AUTOMATION SYSTEMS TO SUPPORT SMART ENERGY BEHAVIOUR OF SMALL CUSTOMERS

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ABSTRACT

Recently several events occurred in the energy scenario, among these EU confirmed its policy against climate change and liberalization of EU power market reached fully completion. Both these events brought to a change not only for industries but also for small final users who found themselves revising their role from passive customers to active consumer. To get the most advantage from this opportunity it is necessary to provide a platform which is interoperable with home and building automation systems and allows to achieve a global energy optimisation in residential and tertiary buildings. This paper describes CESI RICERCA's activity for the development and testing of such a platform in order to reach global energy optimisation and to allow households becoming active "nodes" of the electric network.

INTRODUCTION

During last few years European power sector has been undergoing considerable changes. The "Energy plan for Europe" (the so-called "20-20-20 plan"[1]) put forth an integrated proposal and instruments to reduce EU dependence from fossil fuels, cope with global warming, improve competitiveness and exploit renewable resources. Many of these actions impact also on energy consumers who have been asked to contribute in improving energy efficiency by adopting efficient home appliances, supporting deployment of dispersed generation like small size combined-heat-and-power (µCHP) generators and photovoltaic conversion systems. In addition to this, rules regarding the opening of the internal market established by Directive 2003/54/EC of the European Commission became effective from July 2007. Now EU customers have the possibility to choose their own energy retailer and tariff's schema therefore they can play a much more active role in the energy market even sharing risks and opportunities of participating both as consumers and energy producers.
In this frame automation systems are asked to play a major role, they will have to support the change from passive consumers to active customers and allow residential and tertiary buildings to become active nodes of the smart energy grids. Automation systems will have to support both active participation of customers to the energy marked but also they will have to provide overall energy optimisation of the customer premises equipped with DES/RES and smart appliances. Quite complex optimization strategies are needed. Future optimisation algorithms will have to consider as input parameters not only electric energy and gas prices, but also environment parameters and customer's preferences, since customers are expected to maintain or improve their present standard of life.
Availability of local power generation, energy storages, smart appliances do greatly improve energy management possibilities for achieving energy efficiency. Additionally these resource and an adequate energy management system do also allow making customer premise an active node of the power grid and improving reliability and power quality. Cost-effectiveness of deploying automation systems and the many devices that are necessary to support smart energy behaviour of small customers is achieved by using commercial off-the-shelf components, open development environments and protocols. Such approach does provide extended upgradeability and interoperability with existing and future systems.

LIBERALIZED ENERGY MARKET AND DEMAND SIDE MANAGEMENT

These days all EU customers may choose among several energy retailers who try and attract their customers by providing a variety of different contracts and tariff's schema. Already in some Countries and probably more in the future when competitiveness will increase, end users will be offered the possibility of energy prices closely reflecting real energy costs[1]. Power demand growth is costly not only for consumers but also for producers, since power plants providing peak power are rarely used yet expensive to maintain and operate. Retailers may enhance their offer adding further special tariff schema, e.g. "green energy" (from Renewable Energy Sources, RES) or different prices for the energy taken from, or made available to the network at different time of the day.

The term *Demand Side Management* (DSM) of the electric power is used to encompass the planning, implementing and monitoring of initiatives aimed at stimulating final users to modify their demand habits, hopefully without decreasing the present level of the offered services [2].
A typical DSM load shape strategy is the proper modulation of electricity price with time of use (TOU) tariffs, stimulating change in energy consumption habits over the medium-term period. Other services are much more related to the need of reducing power demand during short periods of time (critical peaks) that should occur only few times in a

[1] Customers will share risks and savings opportunities of energy price volatility.

year. In addition, by reducing demand during peak periods, the need for new power plants and upgrading of distribution networks could be reduced or postponed.
Network and market driven actions need support of customers, acting on their loads and generators. Home and building automation systems may support customers providing effective energy optimization, increasing their awareness and also suggesting change in their behaviour. Cost reduction and provision of ICT integrated solutions for flexible management of interactions between LV customers and the network are challenges of present research. Some solutions are already available and field tested.

ICT ARCHITECTURE

CESI RICERCA has investigated functional requirements for Load and Generation Management systems to be located in MV/LV substations. Such systems (see FRIDOM-FCBT in fig.1) need to manage information received by distribution utilities, traders and retailers, events generated by the MV/LV substation automation system, events generated by the MV network.

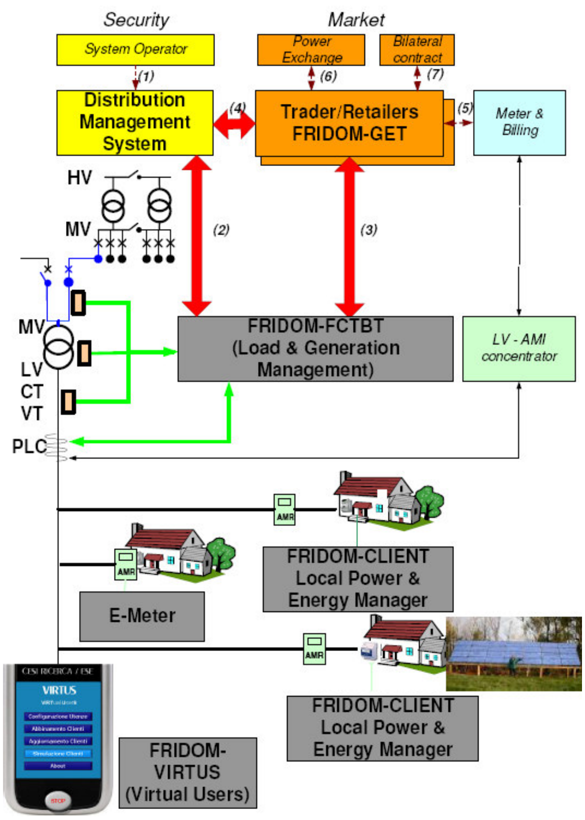

Fig. 1 *Overall Communication infrastructure*

That information is used to elaborate un-ambiguous data structure to deliver to final LV customers either equipped with simple e-meter, smart plug, a gateway for Direct Load Control (DLC) or a system for Local Energy & Power Management. FRIDOM FCBT monitors relevant network parameters at substation level and send messages to active customers to involve them into a cooperative strategy aimed at maintaining an adequate quality of service.
Evidence shows that there are different kind of customers, some of them wish to have full control on their own appliances, some others would allow a local energy manager (which they may setup according to their preferences) to act for them, some others are happy by having just few sockets that switch on/off according to price thresholds fixed by them. Therefore different solutions were exploited both with a central control system put in the secondary substation [3] or partially transferred to a local energy manager located at customers premises. This paper will discuss the last and more advanced solution.

LOCAL ENERGY & POWER MANAGER

The Local Energy Management System represented in Fig.1 as FRIDOM-CLIENT combines signals received from Distribution system operators (network signals), retailers (tariffs) and user preferences to manage power flowing "to" and "from" the network within limits that may even change every hour. FRIDOM CLIENT provides various functions that may be available as stand alone or merged with others:

- Display for Energy Savings
- Load management
- Heating management
- Storage management
- Local generation management

Display for Energy Savings

A display showing few important information, able to store consumption and cost curves, provides the simplest but quite effective possibility to improve use of energy. This feature can be implemented easily even in existing buildings without expensive works. Such device increases users awareness on energy saving [4]. The following picture shows an example of the prototype made available by the FRIDOM environment. The main page shows the current power absorption (P_{ass}), maximum contractual power (P_{cont}) and the threshold defined by the user (P_{disp}).

Fig. 2 *power absorption and thresholds*

Customers with such a display may not need further devices if they have the time and the possibility to manage directly their loads. However their savings will depend only on their knowledge on energy usage and the possibility that they have of spending time in managing their appliances.

Load management

Load management systems allow switching on and off appliances when particular circumstances occur. An effective system for Load Management takes into account several aspects:

- consumer's attitude to use energy as function of the price
- list of appliances and their priorities, criticality levels, maximum interruption time etc.
- load profiles for managed and unmanaged appliances, the possibility to change it in response to price and system signals.

For example, when a power reduction is required because of high electricity price or emergency network condition, FRIDOM-CLIENT switches off some appliances according to the set priority, in case heating is required, gas heating can be preferred to heat pumps. Additionally end users may wish to reduce consumption below a given threshold when the price exceeds a certain value that has been set by the customer. This attitude is translated into a numeric value, the *available power* P_{disp}. The relation between P_{disp}, the contractual power and the price, expresses the user's attitude to consume at any given time. It is worth underlining that P_{disp} is not a fixed value but depends on price or other factors that could vary during the day.

Heating management

Integration of electric load and heat management takes into account gas/electricity prices, external temperature and the temperature set for each room at any time of the day. In this case FRIDOM-CLIENT calculates the current heat pump COP (Coefficient Of Performance) and decides whether to use gas heating, heat pumps, or both of them.

Storage management

To improve load management functions and security level for some critical applications, electric *storage units* are to be included in the energy management of end user premise. Highly automated environment asks for high reliance on energy supply and quality of power. As long as power supply interruption lasts, storage units provide energy for critical devices, i.e. communication, lighting and critical automation like opening and closing of doors. According to battery level and before finishing storages the energy management system has to switch off critical devices (starting from the less critical) to extend life of most critical services. Such function may also be used to enhance "saving" since storages may be used to feed (small) domestic appliances when energy prices are high (i.e. critical peak price periods).

Local generation management

Several Countries are promoting diffusion of small dispersed generators, especially from renewable sources or µCHP. Customers with such systems may provide energy flows to and towards the network according to external circumstances like weather conditions or request of heat e.g. during the cold season. Therefore local energy management systems have to manage the net power exchange with the network and act to maintain it within fixed amounts. Local energy *dispatching* becomes possible controlling some appliances (e.g. dishwasher, washing machine) that can be (de)activated according to power availability.

TESTS ON SIMULATED AND REAL FIELD

Functions development process follows a widely used model ("V" model) for automation applications [5].
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). After these tests, functions are verified in real field.
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.
To carry out these functionalities, there are:

- FRIDOM-CLIENT platform, that manages loads and thermal system; this platform is equipped with a monitoring, acquisition and data storages
- a commercial home automation system managed by FRIDOM-CLIENT to control loads, heating, energy storages, etc.
- 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 heat pumps)
- a photovoltaic conversion system
- a storage unit

The whole environment is based on commercially available systems that allows the user to add further functions.
FRIDOM-CLIENT was created in a open environment, based on a Java platform developed according to OSGi specification. It uses an open protocol specifically created for home automation applications, OpenWebNet (made available by BTicino SpA [6]).
TCP/IP protocol and XML format were considered because they are widely used and it is likely that they will becoming a *de facto* standard also in this domain.

Tests were run firstly on *load management*: intervention time is congruent with fiscal meter action, communications are reliable, load shedding in emergency situation works properly. Current italian energy tariffs are quite flat and do not send sharp messages to customers, hence loads shifting from peak to off-peak hours does not permit significant savings. In countries where prices are already more variables, load management could seize perceptible amount. In the future, true time-of-use tariffs and critical peak price schemes could improve a rational use of energy also in Italy.

A comparison between normal gas heating and *integrated electric-gas management* was carried out. Gas heating or electric heating may be chosen depending on the external temperature which influence heat pump coefficient of performance (COP). Tests were performed considering 24h flat tariffs for electricity (0.2 €/kWh), gas (0.63 €/m^3) and fix temperature in the whole house. Heating management may take into account not only economic savings but include also environmental features, such as minimising CO_2 emission. Electricity and gas consumption was measured over a winter week. With daily average temperature ranging over 7.3÷10.5 °C, a consumption of 71.9 ÷ 108.8 kWh_t/day was observed. This leads to 4.7 ÷ 9% savings by comparison with the temperature maintained with gas heating alone. It is worth underlining that heat pumps used in our experiment are not recent (class “D”), therefore there is margin to increase savings using more efficient devices (class “A”).

Monitoring system highlighted that the deployed home automation system has an energy consumption of 1.1 kWh/day. It can be compared with a “class B” refrigerator. However only 10-15% of this energy is used for heating management. It is reasonable to reduce this figure, additional research activity aimed at improving energy conservation will start soon.

CONCLUSION AND FUTURE ENHANCEMENT

European Union counts on increasing energy efficiency, exploitation of renewable resources to boost competitiveness and face climate change. Energy conservation entails not only efficient devices but also awareness in using them. 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. Distributed Energy Resources and Renewable Energy Sources represent a further opportunity for small users to participate to the energy market. ICT and more specifically automation technologies will play a major role providing the necessary support to the liberalised market even increasing network reliability and security.
Improving customer participation to the market, requires a platform that provides several energy management functions. This paper described CESI RICERCA’s activity committed to develop advanced local energy optimization functions and to test them in a real case.
Results shows that it is possible to develop a platform using commercial of the shelf components to support rational use of energy and to provide the interaction between users and the network. Challenges are integration and development of effective architectures, allowing more awareness and more participation of customers.

Acknowledgments

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