SAVE – State of the Art and Visionary Energetics

R. KASPRZYK, M. CIEŚLEWICZ, K. KRAJEWSKI, M. PERKA, A. STACHURSKI
rkasprzyk@wat.edu.pl

Institute of Computer and Information Systems
Faculty of Cybernetics, Military University of Technology
Kaliskiego Str. 2, 00-908 Warsaw

The paper focuses on the attempt to improve the process of modeling the electrical grid infrastructure, designed within project SAVE (*State of the Art and Visionary Energetics*). The system, which is a response to a still increasing demand for electricity, will enable optimizing and planning the development of the existing energy transmission grid on the basis of the Smart Grid concept. Such an approach may support the process of setting up new companies interested in building renewable power plants and will encourage potential ”prosumers” to share their surplus of energy. SAVE may also show how to wisely use the energy and how expensive energy wasting can be.

Keywords: energetics, grid, network system, optimization.

1. Introduction

Every day we use many appliances powered by electricity. These are everywhere, designed to support our daily duties and to provide various forms of entertainment. Besides, most of the produced electricity is consumed by modern sectors of industry. This proves that our civilization, high standard of living and economic development is heavily dependent on energy.

According to recent surveys, the demand for electricity is still increasing. It is expected that energy consumption only in the EU will grow up by 15% in the next ten years. Even though the waste of electricity during its transmission is inevitable, for many countries around the world this becomes a huge national problem. It is estimated that Poland wastes about 12% of the produced electricity (about a half more than average in EU) [4], which, apart from a significant economic loss, seriously affects our natural environment. To avoid it we should pay attention to the technical conditions of the electrical grid infrastructure. Experts have also estimated, that between 71% and 90% of the existing energy transmission lines should be replaced in Poland [4], otherwise we will suffer a sharp increase in energy prices.

Another key issue, associated with the use of energy, is the emission of greenhouse gases into the atmosphere. The reason is that energy production in many countries is dependent on fossil fuels [1]. Global trends, however, seek to overcome this conventional approach because it has bad influence on the environment and leads to climate changes. To achieve this, we must replace traditional energy production with CO_2 – free sources or optimize the existing electricity infrastructure. At the same time, increased popularity and lower costs of building renewable power generators begin to encourage individuals to produce their own energy. However, it is very expensive to store the energy and the way of its generating from natural resources is strongly dependent on climate conditions (wind, sunlight etc.). As a result, it may be difficult to precisely estimate the amount of produced energy.

The main goal of the paper is to propose a solution showing a possible way of managing and developing optimal infrastructure of the electrical grid, called SAVE.

2. The SAVE project

The main idea of SAVE (*State of the Art and Visionary Energetics*) is to design an efficient power distribution infrastructure enabling to simulate its real features. It seems to be an innovative approach because at the moment there is no system working in a Smart Grid technology dedicated for commercial use [3]. SAVE boosts a great chance to promote the idea of ”the prosumer” [2]. In order to conduct the project, we solved a series of optimization problems attached to electrical grids. These included minimization of transmission losses for the existing grid infrastructure as well as increasing the security of the whole power system. Relying on latest scientific researches, SAVE performs the analysis of the complex networks topology, exploring its key characteristics.

Moreover, within a Smart Grid every consumer of energy can become a producer through the spread of renewable energy sources. In this case SAVE may answer a question of the location of new power generators and energy distribution to make the grid most secure and efficient. As a result, SAVE may affect the environment by reducing energy losses and hence reducing the amount of CO_2 from fossil fuels combustion. In the long term this may lower energy prices and also increase the reliability of the grid.

The system's performance can be regarded as effective because, with relatively small expenses, it may bring rational benefits resulting from the reduction of energy loss and the optimal expansion of the existing grid.

3. SAVE's architecture and used technologies

The SAVE system is a web application working in an n-tier architecture which provides a high level of scalability and extensibility for the system. It is divided into following tiers (Figure 1):

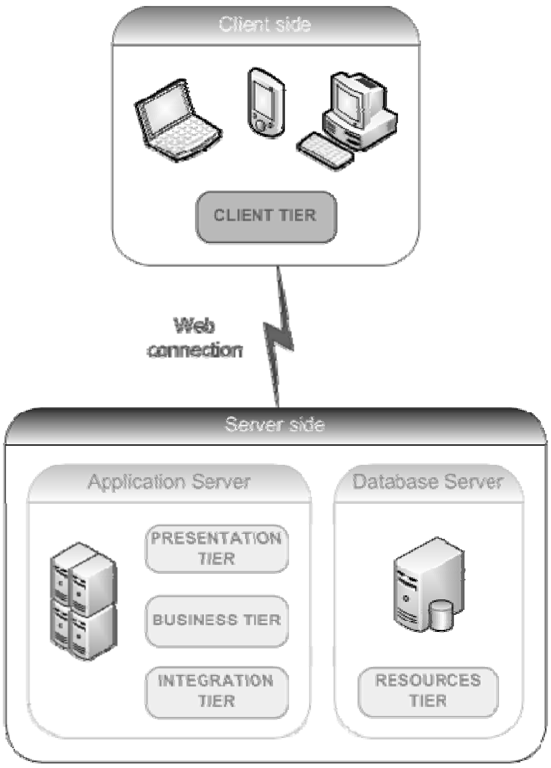

Fig. 1. Architecture overview

- **Client tier** – to enable the user to interact with software (via a web browser)
- **Presentation tier** – designed to generate a user-friendly GUI
- **Logic tier** – responsible for data processing; contains implementation of the algorithms
- **Integration tier** – tasked to separate data processing from data storage
- **Resources tier** – to collect and store data.

The SAVE system consists of three independent modules listed below:

- **Optimization module** (using API and QuickGraph algorithms for deep analysis of network systems)
- **Communication module** for ”prosumers” (using the existing social networking API)
- **Educational module**.

QuickGraph is a portable library, suitable for .Net, Silverlight and Windows Phone environments. It provides commonly used directed and undirected graph data structures and a variety of network algorithms such as depth first search, breath first search, A* search, shortest path etc.

Within the SAVE system, the *QuickGraph* library is mainly used to evaluate the most crucial characteristics, for example the shortest path or maximum flow [5]. It has also been extended by algorithms that enable centrality measures calculation.

In order to create our project we have also used *Prefuse*, that is a set of software tools for creating rich interactive data visualization. *Prefuse* supports an extensive collection of features for data modelling, visualization and interaction. It provides optimized data structures for tables, graphs, and trees, visual encoding techniques, support for animation and database connectivity [6]. *Prefuse* is originally written in Java, therefore it was necessary to rewrite the source code for the .NET platform.

In the SAVE system, *Prefuse* is responsible for visualization of the created network topology or one that was read from the *GraphML* file format. In addition, the edges of the graph are described, showing key characteristics of the grid (capacity, cost of lines or energy loss during its transmission).

There is a built-in communication channel between *Prefuse* and *QuickGraph* for transferring data. All in all, *Quickgraph* performs all of the operations, while algorithmic and calculated results are illustrated by *Prefuse*.

Figure 2 presents a packet-based structure of tiers and layers which shows what technologies were used to perform the created functionalities of the SAVE system.

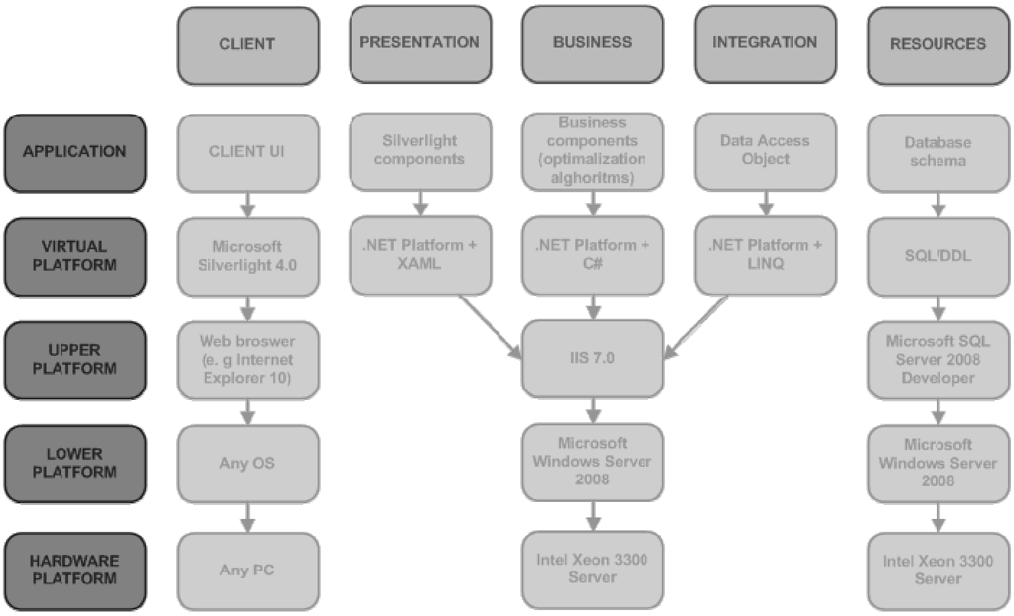

Fig. 2. Packet-based structure of layers

4. Graphical user interface

The intuitive interface allows the user to model the structure of any electrical grid. With the use of the editor, the system enables entering the graph nodes: energy producers (power plants), transformers and end-users, combining them with the edges. In addition, users can add parameters to each edge determining the amount of power production, capacity, the cost of energy transmission, energy loss, maximum load and energy consumption (Figure 3).

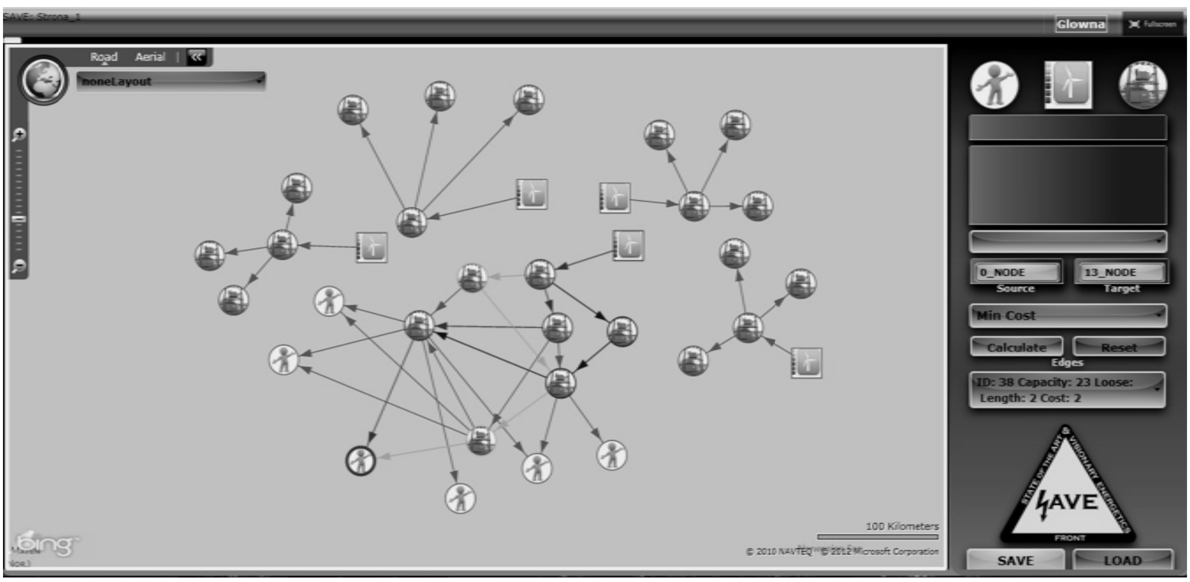

Fig. 3. GUI overview

We have also considered terrain conditions, while building the grid infrastructure. In order to tackle it, we used background maps provided by *Bing* (shown in Figure 4).

After building a dedicated network it is possible to simulate its real features, evaluate the maximum flow, the minimum cost flow, the minimum cost fixed flow in the proposed grid. This is extremely useful when upgrading the existing grid or comparing new building solutions.

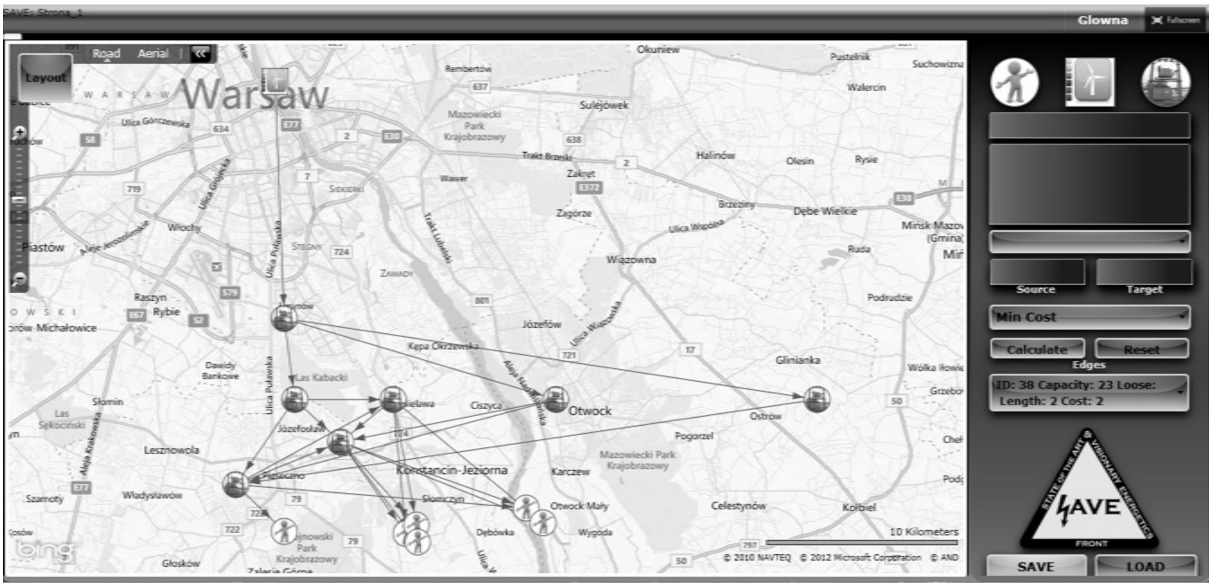

Fig. 4. SAVE System with background map

5. Scenarios

When the grid manager plans to modify its infrastructure, it has to be decided what to do to achieve a significant improvement at a minimum cost. Figure 5 presents a use-case diagram of the system SAVE.

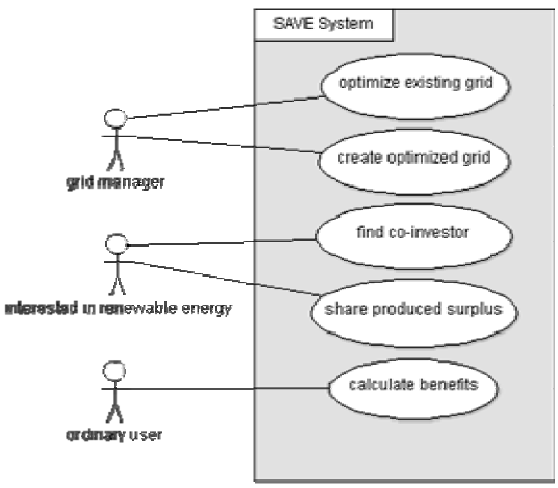

Fig. 5. SAVE use cases

SAVE is a well-developed tool used to build a model of the grid topology. Our system allows to perform a deep analysis of the examined grid, supported by graph theory algorithms, showing exactly its vulnerabilities and bad behaviors. SAVE may answer the question of how to expand the grid, indicating the potential location of new power stations and storage batteries where the transmission losses would be at their lowest.

Apart from that, building renewable power generators for personal use requires a variety of resources such as the appropriate location, money and knowledge. Without any of those, we are doomed to failure. To prevent it, SAVE offers a communication platform that helps to find a co-investor who might provide the missing resources. With this platform, it is possible to easily share or sell the produced surplus of energy.

These days, in fact, an ordinary person cannot even imagine how strong the competition among manufacturers can be, while building energy-efficient and eco-friendly appliances. There is a rich variety of electrical equipment to choose, at different prices, so we included a graphic energy calculator, which shows how long it will take to receive money spent on buying new appliances and then make it profitable, by saving the energy.

6. Development opportunities

Due to a total lack of systems working in the Smart Grid technology SAVE is an innovative solution. It is designed for a wide range of clients including companies from the energy industry, green organizations and individuals. The target customer group is dependent on the dedicated functional module.

The SAVE system is able to reduce financial losses associated with electricity transmission waste and plan the optimum expansion of the existing grid infrastructure. This approach may support the process of setting up new companies interested in building renewable power plants and will encourage ”prosumers” to share their surplus of energy.

Capital resources for further development of the project will be provided by academic grants and partly by a company responsible for distributing energy. Clients will be supplied with software in two separate ways. Currently, it is possible to implement the system directly on their PCs, however, in the near future SAVE will be spread within a Windows Azure cloud.

At present, the SAVE project is in the final stage of prototype development (Technology Readiness Level 6). In the near future we plan to enter cooperation with a company responsible for distributing energy. We count on a fruitful cooperation in a win-win environment: the company receives free-of-charge a prototype of our system, while SAVE developers get valuable feedback on important changes and new functional modules needed.

Currently, the SAVE optimization module performs simulation on the segment of the grid topology, however, it will be dedicated for a larger area. This will result in a significant increase in the need for computing power. Therefore, we plan to use cloud computing models (Windows Azure) for further calculations.

It is also planned to extend the educational module with a strategy game, showing overall benefits derived from wise use of energy. This will also prove an overwhelming advantage of renewable energy resources over conventional ones for the environment in the future.

7. Summary

As we can see, a still increasing demand for electricity determines not only the production growth, but also enforces the search for new and more effective solutions enabling to save it. Currently a large amount of energy is wasted during its transmission from the power plant to the end user. Of course, it is not possible to completely eliminate the problem, however, system that was described in the article is an attempt to make energy system more economical and efficient. It was developed on the basis of the SMART GRID concept and the theory of graphs and networks. With the use of optimization complex algorithms the system allows to assess energy transmission losses and additionally, proposes a sensible and planned energy production process, including the prosumer market share. This solution will certainly help to reduce energy costs and the energy from the alternative sources would become more environmentally friendly. Moreover, a well-planned modernization of the existing energy infrastructure, and the construction of smart grids will definitely improve the energy security of the country.

It is also worth noting that the system, which provides a layered architecture, is flexible and its functionalities can be easily updated and customized for the needs of the particular customer.

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SAVE – Energetyka przyszłości

R. KASPRZYK, M. CIEŚLEWICZ, K. KRAJEWSKI, M. PERKA, A. STACHURSKI

Artykuł ma na celu zademonstrowanie możliwości wykorzystania systemu SAVE w procesie optymalizacji istniejących sieci energetycznych, a także modelowania nowych. System ten jest odpowiedzią na wciąż rosnące zapotrzebowanie na energię elektryczną i brak nowoczesnych technologii w przemyśle energetycznym. System realizuje postawione mu zadania w oparciu o wkraczającą na światowy rynek koncepcję Smart Grid. Takie podejście pozwoli wesprzeć proces tworzenia nowych przedsiębiorstw, zainteresowanych budową elektrowni odnawialnych, i będzie zachęcać potencjalnych „prosumentów", by przekazywali swoje nadwyżki energii. System SAVE może pokazać również, jak odpowiedzialnie korzystać z energii i jak kosztowne mogą być jej straty.

Słowa kluczowe: energetyka, sieć elektryczna, systemy sieciowe, optymalizacja.