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System for Short Term Forecast of Electric Power Consumption in a Distributed Company

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Introduction

An electricity consumer which can choose his energy provider and can negotiate with its chosen provider the prices and the necessary energy power is named eligible electricity consumer (EEC), according to the Romanian legislation. An EEC with a minimum of installed power capacity larger than 1000kVA is required to provide a daily hour-by-hour energy forecast and consumption report to the energy provider with which it has concluded the contractual relationship [1].

When an EEC has several branches spread over a geographical area, it has to supply the aggregate forecasts and daily energy consumption of the subunits to the energy provider. An official of the EEC company is responsible in coordinating a team of engineers in each local branch. Each local responsible (LR) has to do the daily hour-by-hour energy forecasts based on the run schedule of the industrial equipments installed on that location. The common and more used method is based on email exchange. This method is very simple and popular but it has some disadvantages. In this paper we will describe a specialized web-application as an alternative to the email sending method for the collaborative working scenario of branches and company responsible engineers in making aggregate energy forecasts and consumption reports. In addition we will present those methods and highlight the advantages and disadvantages of the each one.

The Previous Procedure Based on Data Exchange through Email Messages

For each consuming subunit a local responsible engineer (LR) analyzes the working tasks for the next day and tries to estimate the necessary electric consumption to accomplish the tasks. Based on the working schedule of the equipments involved in the tasks and their electrical parameters the LR produces a daily hour-by-hour forecast report. In the previous procedure, the LR has to generate an MS Excel file which contains a matrix [n × 24], where on each row there are represented all the n available equipment with its consuming electrical power. If one equipment was running on a certain hour it will get the 1 value on the column corresponding to that hour, or 0 otherwise. For each hour of the day, the energy consumed by the running equipments will be summed. That MS Excel file was sent attached to an email message to the company responsible (CR) with energy consumes and forecasts. The CR has the task to aggregate the daily energy consumed and the forecasts sent by all the local responsible from all the branches. After the aggregate report is done, the CR has to send it to the energy provider.

In the previous system, using the email method, the file with energy consumption and forecasts has to be sent by the LR of each location until a certain hour to the company responsible (CR). The CR will aggregate the energy forecast curves from all the locations and send it to the energy provider of the EEC. For example, until 8.00 AM of each day, the CR has to send to the energy provider, the aggregate hourly forecast for tomorrow and the day after tomorrow. If the consumed energy will not match in a certain interval from the forecast previously sent for that day, the EEC has to pay penalties. Even if the email using method is very popular and simple to use, some problems have to be noticed:

- in fact, this procedure is a collaborative working scenario; sometimes one of the LR wishes to visualize the forecasts report of other locations to see if it is possible to compensate the consuming power. This means that emails have to be sent from one consuming location to all of the other branches.
- the waiting time for accessing, visualizing the others forecasts report is too long;
- the CR has to do a lot of redundant work and to deal with multiple versions of the same reports.
- if one of the LR wouldn't have access to the internet because of some technical problems, the forecast reports have to be sent to the CR by using the phone. In this case the others LR's would have access only to the summed hourly forecast and not to detailed forecast report. In the detailed report the running equipment for each hour and how much power each

one of them is consuming are mentioned.

The most common problem arrives when one of the equipments from a consuming location fails to run or has to be running more time that it was mentioned in the forecast report. The idea is to stop, or respectively, to start other equipment from other location in order to compensate the power consumption difference from the forecast and avoid paying the penalties.

The New Method

The aim of implementing a specialized software solution is to optimize the method of building, managing and sending forecast reports from the LR's to the CR and later to the energy provider in order to:

1) Get a deviation as low as possible between the forecast report and the consumed energy;

2) Reduce the generation time of the company forecast reports;

3) Allow modification of the reports as fast as possible and make them available for all the interested personnel;

4) Reduce the penalties by following the schedule of the running equipments and aggregate energy forecast report.

In the following, we will present some details about the proposed application architecture and how it works from the LR and CR point of view.

Let us assume that the company holding is composed by m local production units or branches. Let there be k the local production unit having n_k equipments with their hourly electric powers

$$P_k = \left\| p_1^{\,k} \quad p_2^{\,k} \quad \dots \quad p_{n_k}^{\,k} \right\|, \tag{1}$$

where $p_i^{\,k}$ are the consuming electrical power and these are expressed in kW.

The calculus of electric power consumed by the local unit assumes that on an entire hour each of the n equipments may be in function or not. We have the matrix

$$T_k = \begin{Vmatrix} t_{1,1}^{\,k} & t_{1,2}^{\,k} & \dots & t_{1,24}^{\,k} \\ t_{2,1}^{\,k} & t_{2,2}^{\,k} & \dots & t_{2,24}^{\,k} \\ \dots & & & \dots \\ t_{n_k,1}^{\,k} & t_{n_k,2}^{\,k} & \dots & t_{n_k,24}^{\,k} \end{Vmatrix}, \tag{2}$$

where $t_{ij}^{\,k} \in \{0,1\}$ and indicate the state of the equipment i at hour j in the k local unit. It may be 1 if the equipment i is planned to work in the j hour of the day, and 0 elsewhere.

The total consuming energy for each hour in the k local unit in each hour of the day will be expressed by the matrix product

$$W_k = P_k \times T_k, \tag{3}$$

where the result is a row matrix

$$W_k = \left\| w_1^{\,k} \quad w_2^{\,k} \quad \dots \quad w_{24}^{\,k} \right\|. \tag{4}$$

Its elements $w_h^{\,k}$ represent the electrical energy consumed by all the equipments in the k production unit at hour h of the day. This matrix of the LR_k responsible must be transmitted to the CR.

At the level of the CR all the W_k matrix are summed in order to obtain the consuming energy by the company holding on each hour of the day

$$W = \sum_{k=1}^{m} W_k \,. \tag{5}$$

This row matrix represents the result of daily power forecast and it will be communicated to the electric power provider.

It was required that the user interface design of the application to be easy to understand and use by any of the LR's and CR's in order to minimize the cognitive effort and the learning time. Also, the interface is personalized by the user rights and responsibilities [2, 3].

The application runs on a dedicated web-server from an internet/intranet network and access is allowed only to those authorized by an administrator. The administrator of the application has the possibility to add new users and locations.

The access to the specialized application for forecast and energy consumption is made by using an internet browser. It is not necessary to install any other specialized software on the working stations of the persons responsible for energy in each branch or headquarter.

When an energy responsible engineer is accessing the web-address of the proposed specialized application he has to provide his authentication data. If the authentication succeeds, based on his profile and rights, the local energy responsible will access in write mode the reports for his location and in read-only mode the forecast reports for the others location. All the details and consuming power of the equipments installed on each location are saved in a database [4]. In order to facilitate the report building the application generates a control panel with checkboxes as in Fig. 1.

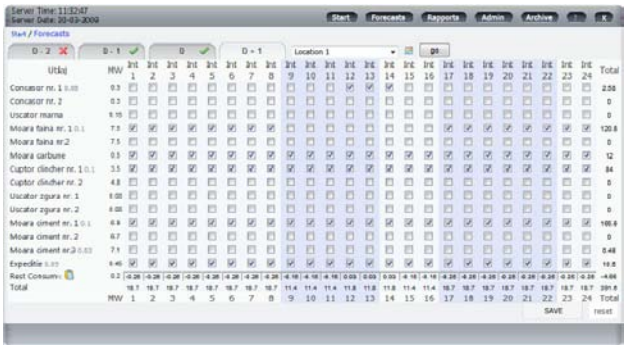

Fig. 1. The personalized control panel for the local responsible (LR) for filling in the matrix T_k

The LR has to mark which equipments will run and the hour at which they will run. When the user clicks on a checkbox the energy consumption is computed in real time for each hourly interval and each equipment. If the user wishes to change the status of an equipment for the whole day, all he has to do is to click on the equipment name and all the hourly intervals for that equipment will be

automatically checked or unchecked. A forecast report will be generated when the user will press the save button.

Some equipments are having a default energy consumption different than zero even in OFF mode [5]. The application supports also this type of equipments in order to generate forecasts as close as possible to the real energy consumption.

The details and type of the equipments installed in each production unit can be modified only by the LR responsible for that location.

Every morning, based on the measuring instruments from each location, the LR has also the task of saving into the web-application the energy consumption for the previous day. As we can see from the Fig. 1, the D-2 tab contains an *X* red sign, which represents that the user didn't save the data for the previous day consumption into the database yet. When all these data are saved, the application will generate a daily forecast consumption energy report for that location.

Besides the control panel with the status of each equipment, the forecasts and consumption reports contain an MS Excel file with energy forecasts on the whole company for each hour and a chart file showing the differences between what was forecasted and what was consumed. All these files are saved on the server's application and are available for all the users which have the rights to access it.

The LR has the rights to add, delete and modify details (such as matrix P_k) on any equipment from the production unit in the location for which he is responsible.

In the Fig. 2 the interface page for the CR user is represented. At this moment we have to mention that each location has a previously negotiated range for which the deviation from the forecasts is possible without paying penalties.

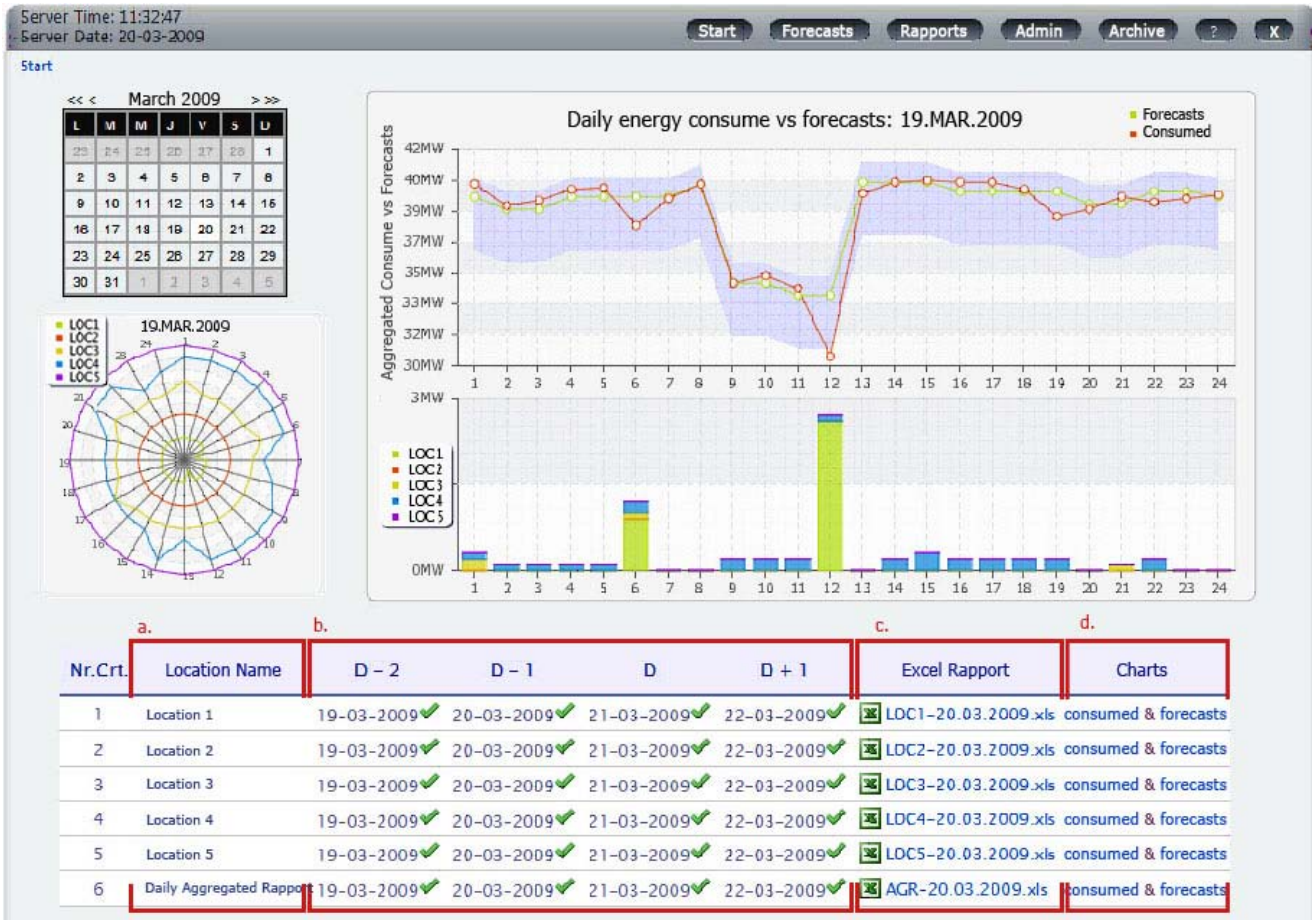

Fig. 2. The start page for the energetic company responsible (CR) official

If the deviation of the consumed energy from the forecasts will not be in the allowed range, for each location, the radar type chart from the top-left side of Fig. 2 will mark it. Any of the available locations represented as a circle means that the energy consumed for that location was in the allowed range from the forecasts.

Also, the entire company has a negotiated deviation range for which penalties are not paid, such as big consumers. If each location will forecast energy within the allowed range then the aggregate forecast will match the allowed range and the eligible electricity consumer will not have to pay penalties. The allowed range for which the EEC will not pay penalties can be seen in the chart from the top-right side of Fig 2. That chart is generated in automatic mode based on the saved data by all the LR's.

The CR can see (Fig. 1) if any of the LR did not save in the application the data for forecasts or consumed energy. The notation from the header of the table in the Fig. 2 represents the notation for yesterday (D-2), today (D-1), tomorrow (D), and the day after tomorrow (D+1). If for any of those days the data were not saved by the LR the application will mark it using a red *X* sign.

If the prognosis and consumed energy data were saved in the application, a daily report for that location will be generated. An aggregate report will be generated even if not all the locations' data have been saved. The exact time on which the last modifications were made is also saved in the MS Excel files. From this page the RC can access the Excel report files and charts (Fig. 2) of any location. Also with a click on days section (Fig. 1), the CR can access the control panel with the running status for each hour of the available equipments from that location.

The advantages of using a dedicated software solution as alternative for the email sending method are:

- Automatic generation of the forecast reports (MS Excel and chart files) by using mouse clicks to check and uncheck the status of an equipment;
- Minimizing the time needed for modifying a report;
- Time-reducing for generating reports;
- Automatic generation of the aggregate reports from all the energy-consuming locations/branches;
- Automatic generation of the monthly, yearly reports, based on the daily data;
- Automatic generation of various charts and files for detailed analysis;
- Support for simultaneously access to the resources;
- Personalized access based on the users rights and responsibilities;
- Support for collaborative working environment;
- Automatic archive mode of the database and generated reports;
- Data security.

The proposed solution has been tested and can be used by any interested company.

Conclusions

The proposed software solution is designed to optimize the system of decision-making, managing and sending energy forecast reports from the local energy consuming units to the headquarters and later to the energy provider.

Using a specialized application, we were looking also for the possibility of improving the forecast report in order to minimize the electricity costs.

Even if the email method for sending reports in attachment seems to be an easy and facile method, on long term it has a lot of disadvantages. A specialized application with support for collaborative working environment, which allows the automatic generation and management of the forecast and consumption energy reports, seems to be the right solution. The application can be integrated in complex multi-agent systems.

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The paper describes a collaborative working system in making aggregate energy forecasts for electrical consumers companies with distributed branches. The aggregate forecasts of the energy consumption must be supplied to the energy provider daily. It is determined from the information provided by local branches connected through a computer network. Ill. 2, bibl. 5 (in English; abstracts in English and Lithuanian).

R. Pentiuc, O. C. Ungurean, S. G. Pentiuc, M. Bernea, C. Popa. Trumpalaikė elektros galios suvartojimo prognozė paskirstytosiose įmonėse // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2010. – Nr. 1(107). – P. 75–78.

Aprašoma sistema, skirta elektrinės galios suvartojimui prognozuoti. Bendra informacija apie prognozuojamą suvartoti elektrinę galią kas dieną turi būti pateikiama elektrinės galios tiekėjams. Nustatyta, kad tokia informacija gali būti pateikiama vietiniu kompiuteriniu tinklu. Il. 2, bibl. 5 (anglų kalba; santraukos anglų ir lietuvių k.).