WEB APPLICATION FOR RESIDENTIAL RENEWABLE ENERGY SYSTEM FEASIBILITY APPRAISAL

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Abstract – *This paper reveals unique features of an originally developed Web-enabled decision support tool for RET (Renewable Energy Technologies) investment appraisal. Furthermore, complete software system architecture is described, providing a detailed insight in the state of the art software development technologies used. Moreover, all functional parts of the system were thoroughly described depicting the necessary steps to perform one simulation run using the proposed tool. Finally, the set of required inputs as well as simulation outputs were explicitly depicted, thus emphasizing the benefits brought in with this online service.*

1. INTRODUCTION

The great environmental impact as well as scarce and limited reserves of the fossil fuels led to the increasing use of the renewable energy sources. However, having in mind the stochastic nature of these resources, one should carefully consider hybrid system architecture along with the appropriate decision making strategy in order to provide non-intermittent power supply, which is a common standard the customers are used to with the traditional power grids.

This paper especially focuses on the development of Web-enabled tool for investment appraisal related to small-scale hybrid renewable energy systems, suitable for supplying the residential users with clean but also reliable source of energy. Moreover, this paper focuses on the user perspective of originally developed web application for RET investment appraisal, based on hourly simulation of different system configurations with objective of providing a generic environment for testing various sizing options as well as different corresponding smart energy dispatch strategies and multi–criteria evaluation of alternative options.

In relation to that, an exhaustive research of the state of the art in the area of RET simulators with the similar objective was performed and the most prominent were recognized. At the NREL [1], a computer model called HOMER [2] was developed, which deals with evaluation of design options for large-scale off-grid and grid-connected power systems for remote, stand-alone, and distributed generation applications. Following is the Hybrid2 [3] software package, developed in RERL [4], representing a tool performing long term performance and economic analysis on a wide variety of hybrid power systems. Furthermore, software for clean energy project analysis, called RETScreen [5], was developed serving as a decision support tool for RET deployment. Finally, a RET simulation and optimization software called HOGA [6], based on utilization of genetic algorithms, was also analyzed. However, neither of the aforementioned applications provides a Web-enabled tool able to generate almost instant evaluation of energy production, savings, life-cycle costs, emission reductions, financial viability and risk for various types of renewable energy technologies.

Although in the aforementioned simulators many different hybrid system architectures were already addressed, and discussed extensively in literature [7-9], the fact remains that the most common approach utilized for the analysis of such systems, was to consider the *island* operation. Since the renewable energy systems were at first utilized in the non-urban areas, where no power grid was available, this was natural approach to adopt. However, with recent increase of the governmental subsidies for the purchase of the renewable energy technology (RET) equipment as well as the increasing price of the electricity generated from the fossil fuels, the use of RET sources even in the urban areas became more and more attractive and economically viable. Nevertheless, maximizing the utilization of the renewable energy sources, and thus minimizing the kWh costs, while preserving the reliability of the system at the same time in the grid-connected system became the challenging task that this simulator is aiming to solve.

The rest of the paper is organized as follows. In the next section, a brief description of the overall software system architecture and its main functionalities is presented. Following are the chapters describing different functional parts of the application user interface, starting from project management towards simulation results, describing the necessary input data as well as various simulation options. Finally, the paper is concluded and the future work is presented.

2. SOFTWARE SYSTEM ARCHITECTURE

The presented decision support tool for RET deployment is basically a Java application based on Java Enterprise Edition 6 (Java EE 6) and a three-tier architecture. For the development and implementation of this application, the Open Source database (MySQL 5.5), Integrated Development Environment (NetBeans IDE 6.9.1) and Application Server (Apache/Tomcat 6.0) were utilized. Having in mind that one of the main objectives was to provide a tool easily accessible at any time or place from a web browser, a thin client three-tier architecture was implemented, which has previously proved to be an immensely useful for enterprise application development.

Furthermore, the tool offers an intuitive, user-friendly interface which was implemented using Java Server Faces (JSF), AJAX and Adobe Flash technologies to facilitate a rich, fast and easy-to-use application development. Moreover, one of the main open source JSF libraries used for the development of this application is Richfaces™. It is an Ajax enabled component library for JavaServer Faces, hosted by JBoss.org. It allows easy integration of Ajax capabilities into enterprise application development.

For the purposes of integration of Flash into Java server side technology, i.e. Java servlets (in order to provide data to Flash applications and send data to back-end data sources), Adobe Flex data access component was utilized.

Apart from these, the list of following open source components was used to support the development of various functionalities, as described shortly:

- *GMaps4JSF* - integration of Google Maps with JSF
- *iText* - creation and manipulation of PDF documents within Java applications
- *Jcaptcha* - captcha definition and integration into JSF
- *JfreeChart* - chart library for displaying professional quality charts in Java applications
- *PrimeFaces* - lightweight component suite for JSF 2.0 featuring 100+ rich set of JSF components
- *Dygraph* - JavaScript library for production of interactive, zoomable charts of time series
- Jersey - Sun's reference implementation for the Java API for RESTful Web Services

The business logic is implemented with over 150 Java classes divided into 18 packages. These packages and their roles in the simulator are listed below and graphically presented in Figure 1:

- beans - Contains JSF backing bean and business logic classes
- captcha - Contains classes used in the implementation of Captcha challenge-response test.
- datatypes - Contains classes which are used to transfer the data to and from JSF pages.
- reporting - Contains classes which are responsible for the creation of simulation reports in PDF format.
- validator - Contains classes which ensure the validity of input data from JSF pages.
- dao - Contains classes which communicate with EWS database and perform retrieval and storage operations for objects. This package communicates with the EWS database using the corresponding JDBC driver.
- transferObject - Contains classes which are used to transfer the data from EWS database to the business logic component.
- flash - Contains classes which perform the communication between Adobe Flash and JSF pages.
- gMaps - Contains classes which enable EWS to use the potential of Google Maps.
- controller - Contains classes used by the simulation algorithm for the optimization of produced and consumed energy management.
- validator - Contains classes which validate various user input.
- solarHeating - Contains classes which implement solar thermal models.
- mcdm - Contains classes required for execution of the multicriteria decision making algorithm.
- Entities, service, wrapper - Contains classes responsible for communication with designated controller using REST-full approach
- calibration – Contains classes which are used to validate and calibrate models and algorithms in the EWS using the data gathered from the EWC.

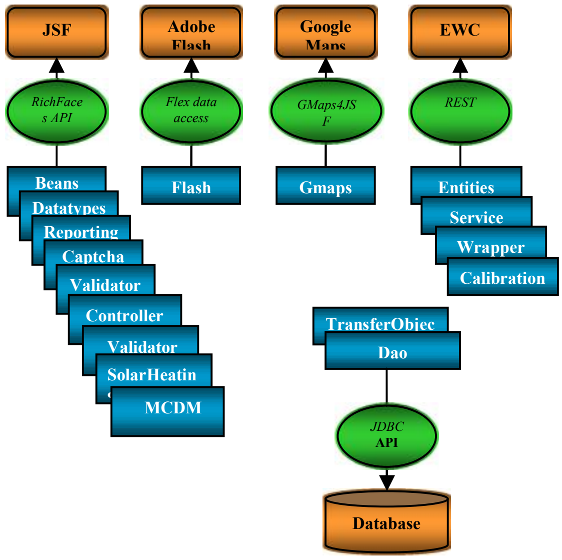

Figure 1. Simulator Java packages and their roles

The following chapters describe more thoroughly all functional parts of the system, thus depicting necessary steps to perform one simulation run. Furthermore, the set of required inputs and potential outputs, which may be retrieved from the system, are presented as well.

3. RET INVESTMENT PROJECT MANAGEMENT

At the very beginning of the interactive session with our Web application EWS, the user is offered with the possibility to either create new or edit existing RET deployment project. The currently active project and a short drop-down menu offers to *View Project Details, Change the active project* and to *Save Project.* Next to the drop-down menu, the user is provided with a check box enabling auto save option. Of course, selecting the automatic save option will save the user from taking care whether the data inserted are properly stored, but on the other hand it will produce a short delay each time the user moves to another tab or window in order of performing the automatic save action. Following to this, an online tutorial containing both the descriptions of how to use the

Simulator as well as main theoretical background of the applied approach is offered through the online *Help* tool.

The general project information is presented to the users and they can easily be entered, selected or chosen from the drop-down menu, depending on the required data. Following to the name of the project and its brief description there is an option of selecting the *Building status,* indicating whether the project is about new building RET-based microgrid planning or the retrofit of the existing building, and a *Building type* suggesting if the case is about Dwelling, Office premises, Industrial building etc. For the purpose of obtaining the correct meteorological data from the database, the location of the building is also required. This includes location latitude, longitude and altitude, which can be inserted both manually, using the text boxes or selecting the desired location on the Google map, integrated within the simulator. Furthermore, *Address* box may be utilized for inserting the building geographical location by giving the opportunity to the user to browse the map using only the location address, and the corresponding coordinates are updated accordingly. Naturally, all the standard navigation features of the Google maps are supported, however when picking a location one should be aware that historical hourly-based meteorological data, used for the simulation, are currently available for the 27 locations across Europe, depicted by small blue icons on the map. Otherwise, the nearest location with available meteo data will be considered.

4. DATA ENTRY

Following to the input of general project information, the user is offered to enter and review various, project specific, information, divided into four main categories: Building data, Meteorological data, Energy Use and Energy Pricing.

4.1 Building data

The building data consider space availability for the installation of RET equipment and four different types are foreseen: Roof surface, Surrounding area, Wall facades and Basement. Entered data will have direct influence on the sizing for RET configuration as they represent space discrimination for each configuration taken into account.

4.2 Meteorological data

The following is the meteorological data part, where the historical meteorological data for previously chosen location are presented. Although the data used for the calculation are based on hourly resolution, at this point only average daily values for each month are presented, aiming for simpler evaluation of the renewable potential of the desired location. Moreover, historical data about ambient temperature, wind speed and solar radiation are provided. Furthermore, to be able to evaluate these values even at an early stage of simulation, user is provided with the threshold values which suggest that a specific renewable energy is not feasible for exploitation. This way, a simple comparison can be made and the first decision about suitable type of renewable energy in the specific location can be made.

4.3 Energy Use

Following is the Energy Use part which aims at collecting the data related to the energy consumption within the user's premises. In order to define hourly energy use profile user is offered with advanced form for inserting the energy consumers and their corresponding working or non-working hours.

The first step is to enter relevant holidays for desired location which will be used for creating some of the corresponding Use profiles. Following is the creation of the Use profiles, for which the required fields include profile name, type, which suggests exactly on which days this profile refers to, the range of dates in which the profile is used and the relevant hours for each day within the selected dates and finally to mark whether the selected hours will be working or non-working. An additional optional field is foreseen for the description of each use profile. The Use profiles can easily be added or deleted without any restriction and regardless of their number.

Once the set of use profiles is defined, one should proceed to the definition of the list of consumers. Adding a new consumer requires entering name, number of units, rated power of a single unit, actual to nominal power ratio and a time of use coefficient, suggesting the percentage of time the consumer is working with its full power. Finally, in order to take a specific consumer into account during the simulation, it should be assigned with at least one use profile or their respective combination.

Following to the definition of all consumers and the corresponding use profiles, intermediate hourly energy consumption results can be reviewed. However, before proceeding with actual simulations, user is offered with calibration option which considers entering energy bills, if they exist. Again, the entry form for energy bills considers definition of name, dates range for which the bill is valid for and of course the quantity and price.

4.4 Energy pricing

Another, maybe be the most important, aspect when it comes to the economic evaluation of RETs is of course the price of energy both purchased and sold. Therefore, a special entry form under the Energy pricing part was developed to address this issue.

The form is developed in such way to support the definition of any pricing scheme since it provides the combination of both energy zones discrimination as well as tariff period discrimination approach. Adding a new energy zone requires the definition of the base price of kWh that applies for the particular energy zone as well as the upper boundary. However, one should be aware that, when a new zone is added, its upper boundary should comply with ascending order of the ones previously defined.

Having in mind very diverse tariff schemes throughout the Europe, the user is also provided with an option to select whether the defined base price of kWh should be applied throughout the billing period or at the end of the billing period, having as a consequence that all kWhs consumed are charged with the corresponding base price. Furthermore, an option to select the billing period interval is given in order to reset the base price accordingly.

Adding a new tariff period requires the definition of name, followed by selection of type of day, the corresponding date and hours range. The price is entered having in mind two options, either as explicit value or as an offset from the base price depending on the energy zones scheme. Of course, only one option can be considered in the calculations and this is achieved as following. If the price has a value different from zero this will be regarded as final price for the corresponding tariff period, otherwise an offset value will be utilized, offering an option for both positive as well as negative discrimination of the base price. However, a usual conflict can occur, i.e. the different tariff periods can overlap in time. This can create a price conflict and a level of priority for each tariff period must be assigned, which is achieved by changing the order of tariff periods in the list. Similarly to the Energy Use part, once all the necessary information is gathered, one may proceed to the revision of the Energy Pricing scheme, based on the previously defined Energy Use.

Following the similar procedure, the pricing scheme for energy selling should be established as well. In this case, the same entry form for energy selling is offered as for the energy purchase, although in most cases a single value, indicating the feed-in tariff for the renewable energy, is needed. However, this advance interface for implementing more sophisticated energy selling pricing schemes aims at supporting the increasing development of the Smart Grids, which consider more diverse energy trading options.

5. RET CONFIGURATION SELECTION AND REVIEW

After revising the intermediate simulation results under the Data Entry tab, a user should proceed to the RET configuration tab for selecting the RET configurations to be taken into account for further analysis. This is done either by selecting explicitly one, or more RET configurations for the analysis or leaving for the tool to go through all possible combinations. Another option is to request for the system suggestion before making the final selection by answering a special questionnaire that is aiming to recommend the best configuration or a set of them that match user's needs. The following step is to review selected RET configurations where it is expected to enter further configuration specific information. Starting with typical financial data, i.e. the cost of capital, state subsidies for acquiring the RET equipment and project budget, the economic framework of the project is established. Following is the selection of desired energy management strategy that will be applied for the simulation of the particular configuration. Currently, four different energy management strategies are pre-programmed, starting with Optimal Financial Benefit (O-FB), Peak shaving with suboptimal FB, Limited battery cycles with suboptimal FB and finally No Grid and suboptimal FB. As indicated, regardless of the selected strategy, the objective is to maximize the operation profit as much as possible. Although the strategies are pre-developed, the user is offered with a list of tunable parameters which are used to fine tune the selected energy management strategy and establish the appropriate thresholds.

Finally, to conclude a review of a RET configuration , the user is provided with the list of criteria that will be used for the Multi Criteria Decision Making (MCDM) analysis. The listed criteria present combination of both economical as well as environmental parameters which provides a unique evaluation framework for each configuration. Moreover, different criteria can be considered with different weights offering the possibility to arrange the relative order between them, thus steering the configuration selection process in any desired direction.

6. RET MANUFACTURER SELECTION

Following to the RET configuration review tab, where the desired configurations are selected and further refined, one should proceed to the RET manufacturer selection where exact devices for each type of RET equipment are assigned. In fact, this way different device's characteristics (i.e. efficiency, durability and etc.) are taken into account and comparison between different manufacturers can be made. Currently, only several manufacturers are offered, however, the near future work will include a connection to an external database especially designed for hosting the information from most respectful RET devices vendors.

7. SIMULATION RESULTS & REPORTING

Prior to the actual simulation run, users are requested to enter some device installation data which have a significant impact on the performance of the corresponding RETs. For example, as widely acknowledged, the azimuth and elevation of the installed photovoltaic can reduce its nominal power by 70 per cents. Therefore, submitting accurate installation data will generate a realistic picture of the overall RET configuration performance and therefore create a useful backward loop for optimizing the installation process. More precisely, installation data consider wind turbine parameters, including height of the wind turbine hub as well as anemometer, and installation parameters related to photovoltaic panels, i.e. azimuth and elevation of panels.

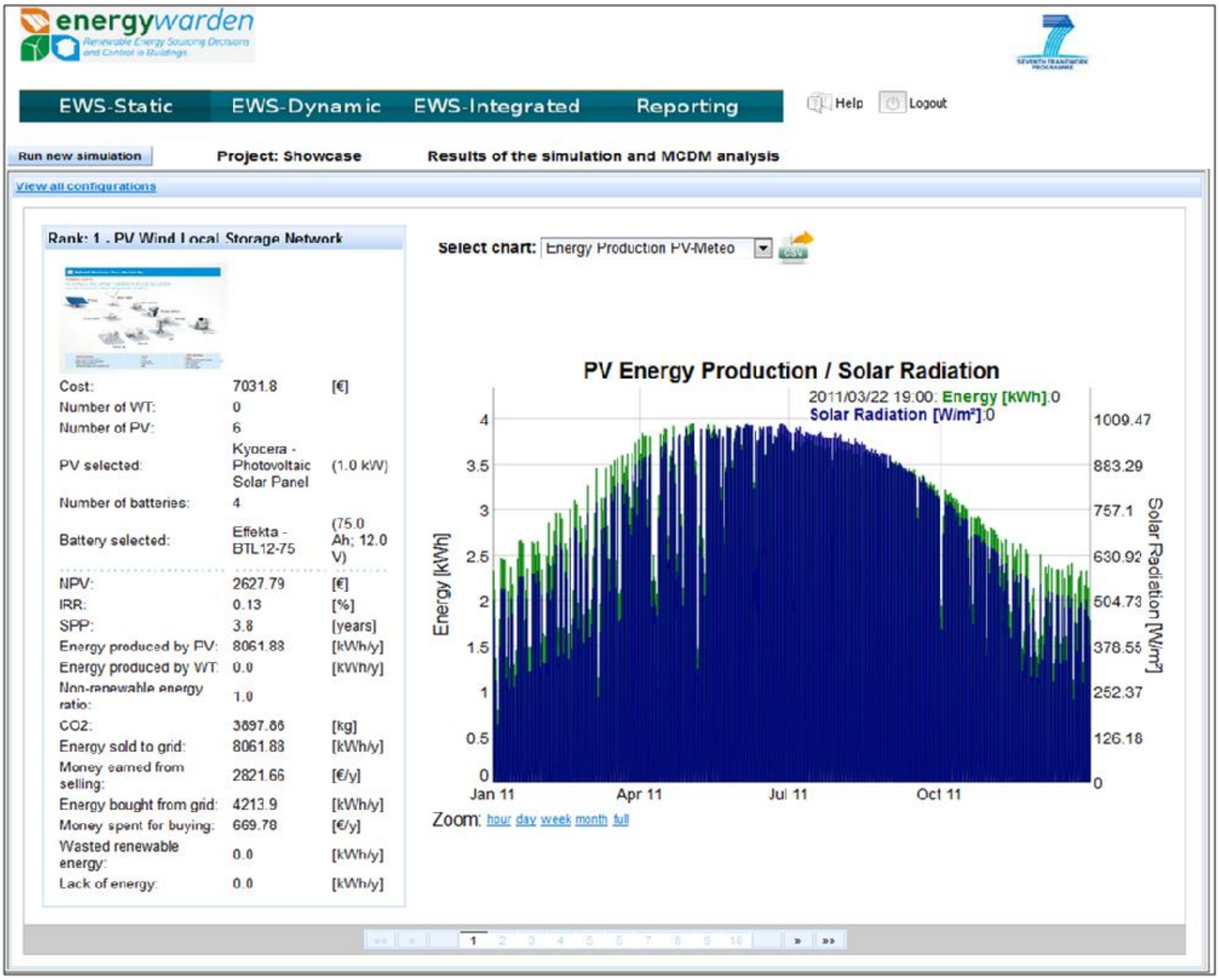

Figure 2. Simulation results

Finally, the user is able to run the simulation and the best ranked configuration with the corresponding sizing of devices is presented, as depicted in Figure 2. Ranking is conducted according to the evaluation criteria previously assigned. Apart from the typical economical evaluation parameters such as Net Present Value (NPV), Internal Rate of Return (IRR) and Simple Payback Period (SPP), a list of configuration performance parameters from the technical perspective are given. These are total energy produced from photovoltaic plant, total energy produced from wind turbine plant, the amount of energy that was bought or sold to the Grid and at what cost. Furthermore, in case when configuration is operating in "island mode", parameters such as "Lack of energy" and "Wasted renewable energy" naturally indicate deficit or surplus of energy, considering user's actual needs. Furthermore, if configuration contains battery storage, the corresponding state of charge (SOC) is also provided. It should be emphasized though that all these parameters are calculated for one year period with an hourly resolution, i.e. 8760 values for each parameter, offering a clear perspective for further optimization. At any times, user is able to check the other configurations and compare the results with those lower ranked. The complete list of all analyzed configurations is also presented and just a slight change in the criteria weights show significant influence on their ranking.

In order to summarize the simulation results together with all input data, a special reporting functionality was developed. This enables immediate generation of the PDF format document which, beside simulation results, contains the most necessary information and milestones related to the simulation procedure.

8. CONCLUSION

This paper provides a general overview of a unique Web-enabled tool serving as a decision support tool for the residential RET-based systems feasibility appraisal. The tool itself manages to combine a wide range of mutually dependent factors, such as renewable potential of location, building space availability, user's financial restrictions and energy consumption habits, existing pricing policies and etc. Furthermore, it creates a generic simulation environment for testing various energy dispatch strategies within both isolated and grid-connected hybrid RET system domain. The overall outcome of the simulation can be summarized in two main results, i.e. the dimensioning of each device type, which inherently contains the information about the proposed configuration as well, and the evaluation of a set of configuration performance parameters. Moreover, these parameters are recorded and provided to the user in the hourly resolution and therefore create a complete picture of the hybrid system operation.

Finally, since the existing simulation involves only electrical domain, the near future work will focus on the implementation and integration of thermal domain into the overall system. Although, it should be emphasized that this integration present a challenging task since these two domains do not operate independently and their mutual influences must be taken into account.

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