belongs to the "Physical Systems for Environment" laboratory of the University of Corsica which is a Joint labs partnered with CNRS (National Centre for Scientific Research) of the Department of Information and Engineering Sciences and Technologies. The central theme of our research is the study of the optimal management of energy systems using renewable energy resources.

Fig. 1. *The research laboratory and 100 kW·e solar power plant*

History of the laboratory

The young Corsican University was created in 1981 but it succeeded to an ephemeral university instituted in 1765 in Corte during Pascal Paoli's government. In the same time, the first research laboratory opened in Ajaccio (after the second oil crisis in 1979) and was dedicated to the study of solar energy systems and more particularly to studies on a 100 kW·e solar thermal electric power plant using solar tracking concentrators installed on the laboratory site (Fig. 1). In 1983, a 44 kW·p photovoltaic pilot plant has been implemented within the solar PV R&D European Economic Community Program (CEE-DG XII) in Paomia-Rondulinu (60 km of our laboratory) (Fig. 2) and the researches, having begun with solar thermal conversion, turned to the photovoltaic conversion and the hybrid systems to provide electricity for remote areas. Today, a large renewable energy research domain is treated and will be presented in the following paragraphs.

Fig. 2. *The 44 kWp Photovoltaic power plant*

Research themes

The particularity of solar or wind conversion system comes from the random aspect of the energy sources lied to the no-foreseeable meteorological variation. Thus, even if the system if perfectly known from a mathematical point of view, some physical variables as, efficiency or productivity are lied to the spatio-temporal variations of the source but also of the load. For this reason, the knowledge and the characterisation of the energy source are essential and the solar and wind sources estimation is one of your main research activities.

Each subsystem (wind turbine, photovoltaic collector, battery…) constituting the global energy system is often precisely and individually studied by a lot of laboratories. Our objective is to study all the energy conversion line i.e. the global energy system.

Thus, the methodology used in our work integrates all these particularities and we use a global system approach integrating all the specificities due to the high variability of the energy source.

We can divide our research activities in 6 themes:

– study of the renewable energy resources;

– integration of thermal and/or electrical energy systems in the building and conception of innovating solar collectors;

– hybrid systems for electrical production;

– energy production using large-scale renewable energy systems;

– diagnosis of complex energy production system;

– drinkable water production using water vapour condensation.

Renewable energy sources characterization

As said previously, the study of the energy resources (solar or wind) is necessary to size, optimize and concept the renewable energy systems.

We developed and compared correlation models between various solar radiation components (diffuse, beam, global) on tilted planes because for our behaviour simulations, we need hourly global irradiations (and sometimes diffuse and beam) not easily available [1-2]. A result of this study is shown in Fig. 3.

Some statistical studies have been performed on wind speed or solar radiation data from Markov or ARMA stochastic models. The objective is to develop meteorological simulators used as an input in the simulation process in view to sizing and/or productivity estimation [3-5].

In view to a better estimation of the wind potential and the productivity of a wind turbine, we studied the turbulence phenomena of the wind using a “multi scaling” turbulence model.

The importance of the relief of Corsica introduces striking contrasts from a solar radiation and wind potential point of view; we project to develop a study concerning the solar estimation on all the territory and to analyse the performance of various small PV systems connected to the grid all over Corsica, thus we envisage to connect small PV systems with several meteorological stations disseminated on all the territory taking into account the spatial variability of the energy resource on a small area.

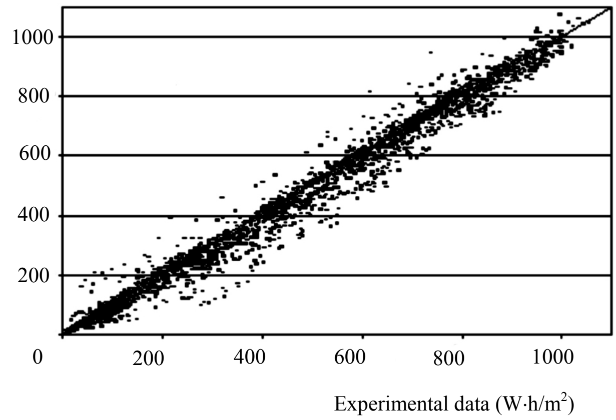

Fig. 3. *Example of result of correlation to calculate hourly tilted global solar irradiations from horizontal ones*

Development of new solar collector and integration in buildings

We develop solar systems with a high integration level in the building to reduce the electrical or the fossil energy consumption. A copolymer solar water heating collector (MISTHERM® & MISFORCE®) [6-7] for which we modelled the thermal behaviour and optimized the configuration; today, the first one is certified and commercialized and the second one is in the process of being certified. We are working on a hybrid thermal/photovoltaic copolymer solar collector (Fig. 4) based on the previous concept and producing simultaneously electricity and heat. The main advantages of such a solar collectors are: of economical order compared to a combination of separate thermal and PV panels, the area covered with an hybrid solar collector produces more electrical and thermal energy than a corresponding area covered half with standard PV panels and half with conventional thermal collector; the average temperature of operation for the hybrid collector being generally lower than for a standard PV module and its electrical production is increased and at last, a hybrid collector provide architectural uniformity on a roof in contrast to a association of two separate solar collectors. This PV/T collector has been modelled (thermal and electrical behaviour) with its environment (water storage, tub) in low flow conditions with a thermal stratifiA solar or wind system is not only dependent on the individual performance and technical reliability of its components, it depends on the configuration and organization of various subsystems, on the running strategy and on its sizing, without forgetting the energy providing. cation of the tank to improve thermal performances [8].

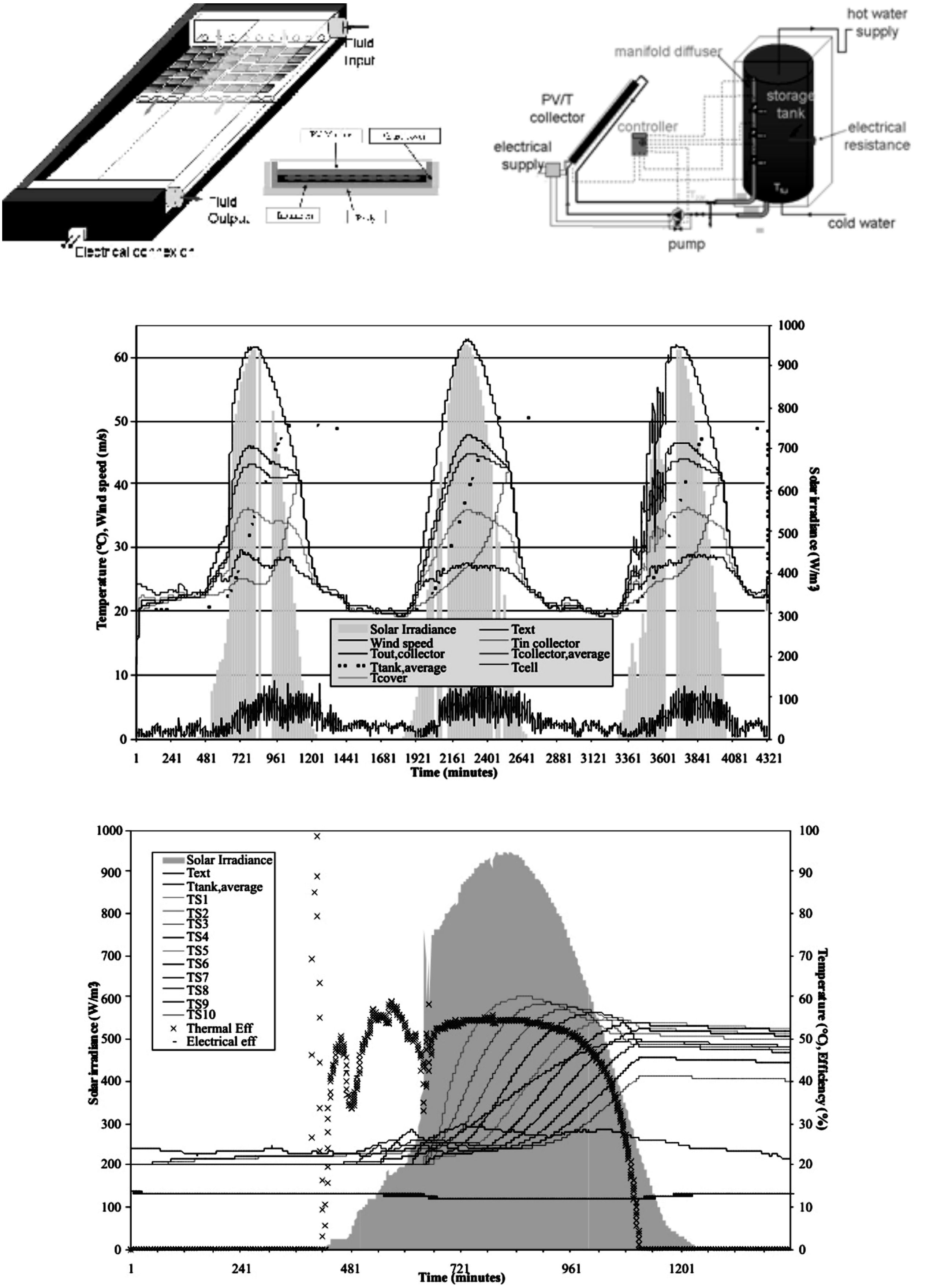

Fig. 4. *The PV solar collector: presentation and results*

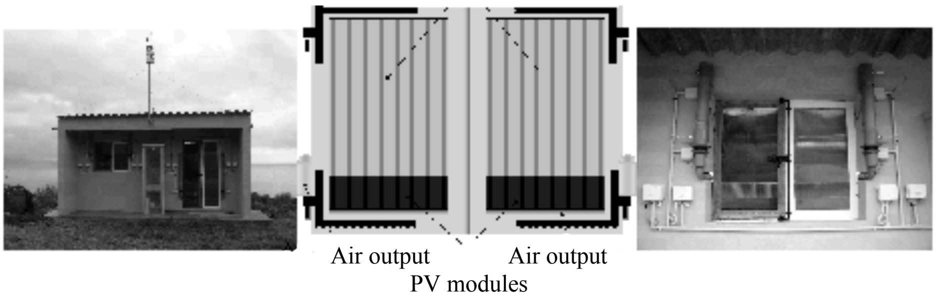

***Fig. 5**. The solar air shutter and the experimental device*

We developed an autonomous air solar collector (CASA® – Capteur à Air Solaire Autonome) with industrial partner SOLARIA SYSTEMS and a new version has been developed with an other local industrial partner (PERI® – Production d'Energie renouvelable Intégrée) about a new concept of air solar collector with high level of integration in the building: a solar air shutter (Fig. 5). The PV modules provide electricity for the air fan into the wall and the air is heated in the shutter before being injected in the house. We are testing, modelling and optimizing this solar air collector totally integrated in the shutter.

Hybrid systems for electrical production

A hybrid system is defined as: a system using more than one energy source and/or producing more than one energy carrier. To couple several energy sources increases the system reliability and the power to provide and to reduce the kW·h production cost. But, it increases too the complexity of the energy system. To produce simultaneous several energy carriers allow to reduce the area of the collector (best integration), to improve the global efficiencies and to reduce the energy losses.
According to this definition, we find:
– hybrid systems for electricity production (this paragraph);
– PV/T solar collector (see previous paragraph).
Hybrid systems are often used to provide electricity in remote areas in coupling various energy production systems as wind turbine, photovoltaic system, engine generator… (Fig. 6). These systems allow a more reliable and less expensive energy production. The problems regarding the design of such a hybrid system are: choosing the correct size of each component, optimizing the system management, optimizing economically the kW·h production cost.

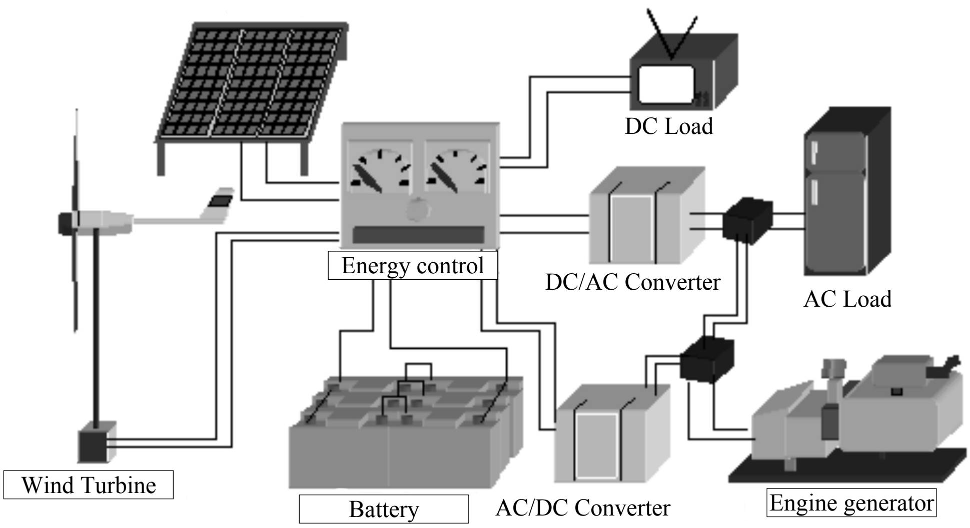

***Fig. 6.** Example of Hybrid system for electrical production*

We developed an optimal sizing methodology [9-12] using energy models for the behaviour of each subsystem. Concerning the behaviour simulation principle, we used a numerical method based on system energy balance and storage continuity equations. At last, a cost optimization is realized and allows to obtain the system producing the lowest kW·h cost.

Large scale renewable systems

It concerns systems directly connected to the grid. This production has some problems due to its high variability which perturbs the electrical network running and limits the integration rate of renewable systems in the electrical network [13-14].

We study the dynamical interactions between the production and the load and analyse the influence of some parameters as: centralisation or distribution of the energy systems, storage energy, electrical network size… to keep the network stability when the renewable production increases. The Corsican electricity network is interesting because it is very small and not connected to the continental network.

We study the influence of dispersed renewable power plant over the territory and the influence of an energy storage to compensate the variations of the renewable power. This storage can be realized by coupling a wind farm with a hydro electrical system as seen in Fig. 7 [15].

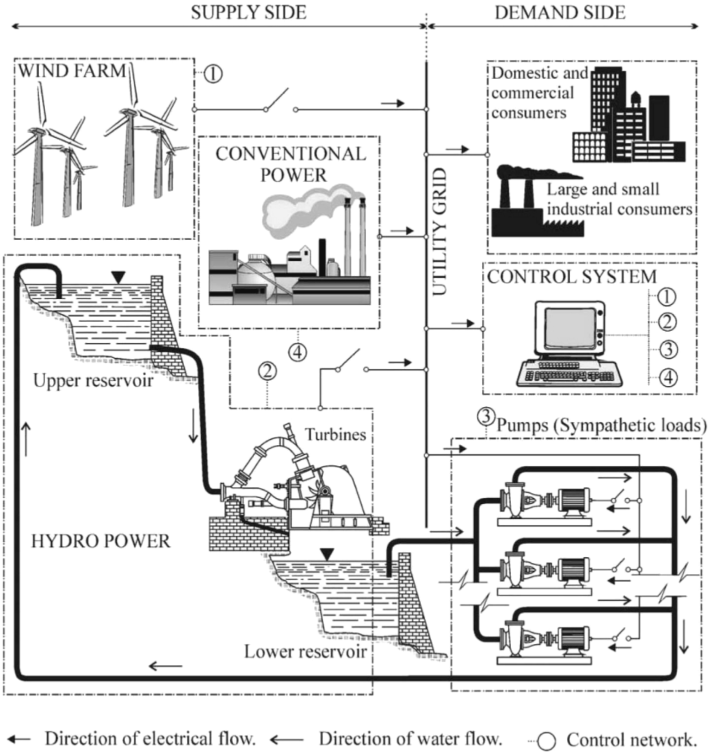

Fig. 7. Coupling wind turbines with hydro-pumping storage

Diagnosis of a complex energy system

The renewable energy conversion systems (wind, solar or hybrid) are often very complex. A lot of physical parameters occur in their running. The reliability of such systems is very important and it is necessary to develop methodologies of validations of data (reliability of information coming from automatic process) and of complex systems observability.

We must be sure of the process state or of the energy system state and we develop FDI (Fault Detection and Isolation) methods applied to renewable energy systems to detect the running anomalies of the system or a fault in the measure system or data transmission system [16-17].

This method is applied to a wind turbine to control the good running and looking for the reasons of faults in view to optimize the wind turbine production. A wind turbine model has been developed and the results have been validated on a 40 kW test platform at the University of Mandragon in Spain (Fig. 8). The final objective is to improve the algorithm to detect in real times the working faults and to realize in real time a diagnostic of the system.

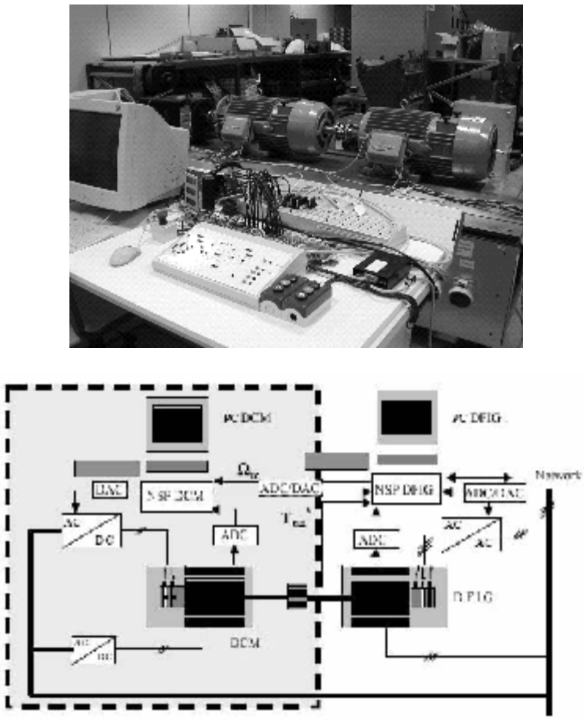

***Fig. 8**. Experimental 40 kW platform at the University of Mandragon (Spain)*

Drinkable water production by condensation of atmospheric water vapour

The objective of this research is to develop passive energy systems (without using energy) able to condense the atmospheric water vapour to provide drinkable water for remote populations and to allow air-conditioning in developing countries.

Various prototype condensers have been developed and tested in various meteorological conditions. We defined two new materials for condensation: a plastic film (radiative foil) and a liquid one (painting) more easy to install using some minerals having interesting cooling and emissivity properties (white colour for hot countries allowing air-conditioning in diurnal cycle and dew condensation for night and uncoloured for only water production during nocturnal periods). These materials can cool rapidly and reach the dew temperature. New architectures have been developed too as for example a conic one allowing to increase their performances of 40 % per m^2. Such systems have been implemented and tested [18-20]:

– in Croatia (12 m² condensing roof);

– in French Polynesia in special windy conditions;

– in Israel (Neguev) with an efficiency of 0.6 L/m^2 per night;

– in India, with two plants : the first one at Saraya (850 m^2 of plane condensers) producing 200 L per night and the other one at Kutch with 15000 m² with a production up to 5 m^3 per night (Fig. 9).

a

b

Fig. 9. *(a) a 850 m² dew plant in Panandhro (India) for bottled fresh water (at the final stage, a surface of 15,000 m² for the production of about 5 m^3/day); (b) a 40 m² dew plant with radiative paint for dew condensation and passive air-conditioning composed by 5 typical rooftop materials encountered in developing countries*

The potability of the water has been verified in a chemical and bacteriologic point of view and allows to conclude that dew water is potable for human use by a low filtering and classical disinfection process from French, European and WHO legislations.

New projects

We described in this paragraph the main research projects for the three next years:

Performance of PV systems

The objectives of this project are: to guarantee the productivity of a PV module, to estimate precisely the energy potential for a photovoltaic production and more particularly in building integration, to predict the production of a PV system connected to the network. Thus, several small meteorological stations will be implemented with 4 standard PV cells measuring solar radiation in various planes. In Corsica, these stations will be coupled with PV systems to study the influence of the grid network quality on the production of the PV systems.

New solar collector H2OSS®

We will study a new concept of water solar collector developed by a collaborating enterprise. It consists to totally integrate a solar water collector into a gutter. A prototype will be available in some months and we will test it, model it and look for optimization of the configuration of the system.

Water vapor condensers

Two objectives:

– development of new materials: less expensive and more efficient. A 30 m² prototype with 4 special substratum applied to developing countries.

– development of new architectures allowing to recuperate not only the condensed vapour but also the rain water. This study will be realized with the Indian Institute of Management.

Hybrid systems: renewable energies and hydrogen

We want to study a new hybrid system using fuel cells as a storage subsystem. Our objective is to develop a simulation model for each element of our system (PV system, fuel cell, electrolyser…) and to build a tool to optimize the configuration of such systems. This tool will be tested on an experimental device installed on the site of our laboratory.

The aim is to realise a modelling, a simulation and a study of the energetic performances of a hybrid system used to feed an electrical typical load for family (4 inhabitants). For instance, this energetic study is not associated to an economic one. The system is constituted by a photovoltaic array (PV), a wind turbine (WT) and a fuel cell used to produce the complementary power, and which is able to satisfy the load alone. The fuel cell used hydrogen produced by an electrolyzer. This electrolyzer used the PV or WT energy not consumed by the load. At the beginning of the simulation, the hydrogen stock is assumed to be able to satisfy a given number of days of autonomy during winter.

The data used are the typical hourly load, the hourly solar radiation in the plane of the PV array, the hourly wind speed for one year, from our local meteorological station.

The objective is to adjust the peak power of the PV array, the nominal power of the wind turbine, the electrolyzer power, the fuel cell power to obtain the same quantity of hydrogen between the beginning and the end of the yearly simulation. We compute various parameters like the hydrogen volume in the stock at each instant. The configuration of the system and the first results are shown on Fig. 10.

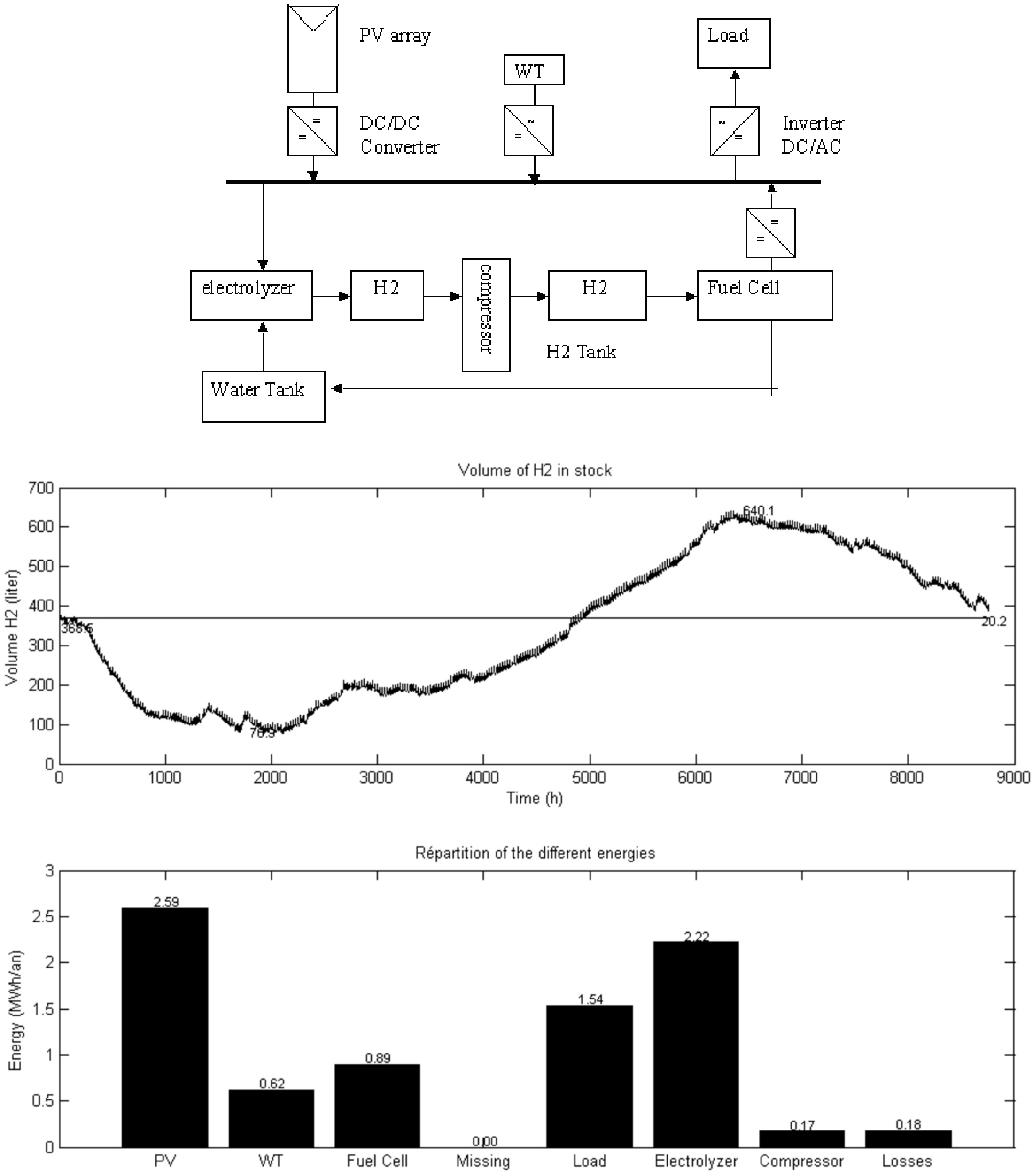

***Fig. 10**. Configuration of the hybrid system and first results*

R&D project: Coupling Renewable energy/H_2/ Fuel cells on an electrical grid

As previously said, the random characteristic of renewable sources limit the integration of renewable systems in an insular electrical grid. One solution to solve this problem consists in introduce an "energy storage". The hydrogen, coupled with renewable energy systems is recognized by scientists as a good solution. We develop with others collaborating organisms an experimental platform with a 3.5 MW PV plant, electrolysers, hydrogen and oxygen storage, and fuel cells (PEMFC) of about 200 kW. The two principal

objectives is, firstly to shave a part of the peak load on the grid, and secondly, after validated the capability of such systems to satisfy this constraint, to disseminate it on specific part of the electrical grid in the island, in view to increase the RES on Corsica.
This project is called MYRTE, and is sponsored by the Corsican Regional Collectivity, the French Governments and the European Community (FEDER).

Scientific collaborations

For three years, numerous collaborations have been developed all over the word.
Our research team is coordinator of a Scientific Exchanges Network between Eastern and Central European Countries and France supported by ADEME (French Environment and Energy Management Agency) and the French Ministry of Foreign Affairs. This network relates to all types of research teams and extends to all the fields from renewable energies. It concerns at the same time scientific and technical projects in Renewable energy. Nowadays, the network is constituted by:
In Eastern and Central European Countries:
− In Bulgaria, Technical University of Sofia, S. Nedeltcheva, V. Lazarov;
− In Romania, Polytechnical University of Bucarest, T. Apostol and Technical University of Construction of Bucarest, I. Colda, A. Damiani;
− In Russia, Moscow Power Engineering Institute and St. Petersburg State Polytechnical University;
− In Serbia, Center for heating, air conditioning and solar energy, University of Kragujevac, M. Bojic;
− In Slovenia, Mechanical Engineering Faculty, University of Ljubljana, V. Butala;
− In Albany, Energy Resources Department, Polytechnic University of Tirana, R. Aleti.
In France:
− Laboratory of Fluid Mechanical, ENSAM Paris, F. Massouh;
− LEG, Electrotechnical Laboratory, INPG Grenoble, C. Schaeffer;
− Electrotechnical Laboratory, Ecole Centrale of Lille, B. François;
− SPE, University of Corsica.
Other scientific partnerships have been developed according to the theme:
− Diagnosis: ENSAM Metz, ENSAM Paris, Mondragon University (Spain);
− Solar Thermal: CSTB (Scientific and Technical Centre for Building), Sophia-Antipolis;
− Radiative condensation: CEA/ESEME; Meteorological Institute of Zagreb (Croatia); The Arid Ecosystems Research Center (Israël); French Polynesian University; Indian Institute of Management (India); Wageningen University (Netherland);
− Renewable energy systems: Building physical Laboratory, University of Reunion; Renewable Energy Group of University of Antilles-Guyana; Physical Laboratory of Genova University (Italy), CEA DTS - INES Chambery and CEA DTH, HELION Fuel Cells Maker.

Teaching activities

In the same “Renewable Energy” field, three formations have been developed:
− a Master called “energy system and renewable energies” with about 30 students on 2 years;
− a Master called “Ecological Engineering” with 40 students on 2 years;
− a professional Licence called “Management of Renewable Energy” opened in the universitary year 2007-2008.

Conclusion

The panel of research activities developed in our laboratory is large but have a common objective which is to optimize the renewable energy systems in taking into account the specific character of these systems lying in the fact that the energy input is a random meteorological data. The large R&D project, 3.5 MW photovoltaic power plant with fuel cell storage, should allow to develop new activities with our partners and increase the potential of the team.

References

1. Notton G., Poggi P., Cristofari C. Predicting hourly solar irradiations on inclined surfaces based on the horizontal measurements: Performances of the association of well-known mathematical models // Energy Conversion and Management. 2006. Vol. 47, No. 13-14. P. 1816-1829.
2. Notton G., Poggi P., Cristofari C. Performance evaluation of various hourly slope irradiation models using Mediterranean experimental data of Ajaccio // Energy Conversion and Management. 2006. Vol. 47, No. 2. P. 147–173.
3. Poggi P., Muselli M., Notton G. et al. Forecasting and simulating wind speed in Corsica by using an autoregressive model // Energy Conversion and Management. 2003. Vol. 44. P. 3177-3196.
4. Muselli M., Poggi P., Notton G. et al. First order Markov chain model for generating synthetic typical days series of global irradiation in order to design PV stand alone systems // Energy Conversion and Management. 2001. Vol. 42, No. 6. P. 675-687.
5. Poggi P., Notton G., Muselli M.et al. Stochastic study of hourly solar radiation in Corsica by using a Markov model // International Journal of Climatology. 2000. Vol. 20, No. 14. P. 1843-1860.
6. Cristofari C., Notton G., Poggi P. et al. Modelling and performance of a copolymer solar water heating collector // Solar Energy. 2002. Vol. 72, No. 2. P. 99-112.
7. Cristofari C., Notton G., Poggi et al. Influence of the flow rate and the tank stratification degree on the

performances of a solar flat-plate collector // International Journal of Thermal Sciences. 2003. Vol. 42, No. 5. P. 455-469.
8. Cristofari C., Notton G., Poggi P. Modelling of a copolymer hybrid PV/T collector // 21th European Photovoltaic Solar Energy Conference and Exhibition, Dresden, Germany, 4-9 September 2006.
9. Notton G., Cristofari C., Poggi P. et al. Wind electrical supply system: behaviour simulation and sizing optimization // Wind Energy. 2001. Vol. 4, No. 2. P. 43-59.
10. Notton G., Muselli M., Poggi P. et al. Decentralized wind energy systems providing small electrical loads in remote area // International Journal of Energy Research. 2001. Vol. 25. P. 141-164.
11. Muselli M., Notton G., Poggi P. et al. PV-Hybrid power systems sizing incorporating battery storage: an analysis via simulation calculations // Renewable Energy. 1999. Vol. 20, No. 1. P. 1-7.
12. Muselli M., Notton G., Poggi P. et al. Computer aided analysis of the integration of renewable energy systems in remote areas using a Geographical Information System // Applied Energy. 1999. Vol. 63, No. 3. P. 141-160.
13. Poggi P., Muselli M., Notton G. et al. Wind farm peak load matching potential in Corsica // 2001 European Wind Energy Conference and Exhibition, ISBN 3-936338-09-4, Copenhaguen, Danemark, 2-6 July 2001. P. 1139-1141.
14. Nedeltcheva S. Poggi P., Notton G. et al. Examination of the influence of the dispersed generation in the distribution networks for medium voltage // IEEE Congress, First International Symposium on Environment, identities in Mediterranean Area, 10-13 July 2006, Corte-Ajaccio.
15. Poggi P., Muselli M., Cristofari C. et al. Coupling hydro and wind electricity production by water-pumping storage // IEEE Congress, First International Symposium on Environment, identities in Mediterranean Area, 10-13 July 2006, Corte-Ajaccio.
16. Bennouna O., Héraud N., Camblong H. et al. Diagnosis of the Doubly Fed Induction Generator of a Wind Turbine // Wind Engineering Journal. 2005. Vol. 29, No. 5. P. 431-448.
17. Bennouna O., Heraud N., Cristofari C. Observability and reliability of a photovoltaic sensor // IEEE International Symposium in Industriel Electronics. Ajaccio, May 4-7, 2004.
18. Muselli M., Beysens D., Milimouk I. A Comparative Study of Two Large Radiative Dew Water Condensers // Journal of Arid Environment. 2006. Vol. 64. P. 54-76.
19. Muselli M., Beysens D., Soyeux E. Is Dew Water Potable? Chemical and Biological Analyses of Dew Water in Ajaccio (Corsica Island, France) // Journal of Environmental Quality. 2006. Vol. 35. P. 1812-1817.
20. Beysens D., Mileta M., Milimouk I. et al. Collecting dew to improve water resources: the D.E.W. project in Biševo (Croatia) // Energy. 2007. Vol. 32, No. 6. P. 1032-1037.