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New interactions between LV customers and the network: further possibilities for home automation functions

Diana Moneta, Luigi Bisone, Giuseppe Mauri, Roberto Meda
CESI RICERCA SpA
Milano, Italy
Email: diana.moneta@cesiricerca.it

***Abstract* – In recent years Italian power sector has been undergoing considerable changes: EU Directive on electricity (96/92/EC) established common rules for the creation of internal markets and required privatization of Italy's dominant energy monopolies, but also extended to all domestic customers the possibility to choose their own energy retailers starting from July 2007. This will involve a new role for the final user who will change from passive consumer to active participant. To get the most advantage from this opportunity it is necessary to provide a platform which will be interoperable with *home and building automation* systems and that will supply several functionalities as communicate with distributor/retailer, interact with consumer, manage loads, energy storages and domestic micro-generation. In this way households will become active "nodes" of the electric network that could also provide services for the network (power modulation) and the market (reduce energy price volatility).**

Index terms – Demand response, Energy management, Home automation, Building automation, Demand-side Initiatives.

I. INTRODUCTION

In recent years the Italian power sector has been undergoing considerable changes: EU Directive on electricity (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.

Customers ability to participate to the market will be substantially represented by the aptitude of modulating their own load profile [1] as result of market signals (electricity price) or network signals (emergency).

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Authors are with CESI RICERCA Power Systems Economics Dept., Italy 20134 Milano, via Rubattino 54 (phone: +39 02 3992.1; fax: +39 02 3992 5597 www.cesiricerca.it).

Contracts may state new services that distribution utilities will provide to their customers, these may encompass: remote management of Distributed Energy Resources (DER), selective load shedding (e.g. through remotely controlled relays, plugs, intelligent devices) according to price signals (e.g. critical peak pricing tariffs) or broadcasting of emergency signals (from SCADA systems). Successful Demand-side Initiatives (DSI) should bring benefits both to customers (wishing reward schemas), Utilities (postponing investments) and the Society (increase global energy efficiency). All these actions (network or market driven) are to be managed by proper ICT systems located in some nodes and levels of the Electric System [2].

The whole system provides services to customers, energy traders/retailers and the network. Figure 1 shows CESI RICERCA vision of the interaction between LV customers and the network: it could be carried out by a local energy manager that acts as a gateway receiving market/system signals and providing load, storage and generation management.

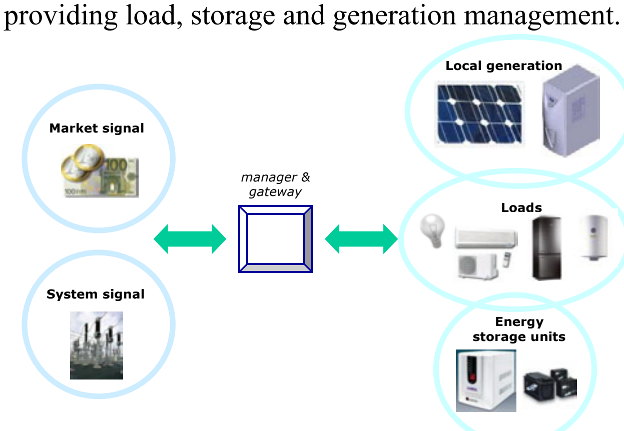

Fig. 1 The gateway manages loads, energy storage units, and local generation in reply to messages received from utility/retailer.

This paper describes CESI RICERCA's activity towards the development and testing of an ICT infrastructure providing the above mentioned functionalities. Commercial-of-the-shelves components and technologies are used to provide the infrastructure. Java™ with OSGi™ specifications are used to maximize dynamic interaction (upgradeability) and interoperability. *OpenWebNet™* communication protocolis used to interface commercial home & building automation system. Formal specification methods based on state and transition diagram are used to verify and validate automation functions.

These function are developed in a *virtual environment*, then they are verified and validated in our *test facility* which helps also to evaluate their integration with already installed *home automation* systems like security, lighting and HVAC (Heating, Ventilating, and Air-Conditioning) systems.

II. Functions development

The platform specified by CESIRICERCA (named FRIDOM-CLIENT) will perform several functionalities: communication with distributor/ retailer, interaction with customers, management of loads, energy storages and local micro-generators. The main functionality to be implemented is actually represented by *load management*, i.e. the possibility of switching off some appliances when particular circumstances occur.

Different strategies for load control may be applied to evaluate their performance and reliability in reply to system or market signals coming from outside the house (utility, retailer). A development environment for Demand Side Initiatives (verification & validation environment, *DSI-VVE*) has been created with the aim to develop and to test the above mentioned functionalities in a virtual case.

DSI-VVE supports creation and testing of home automation functions, evaluation of their features and identification of further improvements, before their actual implementation on a real target. The first system undergoing *DSI-VVE* is the FRIDOM-CLIENT which is a Local Energy Management System combining signal received from retailer (tariffs) and user preferences regarding controlled appliances and their priority. It provides automatic load disconnection and re-connection to maintain maximum power flow with the network under a specified threshold (that may change every hour).

Main functionalities to be tested, developed in the virtual environment, are the following:

A. Comfort

Avoiding automatically energy meter disconnection when power absorption exceeds contractual limit. The user specifies a priority level for each appliance in order that most important loads may keep go on working while FRIDOM-CLIENT sheds less important ones. Critical equipment (security devices, etc.) obviously are not subject to the local power management.

B. Emergency

FRIDOM-CLIENT reduces automatically energy consumption as a result of an emergency signal received from the distribution utility. This emergency signal could be delivered by means of the AMI (Automated Metering Infrastructure) or other communication media (Internet, GSM, …). It could request either to lower consumption under a specified power level or establishing a specified remuneration to the consumer.

C. Savings

When price exceeds a fixed level, customers may decide to reduce their energy usage. FRIDOM-CLIENT permits to determine dynamically which loads are to be disconnected, as price and user requests change. In this case also, the price signal could be received from the retailer by means of several communication channels, not only by the AMI.

D. Energy storage management

To improve load manager functions and security level for some critical applications, it is possible to include storage units in the house energy management. Suitable batteries and inverters could guarantee critical appliances to work during LV supply interruptions, according to priorities chosen by the user. Such equipment could enhance also "saving functions", as support for short period to some (small) domestic appliances when energy price is high.

E. Local generation management

It is worth to consider possible local generation also, to exploit fully distribute energy resources and to enhance load management functions.

DSI-VVE follows the so-called "V" life-cycle approach for function development (Fig. 2).

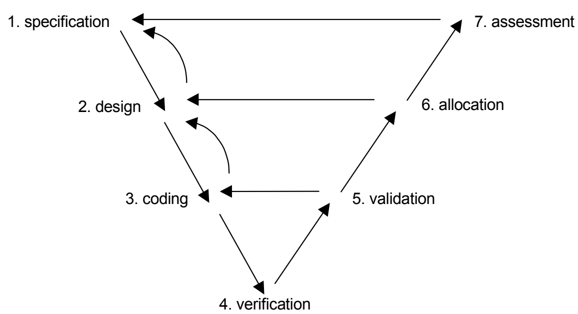

Fig. 2 *DSI-VVE* development process

The first *specification phase* gives requirements for the function to be considered in the next step; we use a natural language, e.g.:

> comfort function: "to avoid automatically energy meter disconnection when power absorption exceeds contractual limit. The user should be able to specify a priority level for each appliance in order that important loads go on working."

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 called by a Labview® application specially developed (*verification*). Our *virtual environment* is composed by these four steps; the same code is then used to evaluate functions performance in a real case on the CESI RICERCA facility in the validation/assessment phases.

III. VIRTUAL TESTING

We developed firstly emergency and savings functions; to test the system with different schemes, besides current flat tariff for domestic user other profiles are considered. From spot market price, daily defined for each italian congestion zone, an automatic procedure was developed to provide various options for several retailers an different kind of customers. For further expansion, also remuneration for local generation (mainly from photovoltaic conversion) is considered.

The virtual environment also simulates a real field, i.e. a family and their appliances (SICA). Each load is represented by an average consumption over 15 minutes or a more accurate daily average profiles obtained from measurement on real appliances [3].

To enable users to define their profile, the platform permits to set several parameters. For example, the user could prefer to reduce consumption under a specified power level only when the energy price exceeds a certain value. This attitude is translated in a numeric value by means of an additional parameter, the *available power* P_{av}, that is taken into account by the load manager algorithm. The relation between P_{av}, the contractual power and the price expresses just the user attitude to consume in a certain instant. It is worth underlining that P_{av} is not a fixed value but depends on price or other factors that could vary during the day. The *emergency signal* could be represented also by a strong increasing of price (critical peak price), therefore the consumer may reduce his consumption.

Periodically the load manager tests current power absorption to establish if some load should be turned off to remain under the current P_{av} level; each controlled load has a *priority* level to define its importance.

The Labview application at the actual progress permits to define and to evaluate different aspects:

- consumer's attitude related to energy price: automatically generated profiles or manual choice are available;
- definition of appliances to be considered in load management and their priorities: the user interface shows the load type (dishwasher, lighting and so on) to be connected to the managed socket and the priority level for the switching functions;
- load profiles, divided into managed or not-managed appliances, and their changes in reply to price signal.

A further application, *VIRTUS* (VIRTual UserS), has been created to simulate a large number of LV customers (~400) connected to a MV/LV substation. This allows to simulate the effect of several signals (price, emergency) sent to users (Fig. 3) and to evaluate performance of communication architecture.

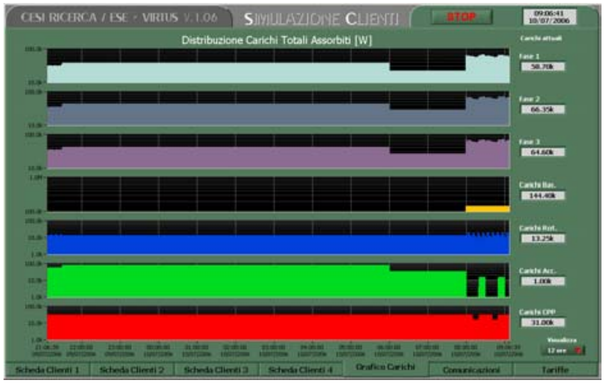

Fig. 3 VIRTUS: total load for each LV phase and controlled sockets action

IV. Real Testing

According to the preliminary results achieved from the virtual tests (*DSI-VVE*, see above), different strategies for load control could be applied to evaluate their performance and reliability in reply to system or market signals coming from outside the house (utility, retailer).

Efficiency algorithms should comply also with user's preferences about comfort: it is not possible, for example, saving energy only removing electric heaters and forgetting the minimum room temperature.

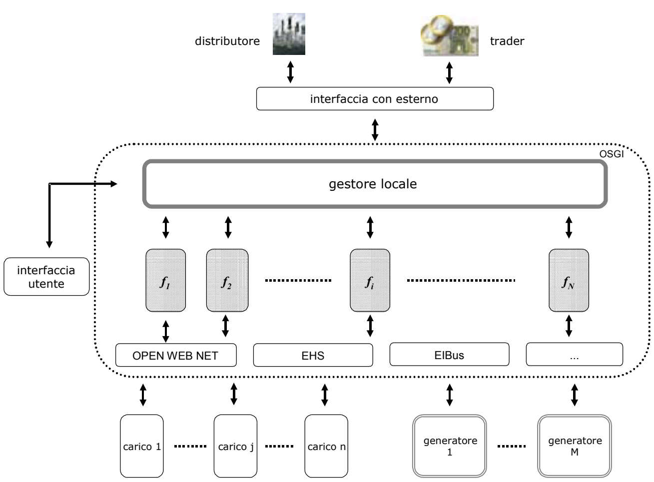

Fig. 4 General architecture

The environment here described (Fig. 4) is based on commercially available systems that permit the user to add further functions. It is created in a open environment, using a Java platform developed according to *OSGi* specification, and an open protocol specifically created for domotic applications, *OpenWebNet* (created by BTicino SpA).

The *OSGi Alliance* is an independent non-profit corporation comprised of technology innovators and developers and focused on the interoperability of applications and services based on its component integration platform. OSGi technology is an *Universal Middleware* that provides a service-oriented, component-based environment for developers and offers standardized ways to manage the software lifecycle.

TCP/IP protocol and XML format were considered because they 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 FRIDOM-CLIENT communicates with ("move the plug from a socket to the other").

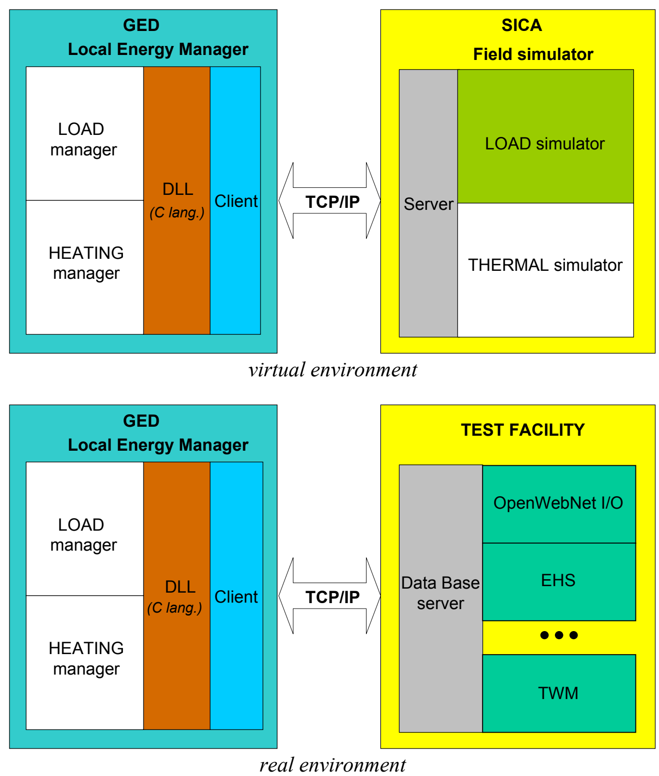

Fig. 5 Virtual and real environment

In the CESI RICERCA facility not only it will be possible to carry out several tests on different algorithms but also it is possible to simulate the user presence thanks to an appropriate system that controls each domestic appliance: oven, dishwasher, lighting and so on are turned on or switched off as if a real family is living in the facility.

Current experimentation is concerned above all about load control and the procedures to implement suitably functionalities in a more or less complex *home automation* system. Despite last announcements about "home of the future" and similar, automation devices are not spread in normal houses but quite a lot of indications suggest that in future years they will be more present. Aging of general population, for example, could promote some technologies that help to carry out housework or activities that old persons find difficult. Whether if energy prices differentiate, customers will be motivated to change their habits, and an automated system will help them to do this more easily.

Preliminary results show that general strategies work as planned, intervention time is congruent with fiscal meter activity and communication are reliable. This outcome confirms also that this architecture is suitable for security services for distribution network, as critical peak price programs.

Current experimentation is also regarding *heating management* and its integration with already verified electrical load management functions. This experimentation is based on the same life-cycle described for load management functions development: strategies are at first evaluated on virtual environment (SICA) and then are performed on a real case (test facility). 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.

The manager will also be able to store and to analyze consumption curves, to highlight efficiency improvement and to suggest changes in the user habits. This information is also precious to obtain favorable tariff from the retailer: a predictable customer is a welcome resource.

Besides we would explore the possibility to use formerly installed technological plants to perform additional services: for example, security system could work not only for security purposes. When customer is present, the system could signal a window opening with the aim to temporarily switching off the air conditioner pump. Starting from a simple load management, it is possible to move towards an overall energy management comprising not only electric loads but also storage units, thermal plant and possible local generation (Fig. 6).

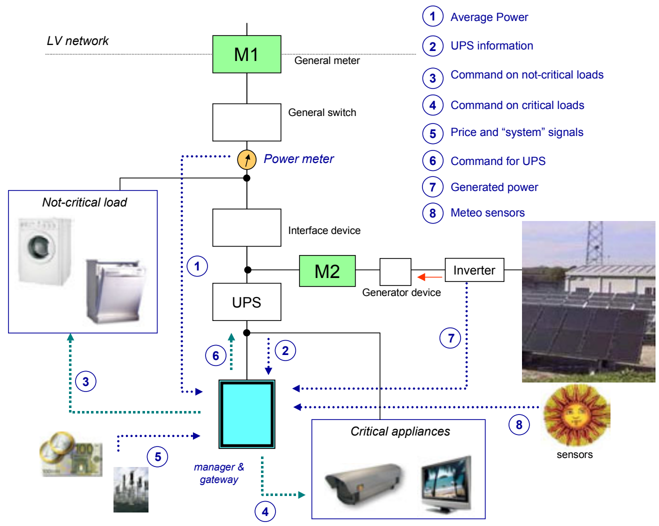

Fig. 6 loads and local generation

An interesting aspect is to investigate the diverse levels of implementation: in old flats it is very difficult to add a complete system but it is possible to put a simple energy manager for comfort and savings functions. International experiences show that such devices could be promoted together with a variable tariff policy [6]. On the contrary, in a new single house or a small office building where complex plants are already considered, these functions could be added profitably and with a little increase of cost.

As mentioned, further development for the test facility foresees the presence of a storage unit to enhance security level for critical loads. It could improve general security level and could improve also load management, especially for high-automation home, where LV network disconnections involve a large discomfort and above all potentially dangerous condition.

A photovoltaic conversion generator represents another future improvement for the test facility, because their diffusion in residential or office buildings will increase in next future. The presence of local generation complicates energy management strategies and could be favourably combined with storage unit.

V. 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 document describes CESI RICERCA's activity concerning designing and implementation of these local automation functions. First results show that general strategies work as planned, and communication are reliable. This outcome confirms also that this architecture is suitable for security services for distribution network, as critical peak price programs.

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. Most evolved platform will become a "intelligence" that manages house according to user preferences and outer signals (price, emergency).

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