Developing electricity forecast web tool for Kosovo market

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Abstract: - In this paper is presented a web tool for electricity forecast for Kosovo market for the upcoming ten years. The input data i.e. electricity generation capacities, demand and consume are taken from the document "Kosovo Energy Strategy 2009-2018" compiled by Ministry of Energy of Kosovo and approved by the Kosovo Assembly. The web tool enables different settings for national electricity grid, divided in seven electricity consume regions, five interconnection lines and using domestic generation capacities, using existing power plants and those planed to be built until 2018. It enables different scenarios, such as increasing/decreasing electricity demand in different regions, energy import/export and increasing/decreasing generation capacities. The developed web tool was tested especially against boundary condition such as heavy increased/decreased energy consumption, i.e. beyond the planned economic growth of the country and the delay of starting time of new generation capacities. For these boundary conditions are proposed extra measures to be considered in order to fulfill the security of energy supply criteria. This web application is developed using latest ASP.NET platform, C# as programming language and Microsoft SQL as database server. The web tool shall server as unique tool for governmental decision makers and to contribute inputs to future policy and management decision-making in the energy sector.

Key-Words: - Electricity Forecast, Simulation, Database, Internet, .NET, Web

1 Introduction

Energy in general and electricity in particular plays a very important role in daily life and economic development of a country. As cited by United Nation Development Program (UNDP) report electricity development is associated with both positive and negative outcomes for a country. It is generally recognized that adequate and reliable supply of electricity is a precondition of sustainable economic development in the context of the global economy. Moreover, improved access to electricity services is closely correlated with increased human welfare. In recent years, however, the negative outcomes of electricity consumption have received widespread attention with growing international recognition of the ongoing process of climate change (also known as "global warming"), probably the most serious threat to the global environment today [1]. A study, as presented in [1], for South East Europe (SEE) region, demonstrated a close correlation between per capita electricity consumption and overall Human Development Index (HDI) score, as presented in Fig. 1.

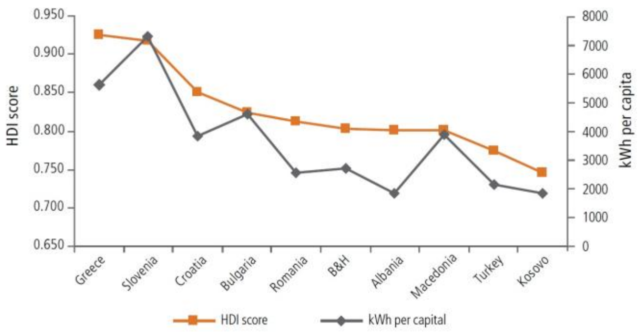

Fig. 1: HDI and kWh per capita in SEE

Energy security of supply is set by the European Commission (EC) as the highest priority on its agenda and it is a common concern of the European Union (EU) member states. For those countries that are not yet members of the EU this issue is addressed through Energy Community Treaty.

As stated in its mission "The Energy Community extends the EU internal energy market to South East Europe and beyond on the ground of legally binding framework. It thereby provides a stable investment environment based on the rule of law, and ties the Contracting Parties together with the European Union. Through its actions, the Energy Community contributes to security of supply in wider Europe"[2]. Development of electricity infrastructure has a key role to assure and fulfill the security of supply as EU requirement. This development must be seen in the regional context. The SEE region has been passing through very intensive political and economical changes in last 15 years. Transition from state controlled economy to market conditions has been accelerated recently. All power sectors in the region are going through turbulent processes of restructuring, market opening and privatization at the same time. SEE region has already made public their plans for building new electricity generation capacities, more than 2000 MW are to be expected to be build during 2010 and 2020 [3]. Therefore it is of critical importance for decision makers in the energy sector to have e simple tool, that has integrated all these properties inside and gives clear values the country electricity needs in the upcoming years

2 Electricity forecast – Kosovo case

2.1 Kosovo electricity market

Kosovo has signed the Athens Memorandum for the establishment of the Energy Community Treaty of South-East Europe that entered into force in July 2006 is obliged to create free market of electricity and promote competition in the energy market. The government of Kosovo is committed to develop the energy sector in compliance with acquis communautaire of the Energy Community Treaty and EU. In 2006 began the restructuring or unbundling of the Kosovo electricity sector. The Division Transmission and Dispatch was the first division which is divided by Kosovo Energy Corporation (KEK). Based on this concept was established KOSTT JSC-System Operator, Transmission and Power Market of Kosovo, which is licensed by the Energy Regulatory Office (ERO). The remainder of KEK has been restructured in several divisions, such as that of distribution, supply, mining and generation. As foreseen with governmental plan, in the next period of time is expected the privatization of distribution and supply, while the same process expected to take place with the generation and mining [4].

Currently the main institutions in energy sector in Kosovo include Ministry of Energy and Mining (MEM), ERO and the Independent Commission for Mines and Minerals (ICMM). While the main energy enterprises include the KEK, KOSTT and district heating companies. Availability and supply customers with electricity last two years has been improving but still there are daily power cuts (at distribution) based on the plan "ABC", which are highlighted during the high consumption [5]. The actual domestic generation units can cover about 90-95% of the demand, while the remaining part is secured by very expensive electricity imports from the regional market, as presented in Fig.2 and application of load-shed plan [6]. During the high electricity demand season, the transmission and distribution network is characterized with the bottlenecks because of insufficient transforming and transmission capacities.

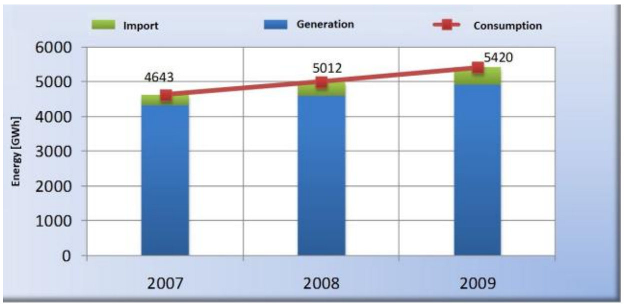

Fig. 2: Electricity generation and consumption 2007-2009

Selected extreme electricity daily load curves for the year 2006 are shown in Fig. 3. A small modulation during winter time, with a high load during night hours, which confirms that many residential customers, as in the past, use electric accumulating stoves which store the heat during the night and release it during the day. In summer curves are similar with lower values of loads [6].

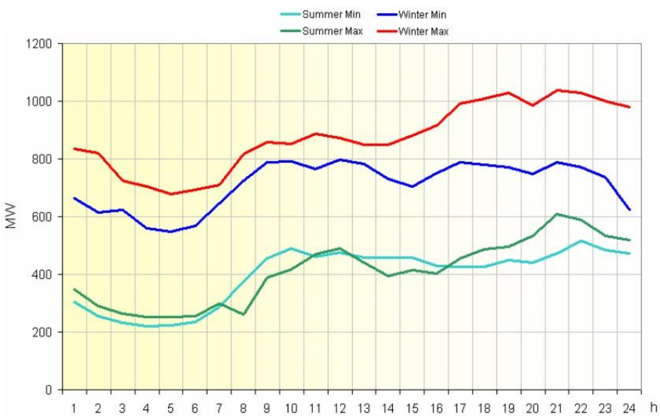

Fig. 3: Extreme daily load curves for year 2006

2.2 Renewable Energy Sources

Kosovo is a relatively rich country with RES, including the potential for biomass in form of wood, as well as water, solar energy, wind energy, biomass from waste, solid waste and geothermal energy. The prefeasibility study has been done for a part of energy hydro-potentials, and in 2008 assessment was done for solar energy, wind, biomass and geothermal energy potentials. It is also completed the identification and preliminary assessment of all small, yet important, hydro-power plants which are available for Kosovo. With the aim of promoting the use of RES, is contracted the implementation of projects for the use solar energy for heating of sanitary water in the University Clinical Center of Kosovo and in the Student Center in Prishtina.

Ministry of Energy and Mining published in year 2007 the indicative targets to be fulfilled by Renewable Energy Sources (RES) 2016. Based on these targets it would envisage that the share of RES production would reach 1 TWh (or 12% of total electricity consumption in Kosovo) in year 2020 [7]. For the implementation of these indicative targets, as presented in [7], the ERO has adopted the feed-in tariffs, an incentive schema for the generation of electricity from RES [8]. Feed-in tariffs should reflect possible electricity price increases, as result of inflation, or possible (but significant) impact of other relevant factors. Application of „feed-in" tariffs are usually accompanied with a suitable system of certification of the origin of electricity sold/purchased with these tariffs. It is important that „feed-in" tariffs are set so that they attract private investors, and for banks to fund RES investments. In EU countries, RES energy investors/purchasers are looking towards countries with the highest tariff rates. It is also important creation of the framework (as started in EU) for using the Photovoltaic Technology in combination with other renewable energies, as a suitable and cost effective option to provide sustainable access to electricity in the developing world and to help fight poverty and climate change. Stand-alone Photovoltaic systems have been confirmed as an appropriate option for bringing electricity to scattered households.

2.3 Demand forecast

Creating accurate computer based model for forecasting long term demand for electricity is essential in the processes of operation and power system planning. Proper forecast of demand helps in proper planning of local needs for developing new generation capacity and the development of transmission and distribution system. Accurate forecast of demand play a very important role for energy suppliers, various financial institutions and other stake holders in the electricity sector as transmission, generation, distribution and market. As such, the forecast of demand is seen by policy makers, Ministry of Energy, in the long term timeframe as very important indicator that reflects the impact and role of power in society. As stated in revised Energy Strategy of Kosovo, two most important indicators used in energy forecasts of any country are energy intensity and energy consumption per capita.

Energy intensity is a measure of the energy efficiency of a nation's economy and it is calculated as units of energy per unit of Gross Domestic Product (GDP) [4]. Three possible scenarios of the GDP growth rate till 2020 are supposed to be more realistic for planning the country economic development and forecasting the energy demand, as shown in Table 1.

Table 1: Growth scenarios of GDP in %

Annual growth (%)	GDP 2010-2014	GDP 2015-2020
Low	2.5%	2.5%
Medium	3.1%	3%
High	5.29%	5%

The medium demand scenario (MDS) for electricity forecast envisages a modest increase of electricity demand, especially in the household sector, whereas high increase of demand is projected for the services and industrial sectors. Based on the electricity consumption for the year 2009 as stated by ERO, which was 5272 GWh and it represents an increase of 6,7% compared to year 2008 [9]. If one continues to increase year electricity demand setting the year 2009 as reference year and increasing the demand for every upcoming year by values given in Table 1 the electricity demand in 2020 could be projected at 7,5 TWh, associated this with a peak load of 1543 MW in the power system, as presented in Fig. 4. The high demand scenario (HDS) envisages the demand of 8,4 TWh/year in 2020, with a peak load of 1671 MW, as presented in Fig. 4 [10].

Based on the revised Energy Strategy the supply of electricity during the period 2009–2018 will be achieved by domestic generation and imports which will be needed until around the mid of 2015.

Fig. 4: Forecasted electricity demand in Kosovo

Government of Kosovo plans in 2016 to have operational the first unit of new thermal power plant (New Kosovo Power Plant), Hydro power plant Zhur and several small hydro power plants and after this time imports will no longer be needed [4]. This electricity disbalance can be significantly reduced by using Renewable Energy Sources (RES) electricity since Kosovo is a relatively rich country with RES, as presented in [7].

2.4 Generation forecast

During the entire period 1999-2008, annual power generation in Kosovo from domestic sources has been below the demand level. The current level of annual domestic power generation is around 4300 – 4600 GWh. The forecast of power generation for the period 2009-2018 is based on generation of electricity from TPP Kosovo B, TPP Kosovo A, HPP Ujman, existing and new small HPPs, HPP Zhur and generation form TPP New Kosovo as stated in the “Kosovo Energy Strategy 2009-2018”[4].

Meeting of electricity demand is envisaged as follows:

(1) Power generation from TPP Kosova A, operating with A3, A4 and A5 units
(2) Power generation from TPP Kosova B, operating with B1 and B2 units.
(3) Power generation from Ujmani Hydro Power Plant (HPP), which with maintenance and rehabilitation could continue its commercial operations for a long-term period.
(4) Power generation from the small HPP (SHPP) of Lumbardh.
(5) Power generation from the Zhur Hydro Power Plant, expected to be constructed by 2015 and begin its commercial operation in 2016.
(6) Power generation from new units of TPP „New Kosovo”. Its first generation unit is expected to enter into commercial operation in 2016.
(7) During the period 2010-2018, more than 16 SHPPs will be developed, entering into operation with a total installed capacity of over 60 MW.

Electricity generation forecast is presented graphically in Fig. 5 [4].

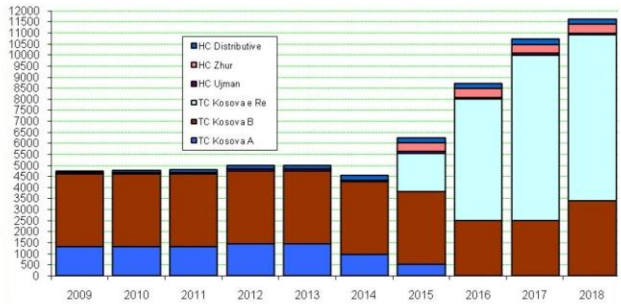

Fig. 5: Forecasted electricity generation in Kosovo

3 Electricity forecast web tool

The developed genuine application provides simulation of different scenarios for the electricity grid of Kosovo, that is comprised of seven regions, five interconnection lines, actual national energy generation capacities (Kosovo A and Kosovo B Thermo Power Plants, Hydro Power Plant of Ujman and distributed Hydro Power Plants) and generation capacities planned till 2018: New Kosovo Power Plant, Hydro Power Plant of Zhuri and the power from other sources (wind, solar, etc.). It serves as an important guide of energy consumption and generation capacities that Kosovo must develop in order to become independent from electricity import. A series of interviews with different stakeholders of energy sector was accomplished

before the user requirement specification document was generated, as recommended in [11].
Development of this electricity forecast web tool is accompanied with several challenges:

- Creation of a consistent model, easily scalable and dynamic,
- Abstraction of real objects, their physical attributes and functionalities into programmatic objects,
- Database modeling is based on document "*Energy Strategy of the Republic of Kosovo for the Period 2009 – 2018",* Ministry of Energy and Mining, Government of Kosovo,
- Dynamic graphical user interface that dynamically represents every simulation or change on the power grid.

3.1 Discrete modeling approach

This power grid simulator is an example of a discrete model simulator. Power grids are usually represented through continuous simulators, as presented at the power grid created at the University of Illinois [12]. The necessity for the discrete nature of this simulator is related to electricity forecast for Kosovo market for the period 2009-2018, it is meant that simulator should provide different scenarios (scenarios from the past, current and future dates within specified period of time) of the power grid with adequate discrete parameters' values, e.g. increasing/decreasing electricity demand in different regions, at a specific date within the specified time interval, 2009-2018. Every scenario is associated with realistic (probabilistic) power grid parameters' values, so we need to design a database model that stores these values, i.e. discrete values of power generation and consumption entities in a given scenario. These values are generated from statistical and forecast data provided by MEM.

Kirchhoff's Current Law (1) conception is used as a basic rule in the business logic of the application: "At any node (junction) in an electrical circuit, the sum of currents flowing into that node is equal to the sum of currents flowing out of that node".

$$\sum_{k=1}^{n} I_k = 0 \tag{1}$$

In (1), n – represents the total number of branches with currents flowing towards or away from the node and I_k – represents the current of branch k.
In the developed web application the Kirchhoff's Current Law is adapted as stated in (2):

$$Fpa + Fha + EI = 0 \tag{2}$$

where:

$$Fpa = \sum_{i=1}^{m} Fp_i \,,\ Fpa \geq 0 \tag{3}$$

$$Fha = \sum_{i=1}^{n} Fh_i \,,\ Fha \leq 0 \tag{4}$$

$$EI = \sum_{i=1}^{l} EI_i \tag{5}$$

Fpi – represents active capacity of power generation entity *i* in a given scenario,
Fhi – represents consumption demand of power consumption entity *i* in a given scenario,
EIi – exported/imported capacity from interconnect line *i* in a given scenario,
In (3), m – represents the total number of power generation entities in the power grid of Kosovo, in (4), n – represents the total number of power consumption entities in the power grid of Kosovo, and in (5), l – represents the total number of interconnect partners in the power grid of Kosovo. As *Fpa* represents generation entities its value may be greater or equal to zero, *Fha* represents consumption entities and its value may be lower or equal to zero. *EI* is greater than zero when country (Kosovo) exports energy, lower than zero when imports energy and equal to zero when it is equilibrated state.

3.2 Application architecture

The application is developed based on ASP.NET web technology, C# programming language. C# facilitates the creation of abstract data types through classes, which hides their implementation from clients. Object-oriented nature of ASP.NET brings power and ease of rapid development of web applications. Another feature ASP.NET brings the development with a compiled language, i.e. C# [13]. Application is modeled based on object oriented paradigm concepts. Software objects abstract the parts of objects in the real world that are relevant to the problem being solved. The model can then be implemented as software using a programming language. A software system implemented in this way tends to be more faithful to the real system, and it can be adopted more easily when the real system is changed [14]. In the Fig. 6 is presented the general architecture of the electricity forecast web tool software solution. The forecast web tool was developed with three tier architecture, whereby the

Microsoft SQL Server was used as database management system and Microsoft's Internet Information Service (IIS) as application server. The web communication is secured by the Secure Socket Layer (SSL) protocol. Similar project is described in [15], but the user interface is windows based and just for calculation of photovoltaic electricity injected into public energy grid. Implementation of object oriented paradigm conceptions in this project is reflected through data abstraction, classes' composition and modularity:

- Data abstraction – every generation entity (Thermo power plant, hydro power plant, interconnection partner, etc.) and every consumption entity (region) in the power grid is represented through class instances whose Properties and methods represent entities' physical attributes and functionalities (installed line capacity, neighbors, etc.).
- Classes' composition – is used in modeling the relationship between nodes in the power grid, where in the case of each specific node its neighbors are represented through a class member that is instance of another class representing neighbors attributes and functionalities,
- Modularity – is achieved organizing methods in functional modules.

In run-time a structure of class instances (objects) is created and instantiated dynamically, depending on data records read from the database. Database is built on Microsoft's SQL technology

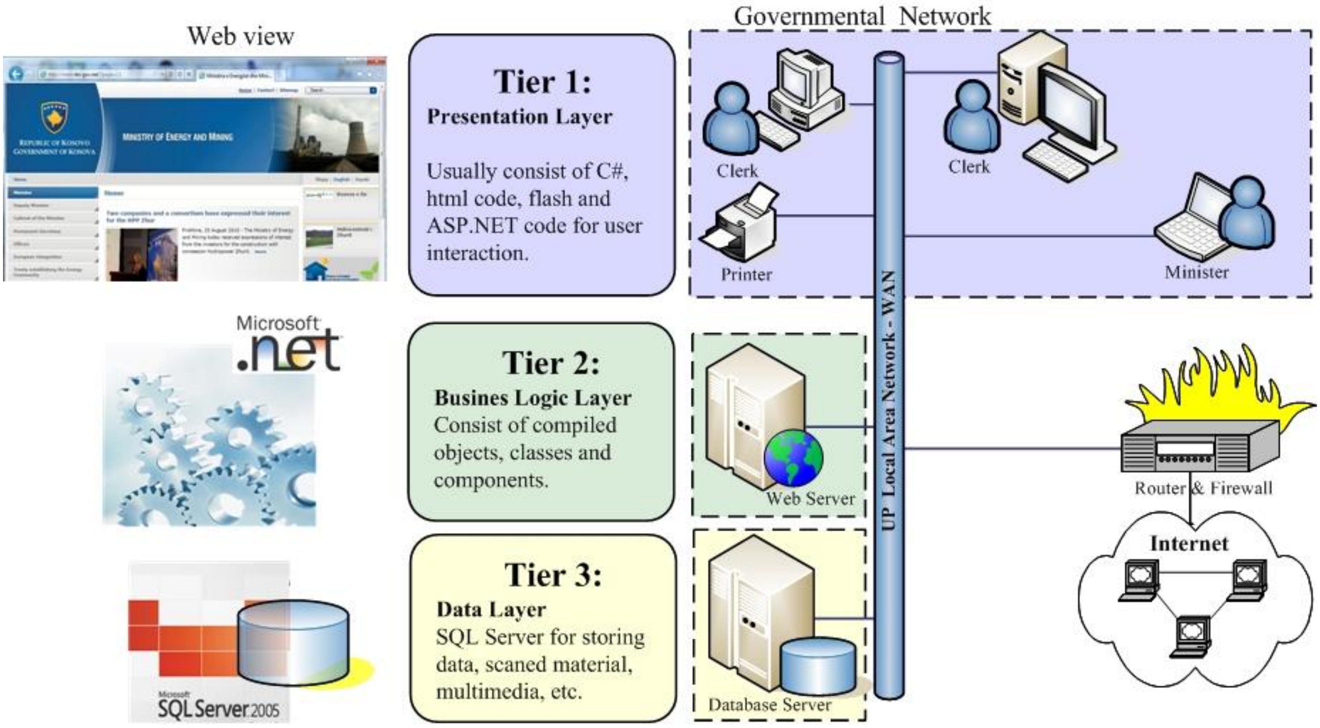

Fig. 6: General application architecture

3.3 Scalability of the application

Abstraction granularity of functional and graphical representation of the electricity forecast web tool is specified at the level of a region, i.e. a whole region is represented through a single programmatic object, its properties and behaviors are represented through object's properties and methods. According to potential interests of different stakeholders for the web tool, there might exist a need to have a simulator that represents a more detailed view of the national/regional electricity grid. In case of such situation scalability issue comes to the point. Object oriented nature of the web tool could resolve scalability issue in a very efficient and flexible manner, in this case through class inheritance. Abstraction of real objects in this project is achieved through a class "Nodes" (Albanian "Nyjet"), as is presented in Fig. 7. Facing a situation where addition of new physical entities with new attributes and functionalities is needed, i.e. regional power stations, etc., makes one to think of class inheritance implementation. Class "Nodes" will become base class for new derived class supplying it with existing properties, data and behaviors. The new derived class, besides inherited members, will implement new physical features and functionality through new class members. In case of addition of limited number of new features to the existing physical entities scalability might consist on addition of new members to the existing class structure, only "The data requirements for simulator models increase as model complexity increases. Models with a broad scope require more types of data. In contrast, models that offer greater granularity require a deeper level of data" [16].

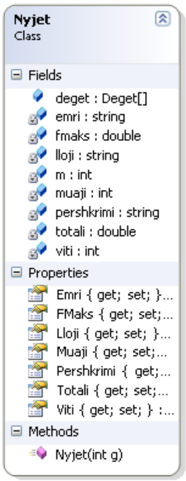

Fig. 7: Node class structure

Data representation granularity, i.e. electricity generation capacities, demand and consume at any specific moment of the time within 2009 - 2020, in this web tool is specified at the month level, and average monthly peak-time conditions are taken into account as representative data for the specified month. This means that for a specific month, any date of this month we choose arbitrarily, we gain in the simulator the same data results and same graphical and functional representation. As peak-time reflects extreme working conditions of electricity grid at a specific moment we are sure that web tool is capable of providing any real scenario of the grid.

In order to increase data representation granularity we should enrich the database with more detailed structure of data that represents daily electricity generation capacities, demand and consume. In such a case more analyses and more frequent power grid parameters sampling must be achieved. The database modification would not impact business logic of the forecast web tool in any way.

3.4 Using SQL server

The web tool database is built on Microsoft's SQL technology. The structure of the database is depicted in Fig. 8.

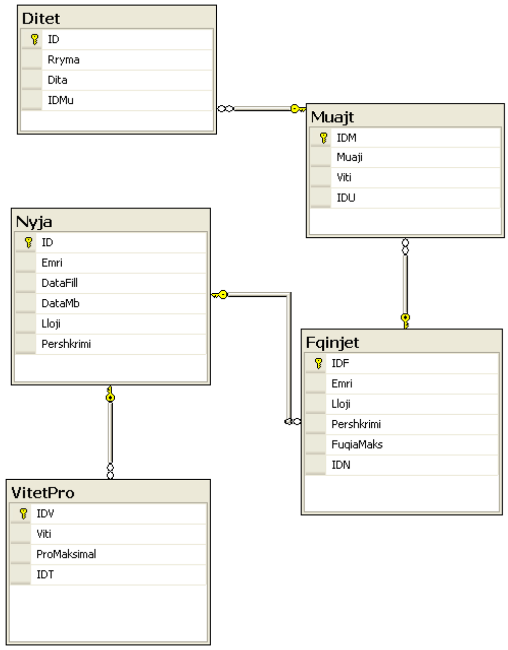

Fig. 8: Database structure

The database design and population is based on data provided by document "Energy Strategy of the Republic of Kosovo for the Period 2009 – 2018". As stated earlier that data representation granularity in this simulator is specified at the month level. In order to increase data representation granularity, i.e. increase granularity at the day level, we need to expand the database structure and involve daily sampling of power grid parameters at the peak-time. The table "Muajt" (eng. Months) contained a field "Rryma" (eng. Current) which represents average monthly peak-time conditions of installed power capacity at the specified year. The table "Ditet" (eng. Days) the field "Rryma" is transferred to the table "Ditet" and now it (field "Rryma") represents daily peak-time conditions of installed power capacity and the overall data representation granularity now is increased at the day level.

3.5 Graphical user interface

Graphical User Interface (GUI) represents the map of Kosovo (divided into regions), its associated electricity grid with generation and consumption entities, and interconnection partners. GUI is comprised of different web controls: images, image buttons, date-picker, etc. The electricity grid is represented as GIF images, as depicted in Fig. 9.

Appearance of interface elements depends on the data for every scenario and represents different conditions of the network, i.e. colors of power lines (blue, yellow or red) present load, transparency of a specific region presents relation between consumption demand and energy supply (a region in black color means that region is faced with a electricity blackout), transparency of smoke presents the level of pollution, etc. Programmatically this is achieved manipulating graphic objects' attributes through C#. Values of the attributes represent specific electricity grid conditions. This electricity forecast web tool is used by a variety of stakeholders including utilities, policymakers, and researchers. Utilities use models to plan long-term expansion projects, formulate short-term operating strategies, and manage real-time operations. Policymakers are interested in examining possible effects of proposed policies prior to their implementation. Academic and industry researchers seek to improve modeling techniques, achieve faster solutions, and enhance result visualizations [16].

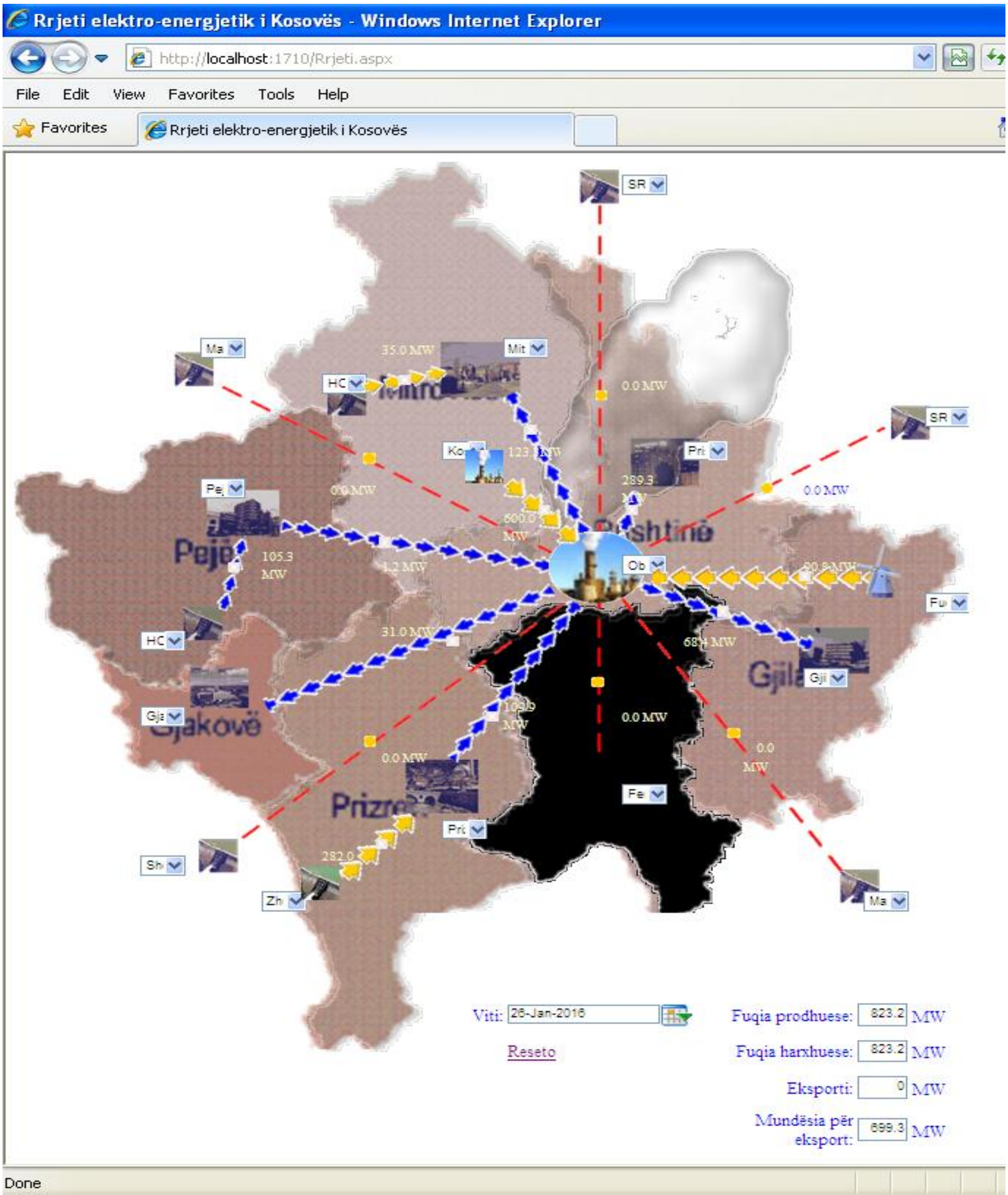

Fig. 9: Electricity forecast web tool GUI

3.6 Testing boundary conditions

Electricity forecast web tool may serve variety of stakeholders and purposes. Fulfillment of electricity demands and needs is an important factor for consistent economic development for every country. Renewable Energy Sources of electricity and fulfillment of relevant standards related with it is other important issue. Web simulator might serve as a very useful tool to simulate different scenarios as regards boundary conditions in relation: electricity consumption – production.

As it can be read from the electricity forecast web tool, the actual value in November 2010, the Kosovo electricity demand at peak-time is 774.2 MW of installed capacity, as is presented in Fig. 10.

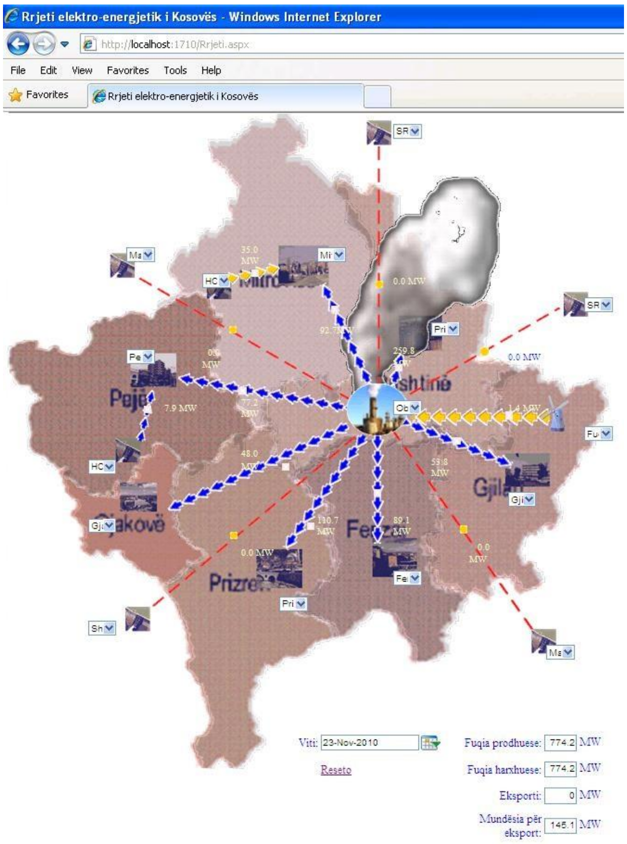

Fig. 10: Cuntry current electrticity consumption

Even though the total effective installed capacity of electricity in the country figures to be 919.3 MW because of the poor availability of thermal power plants (especially thermal power plant Kosovo A) it doesn’t fulfill the electricity demand and therefore Kosovo still needs to import electricity. Currently from the overall installed capacity of electricity 95.18% comes from thermal power plants and the rest comes from renewable energy sources.

In 2016, after New Kosovo Power Plant will begin to work at installed capacity of 600 MW, the total effective installed capacity of electricity will be about 1600 MW and electricity demand will reach 1013.7 MW, 68.58% of electricity will be generated by thermal power plants and the rest by renewable energy sources. The availability of thermo power plants (Kosovo B thermo plant still not with the best availability) will improve and Kosovo will become capable to export electricity, as is presented in Fig. 11. Obviously, New Kosovo Power Plant will carry the main burden of power supply and without it, regardless increase of renewable energy sources, Kosovo would still need to import electricity

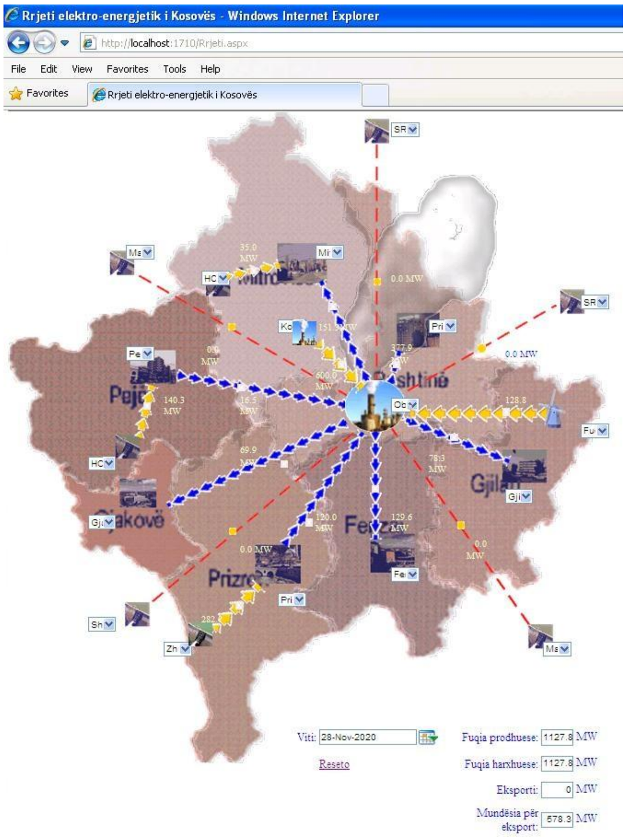

Fig. 11: Country electricity consumption in 2020

4 Conclusion

Electricity web tool represents successfully energy demands in the country and generation capacities that a country or region must develop in order to become independent from energy import. It can be considered an aggregated simulator as it provides a high level data abstraction of the real state of the electricity grid. It cannot serve as an appropriate electricity grid management tool, i.e. a consumption entity (region) is represented through one class instance. The object oriented model provides it to easily be expanded with new objects, attributes and extra functionality, thus, simulator may become more powerful and represent more detailed information about the national/regional electricity grid, i.e. regions' power stations and their attributes and functionalities can be added to the simulator. In order to have more realistic electricity system simulation model, sometimes, other facts, like technical and commercial electricity losses, besides energy consumption and generation capacities must be taken into account in the simulator data model. As electricity grid simulator is used by a variety of stakeholders it deserves more detailed study and versatile modeling approach. It shall server as unique tool for governmental decision makers and to contribute inputs to future policy and management decision-making in the energy sector.

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