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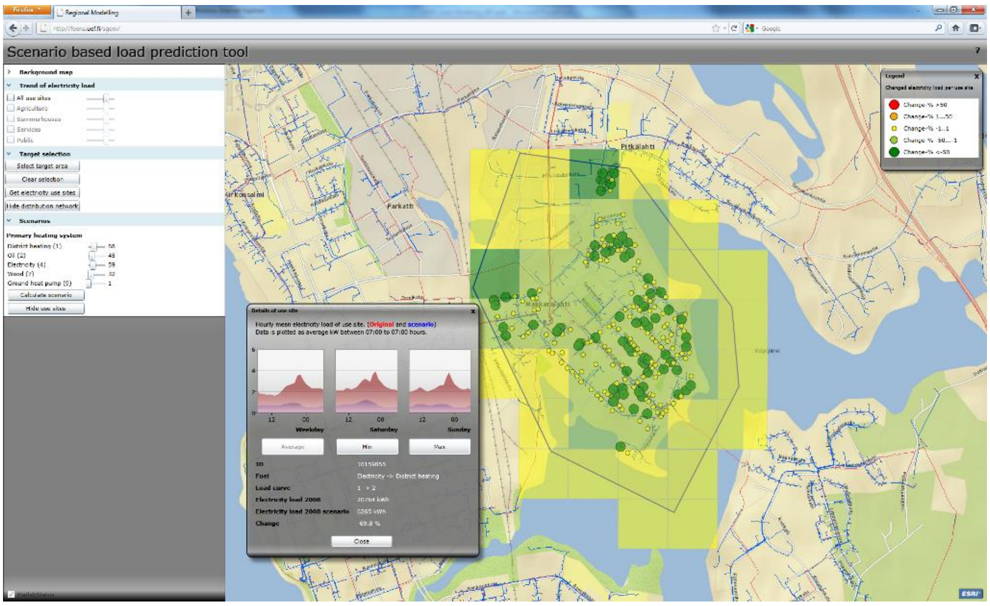
Regional load modelling web application based on ArcGIS server, Matlab and Silverlight



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SOA solution based on GIS server and external modelling program, data and user interface, and NIS interface

Abstract

The report summarizes the technical work related to the 2nd SGEM funding period, WP6.10 (Network analysis and planning methods). The main objective has been to investigate the possibilities and integrity issues related to the use of external data in new types of computational approaches and services for strategic network planning.

Based on that work, a technical demonstration based on ArcGIS Server, Matlab and Silverlight web application framework is presented. It represents a novel solution for building up user-defined regional heating system scenarios for executing hourly based load predictions and for assessing scenarios using the map-based interface.

The research activities were performed in parallel with WP6.1 (Next generation ICT-solutions for network management) and WP4.2.1 (Novel load modelling methods).

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Preface

The work presented in this report is part of the project Smart Grids and Energy Marketing (SGEM). The SGEM project belongs to Cluster of Energy and Environment (CLEEN), financed by Finnish Funding Agency for Technology and Innovation, TEKES industrial partners, universities, and research institutes.

We wish to thank the funding organizations and the steering group of SGEM programme for making this work possible to carry out.

The authors

Abbreviations

CIM	Common Information Model
CIS	Customer Information System
DER	Distributed Energy Resource
DG	Distributed Generation
DSO	Distribution System Operator
DSS	Decision Support System
ESB	Enterprise Service Bus
GIS	Geographic Information System
NIS	Network Information System
SOA	Service Oriented Architecture
WPS	Web Processing Service

1 Motivation

New computational approaches and services, which better utilize the possibilities of IT and external (public sector) data sources, are needed in management and planning of Smart Grids. Whenever the methods and tools are developed, they should be user-friendly, understandable and computationally powerful, enabling interactive functionalities for end-users.

From strategic planning point of view, the assessment of regional loads and their long term development is a relevant question, and can be used as a representative test case for piloting new computational approaches and services based on regional data. Over the years, multitudes of methods have been used for predicting regional (or spatial) electricity load, covering various temporal and spatial scale, i.e., short, medium or long term forecasts on neighbourhood, municipal or national scale [1]. In strategic planning of the grid, the estimation of the future needs must be made on long term. This can mean predictions spanning from 1 to even 30 years ahead. Most of the models, however, are developed for short or medium term forecasts which better server daily or weekly management decisions [2]. Intuitively a conclusion can be drawn that, the longer time span a prediction covers, the more uncertainty it involves.

Usually models try to forecast the future quantitatively. These include computationally intelligent (CI) methods such as artificial neural networks, fuzzy logic and genetic algorithms, among others [3-4]. However, they are criticized for their poor performance on long term forecasting. The results of pure quantitative methods have been particularly unsatisfactory in cases where there are complicated and surprising phenomena of the society involved [5].

One way of controlling the inherent uncertainty that is always present when making predictions or forecasts is to analyze various possible decisions, events and their consequences more closely. Scenario analysis is a technique that fills this requirement. Scenarios are alternative views of possible future events and their outcomes. It is different from predicting and forecasting in that the aim is not to produce only one correct outcome but to present many different alternatives by analyzing possible future prospects. Scenarios stress especially uncertainties which are not controllable. Thereby it is possible to better take into consideration the new unknown factors that a pure statistics-based model could never anticipate. Many long term forecasts are done by taking into account different scenarios but to really harness the full potential of the approach it should be possible to quickly and conveniently produce a series of “what if?” –type experiments. This way scenario analysis can be more of an everyday tool.

Moreover, the scenarios should be applied to the variables that are most uncertain.

Often the modelling of load growth as a whole is not based on realistic regional estimates. For example, two commonly used NIS in Finnish electricity companies consider the load growth via global growth percentage which affects all the use sites and regions equally. [6], [7]. In reality the load growth can have high geographical variation and without considering the changes on more specific regional level the modelling error can be significant.

Economists have been using techniques labelled as geo-demographic analysis to classify people to segments by their socio-spatial characteristics. The theory of geo-demographics is based on a notion that knowing where someone lives provides useful information about how someone lives. There exists some relationship between people and places and between individuals and who they regularly meet. The renowned and widely accepted Tobler's first law of geography also suggests that:"Everything is related to everything else, but near things are more related than distant things". [8] Thus the spatial dimension should not be dismissed when modelling the consumer behaviour.

In the strategic planning, the modelling of new Smart Grid related components and their regional adoption (e.g. PHEV/EV, heat pumps, solar panels) is essential, remembering that they have a significant influence on the patterns and the magnitude of electricity loads at regional level. Being able to estimate at what rate and in what areas the new Smart Grid related components are being adopted has a potential not only to guarantee the uninterrupted delivery of electricity but also to gain significant financial savings. The benefits are evident for DSOs but, as a consequence, the effect is likely to be seen also in the consumer electricity distribution prices.

In this report, the possibilities of external data, overview on DSO data and system integration and common standards for data exchange are first shortly reviewed. This is followed by the presentation of the concept of regional modelling for load prediction. In this context, the technical issues, including especially data integration/interfaces, are considered. The general vision has been in ideating new type computational approaches and services, that can be used to support decision-making related to the planning of the grids.

2 Possibilities of external (public sector) data

The external data sources provide interesting possibilities for several operations of the electricity sector. Utilization of the data however requires addressing several restrictions the data and data sources impose. This chapter lists briefly such data sources and their general problems.

2.1 Data sources

A range of available external data sources exist, which can be exploited for many purposes, in parallel NIS/CIS databases, in the management and planning of the grids. Following the list included in SGEM Research Report D1.2 (2011), the most promising public sector data sources in Finland include:

- Population register centre, Building and dwelling register
- Statistics Finland, Grid database
- Finnish meteorological institute, Temperature statistics and forecasts
- Finnish transport safety agency, Vehicular and driver data register
- Ministry of agriculture and forestry, Agricultural statistics and registers
- Finnish environment institute, CORINE land use data
- Finnish environment institute and the regional councils, Regional land usage plans
- National land survey of Finland, SLICES land usage information

In broad line, these datasets include regional specific geographic information about socio-economic and environmental factors, the latter representing heterogeneous data from various physical, biological and built environments. Such regional information could be of significant use to the strategic planning of the grids.

2.2 Terms of usage and legislative trends

The exploitation of the data are restricted in many ways, which can be seen to be due to: (i) data protection and security (privacy issues), (ii) data resolution (often related to privacy issues), (iii) terms and pricing policy for research and commercial purposes and (iv) technical issues (e.g. data interfaces).

The general trend is globally that the data produced by public funding are opening for research and commercial purposes. This is mainly due to its significant value on information content. As on example, in Europe, the value of the public sector data has been estimated to be approx. 27 billion euros [9]. In EU level, there are INSPIRE and PSI Directives (2003/98/EC) which mainly define common legislative frameworks for release and use of public sector data. However, until now, the Directives have not enabled significant re-use the data. A significant obstacle in this has been that the public sector is allowed to use information disposition pricing to cover their short-term costs. The situation is however going about to change. The European Comission is preparing significant changes to the PSI Directive until 2013. Furthermore, there are significant national-level initiatives and decisions under work. For instance, in Finland a decision in principle has been given by the Council of the State, which aims at releasing the data free of charge.

3 Common standards for data exchange

Standard information models are needed for efficient management of information across different systems. Many companies in the electric sector use different systems side by side. Integrating these separate systems brings obvious benefits but without standard information model, the integration process can be very complex and costly operation. This chapter covers the industry standards for information handling and processing

3.1 Common Information Model

Electrical power industry has adopted Common Information Model (CIM) to be used as a general model for various applications. CIM is defined as industry standard by International Electrotechnical Commission (IEC). The purpose of CIM in the electric grid context is to allow different applications to exchange information about configuration and status of thel network. [10]

In IT-product level, CIM is still in very early phase at 2011. Software providers for electricity industry do not have all the needed functionality implemented for all the software to work via standard interfaces.

3.1.1 IEC 61970

The IEC 61970 is an abstract data model for electricity network operations. This series of standards defines application program for energy management systems (EMS). These standards include guidelines for integration of applications developed by different suppliers into the control centre environment. Also the exchange of information between external IT-systems and the control centre environment is described. This includes systems dealing transmission, distribution and generation which are external to the control centre, but need to exchange real-time data with it. Interfaces for communication between new and legacy systems are described as well.

The IEC 61970 series of standards is originally developed for needs of transmission system operators. The standard that defines the core packages of the CIM is IEC 61970-301.

3.1.2 IEC 61968

The IEC 61968 is a series of standards under development that will define standards for information exchanges between electrical distribution systems. This series of standards extends CIM to be used also with distribution system operators.

IEC 61968 defines following packages:

- Common
- WiresExt
- Assets
- AssetModels
- Work
- Customers
- Metering
- LoadControl
- Payment Metering

3.2 Other standards

Computing environments are currently moving towards service based approach for both data and processing. For GIS-data there are two widely used standards maintained by Open GIS Consortium (OGC), namely OGC WMS and OGC WFS.

3.2.1 Web Map Service (OGC WMS)

Web Map Service (WMS) provides standard way for serving spatial raster data in network environments. WMS is mainly used for providing background maps and application specific map layers for web applications. WMS can be also used to provide any georeferenced images over web. WMS specification includes two requests that any WMS server has to respond. GetCababilities –request returns basic information and metadata about service. GetMap –request is used to retrieve actual map image.[11]

There are several web map server implementations that respect WMS standard. On open source projects WMS is used without exception. During the last years also commercial server developers have enabled WMS in their map services.[11]

3.2.2 Web Feature Service (OGC WFS)

Web Feature Service provides interface for requesting spatial data across networks. Difference to WMS is feature/vector data instead of raster/imagery data. Geography Markup Language (GML) is most often used for payload encoding in WFS responses. In WFS specification three required operations are listed. GetCapabilities requests metadata about the service itself in a same manner as in WMS. GetFeature-request performs the actual query and returns encoded feature or featureset. DescribeFeatureType returns XML Schema for client to be able to process resultset.[12]

3.3 Processing services

3.3.1 Web Processing Service (OGC WPS)

Web Processing Service (OGC WPS) is a definition for requesting data manipulation operations across network. WPS is originally designed for interfacing GIS tools and algorithms on server side from a client application. In addition, WPS can be used to publish interface to any calculation process. Subject and data does not need to be in spatial context. WPS only sets rules for calculation inputs and outputs. It does not describe how calculations are performed.[13]

In GIS context, WPS allows both vector and raster data to be exchanged in requests and responses. WPS requests can be either synchronous or asynchronous. Asynchronous requests can be used if processing is computationally time consuming and response cannot be given right after request. WPS defines three operations: GetCapabilities –request is used to retrieve service-level metadata. Execute-operation returns the output(s) and DescribeProcess is used to get description of a given calculation process. DescribeProcess also returns information about process's inputs and outputs.[5]

WPS specification is relatively new. Before 2010 only few public projects have reported to implement WPS on server side. In 2011 Esri inc. announced that WPS capability will be added to GeoprocessingServices of upcoming version 10.1 of ArcGIS Server.[14]

3.3.2 ArcGIS Geoprocessing Service

ArcGIS Geoprocessing Service is Esri inc's implementation for providing interface to GIS tools via network. A single geoprocessing service exposes interface for predefined geoprocessing task(s) to be executed on server side.[3]

New geoprocessing services are defined using Esri's desktop application, ArcGIS Desktop. Interface for processing (inputs and outputs), as well as calculation logic or model are first defined as a toolbox in ArcGIS Desktop. These toolboxes are created using graphical Model builder –tool in ArcGIS Desktop. Other way to implement toolboxes inner functionalities is to use Python programming language. Python can be used in general to extend ArcGIS Desktop or Server functionalities. Prepared toolboxes are finally published to ArcGIS Server. Server acts as a host for toolboxes and provides their functionality as Geoprocessing Service.[15]

ArcGIS Geoprocessing Services are mainly targeted to Esri's own client applications. For example, multiple ArcGIS Desktop users can use same Geoprocessing Service and server machine's computing resources for certain routine calculations. ArcGIS Server also exposes REST and SOAP interfaces to these services. These are technology-independed services and can be used also with custom applications. [15]

In ArcGIS Server version 10.1 also WPS capability is added as additional feature to Geoprocessing Services. [14]

4 DSO data and system integration

In Finland there were 89 local electricity distribution companies at 2009. All those companies have their own range of IT-systems in operations. Distribution system operators have different opinions about needed functionality and properties for their own operations. [16]

Different operators have also different needs for communication between systems. If two operators have exact same range of IT-systems, they may still have different customized connections between systems.[16]

IT-system providers have also different functionality in their products. The definition for certain application is not clear across markets. For example all available network information systems (AM/FM/GIS) don't have some particular functionality which others have, but system providers have implemented this same functionality in different product. [16]

Choices of used IT-systems in one company have been typically done in very long period of time and range of systems may have been changed over time. This chapter describes the relevant information systems used in the Finnish distribution companies and their integration.

4.1 Network Information System, NIS

In Finland, term "verkkotietojärjestelmä" or VTJ in short is used for a system which is responsible for management of network assets. Also English term Network Information System (NIS) is used but mainly in Finland. Worldwide these systems are known as Automated Mapping / Facilities Management / Geographic Information System (AM/FM/GIS). There are also differences in systems functionalities between different market areas.

Main features include network documentation, reporting, statistics, technical calculations and mapping. System may also have other functionalities for supporting eg. maintenance and construction.

Most common products in Finnish markets are:

- ABB Oy, DMS 600 NE (Integra)
- Tekla Oyj, Xpower
- Tieto Oyj (TietoEnator Oyj), PowerGrid

4.2 Customer Information System, CIS

Distribution system operators use CIS for customer relation management (CRM). Finnish term for this system is “Asiakastietojärjestelmä” or “ATJ”. System provides functionalities for invoicing, customer service, agreement management and marketing.

CIS is database driven system, and it uses customer database for storing all customer related information. This information contains identification of place of electricity use, customer/consumer group and annual energy consumption. Also metering, tariff and billing information is stored in CIS.

Changes in electricity markets have pushed new applications for CIS data. For example web-based customer service-/helpdesk –applications are developed to communicate with CIS.

Most common products in the Finnish markets are:

- Tieto Oyj (TietoEnator Oyj), Forum
- Logica (WM-Data Utilities Oyj), Kolibri (APM)
- CCC Group, Ellarex

4.3 System integration

Typical distribution system operator has a variety of different IT-systems. One system contains information which is crucial for another system to operate. Need for systems to co-operate is obvious.

4.3.1 Point-to-point integration

Lack of industry standards in data exchange has lead to situation where each communication need is handled as custom integration between systems. This approach is called point-to-point integration. When number of different systems inside a company increases also number of needed integrations increases vastly.[16]

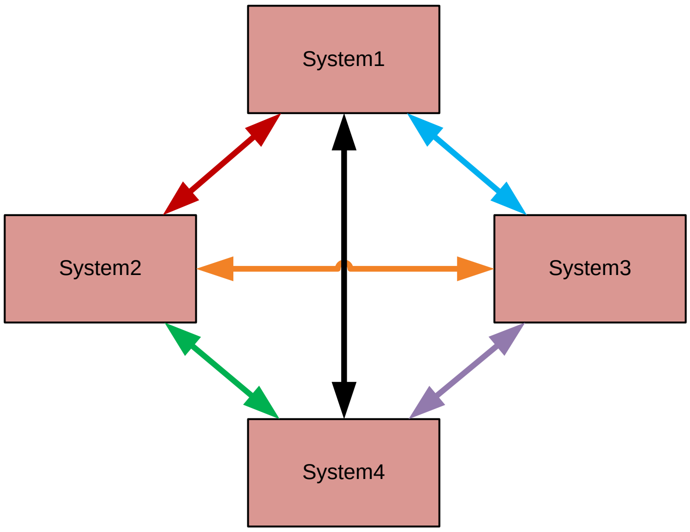

Figure 1: Point-to-point integrations

4.3.2 ESB architecture

Operational environment in IT-field at distribution system operations are changing. This emerges creates a need for proper integration architecture.

Enterprise Service Bus (ESB) is a software architecture which extends Service Oriented Architecture (SOA). The primary aim of an ESB architecture is to integrate enterprise applications in complex software environments. ESB provides a communication bus where distinct applications are connected via standard interfaces. [17]

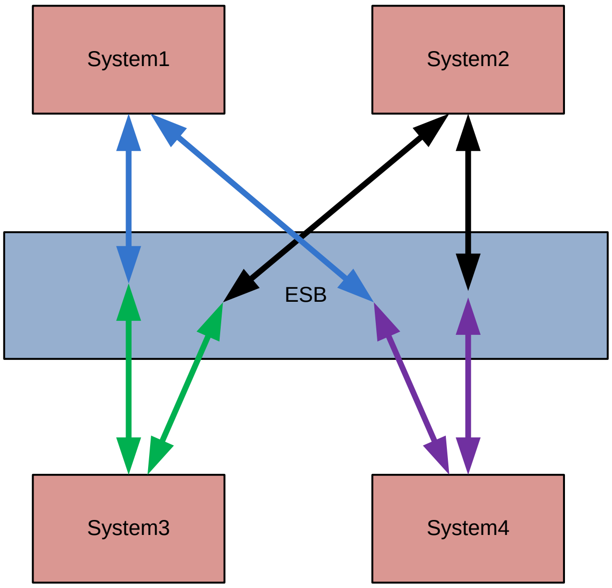

Figure 2: ESB architecture

The Common Information Model (CIM) is a good candidate for information model in electricity network companies operation. CIM is defined for industry standards (IEC 61970 & IEC 61968) but it’s development is still in progress.

5 Regional modelling as a tool for strategic planning of electricity networks

Long term planning of distribution network is carried out to secure the grid's functionality in the future. The investments made on the network infrastructure can be costly. Good planning capability can therefore help in acquiring significant financial savings in addition to the reliable functionality of the grid. This chapter presents an implementation of web based regional modelling tool. The tool currently allows modelling electricity loads in different residential heating system scenarios.

5.1 The main components

The main components of the regional modelling system are:

(i) The database
(ii) The computing engine
(iii) The user-interface

The overall system can be described, i.e. not paying attention to the details of the implementation, using the scheme illustrated in Figure 3. The system includes (i) the GIS/regional database, which is spatially integrated with CIS/AMR data, (ii) the regional model which performs the modelling at some spatial resolution (e.g. 250x250m, 1x1km, 5x5km or polygon/subarea representing similar region) and (iii) the regional scenarios which can defined e.g. the expected heating systems and (iv) the optimization between the scenarios.

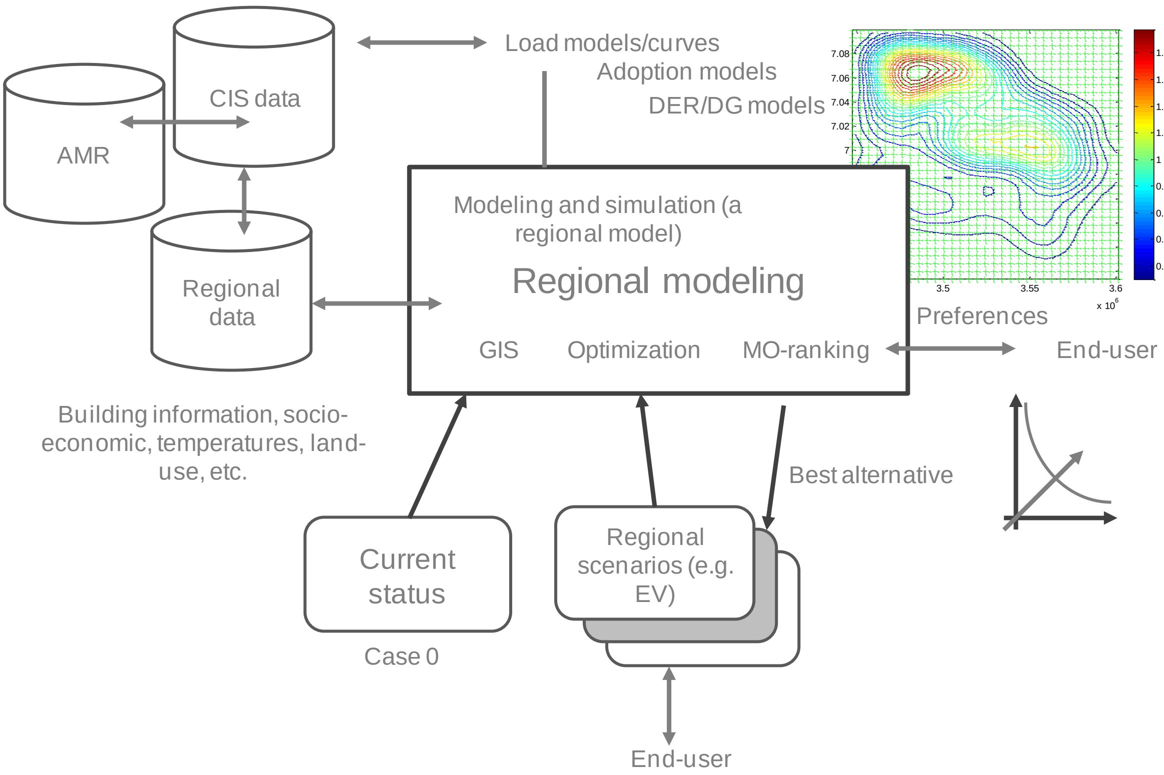

Figure 3: The components of the regional modelling system.

Such the system aims at integrating different data sources and models to one system for limited geographic area. A well-constructed regional modeling system is the composition of database, GIS, models, algorithms, computing engine and user-interface. It serves as a decision support system (DSS) that provides tools for operation and strategic decision-making committed by different actors.

5.2 The web-based regional modelling tool

Based on the above presented ideas, the vision has been to have a powerful tool, which can be used to produce regional load predictions in user-defined scenarios. This can be achieved by the integration of group-specific load models and available region-specific data. The latter is extracted from external information sources.

The web-based tool for regional load modeling has been under development and testing. The tool currently integrates: ArcGIS Server, Matlab-based load models and Microsoft Silverlight web-application framework (the demo available at:

http://feena.uef.fi/sgem). The architecture of the web based regional modelling tool is described in Figure 4.

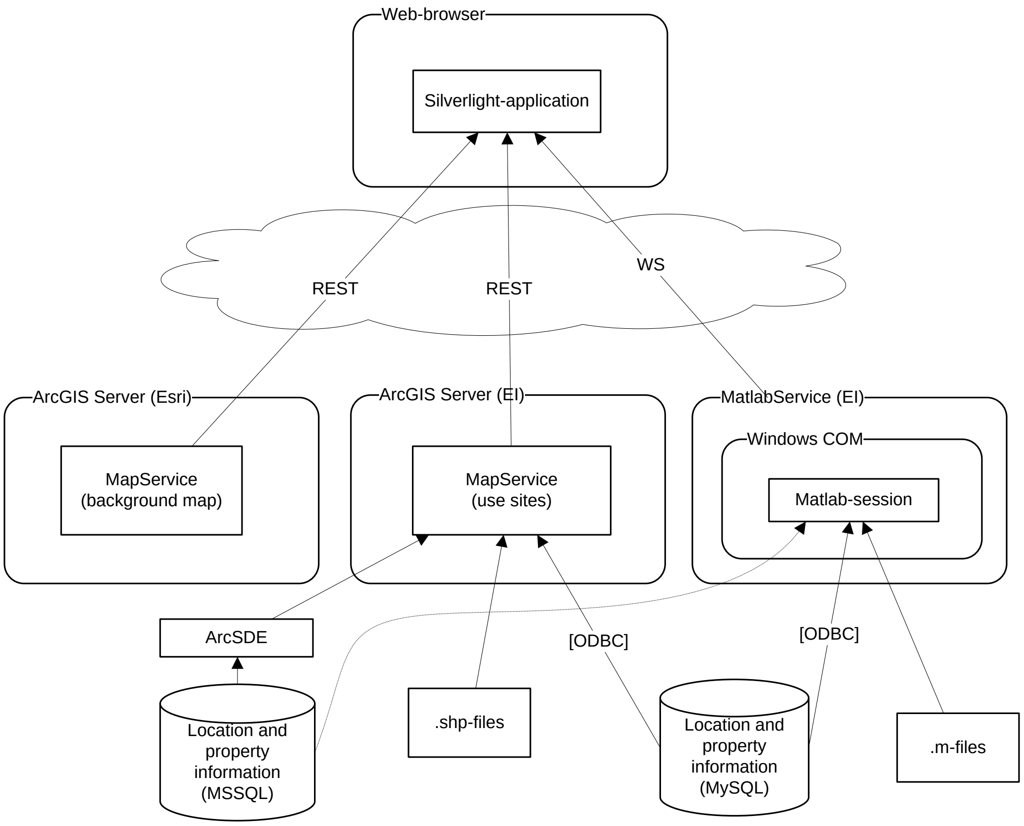

Figure 4: Architecture of the web application [18]

The regional modelling tool aims at demonstrating the quick assessment of hourly loads in different user-defined heating system scenarios. As it stands, the tool allows selecting different target areas from a map, delivering the customer and load data from the target region, inputting a scenario and getting hourly load predictions in a given scenario to inspect (Figure 2). The regional distribution of the loads can be further examined on a map.

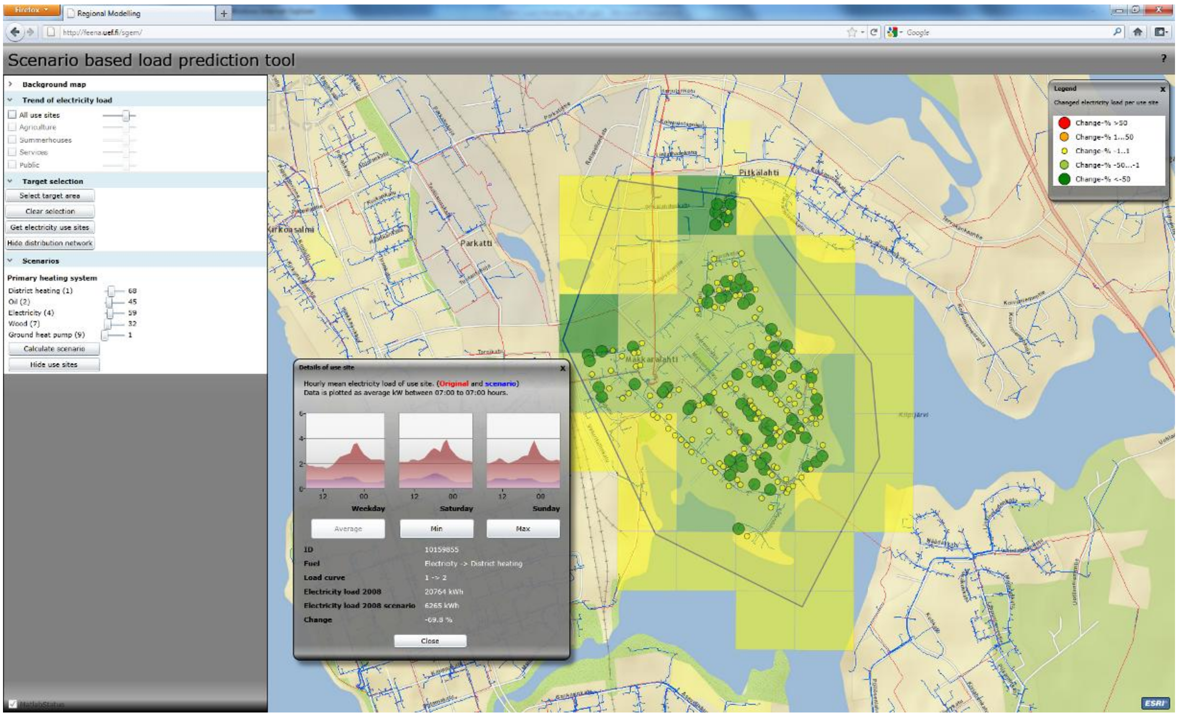

Figure 5: Silverlight interface of the regional modelling application (http://feena.uef.fi/sgem).

Some planned features include: numerical and visual inspection of modelling results, comparison of scenarios and regions, load profile import/update (e.g. EV) and result export.

5.3 Architectural considerations

The current version of the tool present a solution for integrating Matlab-based load models with server based GIS computation and graphical web-interface. However, as it stands, it does not properly utilize the possibilities of data interfaces.

Currently there are now proper data interfaces implemented for most of the public sector data. For instance, the socio-economic grid database (Statistics Finland) is currently delivered only as network distribution. Authorized users can download whole data either in ArcGIS *.shp –file or in MapInfo *.tab –file. Data access via service interfaces (eg. Web Services or WFS) is not available at 2011.

As an exception, National Land Survey of Finland (Maanmittauslaitos) is releasing their data and provides application interfaces to some national wide data as WMS and WFS services. The data can be accessed via WFS interface, but currently it is accessible only for authorities. It can be also accessed for research purposes, providing that raw data is not published.

Furthermore, there are some open questions related to computational efficiency i.e. how to transfer huge amount of the GIS data without losing computational performance and user interactivity. A possible solution can be found through cache-like temporary data storing. Application should anyway manage situations where no data is found locally (cache), but it has to be fetched runtime from another systems.

Further work should be focused particularly on testing data interfaces and their combination with the modelling. Main goal is to proceed towards on software as a serivice (SaaS) i.e. software delivery model, in which software and its associated data are hosted centrally (in Internet cloud) with the following properties and sub objectives:

- The user is for example DSO network planning engineer
- The application provider can be separate IT-company, which provides application/modelling logic to user
- External data is fetched via standard interfaces from providers (WFS, WMS, Web Services)
- Business data from DSO is fetched from DSO service bus or similar
- Queries are executed on basis of spatial location (coordinate boundaries, municipality code, post office number, street address)
- Data includes places of electricity use, customer information, load curves and hourly metered consumption data for certain time period
- The modelling application performs computations for selected scenario and returns output to user
- The computation engine can be diversified from main application service via standard interface like WPS
- The user interface can be implemented as thin client, like RIA web-application. Another approach is to implement user interface as a plugin or extension to AM/FM/GIS system in use.
- The computation output may be used as a design parameter for network planning

6 Conclusions

External, public sector data are beginning more accessible, offering significant possibilities for developing new computational approaches and services in the domain of Smart Grids. Better spatial accuracy of the data (socio-economic, building information etc) could yield significant enhancements in several problem domains of Smart Grids, as exemplified here for long-term load modelling. As a recommendation further work is required especially for data interfaces. Practical demonstrations about the potential solutions are needed as such activities can show new possibilities and can thus lead both to open data interfaces and to the development of new methods and services.

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