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Impact of Novel Energy Management Actions on Household Appliances for Money Savings and CO2 Emissions Reduction

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Abstract: *In order to obtain CO_2 emissions reductions, energy management control actions inside apartments and detached houses have to be carried out. In this work, new control actions devoted to the reduction of electrical energy consumptions inside typical Italian apartments are proposed. These "Distributed on Site" (DoS) actions consist in employing specific control strategies to smartly exploit the hot water provided by a solar panel, the electricity generated by a photovoltaic panel and the delayed starting of appliances.*

Keywords: CO_2 Emissions Reductions, Distributed on Site Control Actions, Combined Photovoltaic and Solar panel (CPS)

1. Introduction

The growing concern about global warming has pushed industrialized countries to reduce CO_2 emissions. This can be done not only by endowing production plants with green "technologies", but also by employing a widespread energy management control actions inside every single building apartment and detached houses.

An effective way of limiting power consumptions (an so CO_2 emissions) consists in applying power levelling techniques (Demand Side Management) and Distributed on Site energy management control actions [1][2] at house level.

The former are implemented by controlling the turning on time of household appliances (washing machines, dishwashers, dryers, electric storage water heaters, oven hobs, fridge freezers, air conditionings) so to lowering power peaks, trying in this way to pursue a flat electrical energy load profile (i.e. the temporal behaviour of the electrical power requested by the apartment) [3]. Power peaks in fact imply large current flowing through the apartment wiring system, thus rising in turn the power losses caused by Joule effects. Even if these losses are small for a single house, they quickly became huge when multiplied by the number of houses of a country. The resulting load flow peak in the distribution network adds even bigger losses. The power levelling strategies try to avoid the synchronous activation of the apartment's household appliances in the most transparent way with respect to the end-user requirements (the apartment's inhabitants) [4].

If this goal can be achieved a considerable quantity of CO_2 emission can be saved

Distributed on Site (DoS) control actions, instead, consist in exploiting some form of local energy generation (electric and/or thermal), nearby the place where the energy will be employed by the final user. In the present work, the DoS control actions taken into account include the production of electric energy from PhotoVoltaic (PV) systems and of the thermal energy from solar panels (see § 3).

The choice of these local energy generators significantly affects the annual request of electrical energy to the National Utility and also turning out in an immediate money saving return for the end-user.

In this paper, section II presents the simulations of household appliances consumptions while in section III an outlook of the Combined Photovoltaic/Solar panel (CPS) conceived is shown. In Section IV the energy lowering effect due to the Distributed on Site control actions are reported. In section V the simulation results are discussed and finally some conclusions are drawn.

2. Simulations of household appliances consumptions

In order to evaluate the annual apartment electrical energy consumptions, with and without the application of the above mentioned DoS control actions, a tailored house simulator has been developed [5]. The house simulator has been designed and implemented starting on a few clear and well defined inputs parameters (Fig.1). As for the house type and plan, popular, middle-class and luxurious apartments have been considered, while the characteristics of the house wiring were defined by topology, cables lengths and sections, loads distribution among the different circuits. Number of inhabitants within the flat and typical days of the year such as summer working days, summer not working, winter working and winter not working days were kept into consideration, correlating them with electric load profiles of real household appliances such as Dish Washer, Washing Machine, Electric Storage Water Heater, Electric Ovens, Dryers, Fridge Freezer, Air Conditioning etc…. Moreover, this house simulator is able to deliver an accurate numerical consumption prediction considering houses equipped with traditional appliances, which means that no energy management control actions can be carried out (defined as “Scenario 0”) and houses with appliances capable of implementing the above mentioned DoS control actions (“Scenario 1”). The house simulator outputs are the apartment’s energy consumption and energy losses per each typical day. These outputs have been here calculated taking into account two kinds of European apartments and by considering a proven statistics of the inhabitant’s behaviours. More precisely, Italy and France countries have been considered to calculate environmental benefits with and without the novel, here proposed, energy management DoS control actions.

By employing a Montecarlo based probabilistic approach [6–11] it has been possible to take into account all the above-mentioned inputs.

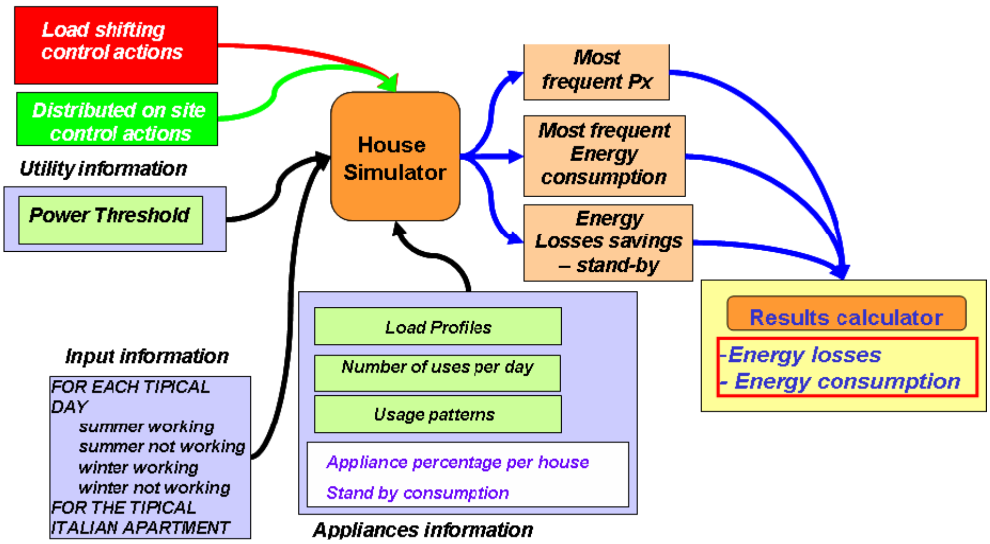

Figure 1: Layout of the house simulator flow diagram

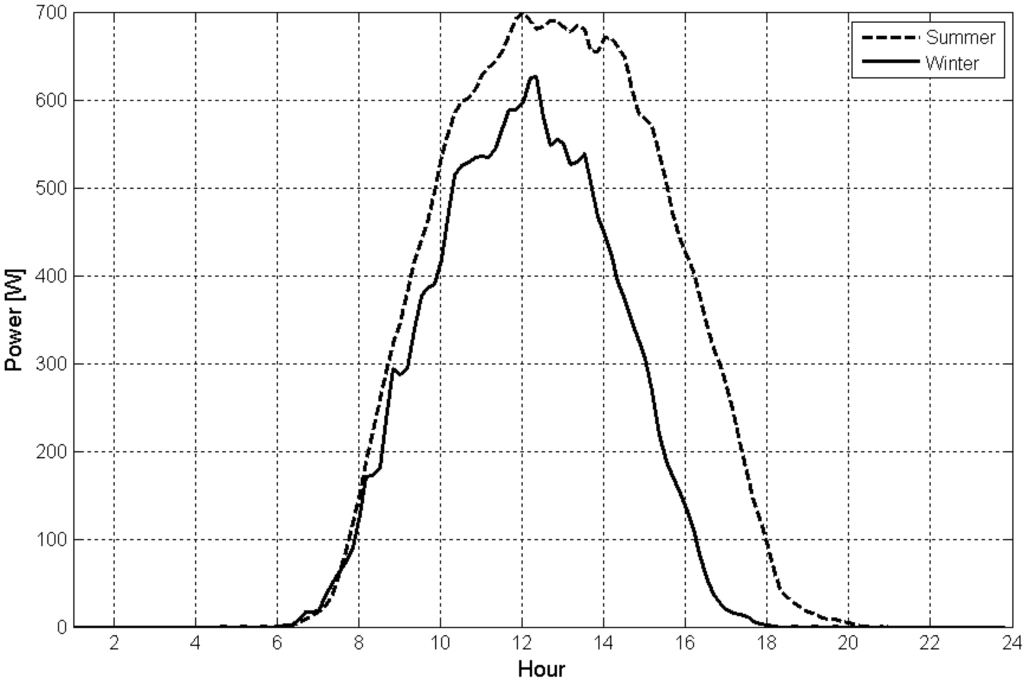

Figure 2: Daily average distribution of PV produced electric energy for a 1KWp PV panel.

3. The Combined Photovoltaic/Solar panel (CPS)

A CPS system is a solar thermal panel integrated with a photovoltaic one (Combined Photovoltaic/Solar panel). This system is composed by a 1.0 kWp photovoltaic panel and a solar panel 8 sqm large. The system is able to produce besides 1 kWp of electric power to accumulate 200 lt hot water with a temperature ranging between 40 and 70 degree Celsius depending on weather conditions and season.
The solar panel is supposed to be able to feed not only the appliances, but the house hot water requirements too. The CPS is supposed to be connected to the apartment Residential Gateway through a communication system.
The PhotoVoltaic system was modelled by considering data recorded from a real system during a whole year as shown in Fig.2, referred to the Italian case.
Starting from these collected data the average level of sun radiation was estimated and the solar panel area was designed to indefinitely fulfil the hot water requirements coming out from the typical household appliances. This choice was mainly due to the author's interest to study the impact that an energy management system could produce onto usual habits.

4. Novel Distributed on Site control actions

The above described CPS capability to deliver both electricity and hot water enables the DoS control actions here proposed consisting in the elimination of the electrical energy consumption related to the water heating phase of dishwashers (DW) and washing machines (WM) by heating the water with the solar panel present in the house (Fig. 3).

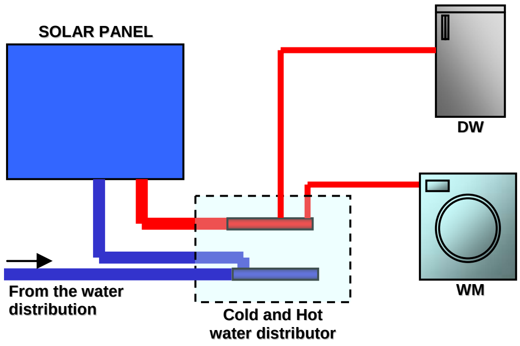

Figure 3: Layout of the CPS connection to the appliances' hot water pipes

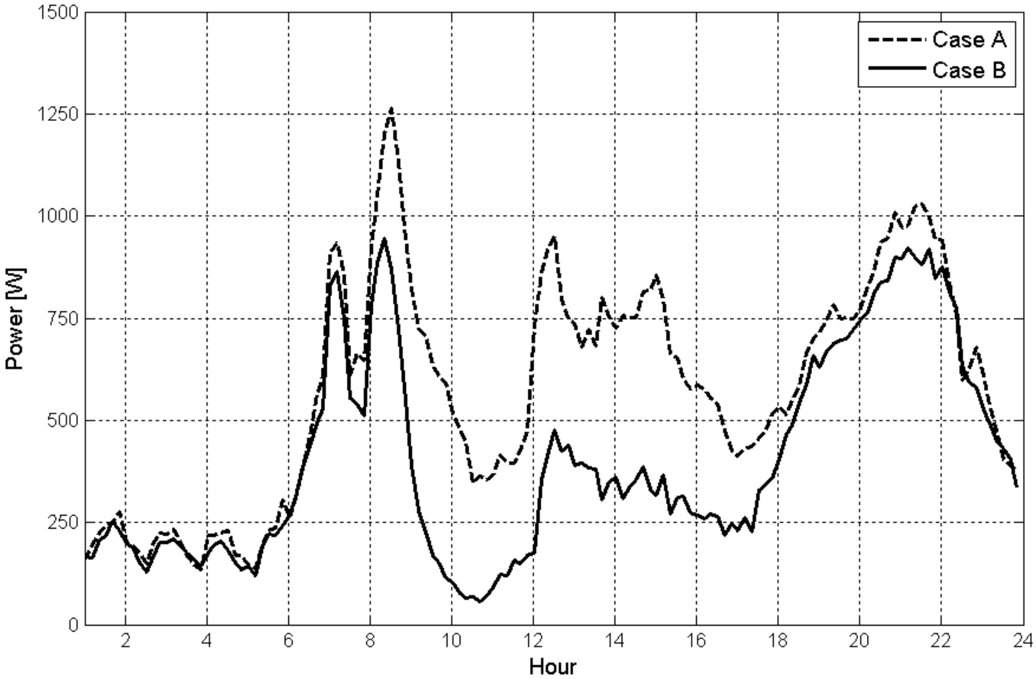

Figure 4: Daily behaviour of energy consumption for a typical summer working day. Case A and Case B refers to the Scenario 0 and Scenario 1 respectively

The other energy component of the DoS control action takes into account the electric energy generated by the PV panel. Both these actions imply a significant reduction of the electrical energy requested to the National Utility. This has a twofold meaning: a direct money saving coming from the cost reduction of the electrical energy and a reduction of the CO_2 emission related to the lower production of the needed electrical energy by power plants.

5. Simulation Results

By applying the CPS model so far described to the house simulator and analysing the estimated energy consumption coming out from an average of at least 1000 iterations related to the previously defined scenario 0 and 1 the following table 1 summarizes the obtained results. As it is clear from the simulation results a 22% saving on the total energy consumption can be easily achieved, together with a 12% fall in the wiring losses, whose absolute value seems to be very little at the first glance. That absolute amount is instead of great interest for the electric energy distributors because they deal with thousands of apartments and design the wiring energy network carefully keeping into account the overall wiring losses coming out from all the houses.

Table 1: Simulation results for the scenario 0 and 1

Simulation data	Average yearly Energy consumption	Yearly wiring losses
Scenario 0	13.437kWh	171.7Wh
Scenario 1	10.500kWh	152.3Wh

The two above described advantages both affect the CO_2 emission reduction by enhancing the local energy generation and usage concept.
Finally the following fig. 4 describes how the energy saving is distributed during a typical summer working day, and the reported area between case A (corresponding to scenario 0) and case B (i.e.: Scenario 1) is the net saving the energy management can afford.

6. Conclusions

The paper describes the main results obtained by studying the impact of a CPS system onto typical apartments' energy consumption profiles. To this purpose a house simulator was designed and implemented with a PC based program aimed to model the inhabitants behaviour and the load energy profiles of the household appliances. The lower estimated energy consumptions and losses, based on measured sun radiation distributions, deeply encourage to further investigate the advantages hidden behind the energy management in order to better exploit their benefits, while trying to pursue a seamless integration with the human habits within their houses.

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