Visualization of the Renewable Energy Resources

Ravil Muhamedyev[1,3], Sophia Kiseleva[2], Viktors I. Gopejenko[3(✉)], Yedilkhan Amirgaliyev[1,4], Elena Muhamedyeva[1], Aleksejs V. Gopejenko[5], and Farida Abdoldina[6]

[1] Institute of Information and Computational Technologies, Almaty 050010, Kazakhstan
ravil.muhamedyev@gmail.com
[2] Moscow State University, Moscow 119991, Russia
[3] ISMA University, Riga, 1019, Latvia
viktors.gopejenko@isma.lv
[4] Suleyman Demirel University, Kaskelen 040900, Kazakhstan
[5] Institute of Solid Sate Physics, University of Latvia, Riga, 1063, Latvia
[6] Kazakh National Research Technical University, Almaty 050013, Kazakhstan

Abstract. The methods of the renewable energy resources visualization are analysed in this work, the examples of the systems and possible architecture of the renewable energy monitoring systems of the Republic of Kazakhstan are considered. Successful practices are analysed, the leading scientific organization in the field of green energy are considered, a comparative analysis of geographic information systems and data sources in the field of green energy is performed. Possible software architecture of the system based on 3M paradigm of geographic information system (multilayer views, multilayer architecture and multi-agent interaction) is considered.

Keywords: Visualization · Renewable energy sources (RES) · Geographic information system (GIS) · Taxonomy · Information and communication technologies · Scientometrics

1 Introduction

The technologies of the energy production from RES have been actively developed in the recent years and in the long term they are going to significantly reduce the usage of non-renewable resources (such as oil, gas, coal, peat), to improve the ecological indicators of the energy production systems and living areas, reduce the energy production costs, increase the autonomy of the life support systems and the country's energy security. By the year 2050 the share of extracted sources will slightly exceed 40 % of the global energy producing [1].

The problems of the Republic of Kazakhstan are related to the depreciation and wearing of the equipment, dependence on electricity supply from nearby countries and low efficiency of energy usage require the establishment of a monitoring system of energy security of different regions and the country as a whole [2].

At the same time prospects of RES (primarily solar, wind and geothermal plants) are very high. Evaluation of technical and economic efficiency of new technologies

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requires special approaches that are yet to be developed for the conditions of the Republic of Kazakhstan.

Modern information and communication technologies provide wide spectrum of approaches to solve the tasks estimation, monitoring and visualization of heterogeneous energy sources and storage systems [3].

Wireless sensor networks, inter-machine communication system (Machine-to-Machine - M2 M), developing a promising direction of the Internet of Things [3, 4] and broadband networks based on new communication protocols will become the technological basis for such systems. Combining disparate technologies within smart grids presents strong interest for researchers both in terms of system architecture, economic indicators [5], security [6, 7] and visualization [8].

These new technologies are characterized by considerable interosculation and intercommunication that is possible to present as semantic network [9]. Participation of Kazakh researchers in the domain of the global research cooperation has a good perspective.

The key element of the presented taxonomy is the visualization domain, which offers a wide range of methods, technologies and software. Visualization of the complex processes is one of the most important ways of aggregating multidimensional and heterogeneous information. Correct visualization and aggregation of the information facilitates the decision-making process. In this case, the construction of the RES monitoring system of the Republic of Kazakhstan is based on the GIS that are complemented by an appropriate functionality, allowing evaluating the possibilities of the new energy technologies application in different areas, the risks, economic costs, environmental impacts, etc. Combining heterogeneous technologies into a single system is of a significant interest to researchers in terms of both hardware and software architecture and impact on the region's economic performance. One of the components in the system is decision support system, which contains the visualization unit. Visualization methods and general architecture of the system are the subject of this paper.

2 Renewable Energy Sources and Their Visualization

Usage of RES is a modern powerful trend in energy development. "Green energy" technologies (i.e. the technologies of gathering energy from the renewable sources) are actively developed and will allow to significantly reduce the usage of non-renewable resources (such as oil, gas, coal, peat, etc.), to improve the ecology around the populated areas, to reduce the cost of obtaining energy in some cases, to increase the autonomy of life support systems and energy security of the country in the future.

At the same time, there is no reasonable alternative to the development of the renewable energy sources and energy efficiency according to the experts as decarbonization of the energy sector will allow to avoid the catastrophic consequences of global warming. In the best case scenario of the development it is planned to reduce the demand for oil (by 30 %), coal and gas with the overall growth of energy supply by 60 %. By the year 2050 the share of use of fossil fuels will slightly exceed 40 % of the total energy.

According to the expert calculations the potential of the renewable energy sources in the Republic of Kazakhstan exceeds one trillion kWh yearly, of which less than 0.1 % are used (as mentioned below). The use of RES is associated with a certain complexity due to the dependence of the systems performance from random natural factors.

RES usage allows improving the national energy system and is an important Successful examples of systems and portals in domain of RES.

Let us note that the idea of renewable energy source monitoring using GIS is not new. Such systems have a social and industrial demand. These systems are developed in Russia, in the United States, and in other countries. The systems include data for resource assessment of RES, technical specifications of installations, economic and social preconditions, and nature preservation aspects. They are divided into local, regional, national, and global.

There are currently no analogues to foreign Renewable Energy GIS in the Republic of Kazakhstan. Unlike Russia, where there are GIS projects on water resources for individual areas, an atlas of solar energy resources and a climatic database, as well as a portal for RES, the information base for the Republic of Kazakhstan is presented poorly. There is a wind atlas [10], however other RES are apparently not represented in the form of web resources.

3 Data Sources

Energy resources monitoring tasks imply collecting data from different sources. Weather stations, autonomous sensors, remote sensing data, surface images from satellites, results of mathematical modelling can serve as the data sources for the parameters of the environment. Besides crowd source data-mining gradually becomes of more importance. SETI@home, Galaxy Zoo, Citizen Weather Observer Program (CWOP) serve as the examples of such projects. E.g. OpenWeatherMap project uses the data from private weather stations in order to improve the accuracy of the weather forecasts as the number of measuring points is more important in predicting than the accuracy of the measurements.

The problem of collecting data for the territory of the Republic of Kazakhstan is quite actual as data itself is not sufficient for full-scale analysis. E.g. in order to assess the energy potential of wind and solar energy it is necessary to get the data about the weather conditions on the territory of the whole country with the best possible resolution in the first place. This data should also contain information about time, the force of wind, illumination and temperature affect the performance of energy plants of the given type directly. In order to assess the parameters, the weather stations are placed on the territory of interest.

However, according to the NASA Global Surface Summary of Day (GSOD) data for the year 2015 the territories of the Republic of Kazakhstan covered by the World Meteorological Organization (WMO) are about 1 km^2 for each 7590 km^2. This cannot even be compared with the coverages in Europe and in the USA and does not allow assessing the weather conditions accurately enough. The presence of a large number of the weather stations should allow improving the weather forecasting models assessing the energy potential more precisely.

Currently, the data provided by numerous subsidiaries of NASA and NOAA are of the highest interest. This data is mostly received from the remote probing of the surface. NCDC (National Climatic Data Center) stands out of these organisations as they offer a possibility to order the data in a certified printed form, so in this case the authenticity is guaranteed.

In addition to the text and numerical information, spatial data may be stored in the form of maps (layers of maps). There is a significant amount of map sources on different subjects. Lately, online map suppliers such as OpenStreetMap (OSM), OpenWeatherMap (OWM) mentioned above, Google Maps etc. are becoming popular.

In order to use the data sources mentioned above their consolidation and subsequent processing depending on the RES domain is required (Fig. 1).

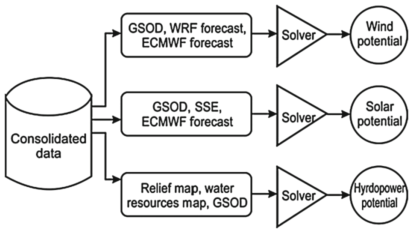

Fig. 1. Data consolidation usage scheme in different domains of green energy

The main problem of the data consolidation is the absence of the unified information exchange standard regarding the parameters of the environment including the climate data. Taking this into account one is forced to work with heterogeneous data sources as well as with the different data formats. Semi-automated data pre-processing, their conversion to the required format and subsequent usage is a typical practice. Even if it is possible to automate the process of the data acquisition (using client web-services, FTP loaders etc.), the process of the data conversion to the universal format requires expenses both for the development of such format and for the resources for the conversion itself. The creation of such system requires the development of:

- The mechanisms of the data input (separate for each type of the source);
- The data update planner (in order to identify outdated data and to launch the whole ETL process for the source);
- The converter for each type of the data sources.

4 System Architecture

To create the architecture for the system that ensures the acquisition and processing of large volumes of heterogeneous data in real time, additional research is required.

Currently, there are yet no standardized methods and systems to provide representation of large heterogeneous data sources, resources, analysis and reporting within the multilayer intelligent GIS (MLGIS) (Fig. 2).

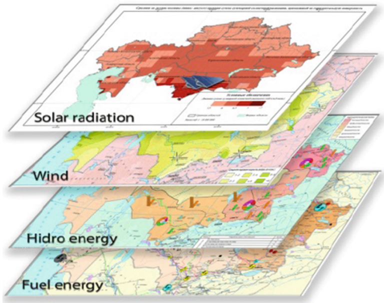

Fig. 2. Some layers of MIGIS

Such system should provide: the choice of an energy production technology platform; evaluation of the economic feasibility of the new technological schemes for energy production; assessment of the accompanying risks; environmental impacts of the transition to the new energy sources; assessment of the possibilities of transition to the intelligent systems of the redistribution and energy storage, etc. Basic layers of MLGIS are:

- Energy sources
- Maps
- Energy consumers
- Energy transport system
- Energy gathering systems
- Energy storage systems
- Ecological condition, caused harm and dangers
- Economic evaluations
- Data protection

By the principles of its operations the planned system is different because of the spatial distribution, large volume of data, and asynchronous work of its components. For the systems design and implementation, the 3M paradigm is proposed: multilayer views, multilayer architecture, multi-agent interaction.

Multilayer system architecture can be illustrated by Fig. 3.

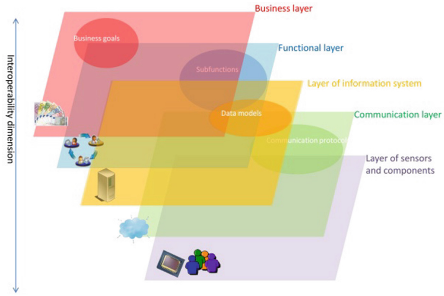

Fig. 3. Multilayer system architecture

It is proposed to develop and implement a prototype system providing a layered view of monitoring data and other graphical data (with different levels of detail and zoom) within this paradigm. Implementation of the system architecture is also contemplated to be multi-layered. This meets the modern approaches in software engineers on the construction of such systems [10]. Asynchronous communication of the system components is presumed to be provided by using the multi-agent approach, which has a number of successful applications, including at the micro level in the monitoring of the wind turbines.

The proposed goal and objectives are not only regional, but also have a general application. When implementing the system, there is a need to find approaches to solve scientific problems that are important in a number of areas of the study in the scientific schools of Europe, Russia and the United States.

These include monitoring resources on a national scale, the development of multi-agent intelligent system architecture, design and/or testing of methods for collecting and processing large amounts of heterogeneous data, the formation of methods to ensure the adaptability of the system to the new communication technologies, providing visualization of large data in the knowledge domain, information security, development of methods of economic analysis of the use of new technologies.

One of the possible prototype described in [11] presents an approach to the creation of the web-based system based on the cloud platform for the integration of the heterogeneous spatial information for the environmental monitoring coal mines. It should be noted that due to a large extent on the territories, point forms of measurements, significant delay of the event registration, and the lack of a unified picture of the environment, the assessment of the environmental status does not provide satisfactory results. It is proposed to use cloud technology in order to deal with the challenges of distributed data processing. The following components are involved in the system: cloud service Google App Engine, authentication service Google Users API, the mapping service Google Map API, database management system PostgreSQL. The data is collected using crowd sourcing methods. Authors are supposed to collect technological data, spatial ecological data, data continuously updated by remote sensing (radar and hyper spectral pictures). Analytical processing can be built using the data from the other sources (such as meta descriptions and cloud services). Computational module is formed as a tree. Computational steps are performed during the “motion” on this tree.

Summing all up we can derive a stack of technologies which can make it possible to build own GIS-based decision support system in RES domain. Current vision of the technologies stack is as follows:

- Map server - Google maps;
- Front-end - Play framework (Java, HTML5, Javascript), JQuery; Javascript mapping libraries;
- Middleware - Akka (Java, distributed asynchronous business logic, actors model), Apache Spark (in-memory data processing;
- Back-end - PostGIS databases (on top of PostgreSQL).

Current technologies stack has been chosen for multiple reasons. Firstly, there are no such systems implemented yet.

Secondly, it is planned to use modern approaches for data collecting including crowd sourcing and web services. Another reason is the requirement for the modularity. In order to provide flexibility and extendibility it is better to break unnecessary dependencies between different layers and modules. So, it is planned to implement the frontend using Play framework. It is a modern web MVC framework, which supports Java and SCADA.

This tool can save the developers a lot of time. Applications written using Play can be easily deployed.

The proposed middleware technologies are suitable for building asynchronous, distributed applications with the ability to scale in the future. The major part of the business logic is planned to be implemented using Akka, which is well suited for building asynchronous applications. This will break the dependency between frontend and backend, and so going to make it possible to parallelize the tasks. During the early stages of the project only Play framework will be used, however later with the growth of the functionality it will be better to implement business logic in middleware.

Data layer (which is situated on both the backend and middleware levels) consists of Apache Spark for fast in-memory data processing, for example, for real-time analysis tasks. Persistence will be implemented basing on the PostgreSQL RDBMS. RDBMS is free and it offers a powerful set of extensions for working with spatial data structures (Post GIS extension). PostgreSQL is also able to connect to different data sources and web services to easily import data from them using foreign data wrappers, i.e. another set of extensions. Google maps can be used in order to display spatial data on the map. It provides rich mapping and visualization functionality, good resolution and well documented Java script API.

On the bottom level we have multiple PostgreSQL databases for data storage, data collecting from different sources, PostGIS database for storing operational spatial data (Fig. 4).

On the upper level the data analysis will be implemented using Spark for the fast in-memory analysis tasks and Akka for the rest of the business logic. Frontend servers will run Play based web application that will be loosely connected with the middleware. Finally, JavaScript-based mapping will reside on the client side.

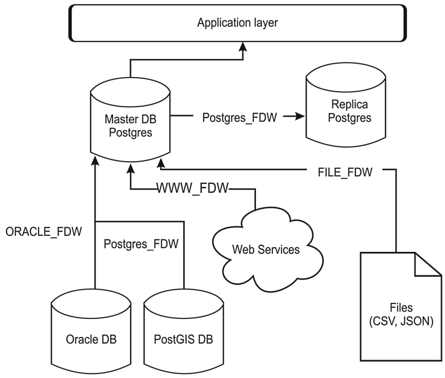

Fig. 4. The realisation of the heterogeneous data sources' connection to PostgreSQL

5 Conclusion

Approaches for the realisation of the RES monitoring system in the Republic of Kazakhstan were considered. The main attention was paid to the visualization data methods and to the architecture of the system. To fulfil this task, the visualization technologies, GIS, information technologies stacks were considered.

Monitoring of the country's resources status allows making the informed decisions in the field of government regulation and the sustainable and safe development of the territory. To develop such system a complex application of some modern concepts and information technologies is required (cloud computing, big and heterogeneous data, machine learning, next generation of communication protocols and other).

Renewable energy resources in the Republic of Kazakhstan are quite high. The accurate assessment of the potential and data aggregation in the easily perceived form facilitates the formation of the solution for their application. Currently, the search for the best methods of the data transformation of the energy systems basing on RES is being performed.

For the decisions on the use of the various mechanisms of the state regulation in the transition to the RES and the use of other useful resources a decision support system at national and regional levels is necessary.

This problem is actual in many countries, which develop the national systems as well as participate in the work of the supranational organizations.

Some successful examples of the monitoring systems are discussed above. These realisations show us several ways to construct the system architecture and to integrate different technologies.

The new system should provide:

- Monitoring of energy sources and delivery systems
- Evaluation of the economic feasibility of the new technological schemes for the energy production

- Assessment of the associated risks, including environmental impacts of the transition to the new energy sources
- The choice of the technology platform for the energy production
- Assessment of the transition to the intelligent systems of the redistribution and energy storage (Smart grids)

Such an intelligent system can become the basis of the next generation of the electronic government (intellectual e-government or smart-government) where, along with the provision of the information services to the public, the systems for the analysis and visualization of the multidimensional data and decision support will appear.

One of the main problems that apply to the conditions of the Republic of Kazakhstan is the low quantity of the data sources, especially the local ones. Nevertheless, it is possible to use the remote probe and global meteorological data for the initial assessment of the resources.

In order to implement the system, it is necessary to solve some important problems related to the detailed system architecture, services, data collection, integration and processing, functionality provided to users, aggregation of the heterogeneous data and the methods of their storage.

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