EXPO 2015 SMART CITY: AN INNOVATIVE SYSTEM OFFERING ENERGY EFFICIENCY SERVICES AND ENABLING ACTIVE DEMAND

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ABSTRACT

The Enel Energy Management System (EMS) is an innovative solution for energy efficiency services. It supports monitoring, controlling and remote management of field devices in order to offer advanced energy management services, towards Active Demand. It is a multi-tenant platform, able to address the needs of multiple stakeholders. EMS can manage both Enel and third party field devices installed in the customer's site for energy monitoring and management. EMS can be also interfaced to other asset management systems and service platforms, in order to exploit a comprehensive set of data and tools.

The system will be firstly applied in the Universal Exposition EXPO 2015 in Milano, integrated with the smart grid therein installed, to manage the exposition area as a real smart city.

The EXPO 2015 application and the lessons learned during the design and implementation phases will pave the way for the next development and application of the system.

In this paper both the system architecture and concept, and the challenges encountered during the implementation phase will be reported as interesting lessons learned in designing a solution for energy efficiency and active demand services

INTRODUCTION

The next coming Universal Exposition "EXPO 2015" will be running in Milan, Italy, between the 1st of May 2015 and the 23rd of November 2015. The theme chosen is *Feeding the Planet, Energy for life* and it focuses on the main purpose of EXPO 2015 that is bringing innovation into food service being energy efficient.

About 80 pavilions will be hosted on 200.000 m^2 of exposition area and they will be fed by a dedicated smart power grid. The smart grid will be equipped with an advanced remote control and protection system, with a MT network management in closed loop. This system will guarantee a high quality of service, allowing, in most cases, an automatic selection of the fault without the final users are affected. The EXPO 2015 site has a peak power required of 75MW; 100 low/medium voltage substation; a charging network system for electric vehicles; 8,500 points of public light; one storage for local optimization of energy flows (270 kW); one show room to engage visitors.

Enel Distribuzione has been selected by EXPO 2015 as Global Official Smart Energy Partner, thanks to the acknowledged leadership in Smart Grids and Smart Cities solutions. In this role Enel Distribuzione is in charge both of the realisation of the power grid that is feeding the exposition area and of the offering of advanced energy management services to the pavilions and exposition areas. As for the first objective, the power grid in place will be equipped with the most innovative network technologies and smart grids solutions. For the second objective, in partnership with Siemens, Enel Distribuzione is releasing an innovative EMS that will provide advanced energy management services to the pavilions and exposition areas, being able to manage the most common field devices for energy management while providing both user-friendly interfaces for the energy managers and public interfaces for the visitors of the exposition.

EMS FOR THE SMART GRID

Smart grids combine the most innovative devices and services with advanced monitoring, control and communication technologies in order to fully integrate renewable energy sources into the electricity grids, engage customers in Active Demand, implement the charging infrastructure for electric mobility, significantly reduce the environmental impact of the electricity sector, enhance the reliability of the whole network.

In this context, EMS aims at providing advanced energy management services to allow large adoption of energy efficiency and active demand programs. The system is conceived to be multi-tenant, offer differentiated services to the various stakeholders, manage multi-vendor devices and able to interact with other asset management systems, such as network management systems, electric mobility management system, public lighting management system. It is able to collect, elaborate, report and exploit the real time consumption data provided by Enel Smart Info[1], which is the interface to the Enel Smart Meter. Together with other data coming from various field devices (such

as sensors) and systems, EMS can forecast and set proper load profiles to each node of its network, such as a pavilion of the exposition. Through the EMS it is possible both to monitor the energy profile of each node and to follow an assigned load profile thus achieving the objective to implement a full chain smart grid. It is possible to manage and supervise the asset installed, with advanced diagnostic functionalities. This design support the adoption of this system in smart cities, where a great variety of field devices are already in place, as well as many other systems are adopted to offer different services.

ARCHITECTURAL MODEL

The architectural model includes four tiers: Field Devices Tier, Front End Tier, Business Logic Tier, and the Presentation Tier. Herein after the architectural model is described making reference to the typical equipment and scenario of EXPO 2015, that is however expected to be quite similar to what could be found in a real smart city.

Field Devices Tier

A pavilion or an exposition area in EXPO 2015 is a node of the network and it represents a technological ecosystem characterized by its own devices, as it could be a building in a smart city environment.
The technological level is constituted by the field infrastructure that allows an energy manager to monitor and control selected loads and the overall energy profile of the pavilion or the area.
In EXPO 2015, each pavilion or area is equipped with a dedicated LV meter, measuring the overall electrical exchange with the power grid, installed at the point of electrical delivery, at the secondary of the MV/LV transformer. This meter is connected to the Front End Tier via GSM and it is able to send data every 15 minutes.
Down line of this meter, the electrical line is sectioned to feed different electrical services. Each of the main electrical lines is equipped with a dedicated smart metering kit.
The solution foresees two types of installation, either direct or semi-direct (this means that a current transformer group is installed), depending on the power of each lines. In the exposition most of the lines are above 50 kW and require the semi-direct kit. Each kit is a box that includes the Enel Smart Meter, the current transformer group if semi-direct, a switch and a DIN module for the installation of Enel Smart Info. The latter is the interface to the Enel smart meter, providing real-time consumption data measured by the meter and it is generally available either in plug-in or DIN HW case. For the exposition, where the monitoring kits are installed in technical rooms, the DIN module has been selected as the most appropriate.
This device is equipped with a WiFi dongle, connected to the USB Host port, which offers the connectivity to Internet in a REST architecture. It is able to push the Front End every 5 minutes refreshing data and responding to diagnostic commands.
An automation station controller is installed in each pavilion to manage the network of sensors, multi-meters and actuators that enable room automation. The station controller supports DALI to control lighting and it communicates on a KNX bus, which allows to be interfaced to the devices that use it. It is embedded with a WiFi module to be connected wireless to the Front End.

Front End Tier

The EMS Front End Tier follows the Internet of Things paradigm. Systems or Devices may communicate field property change of values or field events directly to the M2M component of the Business Logic Tier via Internet using the MQTT protocol. MQTT (www.mqtt.org) is an extremely lightweight publish/subscribe messaging transport protocol suitable for the Internet of Things scenarios.
In case the Device or System that has to be connected to EMS is not able to communicate via MQTT the EMS Gateway may be adopted. The EMS Gateway on premise offers a pluggable architecture where Front End Drivers implement a conversion from the Device/System native protocol to MQTT. The EMS Gateway provides a common infrastructure with some key functionality such as – for instance – downloading the configuration data from the central host.
In case of EXPO 2015 the implemented Front End Drivers (FE) can be resumed into: 1) *GME-BS FE*, which ensures data collection from the meters installed at the delivery points of each pavilions and relevant areas of the exposition; 2) *Smart Info FE,* which ensures the collection of real time data from the Enel smart info; 3) *EMM FE*, which provides information from the EV charging poles of the exposition; 4) *ST FE*, which provides information from the remote control and network automation system, to ensure an integrated and coordinated management of the energy consumed by the exposition nodes; 5) *BACnet FE* that is the module to collect data from the building automation devices; 6) *Archilede FE*, that ensures information from the public lighting system released by Enel Sole to monitor the street lamps that lights up the exposition area.

Business Logic Tier

The Business Logic Tier is hosted in Cloud based on the Azure computing platform and it can be reached by a dedicated URL as access point. Cloud services guarantee the high-availability and scalability features of the EMS platform.
The Business Logic Tier can be divided in the following areas: M2M component that exposes the MQTT Broker for the field data acquisition, Services exposing REST API interfaces to the Presentation Tier applications, and Jobs that perform all background tasks.

Business Logic Tier\M2M

The M2M component includes the MQTT Broker that receives message from the field (change of values and events) and that publishes gateway configuration data and field device commands. M2M provides a general-purpose data acquisition layer; any data value received is stored in a time-series collection in a MongoDB database.
A dedicated database is reserved to EXPO 2015. This solution offers businesses flexibility and scalability according to the level of required resources.

Business Logic Tier\Jobs

The collected data are elaborated and managed by the Business Logic Jobs in order to offer the requested advanced energy management services.
Among these the Trends Job creates trends and profiles of field variables starting from the raw data collected by the data acquisition layer.
On top the Energy Job creates energy curves: load profiles by performing calculations on meters trends, generator forecasts by connecting with weather forecast systems.
Another key component is the Active Demand Job that integrates the Energy Rules Engine. The Active Demand Job manages the sites calendar and may automatically setup field variables (temperature set-point, luminosity set-point, controlled and moduled load commands). The engine is able to determine the best setup of field variables given the configuration and the current operation mode.

Business Logic Tier\Services

EMS follows the Micro-Service Architecture pattern. In short, the Micro-Service architectural style is an approach to developing a single application as a suite of small services, each running in its own process and communicating with lightweight mechanisms. Business Logic Tier Services are a set of components where each one exposes an HTTP interface (REST API).

Presentation Tier

The end user can access EMS from any device connected to Internet, via a web browser. The EMS Operation Center is an HTML5 web application that runs on any browser or any device even if it is optimized for desktop. A smartphone app for iOS and Android is also available.
The figure below details the Presentation Tier modules and the Business Logic Tier Services & Jobs. The related functionalities are described later in the paper.

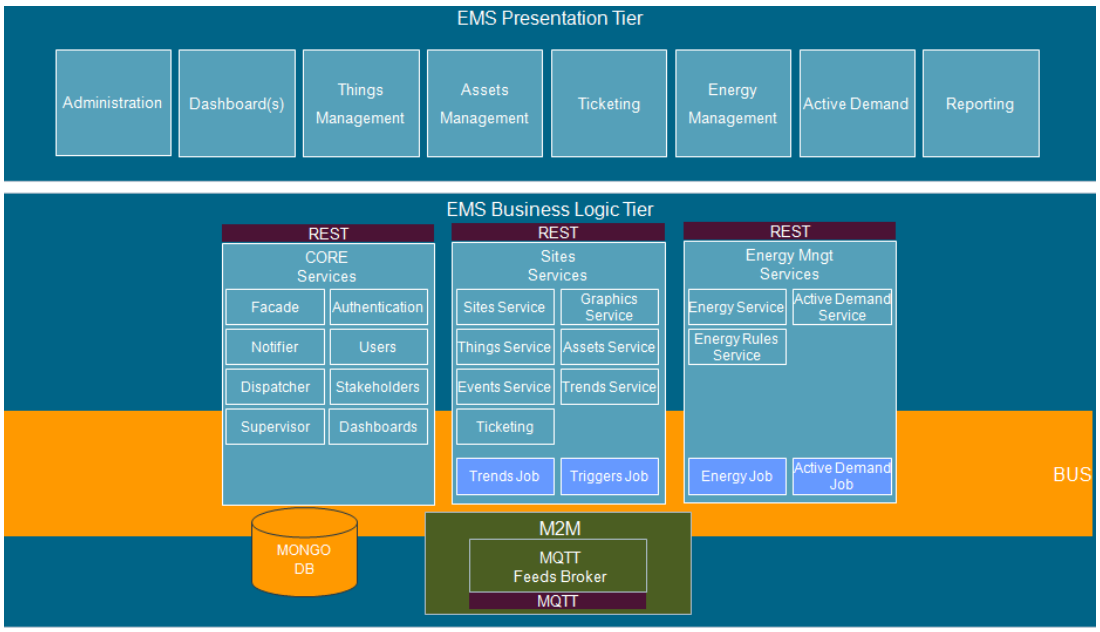

Figure 1: Overall architecture of the system

MULTI-SERVICES SUITE

EMS has been built-up as a multiservice platform addressed to several stakeholders that supports many processes, such as: devices installation and configuration, diagnostics, trouble ticketing, maintenance, energy monitoring and management, contract management, customers clustering and Active Demand management.
The central system is structured with a modular approach wherein a module offers ad hoc features. Through the description of each developed module it is possible to list the services supported by EMS.

Stakeholders

EMS is conceived to support the energy manager's task and – at the same time – it offers different services to others stakeholders involved into the energy management process, such as: asset manager who owns the field devices, service provider which enables EMS according to customer's needs, work force (e.g. installers and

maintenance team), third party interested to exploit collected data (e.g. research and statistical facility, PA, Authority), DSO (Distribution System Operator) to monitor the LV power grid, and the Active Demand aggregator whose initial aim is to enable active participation of final customers in power system markets.
A stakeholder can play concurrently different roles.

Asset Management

The asset management module is dedicated to the asset manager to configure the field devices to be installed (such as sensors, actuators, meters), which can be monitored and/or controlled.
It is possible to monitor the state of devices that are connected to the system (e.g. whether they are online or not, the timestamp of the last update, the set points, where they are placed, which services are linked to, etc..).

Site Management

The site management module is generally reserved to the technicians who physically arrange a site. It support a hierarchical organization of the sites, where each of them can include different sub-sites. After uploading the map of a site, it is possible to place the configured devices. Different views are available: geographical, electrical and technical view. The first allows to view the site in a geographical reference (e.g. each pavilion in the exposition area, or the various plants/rooms within a pavilion) and see in which rooms/plants the devices are placed. This view is targeted both to the end user and the asset/energy manager. The second view shows the electrical diagram of the site and allows to place the devices over the electrical lines. The third one gives the possibility to asset managers and energy managers to create their own personalized view of the devices in field, even starting from a blank sheet. The practice of energy managers suggests that this is a nice tool to have. The maps are interactive and interlinked in order to facilitate asset management.

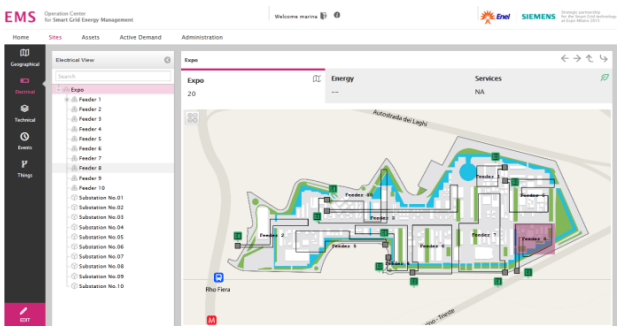

Figure 2: EXPO energy manager monitors the power grid directly from the diagram of electrical connection

Energy Management and Active Demand

These modules represent the core of the system. With them the energy view is provided, where it is possible to monitor the most relevant parameters of each site, sub-site down to a single device (e.g. energy and power consumption/generation trends with adjustable granularity) and the status of each service (e.g. Climate control, Lighting Control, Load Management).
It is possible to select for each site different operative modes and define different scenarios. The operative modes, available to user selection, are Comfort, Energy Efficiency, Active Demand. Actually it is possible to allow the system adjusting the operation of the programmable loads and the set points of climate and lighting control in order either to achieve energy efficiency or to follow a defined/assigned load profile in the active demand mode. Other operative modes are possible that cannot be set by the end-user, but determined by external conditions of the power grid; for example in case of a fault/congestion over one of the feeders, an operative mode will be automatically adopted (if previously allowed by the user) in order to adjust the power consumption to the external conditions. This is a very important feature that is really implementing a smart grid concept, where demand can contribute to solving network operation issues.
The user can define the rules behind each operative mode and can set different scenarios, that is the possibility to define the operation mode of each electrical load over the various periods of time.
With these functionalities an energy efficiency game will be proposed to the pavilions adopting the system. It will be possible to gain points when adopting energy efficiency measures or respecting an assigned load profile. At the end of the exposition the pavilion with more points will be rewarded.

Reporting

The reporting module is a computing tool that allows to query the database and export detailed, customizable reports and analytics related to the energy behaviour of the sites and diagnostics of the assets.

Trouble ticketing

The ticket management module consists of a trouble ticketing console which allows the asset manager and the energy manager to check the state of the configured devices and manage the issue resolution process.
The central system continuously monitors the state of each device providing automatic notification of events.

Dashboard

A flexible and customizable dashboard facilitates the access to the main services according to the role of the end users. A set of widgets are available, such as site map, power gauge, historical consumption/production bar graph, operative mode of selected site and the list of alarms.

Public View

It is a special module released to aggregate data and to share public statistics of the EXPO smart city. Through a heating map the end user is able to understand in real time key energy indicators of the exposition area and its

nodes.

System Administration

The system administration module supports users and permissions management.

DESIGN AND IMPLEMENTATION CHALLENGES

This paragraph provides insights on the challenges encountered during the design and implementation phases. In particular some new features have been introduced in the system and some technical solutions have been adopted in order to meet the needs of the pavilions and of the entire exposition.

As previously mentioned the optimal management of the EXPO power grid may require the active control of the electricity consumption of individual pavillions. For the pavilions that have activated the automatic control by EMS means to enter in the management of emergency operative mode and so allow EMS automatic control of electrical loads previously defined and set by the user.

In the emergency operative mode the manageable loads are set to the minimum consumption possible (controlling their set points or turning them off). When the emergency will be solved by the grid operator the system will set the pavilion to the operative mode that was active before the emergency started.

This innovative grid management has had a strong and controversial impact. In fact, on the one hand the countries exhibitors fully understood and shared the concept of management of the power system of the future and more sustainable but on the other hand, the technical project managers had difficulty integrating systems not yet available on the market and not yet absorbed by the technical culture. The concept of Active Demand is still new and the latter aspect is also substantiated by the many worries expressed several times by technical managers of losing full control of the pavilion functionality. Actually the automatic management of some electrical loads, identified by the user, is at the discretion of the end user and activated only if able to give a real benefit. These benefits in a real electric system should find expression in incentives and reduction in energy costs while in the case of EXPO this benefit will be limited to a less traumatic management of grid emergencies, experimentation and dissemination of Active Demand and participation in energy efficiency game.

Therefore through technical meetings was designed for each pavilion the most suitable and simple system for the active connection to the EXPO smart grid of the pavilion. As a final result EMS will manage each pavilion with a different configuration that will provide in some cases the need for integration with third party building management systems already provided in the pavilion design. This approach has lead to a more complex architecture and the usage of other field protocols such as Enocean and MODBUS.

EMS has thus proved very flexible and able to integrate with scalable solutions according to the characteristics of the pavilion and the requests of the country exhibitor in projects already developed and consolidated by years of exhibition experience.

To further simplify the EMS system, special attention was given to the design of the Smart Meter Kit. Indeed in order to facilitate the operations of smart metering kit installation the supply has been conceived by means of preassembled kit: direct kit and semi-direct kit. Direct kit includes a suitable protecting box with transparent front opening and lock, electronic meter named ENEL CERT, Enel Smart Info mounted on standard DIN rail and wired to the meter through a switch that allows Enel smart info maintenance (e.g. substitution in case of failure, verifications) without interrupting the power supply. Semi-direct kit consists of a board that contains the ENEL CERT meter, current transformer group, smart info and connecting switch as for direct kit.

CONCLUSIONS

The EMS solution will be released officially in the month of May 2015 for the EXPO 2015 event. All along the event, the system will be operated relevant information of the customer experience and system operation and effectiveness will be collected; this will provide interesting insights for tuning the solution to offer the best services in terms of energy efficiency and active demand.

In parallel EMS will experimentally support other two smart city projects in Italy, L'Aquila and NER300, where Enel smart info will be provided to households. EMS will give the possibility to these households to access the data collected through Enel smart info via web browser.

Finally EMS will be further exploited and developed in the H2020 European project FLEXICIENCY. In this project, coordinated by Enel Distribuzione, major DSOs are working together with market players and other stakeholders to develop an open European market place for energy efficiency and active demand services, based on the availability of real-time consumption information and other relevant energy-related data and standardized interaction among all the electricity stakeholders. The vision will be realized in large scale demonstrators in Europe, where EMS will be adopted as a service and asset management platform for the selected use cases. The project is going to start of February 2015.

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