THE MEU WEB PLATFORM: A TOOL DEDICATED TO URBAN ENERGY MANAGEMENT

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ABSTRACT

The MEU GIS-enabled web-platform [1] has been developed in close collaboration with four Swiss cities. The tool enables detailed monitoring and planning for both energy demand and supply at individual building, neighborhood and whole city scale (http://meu.epfl.ch). This web-platform acts like an interface between different tools and allows to establish detailed energy balances for entire cities comprising several thousand buildings.

In its present configuration, the MEU tool does not allow yet to simulate energy networks behaviors, based on the real or projected energy demand in an urban zone. In order to meet this need from energy utilities partners, a specific data model, as well as an user-interface giving access to networks attributes and edition/simulation tools were developed, which will be then functionally integrated in the MEU platform. The idea is to create a "Natural Gas Networks" module built for energy utilities.

The objectives of this project within the larger MEU endeavor were the following:

- Create a platform gathering topological and geo-referenced data
- Develop a gas network pre-design/planning methodology including demand characteristics and gas supply for buildings in a selected area.
- Interface with gas distribution system operators existing tools and add new functionalities within a single platform.
- Include gas distribution system operator constraints and operational realities in the pre-design/planning process.

In order to achieve those objectives, two tools and several visualization concepts have been created, along with an ad hoc data model: (i) a data model able to allow data import, storage and centralization from energy utilities databases: networks, buildings demands and specifications, as well as interface between edition, simulation and visualization tools; (ii) a network edition tool prototype (LEAFLET JavaScript based web page), which allows to display a network on a map, to add/delete or drag&drop pipes, nodes, consumption and biogas production/injection points and pressure let down stations; (iii) a network flows, and pressures simulation device (MATLAB® compressible fluids model) which computes the network behavior for each hour (pressures, flows, power equivalent and temperatures in each point); (iv) a detailed mock-up for visualization and display concept with interactive and GIS data: buildings area, networks paths, pipes characteristics, results from simulation, studied area energy balance, etc.

This paper focuses more specifically on the visualization and network edition tool, as well as simulation results interactive representation on the MEU platform.

Keywords: urban energy planning, energy flows, GIS, gas networks

INTRODUCTION

Due to high level policy decision, energy systems, especially at local scale, have considerably evolved during the last ten years. European Union for example decided in 2008 the 3x20 strategy: decrease CO_2 emission of 20%, increase energy efficiency of 20% and share at least 20% of renewable energy considering the global energy consumptions, at EU scale and since 2020. Such decision had a direct impact on local energy systems, in terms of demand as well as in terms of supply: buildings refurbishment or more efficient devices implementation, saving energy ; decentralized energy production, based on renewable or distributed energy (e.g. : Combined heat and power); substitution of fossil & fissile fuel by renewable or CO_2 free energy [2].

This pressure, coming from different level regulation [3], combined to the availability of high efficiency and renewable new technologies increase the number of possible solutions to achieve a defined territorial objective, like EU 3x20 applied at local scale through the Covenant of Mayors [4]. The solutions, which local decision makers have to compare are more and more complex, tackling spatial and temporal distribution of energy resources and demand, considering multi-energy centralized and decentralized technologies. Computing becomes necessary as a decision support system, taking into account as many solutions as possible, and benchmarking them based on different relevant indicators (primary energy consumption, CO2 emission, share of renewable energy). Such a computation scheme needs a large energy technology model library, as well as huge quantity of "up to date" territorial energy data [5].

In parallel, Information and Communication Technology science highlighted the potential of Smart Cities, to better collect, process and store territorial data including energy data. This approach can strongly support the way that local administration, as well as utility industry, manage and share territorial energy data. The use of such smart cities energy data enhance the knowledge of the local energy system "state of the art", allow the monitoring of local energy system performances, and support the computation of future energy systems scenarios as help decision tool.

METHOD

Dedicated data model

The MEU platform is built around a database that stores and makes data available for display, indicator computation and simulations [6]. In order to integrate gas networks to the platform, the existing data model covering buildings and conversion technologies had to be extended. This was done considering the three following constrains. Integrate data needed by network energy providers; Integrate topological data needed for network simulations; Comply with existing norms and good practices in terms of network representation.

Based on a bottom up approach, interviews were conducted with industrial partners (SOGAVAL SA, Sinergy, Viteos, ESR, SIL) in order to identify their needs in terms of data accessibility and display. These needs were added to the inputs needed by the simulation tool developed in parallel and translated into objects and attributes, based on the technical guidebook n° 2015 [7] given by the Swiss Society of Engineers and Architects (SIA).

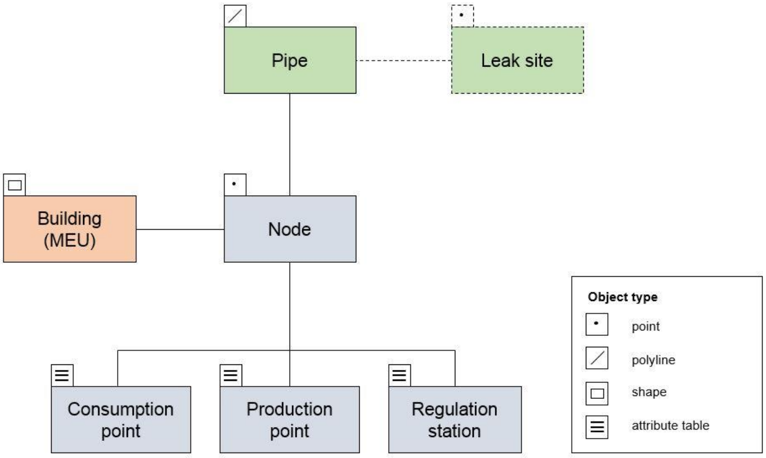

Figure 1: Network data model objects diagram

The resulting data model contains two "geographical" objects: node (point) and pipe (polyline), as well as three "attributes table" objects that can be assigned to a node to form a consumption point, a production point or a regulation point. This basic model can be extended depending on the user's needs (for example with leak site table)

Display and visualization concepts

Georeferenced representations of networks and related data are the key features of MEU+. It is built up on the existing GIS based visualization interface MEU that allows users to activate layers displayed on top of an ortho-picture map and access data by clicking directly on the objects.

The basic representation of the network consists in a layer showing the network's geographical objects on top of the ortho-picture map or any other pre-existing MEU map. Nodes are represented by points or pictograms depending on their type (elbow, junction, production / consumption points, etc.). Pipes are represented by segments joining two nodes and of variable width and color depending on the type of network (mid/low pressure, carrying, delivery, etc.).

In order to avoid over-charging large scale maps, three levels of detail display have been defined depending on the scale. At city scale only the mid pressure network components are shown on the map. At the neighborhood scale the low pressure network components are added. At the street scale the connecting pipes and low pressure consumption points appear.

Figure 2: Concept for the three level network representations (from left to right: city, neighbourhood and street scale)

In addition to the basic representation, the network's geo-referenced data can be used to display thematic maps according to user's needs. Segment width and color scales can be used to highlight aspects of the network state such as flowrate, speed, pressure or location of leaks. Other representation, taking advantage of the building database MEU, highlight new market opportunities like oil heated building within a certain range of the network, or building with higher needs (Figure 3).

Figure 3: Concept of thematic maps (light grey: oil heated buildings, dark grey: big consumers)

Access to network component attributes is done by clicking the object on the map. A pop-up window (Figure 4) displays all information linked to the object. Data are organized in tabs for convenience of use. A first tab displays general information like identification code, coordinates, construction year, etc. A "modify" button allows user to modify the content. The "results" tab displays the simulation results. The "documents" tab shows a list of documents (reports, schematics) related to the object. The "history" tab shows the history of modification. Depending on the object type, additional tabs are used to display specific information (consumption, production, regulation). The same four level metadata (0, 1, 2 or 3 stars) contained in the MEU platform is also used to qualify data quality of networks components (0: default, 1: estimated, 2: simulated, 3: measured)

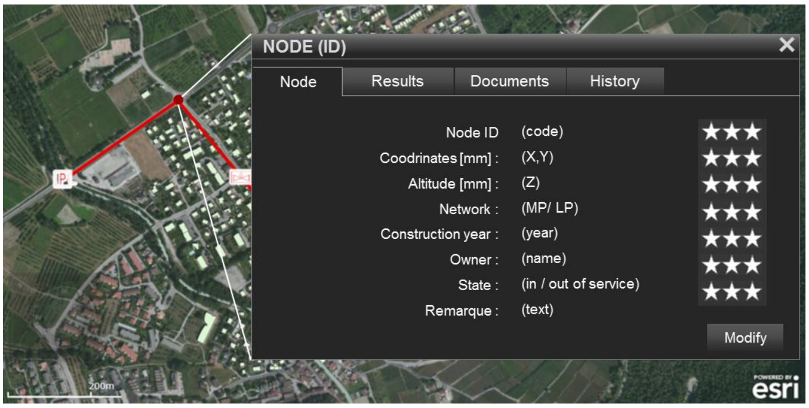

Figure 4: Concept of pop up window for a node

A global network window allows to display synthetic network values like annual volume distributed, global pipe length, average network age, energy vector penetration rate, biogas share, delivered power, etc. as well as graphical representation of the whole network or a selected area.

Network edition tool development

Natural gas network data, are usually owned and directly managed by distribution companies, and are not standardized, at least in Switzerland. Each gas company can rely upon its own information system and data structure. Thus, natural gas network data, as received from utilities, need pre-processing, in order to ensure matching with the data model described previously.

The main underlying idea of the MEU+ project is to create, test and validate new scenarios for natural gas infrastructure. It allows handling both the modification of existing networks, as well as the creation of a completely new network.

Utilities project partners actually work on two completely separate tools to handle natural gas network modification test and validation. The first one, based on a very precise "drawing" of the existing network, manages and displays spatialized data, necessary for network maintenance and intervention; however, this first tool is not able to deal with topological data or flow simulations. The second one (ex: NEPLAN®) is a flow simulation tool which is not designed to manage GIS data.

The need for a tool integrating both GIS data and topological data thus arose from natural gas utilities project partners, in order to simplify the management and exploitation of network data.

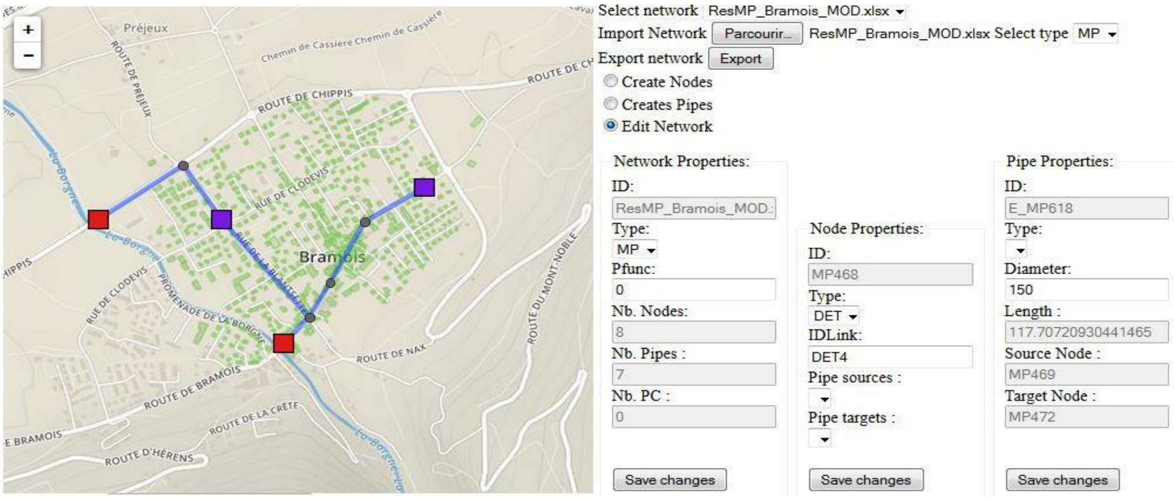

Figure 5: Network edition tool

A more detailed description of the network edition tool features, functionalities and characteristics can be found in [8].

Network flows, and pressure simulation device development

Tool specifications, underlying assumptions and physical modelling, as well as the integrated solving simulation have also been already presented in [8].

RESULTS

Prototype of a gas network simulation module

In order to test and validate natural gas network model with associated technical assumptions, a "basic blocks-like" method has been developed. Basic and simplified network structures have been created and implemented based on real network topology analysis. Those "basic blocks" are designed to simply cover every possible micro-structure occurring in real natural gas network. Overall model computation and simulation have then been performed for each "basic block" structure, while the model core code has been adapted to suit every one of those "miniature network".

The model is currently tested for big-scale network simulation using a comparison between the network simulated behaviour computations and NEPLAN® simulation results on an existing neighbourhood. The results of this validation will be published in a successive dedicated paper..

CONCLUSION

The MEU platform presently allows displaying a precise picture of an urban area, regarding its energy consumption and balances. The platform code is currently undergoing broad refactoring [9], in order to increase robustness, reliability and replicability. New functionalities regarding energy networks and, in particular, natural gas networks are simultaneously developed and tested. MEU tool users from cities and energy utilities will thus be able to perform detailed network pre-dimensioning computations, based on geo-referenced cities energy data. Thus, the impact of selected natural gas network scenarios can be displayed in the MEU platform: the user is enabled to compare current state for a given year to these scenarios, in order to evaluate the impact of foreseen actions. In the future, it shall open the opportunity to directly exchange high added-value data between different local energy stakeholders.

The described platform aims at bringing more transversality in territorial energy planning and management. It will foster urban energy networks analysis and design by precise description and study of fluids flows and energy exchange through energy infrastructures. Such technological and methodological advances will help with: (i) further developments and integration of power and district heating/cooling networks; (ii) modelling, simulating and , improving design methods; (iii) the comprehension of global urban energy metabolism and territorial energy systems.

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