POWER LINE COMMUNICATION SYSTEM IMPLEMENTED IN E.ON MOLDOVA DISTRIBUTION

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REZUMAT. În acest raport, autorii prezintă modul de utilizare a functionalitatilor sistemului TURTLE TS2 PLC implementat in E.ON Moldova Distribuţie SA. Sistemul oferă citiri zilnice ale consumului si curba orara de consum pentru contoarele integrate utilizand reţeaua de joasă si medie tensiune, pentru transmisii date si facand posibilă deconectarea clienţilor, în caz de neplată, de la punctul central. Validarea reconectarii consumatorului este trimisa de la punctul central prin intermediul retelei electrice. Software-ul de punct central oferă rapoarte de prognoze, profile standard pentru diferite categorii de consumatori, datele de facturare ale consumurilor de energie electrica. Sunt prezentate aspecte referitoare la profilarea curbelor de sarcina standard in baza datelor inregistrate de sistem, precum si cateva avantaje ce rezulta din realizarea balantelor pe posturile de transformare gestionate de acest sistem. Ca o particularitate sunt conectate –via GPRS- la serverul de punct central controlere ce inregistreaza temperatura medie exterioara.

Cuvinte cheie: PLC, E.ON

ABSTRACT. In this report the authors presents some aspects regarding the functionalities of the implemented TURTLE TS2 PLC system in E.ON MOLDOVA DISTRIBUTION.. The system provide daily readings and hourly profile consumption from the integrated meters using the low voltage network and medium voltage network, for dates transmissions, and make possible to disconnect of the customers, in case of non-payment , from central point.The validation for reconnect the customer is sending from the central point too, via electrical network. The central point's software provides standard profiles for different types consummers , dates for billing of energy consumptions . There are aspects of profiling standard load curves based on data recorded by the system and achieve several advantages resulting from the transformer balances.. As a feature-connected via GPRS to the central server that records the average outside temperature controllers.

Key words: PLC, E.ON

1. INTRODUCTION

Load curves gathering system using PLC technology, implemented by E.ON Moldova Distribution SA, meet the requirements of Roman harmonized with European legislation:

-Electricity Law - no. 13/2007- Commercial Code of the Wholesale Electricity Market - ANRE Ord 25/2004- Regulation of the electricity supply to consumers - GD. 1007/25.07.2004- Technical Code Electricity Distribution Networks - ANRE Ord 128/2008- Code for Electricity metering - ANRE Order 17/2002- The procedure for changing the energy supplier - ANRE Order 88/2009

Commercial Code of the wholesale electricity market provides network operators the obligation to define the load profiles for producers and consumers are not equipped with interval metering equipment and that metering is not economically justified on the range. [1]

2. SYSTEM FUNCTIONALITIES

Load curves gathering system provide:
-Hourly readings data simultaneously at all points of measurement, equal time intervals (every 60 minutes), so that they can finally obtain the standard load profiles related to a calendar year;
-Providing specific consumer profiles of various categories of consumers;
-Determining the dynamics of consumption curve profile (using the dynamic method by measurements of the load profiles);
-Provide short and medium term forecasts of consumption categories;
-Disconnect / reconnect with commands from the central point of any subscriber in the system;
-Report of attempted fraud;
-Temperature evolution curves for each area and providing consumer information on hourly weather data that is temperature related to each calendar day of the year;
-Generate reports;
-Energy balances;
-Interfacing with other systems: import / export activity data used in billing and energy management distributed / supplied, SAP-ISU, in. Xls,. Csv. Xml [1], [2]

3. SYSTEM STRUCTURE

The implemented PLC system uses Ultra Narrow Band PLC TS2 (UNB) technology (TURTLE), bidirectional with data transmission on LV and MV electical network.

The endpoint (transmitter) generates a low frequency signal (below 50 Hz) to be modulated over the network overlap. Low frequency band allows a carrier wave with the same movement as the power, through transformers and capacitors are not affected. UNB PLC systems are resistant to interference and propagation distance (app. 160 miles).

Each endpoint has its own unique frequency, allowing it to transmit or receive continuously, without danger of interference and jamming signal.

TURTLE schematic diagram of the system implemented by E.ON Moldova Distribution TS2 is shown in Figure 3. TURTLE TS2 technology involves a bidirectional transfer of data and commands via power distribution lines.

Filling: microcontroller for storing average temperature curves is mounted in the control room and substation transformer and transducer temperature sensor is mounted outside. Data stored by the microcontroller are sent via GPRS to a central point ARGUS software.

Transformer coupling (TCU) - **Figure 3 + Figure 1** - is an electronic device is placed in medium voltage station area on a concrete base. **[1], [2], [7]**

Figure 1 TCU

Injection transformer - **Figure 3** - is a standard three-phase transformer 230V/400V Sn = 160 kVA power, mounted on concrete pedestal. Maximum distance (in cable length) between TCU and injection transformer should not exceed 45 meters. **[1], [2]**

SPU 3000 - **Figure 3 + Figure 2** is a process computer, which is mounted in a rack inside the medium voltage station with ER75i Router (compact electronic equipment that provides data transfer in GSM technology, GPRS and EDGE). **[1], [2], [8]**

Figure 2 SPU 3000

Endpoint is an electronic device that fits under the cover of the meter terminal block. Circuit breaker is an electromechanical device that is placed near the meter. Meter + endpoint + circuit breaker assembly may be placed in a single block of protection (recommended), or two blocks of protection: in one meter + endpoint and in the other circuit breaker. **[1], [2], [3]**

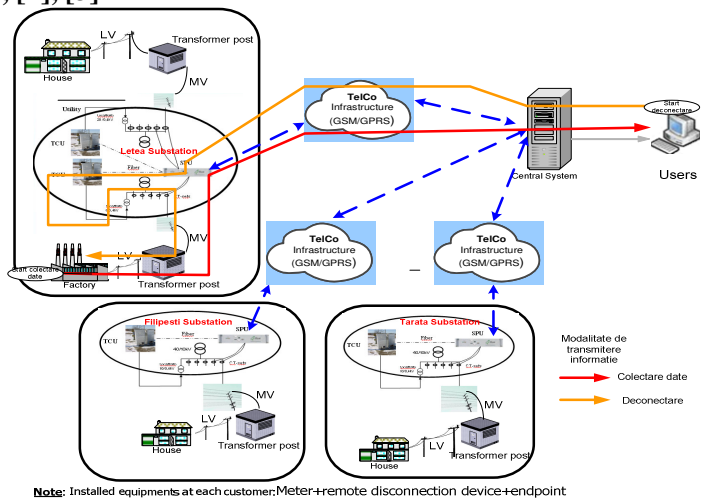


Figure 3

Meters of the system are produced by SC AEM SA Timisoara (single and three mounting direct and semidirect).

The transformer secondaries measurement and protection of medium voltage transformer stations are mounted toroidal current transformers type that take the information from the meters via low voltage line -> post processing -> medium voltage line and are connected to inputs SPS 3000-**Figure 3. [2]**

Between TCU and SPU300 is installed a fiber optic connection

4. CENTRAL POINT SOFTWARE

Central point software provides: -collection, processing and analysis of load curves; -elaboration of consumption-curves (for a frequency and a programmable integration period) expressed as graphics and analytics for intervals settable / consumer demand for each integrated system;

- display of minimum and maximum values for energy and temperature + time stamp associated to each customer (or consumer groups predefined);
-temperature curves (calculated every 15 minutes or 60 minutes) for each consumer the integrated system, graphical and analytical form;
-generation of reports of daily disconnections / conncetions for periods of time defined by user choice;
- generation of status reports (open / closed) of the breakers daily and for periods of time defined by user choice;
-monitoring the actual values of voltages and currents in each consumption point integrated into the system daily for periods of time defined by user choice;
-monitoring of short and long term interruptions
-storing the acquired data for at least 48 months in operational database;
- synchronize the internal clocks of electricity meters and measuring dedicated microcontroller / memory of outside temperature, clock from the central server.
- order the disconnection / reconnection check for each circuit breaker in part, from the system or predefined groups;
- export reports obtained in XLS, CSV, DOC and XLS import, XML, CSV and print them;
- development of standard curves;
- developing forecasts of consumption.

Meter reading from the system, clock synchronization signals and commands to disconnect / reconnect the software are provided "Command Center"-Hunt Tech. Reports, forecasts and data export to other software applications are provided by Argus - SC AEM SA Timisoara interface "Command Center". **[1], [2], [3], [4]**

5. ELABORATION OF SPECIFIC LOAD PROFILES

For each customer category , profiling is based on a history of consumption in monthly installments, containing 30/31 etc. (if applicable) daily consumption profiles. Minimum length of history of consumption is 1 month.

From the application can start profiling module that will generate profiles type / standard, depending on the content database at the time, as follows:

1. A month:
   a) type profiles for each day of the month (by mediation measured load profiles to customers in the category considered);
   b) Profile type business day of the month (by mediation profiles measured for all working days in that month).
   c) Profile type non-working day of the month (by mediation profiles measured for all the holidays in that month).
   d) Profile type holiday of the month, if applicable (through mediation profiles measured for all the holidays in that month).
   e) type profiles for season 1 (corresponding month) is considered the same as the profiles at b), c) and d). etc

Consider a given category of customers, for monitoring NC customers (c = 1, ..., NC). For months it on consumer c, we obtain a profile of NH = (24 * number of days in month) hourly average values of energy consumption

$$P_{c,h}^{l} \qquad h = 1,...,NH \qquad [kWh] \tag{1}$$

Before the procedure profiling, all consumer profiles measured are expressed in u.r. (relative units) by reference to monthly consumption of each consumer

$$W_c^l = \sum_{h=1}^{NH} P_{c,h}^l \qquad [kWh] \tag{2}$$

obtaining the relative values of the measured profiles for each consumer *c*:

$$R_{c,h}^l = \frac{P_{c,h}^l}{W_c^l} \qquad h = 1,...,NH \qquad [u.r.] \tag{3}$$

with property:

$$\sum_{h=1}^{NH} R_{c,h}^l = 1 \tag{4}$$

Type of consumer profiles for each day of the period considered is determined by calculating "coefficients consumer profile" for each hour mediation by all consumers in the category considered:

$$T_h^l = \frac{1}{NC} \cdot \sum_{c=1}^{NC} R_{c,h}^l \qquad h = 1,...,NH \qquad [u.r.] \tag{5}$$

the same property:

$$\sum_{h=1}^{NH} T_h^l = 1 \tag{6}$$

Type profiles characteristic days (working - ZL, weekends - ZN, holidays - ZS) in the period considered is determined by calculating "coefficients consumer

profile" for each hour mediation by all consumers in considered class and always the considered type:

$$T^{l}_{h,ZL}=\frac{1}{NC}\cdot\frac{1}{N_{ZL}}\cdot\sum_{c=1}^{NC}\sum_{\substack{z=1\\ working day}}^{N_{ZL}}R^{z}_{c,h} \qquad h=1,..,24 \qquad [ur.]$$

$$T^{l}_{h,ZN}=\frac{1}{NC}\cdot\frac{1}{N_{ZN}}\cdot\sum_{c=1}^{NC}\sum_{\substack{z=1\\ weekend day}}^{N_{ZN}}R^{z}_{c,h} \qquad h=1,..,24 \qquad [ur.]$$

$$T^{l}_{h,ZS}=\frac{1}{NC}\cdot\frac{1}{N_{ZS}}\cdot\sum_{c=1}^{NC}\sum_{\substack{z=1\\ holiday}}^{N_{ZS}}R^{z}_{c,h} \qquad h=1,..,24 \qquad [ur.]$$

where the last notation $R^{l}_{c,h}$ la $R^{z}_{c,h}$ to indicate that the relations (7) data are used for each day z considered.

For all type of category profiles (b) - (g) "consumer profile coefficients" is based on static profiling method adjusted by defining 5 hourly factors:

$$\left(\quad T^{z}_{h}, \quad a_{1,h} \quad , \quad a_{2,h} \quad , \quad b_{1,h} \quad , \quad b_{2,h} \quad \right)$$

T^{z}_{h} – consumption coefficient profile derived using the procedure described above; $a_{1,h}$, $a_{2,h}$ – regression coefficients as hourly temperatures

; $b_{1,h}$, $b_{2,h}$ – regression coefficients as maximum temperatures / minimum daily. Deduction of regression coefficients is described below.

The regression model is used, on the one hand, for a more accurate representation of the profile type, which takes into account the influence of temperature and, secondly, to generate short and medium term forecasts. The regression model is applied to profiles of type b), c), d), e), f) and g) of the above list.

Z is considered to be available on hourly measurements of temperature note by θ^{z}_{h} (h = 1,…,24). The regression model is applied to each hour, considering that we have available daily consumption profiles expressed in u.r (type R^{l}_{h}) further noted R^{z}_{h} for K days of the same type (business, rest, holidays) and the corresponding temperatures. Further, to simplify notations, individualization is waived by the index c consumer category

For example, for one hour h fixed, we have approximated by linear regression variation of average hourly consumption (in ur) R_h with temperature (in °C) θ_h based on a table form:

Hourly medium consumption in u.r. R_h	R^{z1}_{h} (7)	R^{z2}_{h}	R^{z3}_{h}	…	R_h R^{zK}_{h}
Temperature in °C θ_h	θ^{z1}_{h}	θ^{z2}_{h}	θ^{z3}_{h}	…	θ^{zK}_{h}

z1, z2, z3, …, zK are daily indexes. In relation to this table, the overall regression model to customize as follows.

- It is expected to achieve function approximation:

$$R_h = a_{1,h} + a_{2,h}\cdot\theta_h \qquad (8)$$

Regression coefficients $a_{1,h}$ şi $a_{2,h}$ relations are obtained: $h=1,...,2$

$$a_{1,h} = \overline{R} - \overline{\theta}\cdot a_{2,h} \qquad (9)$$

$$a_{2,h} = \frac{\operatorname{cov}(\theta, R)}{\sigma^2_{\theta}} \qquad (10)$$

where:

$$\overline{R} = \frac{1}{K}\cdot\sum_{k=1}^{K} R^{zk}_{h} \qquad (11)$$

$$\overline{\theta} = \frac{1}{K}\cdot\sum_{k=1}^{K} \theta^{zk}_{h} \qquad (12)$$

$$\overline{\theta^2} = \frac{1}{K}\cdot\sum_{k=1}^{K}\left(\theta^{zk}_{h}\right)^2 \qquad (13)$$

$$\overline{\theta\cdot R} = \frac{1}{K}\cdot\sum_{k=1}^{K}\left(\theta^{zk}_{h}\cdot R^{zk}_{h}\right) \qquad (14)$$

$$\operatorname{cov}(\theta\cdot R) = \overline{\theta\cdot R} - \overline{\theta}\cdot\overline{R} \qquad (15)$$

$$\sigma^2_{\theta} = \overline{\theta^2} - \left(\overline{\theta}\right)^2 \qquad (16)$$

Therefore, profile type for considered caracteristic day (see sections b, c, d, e, f and g of the above list) is obtained as 24 sets of 3 values:

$$\left(\quad T^{z}_{h}, \quad a_{1,h} \quad , \quad a_{2,h} \quad \right) \qquad h=1,...,2 \qquad (17)$$

where T^{z}_{h} type of consumer is a profile of a kind calculated with relations (5) or (7), but only 24 values.

After determining the regression coefficients

$a_{1,h}$ şi $a_{2,h}$ to obtain corrected values of type profiles, denoted TC_h^z, using hourly temperature readings, denoted $\theta\theta_h^z$, in areas other than the monitor:

$$TC_h^z = a_{1,h} + a_{2,h} \cdot \theta\theta_h^z \qquad (18)$$

which finally normalize:

$$TC_h^z \leftarrow TC_h^z \cdot \frac{24}{S} \quad where \quad : S = \sum_{h=1}^{24} TC_h^z$$

For the regression model can be used to forecast, bear in mind that temperature forecasts are available for two values (a minimum and maximum). As a result, the three values in relation (17) would be to add two ($b_{1,h}$, $b_{2,h}$), calculated with similar relations (9) and (10), the statistical parameters of (11) - (16) will be determined using temperature instead of hourly values of minimum and maximum values for the current day:θ^z_{min} şi θ^z_{max}. Thus, the relations (11) - (16) θ_h^{zk}, and $\theta\theta_h^z$ is replaced by:

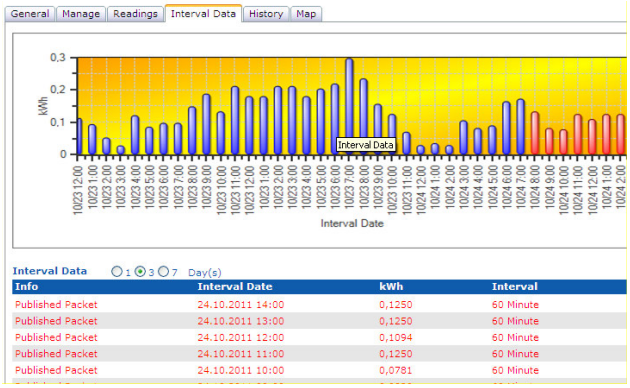
$\theta_h^{zk} = \theta^{zk}_{min}$ $\quad \theta\theta_h^z = \theta\theta^z_{min}$ for h = 1-8 şi 21-24

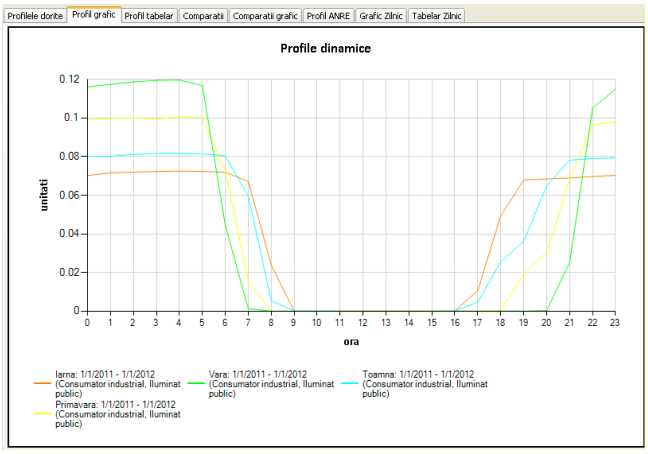
$\theta_h^{zk} = \theta^{zk}_{max}$ $\quad \theta\theta_h^z = \theta\theta^z_{max}$ for h = 9-20

Finally, on z type profile is obtained by filling model (17) in the form of 24 sets of five values:

$$\left(T_h^z, a_{1,h}, a_{2,h}, b_{1,h}, b_{2,h} \right), h = 1,..., 24 \qquad (20)$$

Coefficients a are used for correction of type profiles such as temperature zones and b coefficients are used for forecasting.





6. REPORTS

The system allows creating predefined reports and configurable reports in the form of text, tabular or graphic. Report generation is done so automatically after a predetermined schedule and on request. Reporting module allows export and import data in. Xls,. Xml,. Csv,. Txt,. Html,. Doc and printing.

For each customer profiles can be extracted from load following information:

•Place of consumption
•Type of consumer
• Nature pregnancy (active, reactive)
• Sizes characteristic of each day (or 24 hours)

- hourly power: P_k
- hourly energy: $W_k = P_k t_k$
- daily active energy: $W_a = \sum_{k=1}^{24} P_k t_k$,
- max power: $P_{max} = \max(P_1 ... P_{24})$
- min power: $P_{min} = \min(P_1 ... P_{24})$
- medium power: $P_{med} = \frac{1}{T} \sum_{k=1}^{24} P_k t_k$
- leveling coefficient: $\kappa_P = P_{med} / P_{max}$
- Daily unevenness coefficient: $\alpha_P = P_{min} / P_{max}$
- useful life of the daily maximum power: $T_{utiliz.} = W_a / P_{max} = \sum_{k=1}^{24} P_k t_k \Big/ P_{max}$
- hourly temperature: T_k
- medium temperature T_{med}
- correlation coefficient of average daily energy with average daily temperature:

- where:
  - T=24 hours
  - $t_k = 1h$, k=1…24

The database contains information on hourly temperatures for each day calendar information is stored. **[1], [2], [3]**

7. BILLING

Billing functions ensure application-level data mining mainly billing and saving them in files formatted for use by our billing (CC command "Extract Data"). Besides the main function, application configuring billing cycles in the CC and assigning them to meters, as they are installed. To extract billing data set there are some patterns. If they do not meet requirements, the application can define templates to extract us (CC command "Extract Data Setup"). The application provides data highlighting meters without billing for a billing cycle via CC command "Billing Progress Report".

For billing situations outside billing cycle (closing / cancellation agreement supply) provides application can read custom programming operator or reading. Status on-demand readings were launched in the report can view the final readings (CC command "Final Readings"). [1]

The system eliminates local meter reading costs in the invoice.

8.DISCONNECTION/VALIDATION OF CUSTOMERS RECONNECTION

Central point's applications are assuring the authorizing function of conection/disconection of consumers by a circuit breaker installed between the meter point assembly and consumer's installation. This circuit breaker is operated by endpoint and allows the CC's user yo disconect and to authorize –by sending an authorizing command from central point – reconecting consumers using TS2 technology. Disconection/reconection validation command reaches to the endpoint in 3-5 minutes. Confirmation of execution comand reaches to Comand Center in less than 30 minutes.

At Comand Center level are configuration commands (add, edit and remove circuit breaker with all assembly metter+endpoint), management (disconection/reconection authorization) and reporting (historical commands, circuit braker status: disconnected/reconnected/validated for reconnection). **[1]**

9.DATA READING MANAGEMENT

Measurement data collection is performed automatically or an request from the operator. On the automatically collection, il will be realized, before, an aquisition configuration (CC comand „Readings Settings"). There are two types of data that is collected from meters: the daily packet and horly energy. The automatically readings session mode can be watched by the aplication's control panel (CC comand „Dashboard"), whose refresh rate is configurable (default 2 minutes). The user can evaluate the data reading by different type of diagnosis comands („Diagnostics" menu):

- To view readings status report command (CC command „Dailly Reads Status Report")
- To view the history meter command (CC command „Meter History Viewr), with wich, user can inspect the meter readings history and change the status of a valid reading (billable) into a invalid reading (unbillable) and vice versa.
- To view the unusual meters command (CC command „Meter Exceptions") which displays all consumption points that haven't sent data for a configurable number of days or that sent data but it doesn't recording consumption.

If the communication connection between the central point and a concentrator from a medium voltage substation is interupted for a long time, there is the probability to import data from a file obtained by a local reading of that concentrator.**[1].[3]** Meter reading by the system offers the possibility of realizing energy balances on the transformer point. This analyse reveals the existence or not of illegal consumption and offers an accurate information of electricity losses.

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