NEW ICT INTEGRATED SOLUTIONS FOR FLEXIBLE MANAGEMENT OF INTERACTIONS BETWEEN LV CUSTOMERS AND THE NETWORK

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ABSTRACT

In recent years European power sector has been undergoing considerable changes: from July 2007 all customers will be able to choose their own energy retailers. This will involve new roles both customers who will change from passive consumers to active participants and for energy distributors and retailers which will aim to attract customers providing new services. To get the most advantage from this opportunity there is the need of a technology platforms which can be interoperable with home and building automation systems and that will provide several functionalities: communication with energy distributors, retailers, interaction with consumers, management of loads, heating systems, energy storages and home micro-generation. In this way a global efficiency could be achieved. Households may become active "nodes" of the electric network which may receive and provide services both for the network (e.g. power modulation) and for the market (e.g. contribute to reduce price volatility).

This paper illustrates an ICT architecture for delivering market and network signals to final users and specifies high level requirements for realization of applications and tools to be used by distribution utilities, traders and retailers to support the Integration of Demand-Side Initiatives (DSI) [1].

INTRODUCTION

From July 2007 all European Low Voltage (LV) customers will be able to choose among several retailer/distributors (see EU Directive 96/92/EC) who will probably try to attract customers by providing a variety of different contracts. These contracts might be the most various: they may offer special tariff schema (e.g. different prices for the energy taken from or made available to the network for any time of the day) together with different thresholds for the power flowing in both directions. 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 DSI brings benefits both to customers (wishing reward schemas), Utilities (postponing investments) and the Society (increasing overall energy efficiency). All these actions (network or market driven) are to be managed by ICT systems located in some nodes and levels of the Electric System.

Demand Side Management and Demand Response Services

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]. Two classes of DSM actions are usually considered:

1. load-level measures, which aims at shifting the load curve to lower or greater demand levels or shifting loads from one energy system to another.
2. load shape measures, which seeks to re-shape the load curve over very short (minutes-hours-day) to longer (days-week-season) time periods, as it is shown in figure 1.

This paper deals with technologies typically related to measures belonging to the latter class.

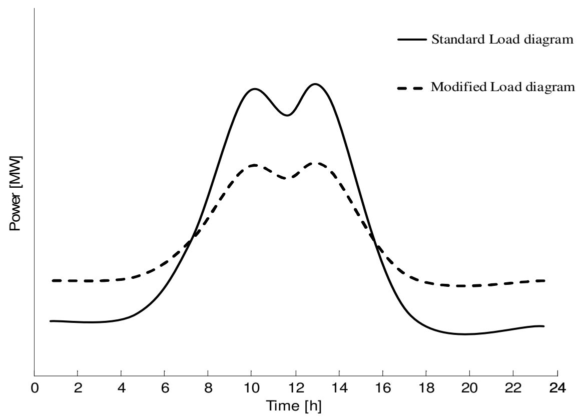

Fig. 1 *Load diagram*

A typical DSM load shape strategy is the proper modulation of electricity price with time-of-use (TOU) tariffs. As a basic requirement, the operation on loads and the effective implementation of DSM strategies require and involve availability of timely and detailed beyond-the-meter information, with no cut down of service quality. To reach this aim, DSM strategies have to be realised through the use of proper measurement and control structures, additionally final user's premises need to be reached with high speed and reliable communication channels.

Demand Response (DR) 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 one year. DR actions should be applicable with quite a short notice (i.e. from 15 minutes to one hour). Actions of this kind are: temporary reduction of the limits on the power available to the customers, selective load shedding achieved by means of remotely controlled plugs (or, simply through relays directly controlled by the meters) and the introduction of Critical Peak Pricing tariffs.

Cost reduction and provision of ICT integrated solutions for flexible management of interactions between LV customers and the network are challenges of the present research. They drive development of new technologies and architectures. Some solutions are already available and field tested.

New role for customers

Together energy market liberalisation and diffusion of local automation systems will promote a new role for customer who will change from passive to active consumer. Customers ability to participate will be substantially represented by the aptitude of modulating their own load profile as result of market signals (electricity price) or network signals (emergency) .

Recently, some LV networks had to withstand high load peaks because of increasing number in air-conditioning systems. These situations could be faced with long-term investments, but innovative load shedding management could help to support Distribution Utilities and lead final users to change their consumption habits.

The interaction between LV customers and the network requires a proper ICT infrastructure. This interaction can be carried out by a local energy & power manager (FRIDOM-CLIENT located at user premise which receives market and system signals and provides local load, storage and generation management (see Fig. 2) [3]. Such a customer will be now on called “active customer”.

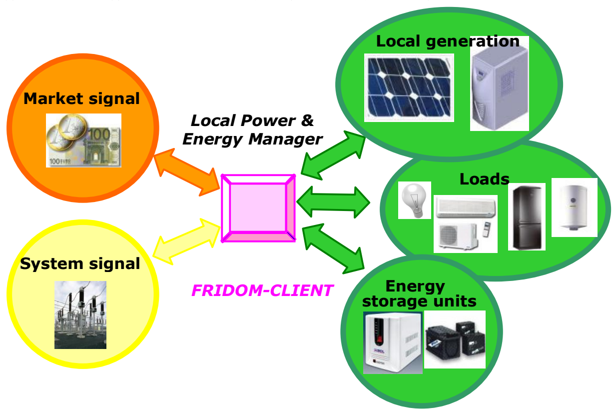

Fig. 2 *Local Energy & power manager*

SYSTEM ARCHITECTURE

Active Customers connected to a LV distribution grid, are managed by a Load and Generation Management system (called FRIDOM-FCBT) which is located in the MV-LV substation (Fig. 3). FRIDOM-FCBT monitors relevant network parameters at substation level and send messages to active customers in order to involve them into a cooperative strategy aimed at maintain an adequate quality of service.

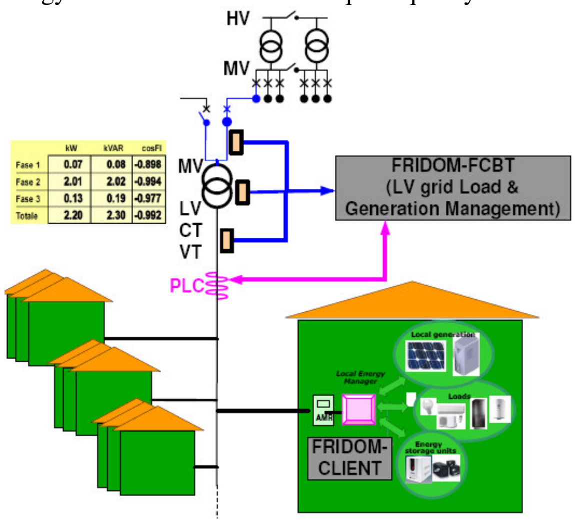

Fig. 3 *LV network power flow management*

CESI RICERCA is currently investigating functional requirements for Load and Generation Management systems to be located in MV/LV substations which have to manage information sent by distribution utilities, traders and retailers, events generated by MV/LV substation automation systems, events generated by the MV network and elaborates un-ambiguous data structure to deliver to final LV customers either equipped with simple e-meter, e-meter with gateway functionality for Direct Load Control (DLC) or system for Local Power & Energy Management (FRIDOM-CLIENT). Fig. 4 shows a real-time control window of CESI RICERCA experimental MV/LV substation (transformer temperature, currents, voltages) and the status of real and virtual direct controlled loads.

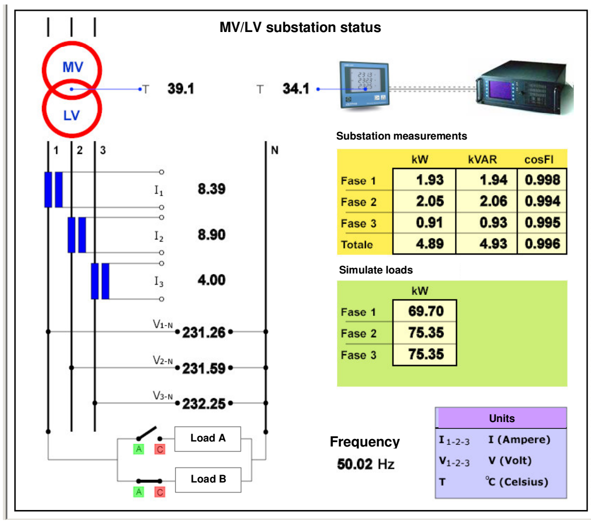

Fig. 4 *MV/LV substation measurement and direct controlled loads*

EVALUATION OF DSI FUNCTIONALITIES

Direct Load Control

FRIDOM environment supports also evaluation and testing of DSI functionalities [4]. An application called FRIDOM-VIRTUS can simulate the behaviour of up to 400 "virtual" customers of a LV grid. Each customer is characterized by a living behaviour (e.g. with respect to family composition), an electricity contract (normal, critical, demand response etc.), a tariff scheme (i.e. flat or multi hour rates), additionally prices may be different in case energy is bought or sold to the LV network. Fig. 5 shows a 12 hours profile [from 21.06h – to 09.06h of the following day] showing effects of load management provided by FRIDOM-FCBT operating on a LV network with a population of customers simulated by FRIDOM-VIRTUS. Low Priority load [green] are turned on only when the lowest energy rate is effective, while they are turned-off when price increases. In the morning, when load increases FRIDOM-FCBT puts into operation rotational detachments [blue].

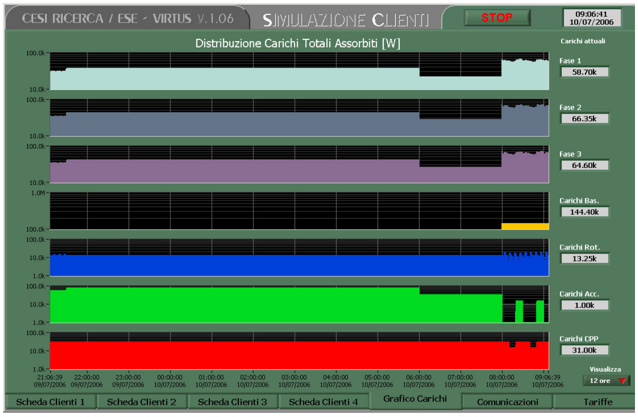

Fig. 5 Effect of Direct load management

Communication infrastructure for DSI

Testing environment and tools developed by CESI RICERCA are able to evaluate adequacy of a communication infrastructure for traders and retailers able to manage millions of customers distributed over a large Country. A tool called FRIDOM-GET generates tariffs schema for each different group of customers, taking into account both information entered by Trader/Retailers and energy prices automatically downloaded after the closure of the day ahead Power Exchange. FRIDOM-GET may also consider regional energy prices (see Fig. 6). Fig.7 shows the process through which FRIDOM-GET generates data structures containing daily tariffs schema. They are actually provided for each region and for each group of customers subscribing a different contract. Customers receive their tariffs scheme by the way of their nearest FRIDOM-FCBT.
Traders and retailers that have customers distributed all over a big country may have to make tariffs schema available to hundred of thousands of FRIDOM-FCBT.

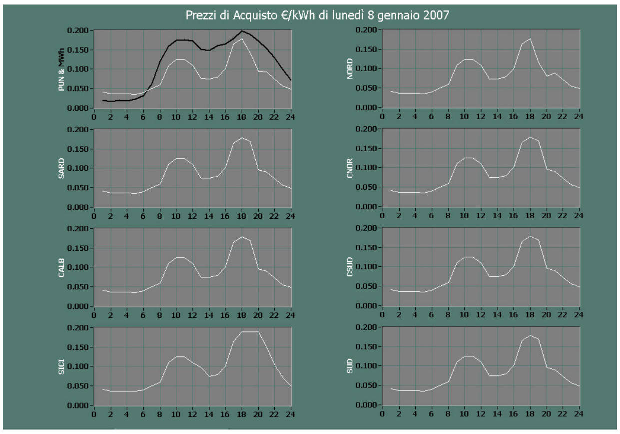

Fig. 6 Regional electricity "Buy" price [24h]

After forthcoming 1st July 2007 liberalization, more than one trader/retailer may have customers depending on the same FCBT i.e. connected to the same LV grid. FRIDOM-FCBT is already able to receive tariffs schema and manage DR programs daily uploaded by several trader/retailers.

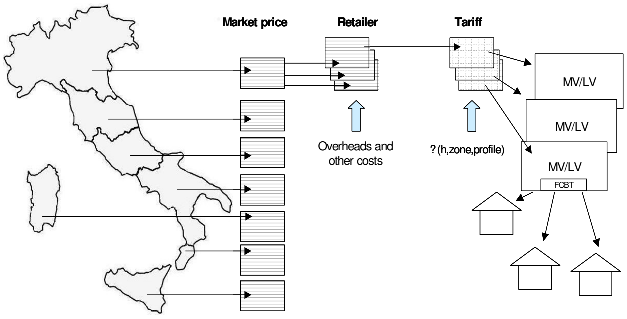

Fig. 7 *Construction of tariff schema*

Load shedding in emergency situation

In case of load shedding in emergency situation [5] a load reduction order is originated by the Independent System Operator in fig. 8 (1). The order to reduce power consumption ΔP in a well defined area, within a certain time ΔT and for a certain duration Δt, is conveyed to all Distribution Companies.

After receiving the reduction order, each Distributor system operator should calculate the ΔP_{1-n}, ΔT_{1-n}, Δt_{1-n} required for each of the *n* MV/LV sub-stations serving the area, then proceed ordering power reduction (2). FRIDOM-FCBT is in charge of the load management of the whole LV grid fed by MV/LV transformer. Therefore when receiving orders from the Distribution Company, it proceeds to reduce or augment the power, either directly controlling smart sockets and appliances or by "negotiating" with Home and Building automation systems at end user premise via PLC. The service interruption may imply a refunding that is sent to customers through their trader/retailer (4 and 3). The figure shows also the exchange of information that occurs for market (6, 7) and billing (5) purposes.

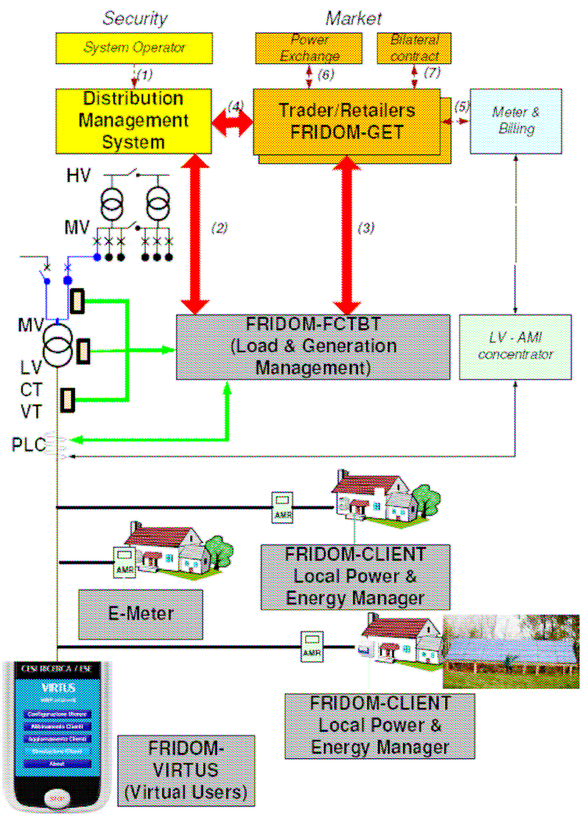

Fig. 8 Overall Communication infrastructure

To explore further solutions to connect users and the network, CESI RICERCA is considering other communication models beside power line communications.

Local energy & power manager

CESI RICERCA activity is also focusing on management of energy storages at customer premise, not only to increase user security level but also to provide services to the network. For example, user demand could be reduced for short time by means of a proper storage unit that supplies critical loads. Furthermore, load and local generation management function could be improved in case storage units are present. The test facility [3] may count also on two identical 60 m^2 buildings quite similar to residential house. These buildings make possible to carry out several tests on different local 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 that houses.

A photovoltaic generation systems is already available in one of the houses. Further developments foresee acquisition of a micro heat and power generation unit that will be used in cooperation with existing PV power generation.

CONCLUSIONS

The paper described an architecture to support DSI programme. Main nodes of this architecture are the FRIDOM-FCBT located in the MV/LV substation and FRIDOM-CLIENT located in customer premise. FRIDOM-FCBT operates on active customers and provides Load and Generation Management on a LV network. FRIDOM-CLIENT provides local load energy storage, heat and power management. DSI functionalities implemented in FRIDOM-FCBT are thoroly tested by the way of tools and the test facility. FRIDOM-VIRTUS simulates the behaviour of up to 400 "virtual" customers of a LV grid, FRIDOM-GET generates data structures containing daily tariffs schema. The test facility allows to evaluation of the integration of experimental systems with a real LV network. The FRIDOM environment comprises also tools for developing and testing of functions for FRIDOM-CLIENT the local energy & power manager placed in the user premises which manages loads, storage units and generators in response to system or market signals. Future work will aim in adding new energy management functions, achieving integration with most diffused Distribution Management Systems and providing support to Traders and Retailers.

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