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Benefit at Grid Level by Using DoS Actions via Combined Photovoltaic and Solar Panel System

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Abstract--- *A systematic evaluation of the potential energy saving and CO2 emissions reduction on buildings and neighbours has been carried out, when a renewable energy system is locally installed. The exploitation of a combined solar and photovoltaic system and the integration of suitable energy management actions were deeply investigated. Saving up to 40% on the energy consumptions at house level and savings up to 10% on wiring losses in the electric chain seem to be easily obtainable. This produces savings at national grid level by applying energy management in a large number of houses and buildings. The results here pointed out suggest the possibility of postponing the strengthening of power grids. The consequent economic relevant benefit could persuade economic lobbies about the importance of energy management through connected household appliances. In the paper a grid simulator has been defined with the specific inputs and parameters to model the distribution system, both at low and medium voltage level of the electric system. In the grid simulator the HV/MV transformers, the MV/LV transformers, the LV feeders, the MV feeders, the LV derivations have been considered. Results at neighbour and country level are very suitable and verify the relevant role of the CPS in the whole electric chain.*

Keywords: Index Terms--- CO2 reduction, power grid, Combined Photovoltaic Solar system

1. Introduction

Global warming and energy demand are nowadays becoming one of the major issues of the third millennium, mainly because human activities seem to have a clear impact on the raise of CO2 emissions as never it has been experienced in the past. Among the different factors affecting this CO2 emissions, energy demand from buildings constitutes one of the most important actors of the described scenario. Energy management actions can reduce the net energy request and minimize consumption peaks at house level, by using a distributed control over every house [1]. These local actions can greatly help to reduce the impact on the global CO2 emissions.

Moreover, these savings in-house produce interesting savings at national grid level if energy management applications are applied by a large number of houses and buildings. These savings consist in energy losses reduction at national grid level which mean money savings and CO2 emissions reduction. Another important benefit which could become by energy management through connected household appliances is the possibility of postponing the strengthening of power grid. By considering that the most important parameter to size the power grid is the load density per km2 it can be easily seen that a significant reduction of the peak load and consequently of the load density allows to postpone the strengthening of power grid.

Two different types of energy management control actions can be addressed to accomplish the energy management aims: the Power Levelling (PL, also named Load Shifting

control action) which reduces the electrical energy losses inside apartments and the Distributed on Site control actions (DoS) that reduce the electrical energy consumptions. The former energy management control actions shift the household appliances turning on/off instants in order to flat the electrical apartment load profile [2]. The DoS goal is obtained instead by exploiting a local energy production obtained from solar radiation.
The Distributed on Site control actions here proposed are linked to the capability of energy production inside every apartments, by installing PhotoVoltaic (PV) panels, for electric energy production, and Solar Panels (SP) for hot water production. These local energy generators significantly affect the annual energy request and turn out in an immediate money saving return for the end-user too.
In order to evaluate the annual electrical energy consumptions in a typical apartment, with and without the application of the above mentioned control actions, a tailored house simulator has been developed by using a Matlab environment [3]. The house simulator has been built considering the model of a CPS (Combined Photovoltaic and Solar Panel) system inside.
In order to evaluate benefits at grid level, a specific grid simulator has here been conceived and developed. The results permit to explain the tangible benefits associated to the presence of connected household appliances within the CPS.

2. The Grid Simulator

The use of Demand Side Management methodologies with DoS ones can slow down the growth rate of the yearly peak load and energy demand; here are evaluated the advantages deriving from the application of a set of load-control end-users policies [4].
The evaluation has be done considering the preliminary assumption that the entire territory can be divided in areas characterized by a uniform electrical load density (urban with high and low load-density) and will be referred to a square km. The methodological approach of modular type, based on the use of functional models and on the modular combination of these models for modelling distribution system, is shown in fig. 1.
In figure 2, a simplified flow-chart of the grid simulator is presented; it needs four inputs and the choice of some parameters before running.

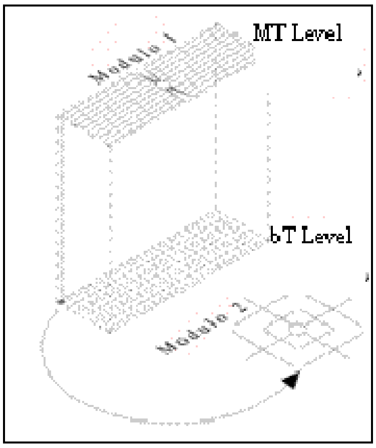

Figure 1: Modula approach to study the distribution system

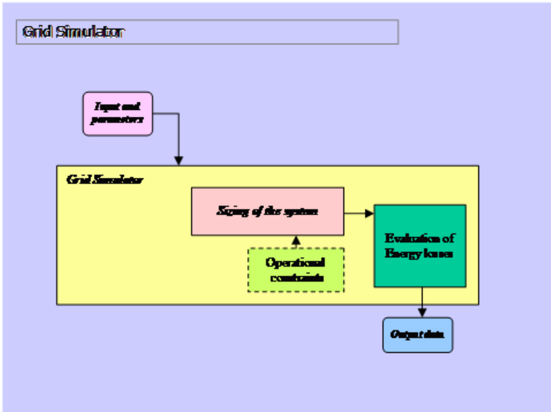

Figure 2: flow-chart of the grid simulator

The inputs needed by the simulator are:
- most frequent Px (peak load);
- most frequent yearly energy consumption Ex;
- equivalent peak load yearly duration, hx;
- equivalent maximum losses yearly duration, $h_{I^2 x}$.

The most frequent house Px is the most frequent peak present in five thousands house load profiles obtained with Montecarlo simulations.
Considering only the load profiles that contain the most frequent Px, the most frequent house energy consumption Ex is calculated.
Equivalent peak load duration hx is calculated by equation (1) :

$$h_x = \frac{E_x}{P_x} \quad (1)$$

Equivalent maximum losses yearly duration, $h_{I^2 x}$ is calculated by equation (2):

$$h_{I^2 x} = \frac{E_{lossses}}{P_x} \quad (2)$$

where E_{losses} is the most frequent yearly energy losses. Each parameter, referred to a single house, will be aggregate with Rusck factor.

$$F_{co}(n) = F_{co\infty} \frac{(1 - F_{co\infty})}{\sqrt{n}} \quad (3)$$

where:

- $F_{co\infty}$ is the Rusck factor for an infinite number of house and it is equal to 0.12;
- n is the number of houses to aggregate in one km2.

The load density σ of one square km is calculated by equation (4):

$$\sigma = P_x * n * F_{co}(n) \quad (4)$$

The parameters to choose before starting simulations are:

- structural model for medium voltage (MV) grid;
- structural model for low voltage (LV) grid;
- average power factor for MV (0.987);
- average power factor for LV (0.985);
- load contemporary factor for feeders (1 for LV, 0.62 for MV);
- load contemporary factor for transformers (0.76 for LV, 0.72 for MV);
- distance factor;
- transmission factor.

The structural model for MV and LV are chosen among the types described in this paragraph.

The distance factor takes into account the not linearity of the distance between transformers and houses; the transmission factor considers the energy losses in transmission system.

A brief description of the functional modules present in literature is given:

- *MV system:*
  - Model AMV: only main feeders model (it's composed by a supply node and a number of outgoing feeders);
  - Model BMV: main feeders and derivations model (it's composed by a supply node and a number of outgoing feeders and derivations);
  - Model CMV: main and combining feeders model (it's composed by a supply node and a number of outgoing feeders equipped with tie-switches allowing the re-closure of each feeder in case of outage);
- *LV system:*
  - Model ALV: only main feeders model (it's composed by a supply node and a number of outgoing feeders);
  - Model BLV: main feeders and derivations model (it's composed by a supply node and a number of outgoing feeders and derivations, with different structure respect the homonymous MV model).

In figures 3, 4, 5, 6 and 7, the above mentioned models are presented.

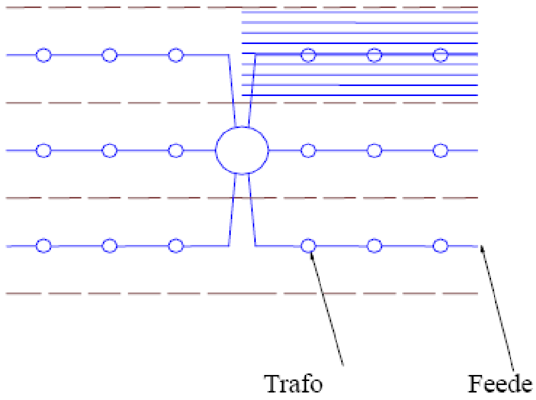

Figure 3: AMV model

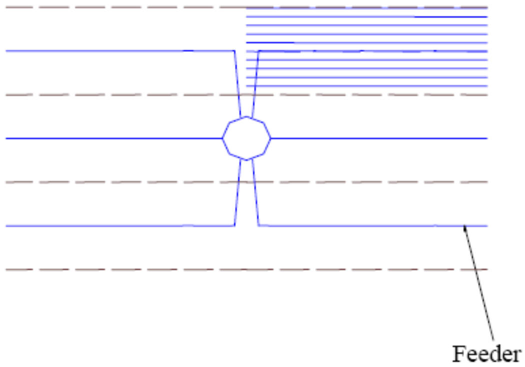

Figure 4: ALV model

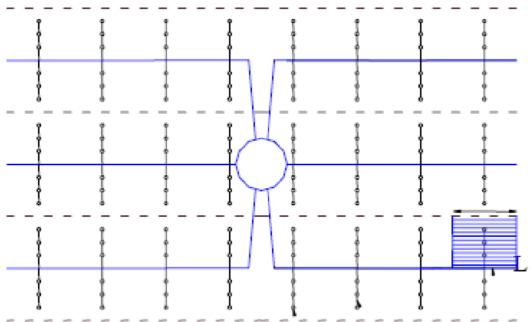
Figure 5: BMV model

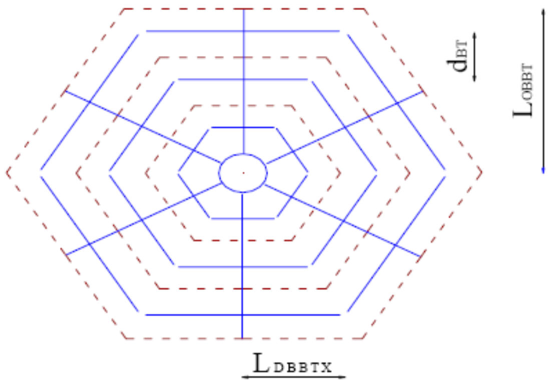
Figure 6: BLV model

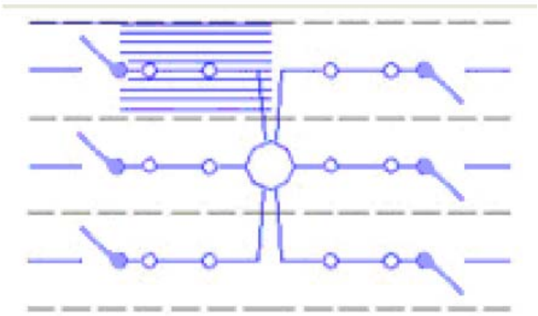

Figure 7: CMV model

In a multi level distribution system, different types of modules may be used at different voltage levels. The study has been done choosing the most used models in distribution system; i.e. CMV and BLV models. After sizing, each module is subjected to operational constraints.
Operational constraints considered by the grid simulator are: the voltage drop for CMV model, the maximum current for cable and transformer sizing in CMV model, the voltage drop for BLV model, the maximum current for cable and transformer sizing in BLV model. The grid simulator output are: the system sizing, the evaluation of the losses in CMV model and the evaluation of the losses in BLV model.

3. Scenarios analyzed

The evaluation of benefits (energy savings in terms of losses saving) obtained by Demand Side Management (DSM) and DoS policy application, has been done making comparisons between different scenarios.
The scenario without the CPS input and with the application of DSM is called scenario A. The scenario with only the Solar thermal energy input and with the application of DSM is called scenario B. The scenario with the complete CPS input and with the application of DSM is called scenario C.
Moreover, four typical days have been considered: Winter: not working day, Winter: working day, Summer: not working day, Summer: working day.
In Italy the square km object of study is a residential community with high load density where the 30% of total surface is occupied by buildings and in particular:

- 500 m2 is the surface of one building;
- 600 is the number of buildings in one km2;
- 15 is the number of apartments per building;
- 9000 is the number of flats in one km2.

Country	kind of day	Energy consumption per Day [KWh/Day]	Peak Px [KW]	Energy losses [Wh]	Energy consumption per year [KWh/Year]
Italy (no solar input) SCENARIO A	Winter: not working day	8,98000	2,95000	86,97000	
	Winter: working day	10,90000	3,22000	117,94000	
	Summer: not working day	11,50000	3,18000	146,07000	
	Summer: working day	13,40000	3,41000	183,12000	4011,84
Italy (only solar input) SCENARIO B	Winter: not working day	7,28000	2,23000	48,56000	
	Winter: working day	9,22000	2,60000	78,98000	
	Summer: not working day	10,00000	2,54000	112,30000	
	Summer: working day	11,90000	2,82000	144,90000	3413,82
Italia all inputs SCENARIO C	Winter: not working day	5,56000	1,95000	47,82000	
	Winter: working day	7,52000	2,44000	78,51000	
	Summer: not working day	7,41000	2,26000	112,40000	
	Summer: working day	8,90000	2,46000	144,90000	2681,52000

Table 1

Country	Scenarios	Total losses [kWh/km2]	Losses saving % in comparison to Scenario A
Italy	Scenario A	372246,42	
	Scenario B	355398,68	-4,53
	Scenario C	333988,2	-10,28

Table 2

4. Results analysis

In table 1 and table 2, particularly the energy consumptions, the losses savings in percentage and the Px are reported.

As a result of the above mentioned DSM and DoS actions via Combined Photovoltaic and Solar Panel System, it is important to underline how the savings are more than the 10% with respect to the A scenario and more important the maximum Px is 28% lower than the A scenario Px. This means that by considering a growing of the country energy demand equal to 3% per year it is reasonable to think that the strengthening of the country power grid can be postponed of more than 9 years by adopting scenario C conditions. The consequent economic relevant benefit, to be evaluated in a further step, could be the most important element to persuade economic lobbies about the importance of energy management through connected household appliances.

5. Conclusions

The above described work reports on the investigations carried out within the encouraging field of CO_2 emissions reductions, caused by the smart management of buildings' energy consumption profiles. The impact of a renewable energy system has been studied, starting from a complete in-house developed, house simulator and a complete grid simulator. The grid simulator has been defined with the specific inputs and parameters to model the distribution system, both at low and medium voltage level of the electric system.

The stochastic nature of the inhabitants' behavior, the use of intelligent appliances and a model for the renewable system has been integrated within the simulator in order to collect the overall apartments' energy consumptions and wiring losses.

The exploitation of a combined solar and photovoltaic system and the integration of suitable energy management actions were deeply investigated.

Results at neighbour and country level are very suitable and verify the relevant role of the CPS in the whole electric chain.

Acknowledgement

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References

[1] Appliance Design February 2OO7 "Customers will choose energy savings", Whirpool Corporation.

[2] Capasso, W. Grattieri, R. Lamedica, A. Prudenzi "A Bottom-Up approach to residential load modelling", IEEE Transactions on Power Systems, vol. 9, No. 2, May i994, pp. 957-965;

[3] R. Miceli, D. La Cascia, A. Di Stefano, G. Fiscelli, C. Giaconia, F. Lo Bue "Integration of Distributed on Site Control Actions via Combined PhotoVoltaic and Solar Panels System, proceedings del congresso internazionale IEEE ICCEP 2009 International Conference on Clean Electrical Power, Capri, Italy, June 9th-11th, 2009;

[4] The Distribution Working Group of the IEEE Power System Planning and Implementation Committee: "Planning for effective distribution" IEEE Power and Energy Magazine, Sept/Oct 2003, pp.:54-62.

[5] D. La Cascia, R. Miceli, A. Di Stefano, G. Fiscelli, C. Giaconia: "Impact of Novel Energy Management Actions on Household Appliances for Money Savings and CO2 Emissions Reduction" proceedings del congresso internazionale EVER '09 (Ecological Vehicles & Renewable Energies), Principato di Monaco, March 26 – 29, 2009;

[6] R. Miceli: "Energy Management via connected household appliances" - Mc. Graw & Hill, isbn 978-88-386-6676-6;

[7] Romero, R.; Rocha, C. Mantovani, M.; J.R.S. "Analysis of heuristic algorithms for the transportation model in static and multistage planning in network expansion system generation, transmission and distribution" IEE Proceedings, Vol.150 Issue:5,15 Sept. 03, pp.: 521-526;

[8] The Distribution Working Group of the IEEE Power System Planning and Implementation Committee: "Planning for effective distribution" IEEE Power and Energy Magazine, Sept/Oct 2003, pp.:54-62;

[9] Ippolito, M.G.; Morana, G.; Riva Sanseverino E. "A modular approach to the strategical planning of distribution system using a genetic algorithm", IASTED International Conference, Orlando (USA) 27-30 October 1997.