X-th International Workshop on Optimization and Inverse Problems in Electromagnetism
September 14 – 17, 2008, Ilmenau, GERMANY

Optimal sizing of PV based multi-source system for household application

T.T. Ha Pham(*), F. Wurtz(*), S. Bacha(*), S. Ploix(**)

(*)Grenoble Electrical Engineering (G2ELAB)
CNRS - INPG / UJF
BP 46-38402 Saint Martin d'Hères, French
E-mail: Ha.pham-Thi-Thu@g2elab.inpg.fr

(**)Laboratoire des sciences pour la conception, l'optimisation et la production (G-SCOP)
CNRS - INPG / UJF
46, avenue Félix Viallet 38031 Grenoble, French

Abstract: The study presented in this paper deals with a project aiming to increase the value of photovoltaic production for residential application; the main guideline vision is to reach a relative independence regarding the public subsidies. A sizing optimization of a PV based multi-source system with household energy management method has been developed. It consists in searching, in the one hand the appropriate configuration for power supply system and on the other hand, the best operation control strategy to be applied. A Mix Integer Linear Programming formulation is proposed. The economic analysis using a Net Present Value and Profitability Index basis allows estimation of the viability of the proposed system under different factors of influence. Simulation results on a study case will be shown to illustrate the possibility of PV penetration in the next coming year.

Keywords: sizing optimization, Mix Linear Programming, multi-source system, household application

I INTRODUCTION

In Europe, the rapid growth of PV systems in the residential sector over the last year has been promoted by government supported programs. However, actual tendencies to develop the use of renewable energies would evolve. Advantage conditions would be revised to be replaced by another system less attractive. It is expected that an appreciate PV penetration will be ensured without public subsidies in the next coming year. These issues need to investigate innovative energy architecture for housing applications including optimal processes granting an economic interest sensitive to the user [6]. The system has been built up with: a PV based multi-source system at supply side, and an optimal supply and demand co-management.
A sizing and multi-sources management optimization method is presented in this paper. In order to define an accurate configuration for the system, the algorithm takes into account the characteristics and constraints related to each type of source, loads and several exogenous factors. A Mix Integer Linear Programming (MLP) formulation is proposed to handle with the complexity and high dimension of problem. The Net Present Value (NPV) and Profitability Index (P.I) basis are used to analyze the economic feasibility of solution.

II PROBLEM MODELLING

II.1 Source modelling

II.1.1 PV generation modelling

The available PV energy production is calculated based on the meteorological information for an installation at a specific geographical location and PV panel characteristics. The calculation of PV production is performed in two steps: calculation of DC electricity generated by each PV module, and calculation of total AC electricity generated by all installed PV modules.

II.1.2 Battery modelling

The lead-acid batteries are the most used in PV application. The storage system is known as a flexible element of multi-sources system. It can store the total or surplus of production which is not used locally and provide energy when needed. On the other hand, battery storage system constitutes a weak point due to short lifetime period which are strongly influenced by many factors relating to the way it is operated such as: discharge rate, partial cycling, charge factor, temperature ...etc. Therefore, two parts will be considered in storage system modeling: operating model and ageing model [1], [2].

II.2 Loads modelling

Independently from electricity price paid, each household's total hourly desired use of electric power is composed of no controllable loads and controllable loads. A model for controllable loads is presented in form of consumed energy that can be rescheduled in the day.

III MLP FORMULATION

In sizing optimization problem, variables are composed by sizing variables, operating variables and decision variables. Sizing variables are constituted by: number of PV modules, battery capacity, grid selected power rate and nominal power of possible other conventional source. Hourly operating variables include charging and discharging set-points of battery, consumed grid power, exported PV power to grid, consumed power of

conventional source. Moreover, there are some operation processes that cannot be carried out at the same time the decision binary variables are then added. Objective is to maximize the benefit of system to be installed. The Net Present Value (NPV) method is used to formulate the objective function. Characteristics and constraints related to each type of source, loads and several exogenous factors are considered. They could be all expressed in linear representation. By this way, this is a large-scale mixed integer linear (MLP) problem as the calculation is made for long study period (equivalent to the lifetime of installation i.e. 20 to 25 years).

IV STUDY CASE AND RESULTS

The proposed sizing optimization method is tested on a case of a residential house located in France at a sunny place with mean of available surface for PV installation. The test case takes scenario as in the context of deregulated electricity market in which feed-in tariffs and purchase obligations for produced PV energy are finished. These assumptions are made closing to previsions of PV development in 2020-2030 and electricity market design. The problem is solved by the CPLEX Mixed Integer Optimizer [3]. The optimization program is implemented in Java environment.

The optimal results are obtained in the next figures. It is shown that when energy cost increases, the PV based multi-sources system becomes more interesting. When it overpasses a certain threshold (25c€/kWh in this case) the system can be self-amortized. The higher value on the energy cost, it will be more profitable for householder to reduce the consumption of grid energy, produce energy locally and adopt an intelligent energy management on demand side.

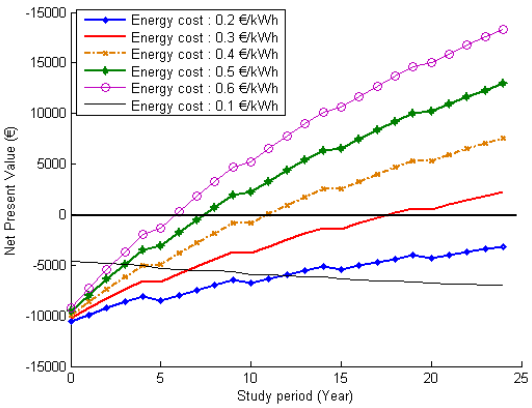

Figure 1: NPV of installation corresponding to different energy cost

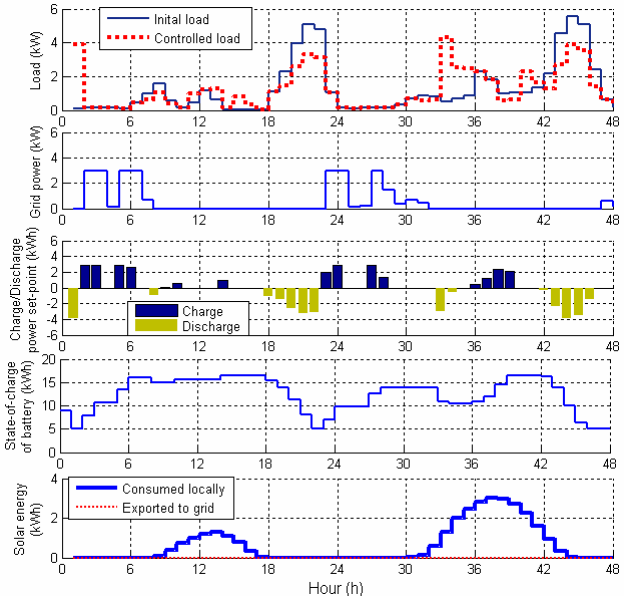

Figure 2: Typical two days operation plan for production and controllable load activities (energy cost of 30 c€/kWh)

IV CONCLUSIONS

The objective of this paper is to propose a method of optimal supplying system sizing. The approach also synchronizes the supply and demand side management for residential application with criteria of economic profit for user. MLP method is used and seems to be effective to deal with the large-scale size and complexity of problem. The formulation is reported on a test case and the problem is solved by CPLEX Mixed Integer Optimizer. Optimal results are obtained. It is shown that the proposed solution for residence application would be profitable nearer than expected without public subsidies. This could be served as a good appreciation for household customer to shift their consumption more intelligent and to be willing to invest in lower environment impacts energy productions.

REFERENCES

[1] H. Bindner, T. Cronin, P. Lundsager, J.F. Manwell, U. Abdulwahid, I. Baring-Gould. “Lifetime Modelling of Lead Acid Batteries”. Project ENK6-CT-2001-80576. Risø National Laboratory, Roskilde, Denmark, April 2005.

[2] A.Cherif, M. Jrairi, A. Dhouid. “A battery ageing model used in stand-alone PV systems”. Journal of Power Sources 112, 2002, pp.49-53

[3] CPLEX Mixed Integer Optimizer. Available information on http://www.ilog.com/products/cplex/

[4] V. Gowrishankar, D. Hutton, C. Fluhrer, N. Dasgupta. “Making photovoltaic power competitive with grid power”. Conference Record of the 2006 IEEE 4th World Conference on Photovoltaic Energy Conversion.Volume 2, May 2006 Page(s): 2532 - 2535

[5] J.C. Hernández, P.G. Vidal, G. Almonacid. “Photovoltaic in grid-connected buildings: sizing and economic analysis”. Renewable Energy, Volume 15, Issues 1-4, September-December 1998, pp. 562-565

[6] F. Wurtz, S. Bacha, T.T.Ha. Pham, G. Foggia, D. Roye, G. Warkosek, "Optimal Energy Management in buildings: sizing, anticipative and reactive management" Energy Management system Workshop – Torino 24 - 25 May 2007