TEST FACILITY FOR THE ASSESSMENT OF LOCAL ENERGY MANAGEMENT SYSTEMS

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ABSTRACT

The Italian Electric Sector has been undergoing considerable changes: EU Directive on electricity (2004/54/EC, ex 96/92/EC) has established common rules for creation of internal markets and required privatisation of Italy's dominant energy monopolies. From 2007 all EU domestic customers will have the right to choose energy suppliers; this will involve a change from a passive role to active participant. Final users participation to the market will be substantially represented by the ability of modulating their own load profile as result of market signal (price) or network signal (emergency). This requires the provision of a platform that performs several functionalities: communication with distributor/retailer, interaction with user, load management, energy storage and management of distributed micro-generators.
This paper describe CESI RICERCA's facility devoted to develop and test the above mentioned functionalities.

INTRODUCTION

In recent years the Italian power sector has been undergoing considerable changes: EU Directive on electricity (2003/54/EC, ex 96/92/EC) has established common rules for creation of internal markets and required privatization of Italy's dominant energy monopolies. All business customers have the right to choose energy suppliers by July 2004, this will be extended to all domestic customers by July 2007. For the italian gas market, this liberalisation started in 2003, but gas price for residential users is not yet determined entirely on market basis.
Customers ability to enter to the market will be essentially represented by the aptitude of modulating their own load profile [1][2] as result of market signals (price) or network signals (emergency). Moreover the availability of responding users could permit to reduce power demand during critical situation and therefore to avoid rotational blackouts, safeguarding critical users.
In order to reach these aims and to achieve a global efficiency in residential and tertiary employ, a complex strategy including not only energy and gas prices but also their specific exploitation, customer preferences and external parameters as seasonal temperature change is required. Local generation, that is spreading, must be included also because it could imply a power flow towards the network instead of consumption. Fig. 1 shows authors' vision of the interaction between LV customers and the network: customers responds to market/emergency signals modifying their power absorption . This could be carried out by a local energy manager that acts as a gateway receiving external signals and providing load, HVAC (Heating, Ventilation and Air Conditioning), storage and generation management.

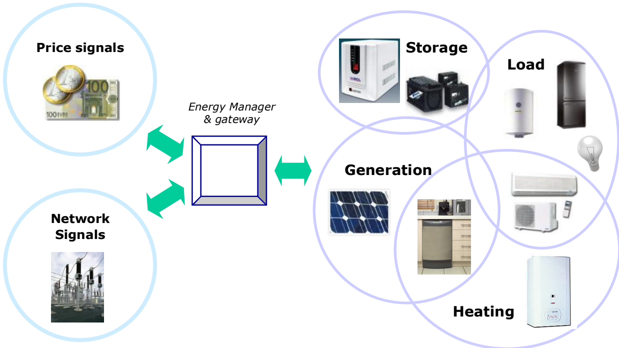

Fig. 1 *general scheme*

This paper describes the CESI RICERCA facility for demonstrating potentialities of the interaction between LV customers and the network by testing functions supporting Demand-side Initiatives (DSI) and increasing electric system security level.

DEVELOPMENT OF FUNCTIONS

The platform specified by CESI RICERCA (named FRIDOM-CLIENT or GED) is a Local Energy Management System combining signal received from retailer (tariffs) and user preferences regarding comfort. In order to succeed with this management, several *functions* should be developed and tested [3].
The main functionality to be implemented is represented by *load* and *heating management*, i.e. the possibility of switching off some appliances when particular circumstances occur or decide whether if it is better to use electric or gas devices for HVAC purposes.
For example, when a power reduction is required because of high electricity price or emergency network condition, GED switches off some appliances according to desired priority, and the gas heating is preferred to heat pumps.
Functions development process follows a widely used model ("V" model) for automation applications. According to this model, the first development phase

gives requirements for the function using a natural language. Requirements are then represented in a formal scheme using state and transition diagrams (design phase). Further step is the source code writing (coding); the code is then embedded into external libraries in C languages called by a LabVIEW™ application specially developed (verification phase) [4].
These functions are firstly tested on the *virtual environment*, that simulates a real field, i.e. a residential building, a family and their appliances (SICA). Beyond electrical loads, a complete thermal model of the test facility and outer environment has been developed to include several parameters as daily temperature profile, heat pump performances and thermal behaviour of the specified building.
Availability of virtual environment allows to verify functions before their validation on real case, and permits to develop new functions when the test facility is already engaged in verifying old functions.
The implementation of the model has been made also with LabVIEW™ and it can communicate during the simulation with GED using IP connections. The choice of IP connections (Ethernet in CESI RICERCA facility) provides easy transition from the virtual testing to the real testing, as described in the following schemes (fig. 3).
New devices, for example weather sensors, could be easily added to the test facility because there is a common interface and only the translator from their own protocol must be created.

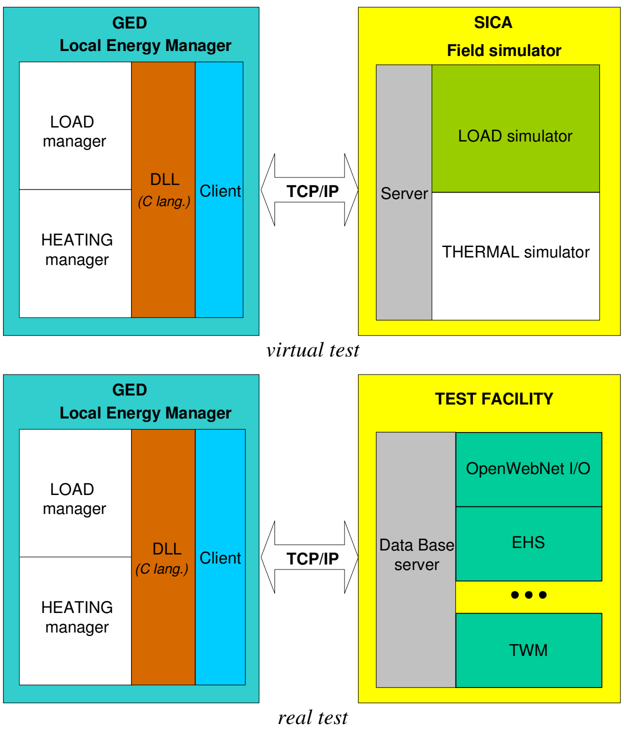

Fig. 3 *virtual and real test*

CESI RICERCA TEST FACILITY

The CESI RICERCA test facility is a 60 m^2 building representing a common residential flat with living room, kitchen, bedroom, and bathroom.
This facility makes possible to carry out several tests on different energy management strategies but also simulates the user presence thanks to an appropriate sub-system which operates each single domestic appliance as it may do a real family living in a house [5] [6] [7]. To carry out these functionalities, there are:

- *GED platform*, that manages loads and thermal system; this platform is equipped with a monitoring, acquisition and data storage system;
- a commercial home automation system managed by GED to control loads, heating system, and so on;
- an automation system that switches on and off each load according to profiles representing different family habits ("user simulator"),
- a whole set of common appliances,
- heating system (boiler + fan coils and air conditioners).

This test facility already comprises a photovoltaic conversion generator and soon also a micro-cogenerator (μCHP) and a storage unit will be installed; they will be included in the *manager* strategies in following months.
Commercial-of-the-shelves components and technologies are used to build the infrastructure. Java™ with OSGi™ specifications are used to maximize dynamic interaction (upgradeability) and interoperability. *OpenWebNet™* communication protocols is used to interface commercial home & building automation system.
TCP/IP protocol and XML format are considered because are widely used and it is very probably that their diffusion will extend even further in next years, becoming a *de facto* standard. As mentioned, they permit also to pass easily from virtual environment (SICA) to real test facility, changing only the device GED communicates with ("move the plug from a socket to the other").
Figure 5 shows a scheme of the CESI RICERCA test facility with GED platform and the user simulation sub-system.

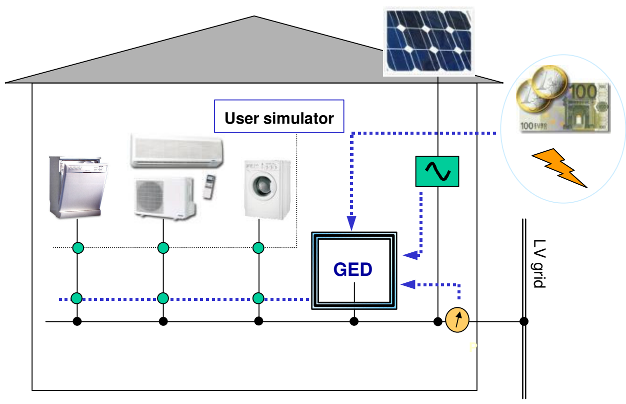

Fig. 5 *test facility: equipment and information flows*

In the previous diagram one could see information coming from outside the facility (prices/emergency), from local power meter and from local generation. The user simulator sub-system allows to perform several tests also from remote.
Further development foresees the presence of a storage unit to enhance security level for critical loads. At the present time only personal computers or lifesaving devices are equipped with storage units, but their presence could improve general security level and could improve also load management. This is true especially for high-automation home, where LV network disconnections involve a large discomfort and above all potentially dangerous condition. For example, one could think to electrical blinds that cannot be opened or other helpful devices for elderly people that suddenly don't work, causing fear situation.
A photovoltaic conversion generator represents another future improvement for the test facility, because their diffusion will increase in next future. The presence of local generation complicates energy management strategies and could be favourably combined with storage unit.

REAL TESTING

Once verification and validation of functions succeeded the virtual test phase, performance and reliability tests are conducted in the test facility.
At first these functions was evaluated:

- Comfort: avoid automatically e-meter disconnection when power exceeds contractual limit. The user specifies a priority for each appliance. Critical equipment (safety devices, etc.) are not subject to local energy management system.
- Emergency: shedding of loads according to their priority as a result of an emergency signal received from the distributor (CPP critical peak price, i.e. sharp raising of price for short time).
- Savings: customers may set GED for shedding of loads when energy price exceeds a fixed threshold. The customer may choose load shedding priority.

All the above functions are implemented using only one internal parameter (*available power*) that represents user preferences about power consumption in different hours. Available power is always under contractual limit, but each user could choose a specific level corresponding to different energy prices. The above mentioned functions (emergency, comfort, savings) correspond essentially to different available power levels.
The following picture shows the GED form that permits to set this threshold from price and contractual power for each hour. *Pcont* is the contractual limit (3.3 kWpeak in this example, red bars), and *Pdisp* (blue bars) is the available power as fixed from the user in each hour.

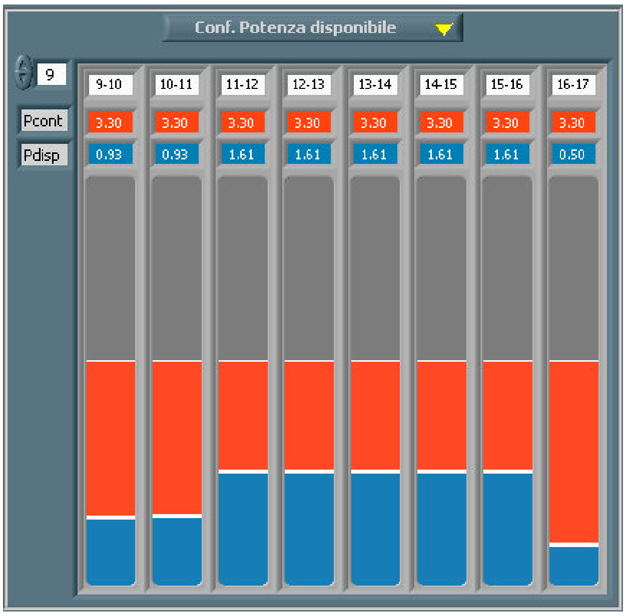

Fig 4 *available power form*

Verification was at first carried out with a small set of appliances: one electric heater, at maximum priority level, and three table lamps respectively at the three lower priority levels.
The following diagram shows an example of this verification phase, when blue line represents power threshold and red line real power absorption (Pass). One could see that every time that absorption exceeds the threshold, in short time GED switches off a load to remain under the desired power, according to desired priorities. As above mentioned, the threshold could vary during the day, according to energy price and user preferences.

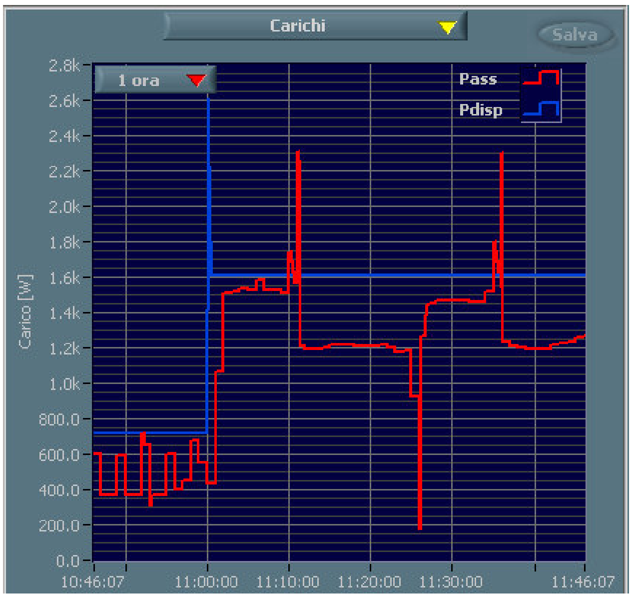

Fig. 4 *power absorption and available power*

To avoid subsequent cycles of switching on/off, an hysteresys for threshold and delay time before re-connection of loads are considered.

Preliminary results show that general strategies work as planned, intervention time is congruent with fiscal meter activity and communication are reliable. These results lead to the conclusion that strategies and architecture are ready to be employed in a wider environment, i.e. the whole test facility. This outcome confirms also that this architecture is suitable for security services for distribution network, as critical peak price programs.

Current experimentation is regarding thermal management and its integration with already verified electrical load management. This experimentation is based on the same life-cycle described for load management functions development: strategies are at first evaluated on virtual environment and then are performed on a real case. Unlike load management, heating management doesn't require quick time of intervention because of thermal inertia of building. In addition this inertia permits to disconnect devices for short time without significant comfort reduction and could be favourably exploited in combination with load management.

Current activity is also focusing on integration with already installed home automation systems to improve load/heating management. For example, window opening alarm could be used by GED to temporarily stop heating of room, reducing misuse of energy.

CONCLUSION AND FUTURE ENHANCEMENT

Together energy market liberalization and diffusion of local automation systems may promote a new role for the customer who will change from passive to active consumer. Improving customer participation to the market, requires a platform that provides several energy management functions.

This paper describe CESI RICERCA's facility devoted to develop and test these local automation functions in a real test case.

Future development foresees the presence of energy storage units even in combination with local micro-generation placed at customer premise. This will improve security level and local energy management possibilities aiming at a global increasing of energy efficiency.

Acknowledgments

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