PUBLISHER & EDITORIAL OFFICE
University of Oradea Editing House,
Str. Universitatii Nr. 1, Oradea, jud. Bihor, România, Zip code: 410087, Tel.: 00-40-259-408171, Fax: 00-40-259-408404
ISSN: 2067-5534 (print version)

The Journal of Sustainable Energy (JSE) had its first appearance under this name in 2010. The history of JSE is the following: is formed in 2010 by transforming of 1993-2009 Analele Universitatii din Oradea. Fascicula de Energetica, 1224-1261. Which superseded in part (1991-1992): Analele Universitatii din Oradea. Fascicula Electrotehnica si Energetica (1221-1311); Which superseded in part (1976-1990): Lucrari Stiintifice - Institutul de Invatamant Superior Oradea. Seria A, Stiinte Tehnice, Matematica, Fizica, Chimie, Geografie (0254-8593);

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Publishing House name/address:
University of Oradea Editing House
Universitatea din Oradea, Universitatii Str., No. 1, 410087, Oradea, Bihor, Romania

- ISSN: 2067-5534
- Tel.: 00-40-259-408171 (231, 288)
- Fax: 00-40-259-408404
- Place of publishing: Oradea, Romania
- Year of the foundation of publication in domain of power engineering: 1976
- Releasing frequency: 4 / year
- Language: English

CONTENTS

THE RELIABILITY MODELING OF URBAN TRANSPORT SYSTEMS USING ELECTRICALLY DRIVEN TRAMS

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Abstract: **This paper is dedicated to specific reliability evaluation prediction of an urban transport systems using electrically driven trams (UTSUEDT). The first part refers to topicality, justifying the need UTSUEDT treatment as a result of interconnection of three subsystems. The second part details the application of the concept model parametric UTSUEDT reliability. UTSUEDT states are detailed in part three of the paper, detailing the significance of six states and express the probability of state and transition. This paper contains references to reliability forecasting modeling of the three subsystems of the structure of UTSUEDT Company "Oradea Local Transport" (OTL). In the last part of the paper one presented the conclusions of the analysis.**

Key words: reliability prediction, electric traction, modeling.

1. INTRODUCTION

Applying the concept of sustainable development [1] is one of the most important priorities of modern society. In this context, in large urban areas, urban transport of people is a priority area of great importance and implications. Special contribution of transport, mainly urban public transport (UPT) to the environmental pollution is well known [2]. Pollution in big cities is a major problem and by sharpening it may decide even fate of transport strategies, implicitly the UPT. In these conditions, in terms of sustainable development, local city fathers are required to seek:

• Developing priority of UPT will reduce car traffic with all their implications

• Developing, especially of the urban public transport system operated by electrically driven trams, a transport system that is much cleaner than the car s, is relatively quiet and safe in circulation.

Specific problems of urban public transport systems are largely reflected in the literature. Much of the work aimed at UPT performance systems (urban public transport), performance measured by efficiency, service quality, environmental impact. In [3]on can identify the factors that influence the demand for UPT insisting mainly on service quality, and in [4] proposes and illustrates a methodology for the elaboration of UPT systems quality. A detailed assessment methodology of the transport service quality is in [5], appealing to the decisive impact factors such as availability, comfort and convenience. Availability of transport is examined in terms of hourly service frequency and service coverage. For an UPT system using buses, comfort and convenience are analyzed. Effectiveness of a specific UPT systems is analyzed in [6,7] Thus, in [6] one analyzed the effectiveness of 7 out of 12 UPT systems from Europa and 7 from Brazil. Based on these results the authors conclude that only nine cities in Europe and one in Brazil have an efficient UPT system, the inefficiency is due mainly to a social cause. Using data taken from 15 European UPT systems in [7] one aims to answer three questions identifying essential performance of transport systems: the impact of design methodology, the impact of organization and the performance of UPT systems size.

This paper is part of the concerns mentioned above, but on can distinguish it categorically, being dedicated to the forecasting of reliability modeling for an (urban transport system operated by electrically driven trams (UTSUEDT). Forecasting the reliability of modeling is essential to treat UTSUEDT's rigorous quality and efficiency. Functional aspect of UTSUEDT can be viewed and treated as a result of the interconnection of three subsystems (Fig. 1), [8,9].

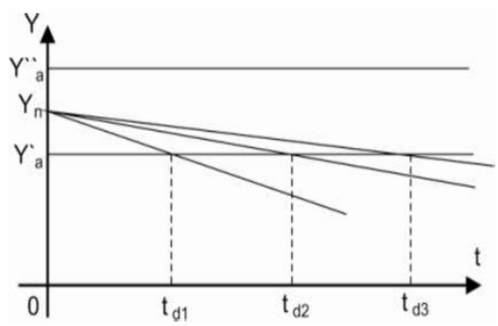
Fig. 1 – The structure bloc of an UTSUEDT

Where:
SSAD - subsystem of adaptation for electrical values of the electroenergetic system levels (EES), the electrically driven trams (EDT) need;
TFSS-transfer subsystem (distribution) of electric energy (EE) between SSAD and EDT, including: bars of recovery stations (RS) and DC power supply grid from

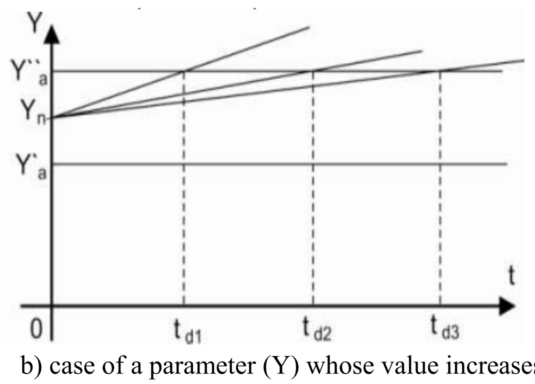
RS, including injection sections (IS), the wires contact system (WCS) and rails (R).
SSEDT-subsystem of electrically driven trams covering the entire vehicle, actuators, with the transfer of EE (pantograph), with speed control equipment (controller, inverter, converter), with own facilities (lighting, thermal comfort) and other specific equipment and facilities.

2. CONCEPT OF PARAMETRIC RELIABILITY ON THE UTSUEDT

A lot of UTSUEDT components failure modes are characterized by parameters derived [9]. Due to wear, aging time, fatigue and other phenomena, certain elements of UTSUEDT structure parameters have a slow evolution over time (Fig. 2.). Moments (t_{di}) are basically parametric failure times. By the treatment of the statistical values of (t_{di}), one can obtain the parametric reliability of UTSUEDT respectively the structural elements referred to.



a) case of a parameter (Y) whose value decreases with time (insulation resistance, pressure, mechanical tension, section, surface contact, et. al)



b) case of a parameter (Y) whose value increases over time (contact resistance, the game, electrical resistance, et. al)

Fig.2 – Time variation of a significant parameter (Y) for elements of UTSUEDT structure (Yn - nominal value of the parameter)

Therefore, the reliability function of UTSUEDT (R_{ST}) can be expressed as:

$$R_{ST} = R_{ST}^{b} \cdot R_{ST}^{p} \quad (1)$$

R_{ST}^{b} - function of reliability (safety time) assessed against sudden failures statistics

R_{ST}^{p} - reliability function determined by statistical parametric failure events.

If one approximates the evolution of an element of UTSUEDT by a significant parameter (Y) with a straight (Fig. 2.), the equation that gives the momentary value of the parameter is:

$$Y = Y_0 \pm v \cdot t \quad (2)$$

v - rate of degradation
Y_0 - initial value - can be equal to the nominal value Y_n or can be defined as Y_n, with the condition of being between Y_a' and Y_a'' values.

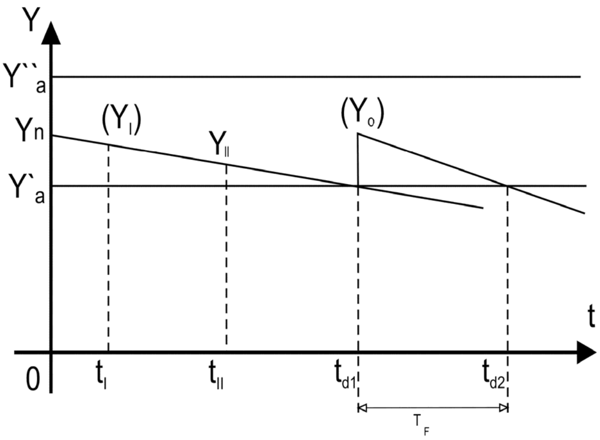


Fig. 3 - The evolution and correction of the Y parameter

Based on (2), by measuring Y parameters, one can determine the essential random values for UTSUEDT diagnose: rate of degradation (v) and proper operation time (T_F) between two preventive maintenance actions designed to make the correction of (Y)parameter- Figure 3 [10].

3. STATES OF UTSUEDT

To analyze the safety performance, availability and efficiency of UTSUEDT is essential to define states and assessing the probability of their existence. Figure 4 and 5 plot UTSUEDT states, emphasizing realistic transitions between them. Theoretically, other ways of transition are possible, but in practice [9] they are not confirmed during UTSUEDT operation.
The significance of the two figures are:
F(1) - normal functioning ≡ 100% availability of UTSUEDT;
AS(2) - waiting (for ex. night waiting, not planned for duty);
C(3) - critical (exposed), because of structural elements and parameter overuse like (used rails, used insulation resistance, lack of contact resistance, brake system damage, etc..);
D(4) - damage ≡ irreversible failure (sudden or parametric), which requires stopping

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CM(5) - corrective maintenance;
PM(6) - preventive maintenance, which can be applied in two ways [10,11,12];

- PPM(7) – programed PM
  → regarding time (de ex.: daily, weekly, monthly, annually);
  → regarding travelling distance (for ex.: la 5.000, 10.000, 50.000, 100.000 km);
- PMO(8) – PM to the object (opportunistic, predictive) by human decision .

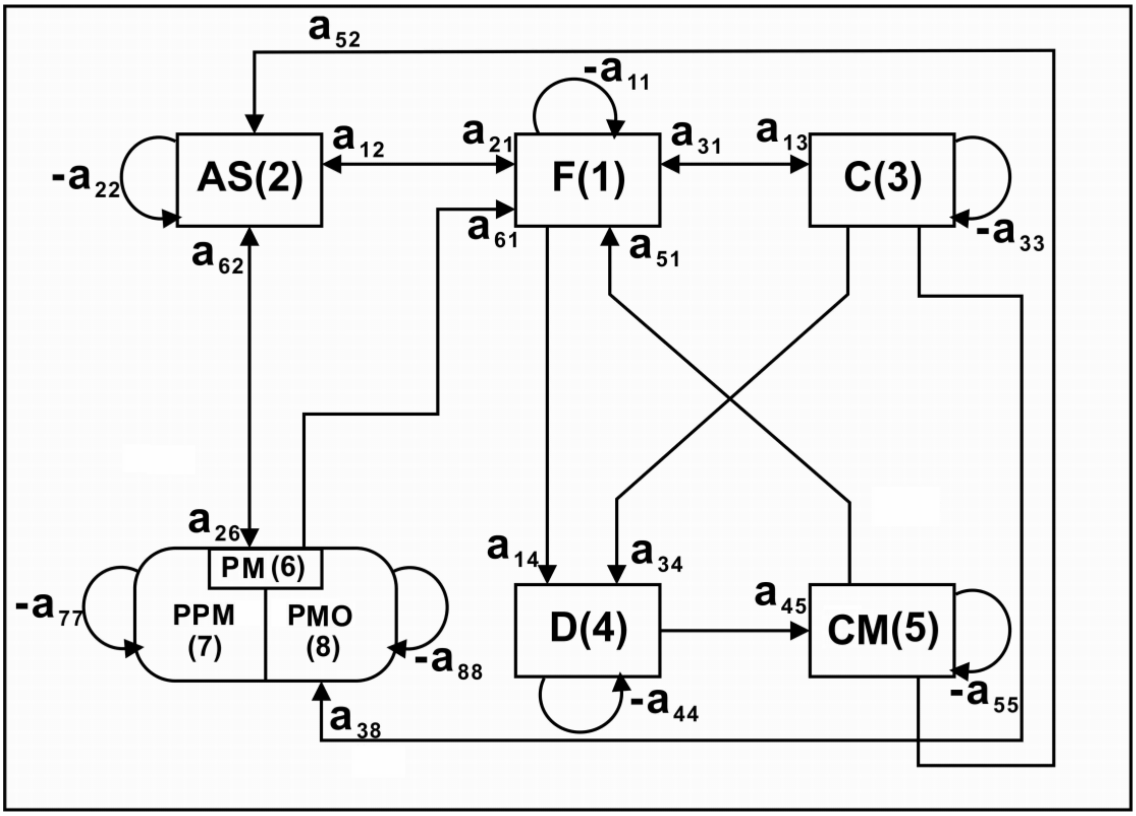

Fig. 4 – States of an UTSUEDT using state intensity indicators (-aii) and transitions (aij)

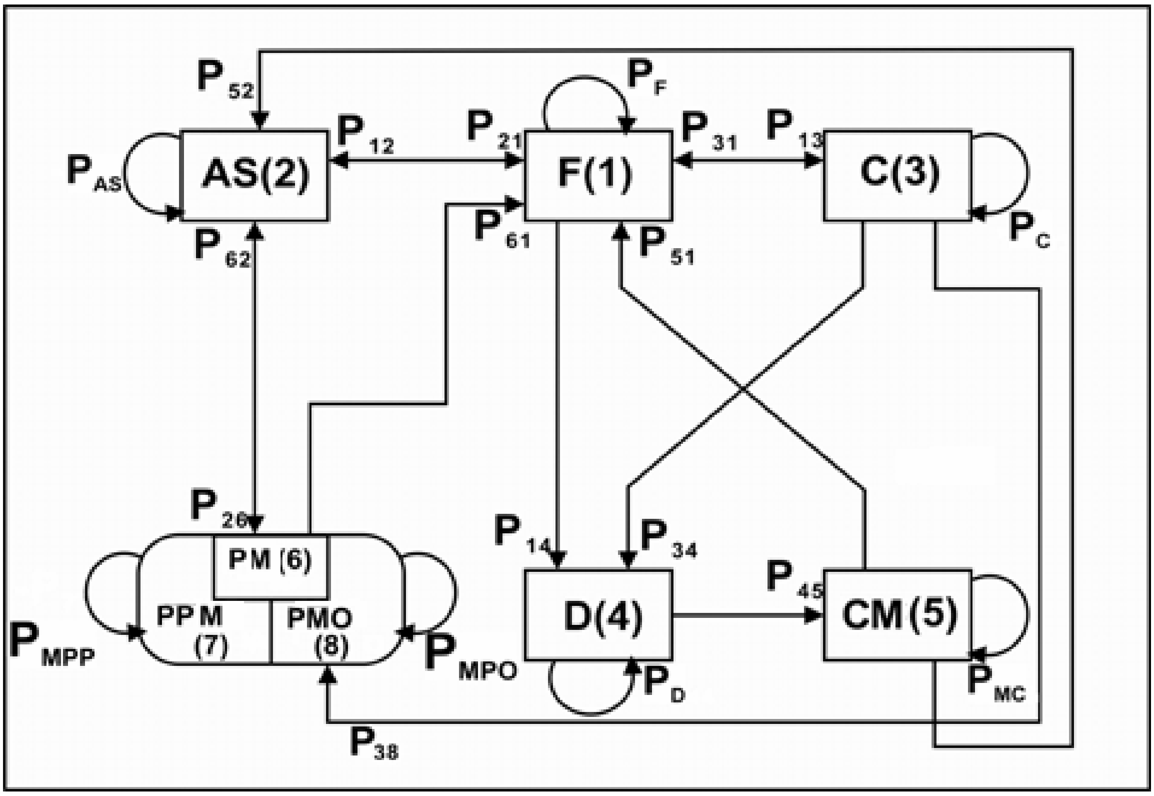

Fig. 5 – States of an UTSUEDT using state probability indicators (Pi) and transitions (Pij)

The two figures are valid for UTSUEDT subsystems (rails -R, electrically driven trams -EDT, recovery stations -RS), if these conditions are met simultaneously:

• There is EE supply from EES for all RS, with unrestricted power;
• Rail contacts and rails are 100% available;
• Sufficient EDT transport to service on schedule;
• RS and injection sections SI state allow to supply the power required for movement of all scheduled EDT and other receivers of EDT structure.

Therefore, the probability of state F (1) is determined as follows:

$$P_F = R_{EES}^{4of5} \cdot R_R \cdot R_{CW} \cdot R_{EDT}^{k.of.n} \cdot R_{RS}^{4of5} \cdot R_{SI}^{(n-1).of.n} \quad (3)$$

where:

R_{EES}^{4of5} - EE supply form EES for 4 out of 5 RS;

R_R – reliability of the whole rail system routs;

R_{CW}- reliability of the whole contact wire system routes;

$R_{EDT}^{k.ofn}$ -reliability of „**k** of **n**” system for EDT ≡ probability that from the totalof „**n**” EDT, at least a number of „**k**” – is necessary to be available;

R_{RS}^{4of5} - the probability the 4 out of 5 RS are available ≡ reliability of 4 out of 5 RS;

$R_{SI}^{(n-1)of.n}$ - probability that at least (n-1) of the „n” SI of each RS to function.

We find that „F” state doesn’t mean an ideal energy efficiency functioning. Moving from an un programed state F in a waiting state happens at the appearance of one of the adverse events:

- EVN1 ≡ Loss of power of EES to all RS - during functioning hours, loss of power at the RS that fuels the depot;
- EVN2 ≡ failure of rail between depot and exit/entry of EDT, or contact wire on this section;
- EVN3 ≡ Loss of power of SEN or RS failure before EDT got out of the depot.

Programed change from F state while PM or CM into waiting state AS is possible while night waiting (not functioning time). Therefore the probability of AS state can be expressed as

$$P_{AS} = P_{AS1} + P_{AS2} - P_{AS1} \cdot P_{AS2} \quad (4)$$

P_{AS1} - probability of moving to a programed waiting state AS

P_{AS2} - probability of moving to AS state after the appearance of an unwanted event (EVN1, EVN2 or EVN3). The two components of P_{AS} are determined as:

$$\begin{cases} P_{AS1} = \dfrac{T_{AS}^{P}}{T_A} \\ P_{AS2} = P_{EVN1} + P_{EVN2} + P_{EVN3} \end{cases} \quad (5)$$

where:

T_{AS}^{P} - programed waiting time, waiting at night.

In the P_{AS2} relation one regarded (EVN1, EVN2 or EVN3) which are rare events so the probability of multiple events like this is negligible.

The "C" state (3) can occur during operation, because they exceeded allowable limits of UTSUEDT working by some determinant parameters for items or sizes. This state is short (transient), and is happening until the occurrence of one of the events:

• intervention controls, Protection and Control, resulting in return to state "F"

• The human operator decides on technical diagnosis based on-line or off-line switching elements in PMO degraded;

• irreversible damage occurs, leading to state "D".

The probability of state "C" can be expressed as:

$$P_C = \text{Prob}\,[\delta_M \text{ U } P_{Fm} \text{ U } I_M \text{ U } Um \text{ U } \theta_M\,] = \\ = \text{Prob}(\delta>\delta_M) + \text{Prob}(P_F<P_{Fm}) + \text{Prob}(I>I_M) + \\ \text{Prob}(U<Um) + \text{Prob}(\theta<\theta_M) \quad (6)$$

In (6) one has shown the probability of exceeding the limits m - minimum and maximum M-quantities that characterize the main elements or specific UTSUEDT processes as follows:

δ - interplay between elements in contact and moving;

P_F – pressure produced by the braking subsystem while braking;

(I,U) – effective value of current and voltage;

θ - temperature.

Obviously the values of (I, U) reflects the values of: insulation resistance (R_{iz}) and contact resistance (R_{CT}).

Relation (6) was written assuming the neglect of multiple events, which is admissible because the listed events are listed as "rare events" category. The first and second values of P_C probability are essential for risk assessment and security of UTSUEDT. Fault condition (D) is obviously undesirable since it involves the most risk, social and economic consequences. The defect state (D) is a state when UTSUEDT can not operate at capacity scheduled, in accordance with requests transmission service beneficiaries. Therefore, in addition to total fault condition, the UTSUEDT is completely blocked, and there are plenty of defect states (unavailable) in state (D_i), which are analyzed in correlation with structure and functional levels (availability) of UTSUEDT. He passes the fault condition (fully or partially) if the conditions of operation and the state of UTSUEDT is not the AS waiting state. Therefore, we can write with good approximation:

$$P_D = 1 - (P_F + P_{AS} + F_{EES}^{4of5}) \quad (7)$$

In (7) to be noted that the associated conditional non reliability of EES (F_{EES}^{4of5}) is the only cause of downtime and not failure cause of UTSUEDT. CM state is the consequence of the existence condition "D". MC state begins with identifying the affected continuously with the causes and remedies and be completed by repairing and testing of equipment / facilities in question. State probability of failure is considered equal to the CM (P_{CM} = P_D). After the work of CM, UTSUEDT or structural

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elements subject, are written in one of the states "F" or "AS", according to the needs of the transport service

PM state transition can be done in two ways:

- Following a schedule based on lifetime or travelled distance of EDT, being performed as PPM. PPM transition state is in standby (AS) by appointment, usual procedure for EDT to which the two ways of PPM is applied[9]
- After the deterioration condition of equipment or facilities, which is referred by human operators directly or through sub-technical diagnosis, cases registered in the state "C". In this case preventive maintenance to the object (PMO) is applied to the identified components. After performing the PM works UTSUEDT structural elements subject to these works are listed in "F" or "AS", according to the needs of the transport service. PM state probability can be determined by the relation:

$$P_{PM} = P_6 = 1 - \sum_{j=1}^{5} P_j = P_{PPM} + P_{PMO} \quad (8)$$

4. CASE OF STUDY FOR UTSUEDT OF OTL

UTSUEDT structure of the company "Oradea Transport Locate" (OTL) and its application diagram is given in [9]. UTSUEDT has several functional levels that can be analyzed according to the condition of structural subsystems and the time of a normal working day or a holiday, which determines the application range of the EDT. According to current analysis of the transport operator, one will perform in this context, analysis and representation of the reliability block diagram (RBD) of functional levels for maximum loading level: 40 of 73 EDT existing at OTL facilities, an analysis for the period when the application of EDT is lower. Obviously, based on ERD represented in Figure 1 can be written:

$$R_{ST} = R_{SSAD} \cdot R_{TFSS} \cdot R_{SSEDT} \quad (9)$$

We refer, further, the reliability of forecasting modeling for each SS, necessary step to identify the relationship between the level of reliability and functional level of UTSUEDT. In the OTL, SSAD is the type "4 of 5", meaning that if it at least 4 RS out of 5 are working, the SSAD function achieves its adaptation to any application level with EDT. RS - RBD is presented in Fig. 6.

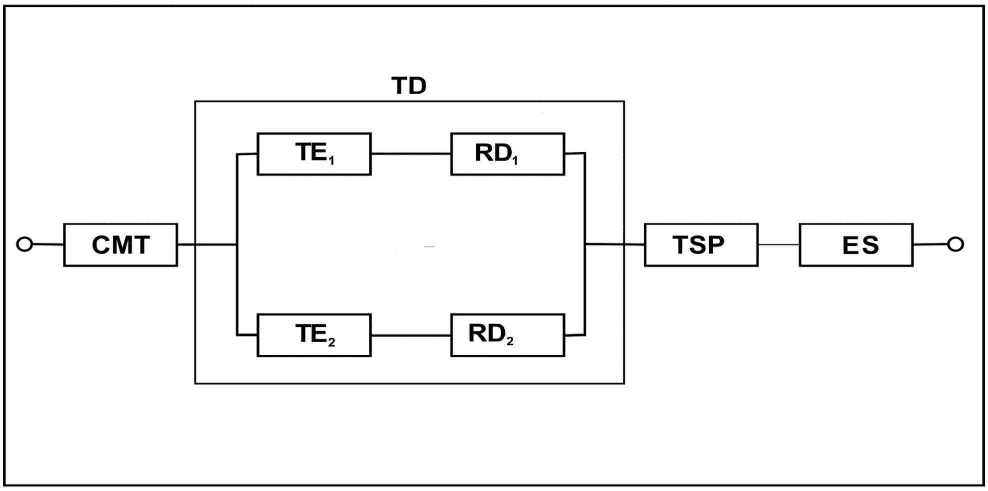

Fig. 6 – RBD of a RS

All the points of connection between the NPS and DC bars are considered included in the RS, clinging and auxiliaries transformer (TSP) and other specific elements (ES) required for the RS and maintenance workshops powered by own service transformer TSP. Significance others notations in Fig. 6 is:

CMT – medium voltage cell
TE1, TE2 – main transformers
RD1, RD2 - electrical rectifiers

One consider attached all the power equipment highlighted in the RBD, protections, control, measurement, automation necessary for proper functioning of RS. The reliability forecast evaluation of such structures is detailed in [10,11,12,13,14], so that in this framework we restrict the expression of the reliability function of the SSAD structure based on RS - RBD in fig.6 (" 4 of 5 ").

$$\begin{cases} R_{RS} = R_{CMT} \cdot R_{TD} \cdot R_{TSP} \cdot R_{ES} \\ R_{TD} = 1 - (1 - R_{TE1} \cdot R_{RD1})(1 - R_{TE2} \cdot R_{RD2}) \\ R_{SSAD} = \sum_{i=4}^{5} C_5^i \cdot R_{RS}^i \cdot (1 - R_{RS})^{5-i} = 5 \cdot R_{RS}^4 \cdot (1 - R_{RS}) + R_{RS}^5 \end{cases} \quad (10)$$

In the OTL, TFSS components (R, CS, SI) are subordinated but can be supplied and neighboring RS. Functional level of 100% of TFSS necessary to function fully, R,CS and to operate an adequate number of SI. Analysis [9] by comparing the number of SI. ascribed to each RS to load the supply network (SN) leads to the conclusion that the number of SI reserves is different for every RS. Based on these considerations, in Fig. 7 the RBD of TFSS at a 100% functional level is presented.

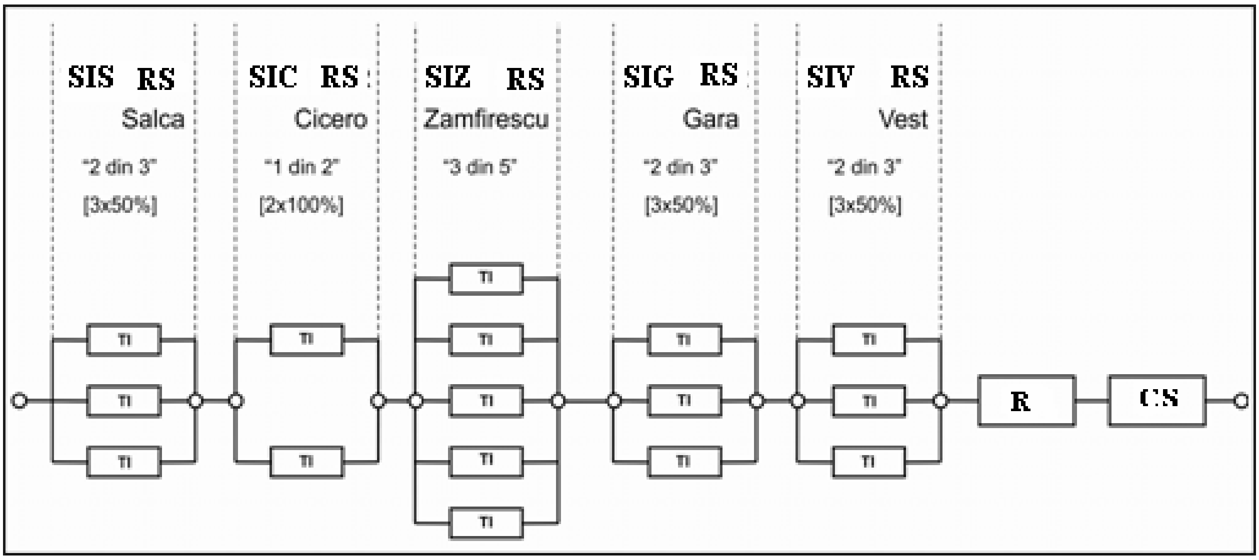

Fig. 7 – RBD of a TFSS [100% functional level]

Reliability function of TFSS can be expressed based on the RBD as:

$$R_{TFSS}=R_{SIS}\cdot R_{SIC}\cdot R_{SIZ}\cdot R_{SIG}\cdot R_{SIV}\cdot R_{R}\cdot R_{CS} \qquad (11)$$

Neglecting the length of IS that influence its reliability, one can write:

$$\begin{cases} R_{SIS}=R_{SIG}=R_{SIV}=\sum_{i=2}^{3} C_3^i\cdot R_{SI}^i\cdot(1-R_{SI})^{3-i}=3\cdot R_{SI}^2\cdot(1-R_{SI})+R_{SI}^3 \\ R_{SIG}=2\cdot R_{SI}-R_{SI}^2 \\ R_{SIZ}=\sum_{i=3}^{5} C_5^i\cdot R_{SI}^i\cdot(1-R_{SI})^{5-i}=20\cdot R_{SI}^3\cdot(1-R_{SI})^2+5\cdot R_{SI}^4\cdot(1-R_{SI})+R_{SI}^5 \end{cases} \qquad (12)$$

R_{SI} - probability of proper operation of an SI

Electrically driven tram subsystem (SSEDT) is the „k out of n" type, fig.8.

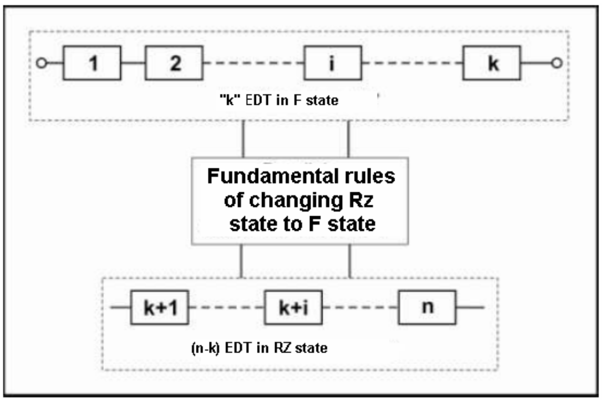

Fig. 8 – RBD of a SSEDT

From "T_F" in the analysis period T_A of the "n", EDT number "k" in use, and "n-k" is the reserve (RZ).This reserve is known as sliding or half active backup. In this case, the condition is more general RZ, whereas some of the "n-k" EDT may be in the state of PM, others in the CM, and others in waiting AS. Please note that the numbering of fig.8 is fictitious, unrelated to registration or inventory of EDT. For current UTSUEDT of OTL: n = 73 and k_{max} = 40. To express SSEDT reliability function, one uses the binomial method, which allows us to write:

$$R_{SSEDT}=\sum_{i=k}^{n} C_n^i\cdot R_{EDT}^i\cdot(1-R_{EDT})^{n-i} \qquad (13)$$

R_{EDT} - probability of good functioning (reliability)of EDT.

OTL - UTSUEDT has three types of EDT with differentiated levels of reliability. Therefore, to assess R_{SSEDT} is necessary to determine, first, an equivalent amount of indicator R_{EDT}. Note: (a, b, c) - the number of the 3 types of EDT [a-ULF, b-T4D, c-KT4D] (λ_{EDTi}, μ_{EDTi}) - intensities of failure and maintenance of the 3 types of EDT, values calculated in the study of operational reliability [15]. The values of equivalent indicators (λ_{EDT}, μ_{EDT}) are calculated using the relations:

$$\begin{cases} \lambda_{EDT}=\dfrac{a\cdot\lambda_{EDT1}+b\cdot\lambda_{EDT2}+c\cdot\lambda_{EDT3}}{n}. \\ \mu_{EDT}=\dfrac{a\cdot\mu_{EDT1}+b\cdot\mu_{EDT2}+c\cdot\mu_{EDT3}}{n} \end{cases} \qquad (14)$$

$$n=a+b+c$$

Having the values of fundamental indicators, one can calculate the equivalent reliability function for EDT, with the relationship [10,11]:

$$R_{EDT}=\frac{\mu_{EDT}}{\lambda_{EDT}+\mu_{EDT}} \qquad (15)$$

For OTL - UTSUEDT, for a maximum load level of (k_{max}=40), we have:

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$$R_{SSEDT} = \sum_{i=40}^{73} C_{73}^{i} \cdot R_{EDT}^{i} \cdot (1 - R_{EDT})^{n-i} =$$
$$C_{73}^{40} \cdot R_{EDT}^{40} \cdot (1 - R_{EDT})^{33} + C_{73}^{41} \cdot R_{EDT}^{41} \cdot (1 - R_{EDT})^{32} +$$
$$+ C_{73}^{72} \cdot R_{EDT}^{72} \cdot (1 - R_{EDT}) + R_{EDT}^{73} \quad (16)$$

The calculation of core (λ_{EDTi}, μ_{EDTi}) and therefore the calculation of equivalent indicators (λ_{EDT}, μ_{EDT}, R_{EDT}) is considering the two components of the intensity of maintenance (μ_{CM}, μ_{PM}), whereas for EDT, preventive maintenance is mandatory within the PM, EDT is not available. Given values for fundamental indicators [15], and when using the constant values (a = 10, b = 43 and c = 20), the EDT in the OTL at a maximum application, we obtain: λ_{EDT} = 0,031 [h^{-1}] μ_{EDT} = 0,065 [h^{-1}] R_{EDT} = 0,694. Bearing in mind the expression (16) only get 10 terms, we obtain: R_{SSEDT} = 0.9968. From this brief analysis shows that, SSEDT reliability is high, even for the maximum demand (k_{max} = 40), which means that for lower levels ($k<k_{max}$), demands are even better. This is confirmed in UTSUEDT practice operation and is reflected in the statistics presented in [9].

5. CONCLUSIONS

For analysis and evaluation of UTSUEDT reliability and subsystems of its structure is recommended to apply one or more of the models: direct assessment, based on equivalent diagrams reliability assessment based on events and fault trees, Markov chains method based with continuous parameter binomial method.

A lot of UTSUEDT components are characterized by failure modes of the derived parameters , implying their parametric reliability assessment.

The modeling of UTSUEDT reliability forecasting is by carrying over the overall system performance, characterized by the vector quantity components: for safety, availability, maintainability, efficiency, reliability and security.

UTSUEDT and its components can evolve over a sufficient period of analysis, the following states: running, critical, waiting, defects, corrective maintenance and preventive maintenance.

The first step in the systematic analysis of the reliability of forecasting UTSUEDT - RBD is its representation that reflects the utility of systematic analysis of three subsystems with specific functions: adaptation SS, transfer SS and electrically driven trams SS.

Execution subsystem SSEDT is "k of n" type, often with a consistent number of spare parts, whose level of reliability is convenient, sufficient and precisely estimates by applying the binomial method.

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REABILITY ANALYSIS OF A GEOTERMAL BINARY POWER PLANT, NO.4, FROM SVARTSENGY, USING MONTE CARLO SIMULATION

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Abstract: The paper presents a reliability study of geothermal plant with secondary fluid made with two computation methods, which are: the Markov chain method and Monte Carlo simulation method. Then, was made a comparison between the obtained results by applied computation methods. This type of plant as working fluid uses isopentane, and its cooling in the condenser is made by water.

Key words: reliability, geothermal plant, Monte Carlo simulation, Markov chains

1. PRELIMINARIES

The renewable energy is defined as a form of energy, derived from a large range of natural resources having capacity of renewing after some renewable cyclic natural processes on a relative short and predictable scale.

The most important renewable energy forms are: the energy of solar radiation (solar energy), the wind (wind energy), of water (hydraulic energy, tidal energy, osmosis potential energy), of biological processes (the obtained energy after oxidation of biogas, bio-ethanol, biodiesel, and biomass) and of the stored heat in the earth's crust (geothermal energy). These forms of renewable energies are nowadays the most recognized energies and may be captured by actual technologies and used directly or indirectly [9].

The reliability is one of the decisive parameters of competitiveness product, because the merchantability degree grows significant for reliable products. After 1990, worldwide the reliability domain entered the new stage of development. If in '60 the reliability referred to control / verification, as in '70 / '80 to assurance, now the key word is the management of reliability with all which it implies: adequate predictable methods, reliability design, process reliability, convergent engineering, total quality control, etc. [8].

Considering all these aspects is important to define the reliability of geothermal plants. To establish the reliability of a certain type of geothermal plant, it was chosen a plant with binary cycle. This plant is the type of Ormat located in Island, at Svartsengy at approximately 40 km from the capital of the land. To make the analyze of the proposed plant it were chosen two computing methods, one, the analytical way with Markov's chain method, as the second way the Monte Carlo simulation method.

2. RELIABILITY OF GEOTHERMAL ELECTRIC PLANTS WITH BINARY CYCLE. CASE STUDY

As was stated above, the analyzed geothermal plant operates with binary cycle, with Clausius Rankine cycle, and for this type of plant the operating condition is that all compounds of the plant must activate. The scheme of the system is given by the equivalent serial reliability diagram, fig.2, and the scheme of the plant is given in fig.1. The mean time between failures and of faults was taken for the great compounds of the plant as: the vaporizer, turbine, generator, condenser, and cycling pump of the work fluid.

 ISSN 2067-5534

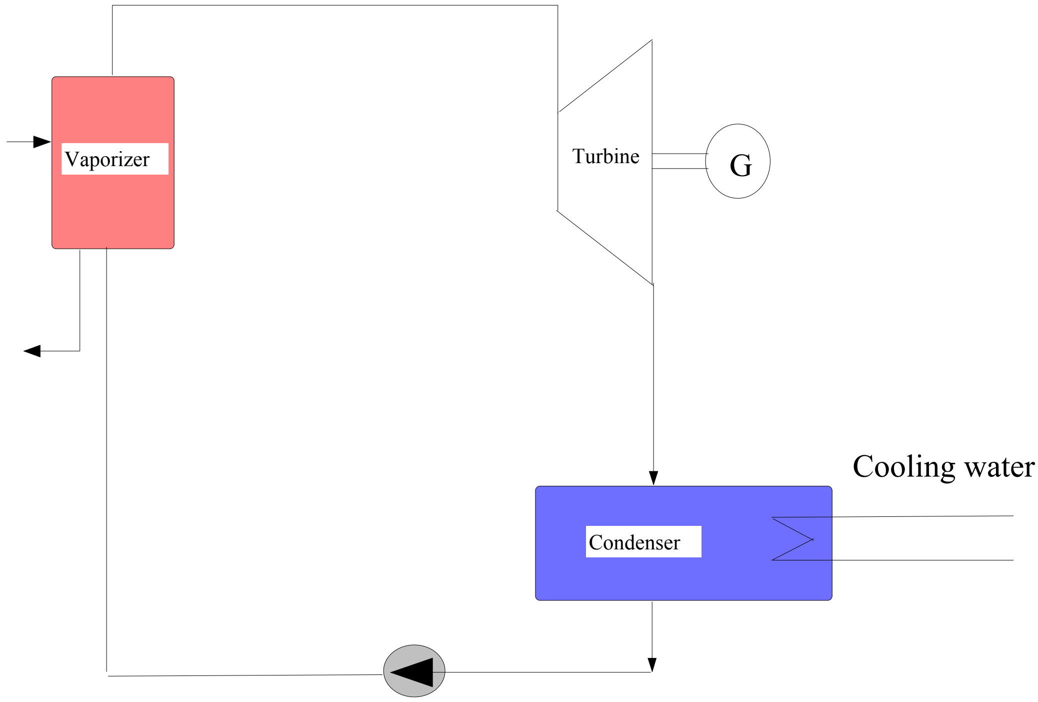

Fig. 1 - The simplified operation scheme of the electric geothermal plant (C4)

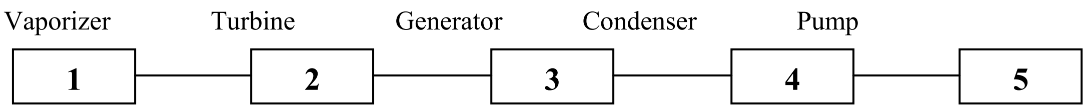

Fig. 2 - The equivalent reliability scheme of the geothermal plant

As input data it was used the values of λ and μ parameters, given in table 1.
Where: λ [h^{-1}] – is the failure intensity;
μ [h^{-1}] – is the intensity of reparation

The values for λ, μ has been calculated based on the exploitation data of mean time between failures and mean time to failure for analyzed geothermal plant with binary cycle.

Table 1 - Input data lambda and miu

Crt.No.	Equipment	λ [h^{-1}]	μ [h^{-1}]
1	Vaporizer	1,98597*10^{-5}	0,058823
2	Turbine	2,046287*10^{-5}	0,0006662
3	Generator	1,98736*10^{-5}	0,01923077
4	Condenser	2,01849*10^{-5}	0,001208
5	Pump	1,9862156*10^{-5}	0,0434782

2.1. Application of Monte Carlo simulation program

The numerical modelling of different processes about the elements' and systems' behaviour in time, is made by relationships including VA, those influences is estimated with some specifically operating and failure coefficients.

In this chapter was simulated the reliability of an electrical geothermal plant with binary cycle, with Monte Carlo simulation software, being an adaption of [6,7,8]. The software was made in MATLAB, a programming language frequently used to resolve scientific problems with research character. The estimated operation and non-operation times are computed by the programme with relations (1.1) and (1.2), where values of VA (random variable) u_i, v_i, are automatic generated by *rand* function of MATLAB [1,2]:

$$t_{func} = -\frac{1}{\lambda_n}\ln(u_i) \qquad (1)$$

$$t_{def} = -\frac{1}{\mu_n}\ln(v_i) \qquad (.2)$$

For the components from fig.1 was introduced the parameters λ and μ, in the simulation Monte Carlo program of the analyzed system, as well as its structure [8].

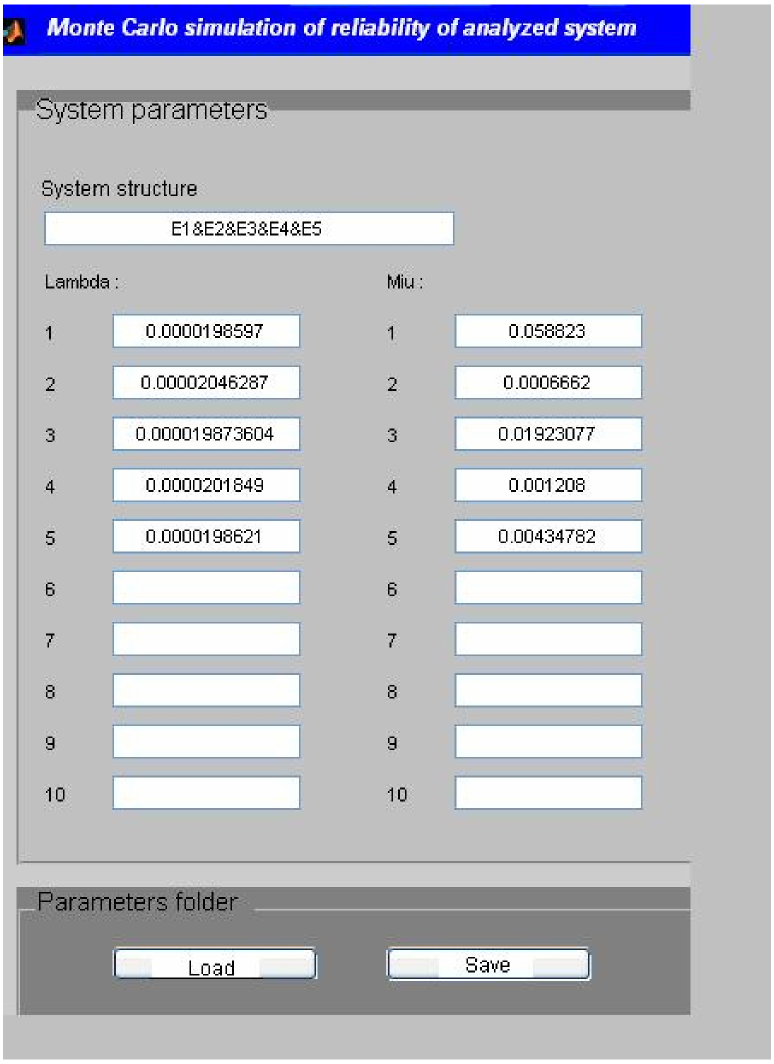

Fig. 3 - Parameters of the system

After introduction the parameters (λ, μ) and equation of the system, the user has the possibility to save the data, in order to be able to restore it if necessary, figures 3, 4, and 5.

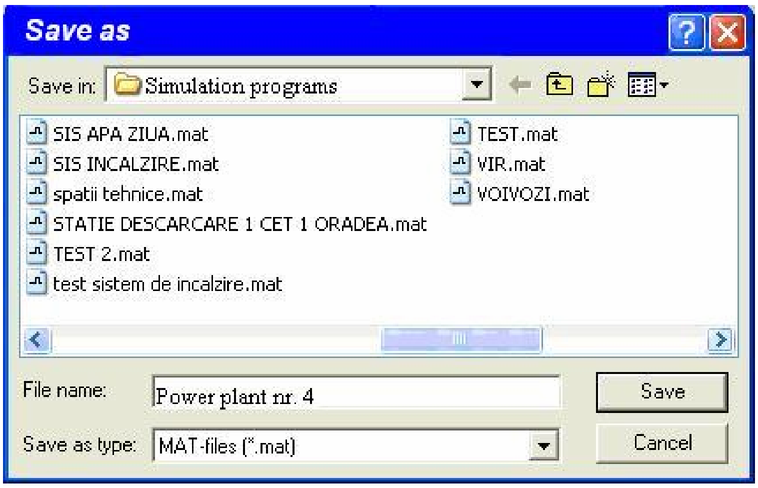

Fig. 4 - Module of the saving program of data

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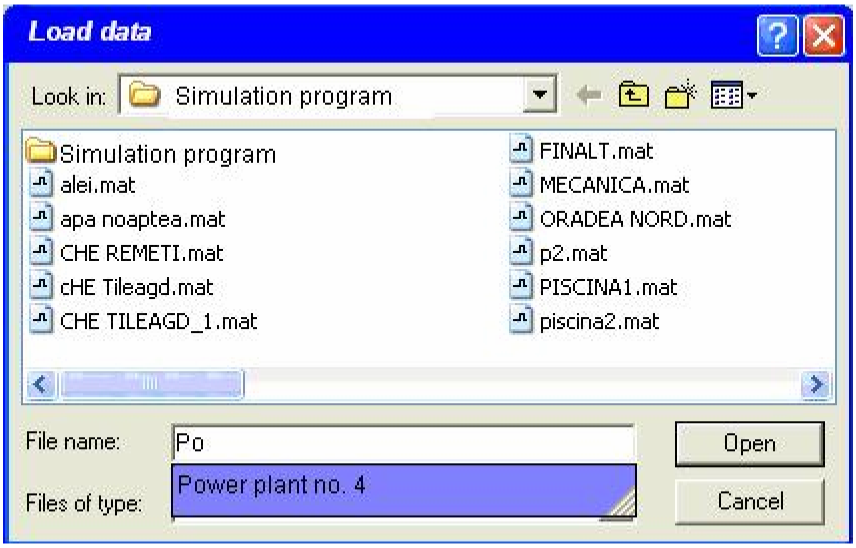

Fig. 5 - Module of the input program of data

After the system parameters introducing (μ, λ, and the system structure) the user will introduce the parameters of simulation that refers on:

- the number of simulation / analyze of TA (analyzed time);
- number of simulation N;
- number of simulation intervals, after this, will be successive accessed the results of numerical calculus, displaying the operation diagram and the diagram of reliability, all these have a saving action. In figures 6 – 9, will be presented some captures of window with precisions.

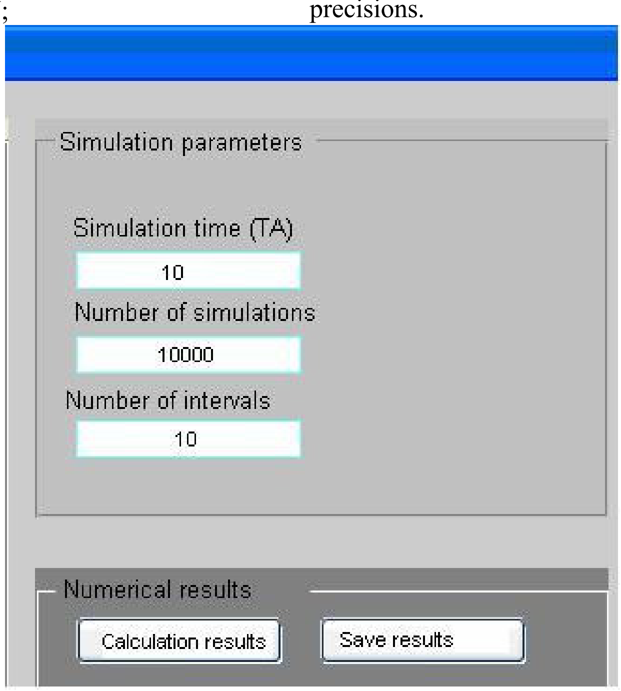

Fig 6 - Example of simulation parameters introducing

Fig. 7 - Calculation of the results of simulation

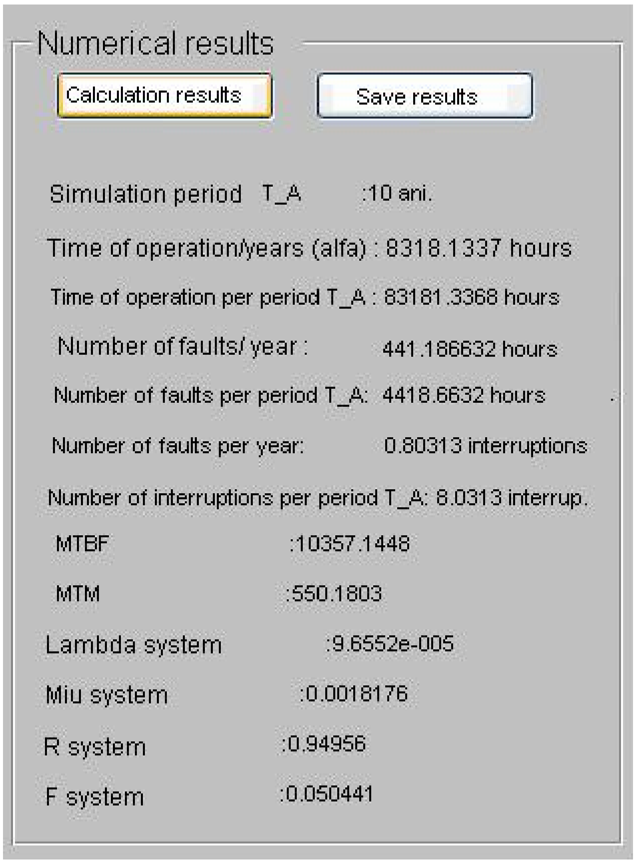

Fig. 8 - Numerical results of the simulations

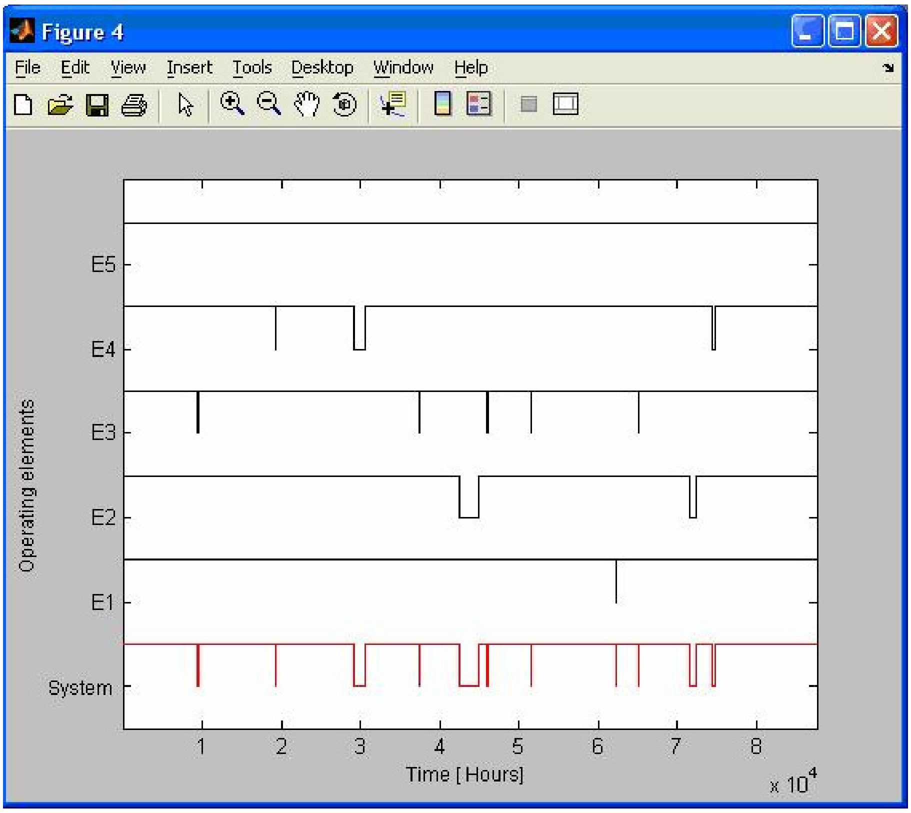

Fig. 9 - Operating diagram for the analyzed system after the analyze of the simulation and saving

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2.2. Comparison of the obtained results applying the Markov and Monte Carlo simulation methods

In table 2, are given the results obtained from simulation, simultaneously a comparison study between analytical and simulation results for the analyzed plant. In the left column of the table 2, are the results obtained by Markov chains method, and in the right column are the results obtained from the Monte Carlo simulation obtained by the program.

The results obtained by analytical method with Markov chains have been taken from [9], these calculus were made for the same system as the analyzed one in this article and the analyzed period being the same.

For Monte Carlo method, the investigation period is 10 years, because it is useful to observe the system's behaviour for a longer period, but there were evidenced the indicators resulted from the calculus for one year.

Table 2 - Comparative analyze between the obtained results by simulation Monte Carlo and analytical way Markov Chain

No.	*Indicators*	*Symbol*	*Units*	*Monte Carlo simulation*	*Markov chain*
1.	*Time of operation/ year*	α	*h*	*8318.3368*	*8348.80*
2.	*Number of faults/ year*	β	*h*	*441.8663*	*412.841*
3.	*Number of interruption / year*	ν	*intreruption*	*0.80313*	*0.83691*
4.	*Mean time between failure*	*MTBF*	*h*	*10357.1448*	*9975.74*
5.	*Mean time of maintenance*	*MTR*	*h*	*550.1803*	*493.31*
6.	*Lambda system*	λ_e	h^{-1}	*9.6552e-005*	$10.0243 * 10^{-5}$
7.	*Miu system*	μ_e	h^{-1}	*0.0018176*	0.0020271
8.	*Reliability of system*	R_{system}	-	*0.94956*	0.952878
9.	*Non- reliability*	F_{system}	-	*0.050441*	0.047122

The differences between the indicators aren't significant; they are due to the number of simulations, due to the fact how Mathlab works in its memory with 14 decimals, even if displays fewer differences that are on the limit of an admissible computation error; also the simulation results are influenced by evolution of the systems in time, taking into account the failures appearing the period of analyze.

3. CONCLUSIONS

The reliability analyze of electric plants are a need for the manufacturers of equipment's, as well as for potential customers. The scientific literature is poor in treatment of electric geothermal plants reliability. For a reliability indicator computation of electric geothermal plants, may be used the classical analytical methods, but it is preferable to apply a simulation method, for example the Monte Carlo simulation method. The simulation program in Mathlab allows:

- the reliability indicator computation for the secondary fluids in geothermal plants;
- drawing of operation diagrams for all elements and for system;
- drawing its reliability diagrams.

The obtained values by Monte Carlo simulation for the reliability function, confirms the accuracy of the method. The differences are between allowable limits and appear due to the decimals with the Mathlab works, and to the fact because the results of the simulation are supposed to the influence of evolution in time of the system.

The obtained results by applying the two computation methods show, that the analyzed system has a very good reliability.

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RELIABILITY ANALYSIS OF POWER DISTRIBUTION SYSTEMS

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Abstract: Systems for the distribution of electricity are a component part of the electro energetic systems and the whole process of supply of electricity to consumers depends on their operation. At present the process of distribution of electricity is accompanied by many problems, of which the key problem is the reliability of electricity supply to all consumers, and we must pay a special attention to it. The present work is devoted to problems of calculation and assessment of indicators of reliability of distribution systems and supply of electricity to consumers, both agricultural and industrial.

Key-words Electrical equipments, power energetic systems, reliability of distribution systems.

1. INTRODUCTION

Operation of distribution systems is accompanied by many problems of which the most important is the reliability of these systems, which at present is the key issue for the development of electro-energetic [1, 5].

To determine the level of reliability is an essential process, which can be both of foresight and of real calculation in the process of operation of respective systems. The process of analysis and calculation of reliability of distribution systems shall be carried out by means of reliability indicators. The determination of these indicators for the current systems, is quite a difficult matter, due to the fact that at the time these systems are very complicated.

To simplify the calculation mode, the indicators of reliability of these complicated systems can be determined on the basis of their decomposition into subsystems, but the determined indicators must reflect the stability of the quality of operation of the entire system. To determine the indicators of reliability it is required in relation to the studied system to designate all the requirements that these systems are to meet [2].

This article is devoted to the calculation of key indicators of reliability of systems for the distribution of electrical energy in the Moldova Republic resulting from the influence of random factors that have caused the occurrence of interruptions in electricity supply to all customers.

2. RESOLVING OF THE PROBLEM

Research on the evolution of indicators of reliability of distribution systems have been carried out during the last 5 years. The distribution systems have been analyzed and studied according to their geographical-territorial deviation from Central and South of our country. Characteristics of electric energy distribution systems studied in this paper are presented in table 1.

Table 1 - Main characteristics of the studied distribution systems

System	Subsystem	The number of supplied consumers	The summary length of the distribution networks 6-10 kV, km
1	1.1	287114	2829,288
	1.2	30576	
2	2.1	28862	3857,236
	2.2	31490	
	2.3	41068	
	2.4	33938	
	2.5	27217	
3	3.1	25065	3196,428
	3.2	22765	
	3.3	45441	
	3.4	32802	
	3.5	25860	
4	4.1	29046	2159,293
	4.2	19485	
	4.3	33472	
	4.4	18423	
5	5.1	22889	2013,195
	5.2	25428	
	5.3	13114	
	5.4	19954	
Total	**20**	**814009**	**14055,440**

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To assess the development of the reliability indicators of electric energy distribution systems, during the investigated period, the outages that occurred in those schemes were analyzed and studied: random (R), scheduled (S) and exercises (E). These interruptions were recorded daily during the years 2006-2010.

For the processing of statistical data computers have been used with computing programs "Microsoft Office Excel", "Matcad", "Statgrafixs". Because the process of assessing the reliability of distribution systems is quite difficult and includes a lot of operations in order to systematize the process of calculation the structural scheme and algorithm of reliability indicators were developed.

As a result of the researches the values of flows of random interruptions that occurred in systems researched for five years have been obtained. The results are presented in table 2. Analyzing these values you can see that the number of unplanned interruptions is big enough. This is due to the action of the various factors which have a random character and have a particularly high influence over indicators of reliability in the supply of electricity to consumers.

Table2 - The number of random interruptions that took place in the investigated systems

System	Subsystem	The number of random disconnections from different periods				
		2006	2007	2008	2009	2010
1	**1.1**	1102	907	1093	858	1112
	1.2	749	353	377	501	566
	TOTAL	**1851**	**1260**	**1470**	**1359**	**1678**
2	2.1	270	186	403	425	573
	2.2	651	614	567	524	644
	2.3	1040	1160	840	622	845
	2.4	529	458	530	403	567
	2.5	210	122	260	386	385
	TOTAL	**2700**	**2540**	**2600**	**2360**	**3014**
3	3.1	260	250	460	277	379
	3.2	412	235	309	237	320
	3.3	680	415	1011	596	650
	3.4	498	472	875	383	636
	3.5	130	198	265	372	495
	TOTAL	**1980**	**1570**	**2920**	**1865**	**2480**
4	4.1	330	580	340	286	481
	4.2	411	240	320	283	407
	4.3	520	468	650	485	546
	4.4	359	202	320	208	233
	TOTAL	**1620**	**1490**	**1630**	**1262**	**1667**
5	5.1	243	250	220	231	313
	5.2	259	165	270	245	360
	5.3	297	195	349	316	391
	5.4	324	350	301	396	492
	TOTAL	**1123**	**960**	**1140**	**1188**	**1556**
TOTAL SYSTEMS		**9274**	**7820**	**9760**	**8034**	**10395**

Reliability indices of researched distribution systems have been determined, on the basis of variation of interruptions in different periods, and that have taken place according to the action of random factors of influence.

The values of the researched indicators have been determined in accordance with the following analytical expression for calculating [3, 4].

As a result of analytical calculations the values of indicators of reliability were obtained for various periods (2006, 2007, 2008, 2009, 2010): the average duration of the interruption τ_m, frequency of restoration λ, mean time of interruption T_{med} . As an example in table 3 are shown the respective indicators values determined for the period of 2010.

Table 3 - Indicators of reliability of researched systems calculated for the period of 2010

System	Indicator	Seasonal values			
		Spring	Summer	Autumn	Winter
1	**τ, h**	1,01	1,99	1,46	1,69
	λ	0,53	1,76	1,73	1,52
	μ, h	1,91	1,13	0,84	1,11
	T_{med}, h	5,16	6,13	4,76	5,67
2	**τ, h**	4,17	8,32	7,73	9,26
	λ	3,21	6,12	3,95	5,12
	μ, h	1,30	1,36	1,96	1,81
	T_{med}, h	2,89	2,76	3,56	3,23
3	**τ, h**	8,31	10,67	6,33	5,96
	λ	4,53	3,45	4,68	5,11
	μ, h	1,83	3,09	1,35	1,17
	T_{med}, h	6,84	5,98	7,26	2,49
4	**τ, h**	2,81	4,52	2,23	3,95
	λ	1,64	3,86	2,86	3,72
	μ, h	1,71	1,17	0,78	1,06
	T_{med}, h	3,24	2,93	2,65	2,22
5	**τ, h**	4,01	2,96	3,33	4,12
	λ	2,42	3,45	2,65	4,36
	μ, h	1,66	0,86	1,26	0,94
	T_{med}, h	5,40	3,68	3,84	4,86
Total	**τ, h**	3,25	6,24	4,03	4,21
	λ	2,71	4,11	3,28	2,61
	μ, h	1,20	1,52	1,23	1,61
	T_{med}, h	3,66	4,33	5,93	2,94

The mode of variation in time of the calculated indicators of reliability is presented in Figure 1.

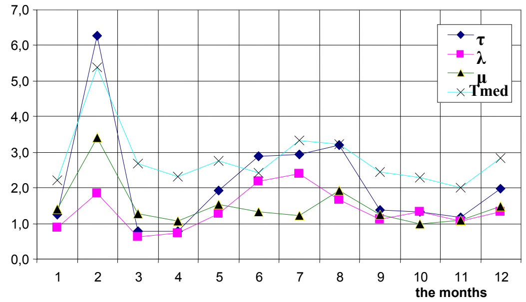

Fig.1 - Variation in time of calculated indicators of reliability

Based on the analysis of the results obtained it can be stated that the assessment of the reliability of the systems of power distribution can be achieved by means of indicators calculated, taking into consideration their variation over time, based on the influence of random factors. The obtained values of the indicators analyzed, fully corresponds to the actual level of reliability of distribution systems and allow you to define ways of increasing the safety of operation of these systems.

3. CONCLUSION

The level of reliability of energy distribution systems is characterized by means of reliability indicators. To assess the reliability of these systems it is sufficient to determine the four indicators: average duration of the interruption of the frequency of interruption τ_m, frequency of restoration λ, the average time of interruption T_{med}.

Calculation of reliability indicators can be performed using an algorithm of simplified operations, which allows to determine the variation of these indicators, given the influence of random factors that have caused the occurrence of interruptions on various periods.

The determined indicators characterize fully the level of reliability of the researched distribution systems and the values obtained in this paper confirm that their variation in different periods is uneven for the Republic of Moldova, which is due to the action of the various factors which have a randomize influence.

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SUSTAINABLE GREENHOUSE HORTICULTURE IN EUROPE

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ABSTRACT - The European greenhouse horticulture represents one of the most intensive energy sector in agriculture and strongly contributes to increase the energy and environmental vulnerability within regions having a large greenhouse farming systems. Specifically, the European greenhouse farming sector is facing a trend that responds to the changing consumer's demands in a society that, globally, is increasingly affluent but more aware about some negative consequences, such as high energy-demand processes, and CO_2 emissions. About 200,000 hectares of greenhouses in Spain, Italy, The Netherlands and Greece is the estimated covered surface, with not less than 3.4 MTOE of energy consumption and 9.2 MtCO2eq, and an yearly economy value of 7 billions of Euros. The installed energy power load of greenhouses in Europe depends on local climate conditions, and varies from 50-150 W/m^2 (Southern regions of Europe) to 200-280 W/m^2 (Northern and Central regions), while complete conditioning could even reach an energy load of 400 W/m^2 (heating, lighting, cooling). Nowadays, the proportion of renewable use in the total energy consumption of greenhouse farming in Europe is very low, and there are no clear priorities set in this area, yet. Comprehensive and complete studies that evaluate the opportunities of renewable options in greenhouse sector are still not completeted. This, strongly hinders the process of setting concrete goals and legislative targets to support a wider introduction of sustainable energy technology, and appropriate legislation in greenhouse regions of Europe. This paper deals with the proposal of supporting the organization of a sustainable greenhouse agriculture, based on renewable energy sources, i.e. geothermal energy at low temperature, photovoltaic solar energy and solid biomass, in tune with the specific local assets, the local geo-climatic conditions and the protection of landscapes rather than with a careless perspective for local environment and potential societal costs.

Keywords: energy efficiency, greenhouses, solid biomass, photovoltaic technology, geothermal energy

1. INTRODUCTION

The greenhouse horticulture sector in Europe represents an important economic reality in countries such as Italy, The Netherlands, Spain, Greece, and one of the most intensive energy sector in agriculture (Tab. 1). As general figure, in Europe are operating about 200,000 hectares of greenhouses, of which about 30% with permanent structures, and provided with acclimatization systems using fossil fuels. Between the most important European countries regarding to the surface covered with greenhouses (i.e.: Spain, Italy, The Netherland and Greece), it has been estimated not less than 3.4 MTOE of primary energy consumption with 9.2 $MtCO_{2eq}$ and a total economy of 7 billions of Euros. The installed energy power load of greenhouses depends on local climate conditions and varies from 50-150 W/m^2 (Southern regions of Europe) to 200-280 W/m^2 (Northern and Central regions) while complete microclimate conditioning could even reach energy load of 400 W/m^2 (heating, lighting, cooling) [5]. The greenhouse sector in Europe should limit its use of fossil fuels, therefore reducing its CO_2 emission to positively respond to the European Directives on energy, renewable energy, energy efficiency and environment [7, 9]. Since it is general conviction that the oil price will continue to increase for the coming years in Europe, great efforts must be made to develop actions for supporting the use of the large availability of solar energy irradiation, the abundant resources of both geothermal energy and solid biomass. Amongst the actions to step up the development of a sustainable dimension of the greenhouse sector, high significance gains the enactment of laws and regulations to re-orient the greenhouse agriculture in line with both the Kyoto Protocols.

Tab. 1 - Energy and economy in some of the most important countries for greenhouse agriculture

Country	Greenhouse[a] surface (ha)	Economics[b] (€)	Heating[c] (MWh_t)	Electricity[d] (MWh_{el})
Italy	30,000	3 billion	706,786	24,830
The Netherlands	10,311	6,8-7,7	29,510,800	3,723,000
Spain	43,964	1.5*	989,627	33,623
Greece	5,646	0.5	87,644	1,700
Total	**89,921**	**About 12.0**	**31,294,857**	**3,783,153**
TOE			2,691,358	760,414
MTOE			2.7	0.77
$MTCO_2$			7.5	2.1
TCO2eq			7.2	2.04

a. referred to both plastic-houses and glass-houses;
b. referred to yearly value, including plant products and construction materials of greenhouse;
c. referred to yearly energy consumption;
d. referred to yearly electricity demand of greenhouse users (ventilation, opening, pumping);
* greenhouse construction materials are not included.
Conversion factors:
- 0.0860 TOE/MWht.
- 0.201 TOE/MWhe.
- 1 TOE equal to 2.81 tons of CO_2 emissions.
- 2.683 TCO_{2eq}/TOE (IPPC, revised in 1996).

Source: The Regulatory Authority for Electricity and Gas of Italy, 2009.

Elaboration of authors from data EUROSTAT 2008 and 2009, national statistics and bibliography.

In addition to strictly occupational effects, the development of sustainable greenhouse system surely can increase on-site income and puts into motion a virtuous cycle which local communities can only benefit from, i.e. more circulation of money due to investment in technologies and infrastructures, and increase in collection of local taxes for authorities.

2. METHODS

Geothermal resource at low temperature. The use of hot warm water from geothermal or industrial thermal effluents at low temperature as energy for greenhouse heating has much potential of supplying a great part of the energy needs in greenhouse agriculture. Geothermal water at low-temperature is compatible with a wide range of heating system designs including forced-air distribution systems, water-to-air heat exchangers, plastic pipes and finned tubes, liquid-based radiant heat in the floor, bench-mounted-liquid based radiant heat, and direct soil heating.

The advantages and disadvantages of these heating systems have been investigated by several experimentations, with a wide collection of data and results which showed that all these systems are able to produce heat energy ranging from 30 to 70 W/m^2 as referred to the horizontal projection of ground occupied by the system [1, 10]. The feasibility of this resource of thermal energy for greenhouse heating is mainly for providing base-thermal load with peak thermal load covered by traditional installations. There are two main approaches under which greenhouse owners can operate: retrofitting an already-in-use system or building new greenhouse plants and introducing new energy technologies to make cost-effective use of geothermal energy. In the first approach, the agriculture company can use an existing geothermal well and operate the entire geothermal energy system from the well to the heat delivery equipment in the greenhouse structure. This option includes that the cost of energy delivered to the greenhouses is not affected by actions of others but must provide by himself all actions requested for maintenance of geothermal installations. In the second approach, the agriculture company could purchase geothermal heat from the owner of the low-temperature effluent resource. Both approaches require tax considerations, permits, national, regional and municipality laws and regulations. A recent type of geothermal space heating is the application of ground source heat pump, which is mainly adapted in systems providing only space heating for greenhouses [15].

A ground source heat pump uses underground heat exchangers of different types to extract heat from usually shallow depths (a few meters to a few hundred meters) and use it for space heating during the cold season. Several data report that simple horizontal ground-source heat pump configurations can supply 20-35 W per m^2 of ground surface occupied by the loop. It is possible with some research and more optimization to have 40-45 W per m^2 from a simple low cost ground loop. So, applied to 1000 m^2 greenhouse, a power of 45 kW can be extract from the earth.

Surely, some electricity from compressor (if COP = 5 part of energy from electricity and 4 parts from ground) so if COP = 5 then total energy delivered will be 60 to 66 W per m^2. Other configurations (more dense but 30-50% more expensive) already give around 75 W per square meter plus the electric power load(i.e. total energy up to 100 W_{th}/m^2. The availability of these systems can be 100% of the period of heating (and cooling). In order to calculate the whole energy deliverd during one year, if the system operates as much as 25% of time a 100 $W_{\mathbf{th}}/m^2$ geothermal heat pump can give as much as 100 W_{th}/m^2 x 0,25 x 8760h = 219 kW_{th}/m^2/year, at very low operating cost lower than 50% of conventional energy.

2.1. PV solar

During the last decade, photovoltaic solar energy as sustainable option for greenhouse acclimatization in regions characterized by high irradiation has been raising importance, in accordance with both the growing market of renewable energy and the demand coming from society for reducing energy fossil fuel consumption and emissions of CO_2 [11].

In most Mediterranean areas, annual solar radiation can reach an average of 1500 kWh/m^2/year, but some areas of Spain, Italy and Greece present more than 1800 kWh/m^2/year. Among the immediate applications for PV systems in greenhouse, are the following ones:

- irrigation control (pumping, automation, electro valves, computers)
- fertilization control (automation, recycling of the nutrient solution, fertilizers mixing) climate control:

- ventilation (vents motorization and automation, electrical fans);
- cooling (cooling pads, fog-systems);
- shade screen (motorization, automation);
- heating (when heating requirements are low);
- photoperiodic lighting (5 to 10 W m^{-2}).

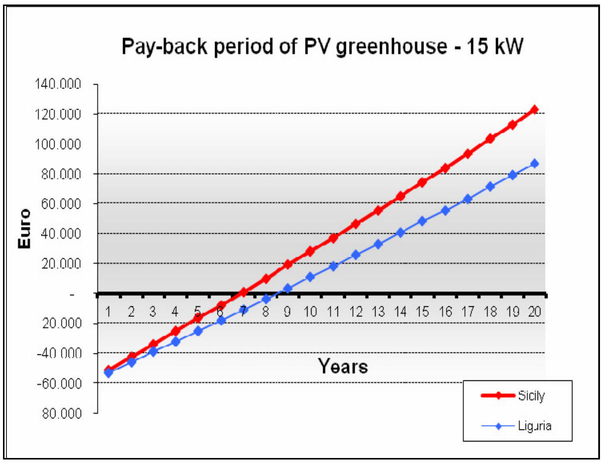

Fig.1 - Comparison of pay-back period for PV greenhouses located in different climatic areas of Italy areas in Italy (Source: Report "Stato dell'arte e prospettive di sviluppo delle tecnologie per la produzione di Energia Elettrica, di Calore e di Biocarburanti e delle tecnologie per l'Efficienza Energetica". ENEA, January 2012 (in Italian).

A greenhouse requires a yearly average power electrical requirement ranging from a maximum of 90,000 $kWh_{el}.ha^{-1}$ for greenhouse with a good climate control (heating, cooling or ventilation) to 20,000 $kWh_{e}l.ha^{-1}$ for very low technological greenhouse structure. ENEA data on the PV technology as electricity demand for 1 ha of greenhouses estimates not less than 32,000 kWh in the southern Italy area.

Assuming PV module efficiency (ηPV) equal to 0.13, a 7.5 m^2 panel area is needed to generate 1 kWp DC peak power and an annual yield of 1500 kWh_{el}. This leads, on yearly basis, to a value of DC peak power installed to generate 1000 kWh_{el} equal to 1000/1500 = 0.66 $kWp.(1MWh_{el})^{-1}$ to contribute the greenhouse energy demand [2, 3, 6]. Assessment European average cost for PV power generation turns out to be around 2-3 □.Wp^{-1} (VAT and installation not included), especially when poly-crystalline solar cells are used. Figure 1 shows the time to re-pay the investment (pay-back period) of 15 kWp PV installations, based on multicrystalline silicon plants, installed in Italy at different latitudes (the region Sicily at latitude 37° has the highest insolation in Italy, and the region Liguria at latitude 44°).

Apart from the estimated emissions associated with the manufacturing, transport and future decommissioning of PV plants, of importance are also the negative impacts in terms of vision and land use (between 2.5-3.0 hectares per 1 MWp) on the agro-ecosystem, which today are not properly accounted neither by the governments and the producers, nor by the consumers of energy. Such costs should be seen in comparison with the benefits for better quality environments due to the avoided CO2 emissions, and for the advantages in terms of new income-productive activities associated to the greenhouse industry. The external costs (socio-environmental and health costs) for Southern Europe would be 0.15 c□.kWh^{-1}, with a corresponding GHG emissions between 21-45 g CO_2-eq.kWh^{-1} [8].

2.2. Solid biomass as energy source

It was estimated that not less than 300 million tons crop residues and over 230 million tons green residues and animal wastes are produced in Europe as unutilized by-products, which can be made available for partial substitution of commercial energy sources in the future (data from FAO). According to EU's energy projections, the use of biomass for energy generation in Europe, today estimated around to 180 Mtoe, would reach 210-250 Mtoe by 2030 to meet the European renewable energy targets. Among the different wood energy opportunities which are taken into consideration hereafter are those relating to heating market of chip, pellet and briquette.

According to ENEA data, 150 tons per year of biomass are requested for greenhouses of 1000 m^2 with at least 2,000 hours of heating. Averagely, the cost of a modern biomass boiler is about 325 □/kW till 100 kW, 156 □/kW for size of more than 100 kW and till 500 kW, and 136 □/kW for biomass boiler with energy load of more than 500 kW and till 1,000 kW. As fas as the price of fossil fuels together with the environmental and energy security concern continue to increase in Europe as in the rest of the world, bioenergy raises higher interest as sustainable fuel for greenhouse agriculture and small scale district heating plants applications. As reported from a number of investigations, biomass energy is capital intensive as initial investment and remain low as running costs in respects of the traditional fossil energy technologies. Evaluations made for the greenhouse horticulture in Italy with solid biomass show that the years necessary for re-pay the investment (pay-back period) decrease in relation to the increase of the installed power biomass boiler (Fig. 2). The economy of biomass heating strictly depends both on actual fossil fuel prices and on availability of government incentives, and this makes that most often the energy market demands/loads and the tax facilities (incentives or income tax exemptions) are the final rule for defining the real biofuels price.

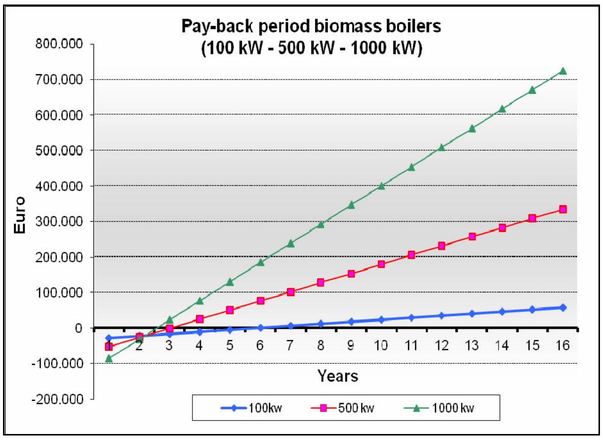

Fig. 2 - Comparison of pay-back period for different energy load of biomass boilers (Source: Report "Stato dell'arte e prospettive di sviluppo delle tecnologie per la produzione di Energia Elettrica, di Calore e di Biocarburanti e delle tecnologie per l'Efficienza Energetica". ENEA, January 2012 (in Italian).

2.3. Energy Performance Certificates (White Certificates)

Europe-27 has placed the promotion of energy efficiency among the priorities of its energy policy. The Directive 2006/32/EC provides further pointers for encouraging energy efficiency, as an essential prerequisite for achieving the renewable energy and CO_2 reduction targets. The European Energy Efficiency Action Plan 2011 points to the role of energy efficiency as an essential tool for reducing consumption among Member Nations, in order to achieve the more ambitious goal of a reduction of 20% by 2020 and to stimulate the efficient use of resources.

Directive 2006/32/EC establishes that Member States must draw up an Energy Efficiency Action Plan aimed at achieving an overall national indicative energy savings target by 2016, equivalent to 9% for the ninth year of application. The target is to be reached by way of energy services and other energy efficiency improvement measures, such is the incentive mechanism consisting of the creation of a market in Energy Performance Certificates or White Certificates, which attest the reduction in consumption of primary energy resulting from energy efficiency measures and actions.

The White Certificate mechanisms aimed at projects that adopt efficient energy-saving technologies, enable the adoption of renewable technologies for heating, including: solar panels for the production of hot water, high-efficiency heat pumps, low temperature geothermal systems, or systems that use vegetable products and organic or inorganic refuse, etc. [13]. To counter energy costs on the one hand and the need to reduce CO_2 emissions on the other, greenhouse agricultural businesses can now no longer delay either the introduction of environmentally friendly energy technology or the adoption of innovative agricultural practices, systems, production processes capable of maximising the energy efficiency of the agricultural cycle and the use of locally available renewable energy.

Table 2 reports the schedule of energy-efficient measures proposed in Italy.

Tab. 2 - Energy efficiency for greenhouse agriculture

Systems and devices to increase energy efficiency	**Benefits to the company, agriculture and the micro-climate**
Greater insulation of the greenhouse	Reduction of surface area losing heat
Use of "thermal blanket" systems	Reduction in the volume of greenhouse to heat
Strategies of controlling and planning temperatures and relative humidity	Heating of the air correlated to the intensity of external light
Systems and techniques for passive accumulation for solar heat	Maximisation of solar heating
Transparent/filtering covers for regulating the transparency of Covers that increase the diffusion of direct sunlight	Increase in visible radiation (PAR) and reduction in infrared radiation (NIR)
	Increase in visible ventilation for cooling
Increasing the heat dispersing area of windows	Greater natural ventilation for cooling
Cogeneration systems	Use of local energy resources (biomass)
Low-energy bulbs or Light Emitting Diode (LED) lighting	Improvement of vegetable productivity and increase in the life cycle of light bulbs
Biomass boilers, geothermal heat pumps, photovoltaic systems	Energy innovation, reduction in emission of CO_2

3. RESULTS AND DISCUSSION

The greenhouse horticulture sector has an important role to play in the future European agriculture economic and this asks both the growers and the farmers to adapt the energy technology to changing circumstances and market pressure as well, and to incorporate the energy efficiency policy, the technology innovation and the renewable energy sources. Renewable energy resources (geothermal energy, PV technology and solid biomass) together with the use of sustainable plant process for greenhouses are recommended as one of the cornerstones in order to innovate the greenhouse agriculture in Europe.

The governments and stakeholders should contribute by providing special financing to encourage both the private enterprises and the growers to invest in renewable energy and innovative technologies. Furthermore, the research and the technicians should assist growers by assessing the potential of each local energy source available on the specific site, and by estimating the energy investment cost required to use it. Based on these data, the task of elaborating a conceptual design of sustainable greenhouse districts and its implementation must be carried out with care.

Much attention should be provided by researchers, authorities and stakeholders to inform growers on the potential impacts on the agriculture traditions and the environment in order to increase acceptance and penetration of innovation and renewable technologies.

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4. CONCLUSIONS

The prospects for growth of a sustainable greenhouse industry based on geothermal, biomass and photovoltaic solar technologies should be excellent. The integration of renewable energy resources and technologies into existing greenhouse agriculture represents a great opportunity of supplying most of the yearly energy demand in European horticulture. However, one of the most important aspects for greenhouses farms is to document the technical and economic performance and reliability of local available renewable resources as well as the impact of renewable energy installations on greenhouse horticulture productivity and agriculture territory.

Renewable technology offers an opportunity to strongly reduce both the fossil energy for greenhouse acclimatization and the CO2 emissions of agriculture in Spain, Italy, The Netherland and Greece. Europe is currently supporting either the policy of developing of renewable energy or the decreasing of CO2 emissions. The governments and the authorities should encourage growers and companies by providing incentives to improve the Energy Efficiency and to foster the application of renewable resources. Of particular interest for supporting the introduction of renewable technology in greenhouse horticulture is the mechanism of White Certificates (WC) or Energy Performance Certificate (EPC). The mechanism lays down that White Certificates will be issued in response to energy savings verified and certified by authorized authorities. The Italian White Certificates as mechanism to improve Energy Efficiency is internationally recognized as a benchmark, since no other country has implemented such a well-defined system in agriculture. These kinds of encouragements and economic incentives, however, should be supported with adapted regulatory measures, programs of research, and demonstration activities to allow renewable greenhouse horticulture to substitute in the short term traditional greenhouse horticulture activity.

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SOLAR ENERGY APPLICATION IN MACEDONIA

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Abstract - Macedonia has perfect geographical and climate conditions for solar energy application. But, despite these, the use of this energy source is at minimal level. The reasons for this situation are multiple and have political, economical, educational background; the level of public awareness has its role, too. Solar thermal systems are mainly used for sanitary warm water preparation, but also there are rare examples for space and swimming pools heating. So far, the generation of power from solar energy is limited to photovoltaic plants with capacities up to 1 MW. This paper gives general overview of the current state of the solar energy application in Macedonia, the perceived obstacles / barriers and the necessary conditions to be provided to achieve wider penetration.

Keywords: solar energy, state of application, Macedonia.

1. INTRODUCTION

Macedonia has rich solar radiation and large number of sunny days (more than 260).[8] Unfortunately, sun has weak application as an energy resource; it is not even mentioned in the state energy balance.

In the last thirty years we have witnessed rapid growth in solar energy application in many countries, but the most characteristic are the examples from China, Greece, Austria, Germany and recently France and Spain. Perhaps the solar application in Greece or Spain is not surprising – they have rich solar radiation, but the rapid growth in Germany and Austria is really interesting. Obviously climate predispositions are not the single important factor.

Leading countries in solar energy use have proven and still prove the possibility for fast, economically and energetically justified growth accompanied with great social benefits, when public support, long term and permanent positive policies are provided.

Solar thermal production technologies are already mature, i.e. the risks in their application are minimized. Moreover, developed countries have introduced standards and methods for their use and control in order to guarantee the quality of installed solar systems and energy gains.

Due to the difficult economic situation of the country and unrealistic price of electricity, interest in solar energy (and other RES) hardly exists. Nevertheless, the business sector, receiving information from abroad for renewable energy resources and their economic and social importance, makes initial efforts to penetrate the market. But the list of obstacles is long and unfortunately still preventing broader application.

2. SOLAR ENERGY APPLICATION IN MACEDONIA

Solar energy utilization can be summarized in the following applications:

- heat generation (warm water, space heating and cooling, cooking);
- power generation (photovoltaic, thermal systems);
- transport (solar vehicles);
- natural lighting;
- photosynthesis.

The most common application of the solar thermal technology is for sanitary warm water preparation in the households. Worldwide there are hundreds of thousands of solar systems for water heating, especially in regions where intensive solar radiation exists.

Solar energy is used to generate power as well, employing more complex technologies.

There is a big interest and potential for solar space cooling. It is expected that this technology will experience commercial level of development and huge application. Such forecasts are based on very simple fact – the largest cooling requirements match the most intensive solar radiation. When space heating is in question, the situation is opposite – the largest heating requirements match the lowest intensity of solar radiation. (fig.1)

In Macedonia, solar thermal energy is mainly used for sanitary warm water preparation with simple thermo-siphon or pumping systems. In tourist areas like Ohrid, Struga, Dojran, there are large size solar systems for sanitary water heating, placed on hotels and hotel complexes. Few years ago also individual solar combi systems appeared for combined space and sanitary water heating. Swimming pools heating with solar energy is not the practice in Macedonia (it is not even practice to heat the swimming pools out of the heating season), although recently there are a few examples derived.

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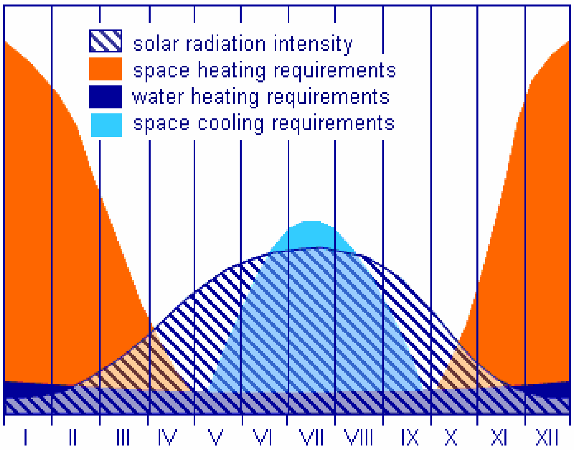

Fig. 1 - Annual energy needs of a household [10]

Considering the power generation with solar, currently there are nine grid connected photovoltaic power plants with total capacity of 2398 kW (2882 MWh planned annual production) having benefits from the preferential tariff. There is great interest for investments in such plants (larger capacities), but meanwhile the preferential tariff has undergone two changes and the process of gathering all the necessary permits and documents is very slow. In addition, maximum total capacity that can now be installed and connected to the grid is limited to 10 MW.

Annual daily average solar radiation in Macedonia is in the range between 3,4 kWh/m^2 in the northern part (Skopje) and 4,2 kWh/m^2 in the western part (Bitola). Therefore, the total annual average solar radiation ranges from 1250 kWh/m^2 to 1530 kWh/m^2 (fig.2) [1].

Despite the favorable geographical position and climate offering excellent solar energy potential, its utilization in Macedonia is at minimal level. The total installed operative capacity for heat energy production (flat plate and vacuum collectors) is 13,5 MW_{th} or 6,6 kW_{th} per thousand inhabitants (fig.3, fig.4).

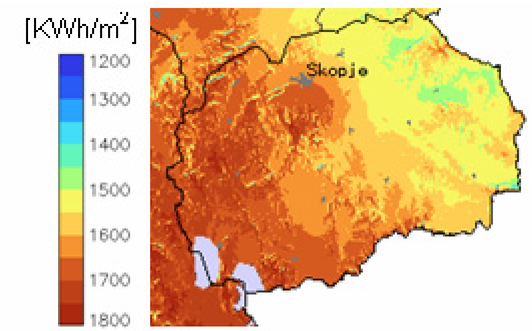

Fig. 2 - Map of average annual solar radiation in Macedonia [1]

The reasons for this situation are multiple, some of them are:

- long-year ignorant attitude of the state politics towards the RES, especially for heat production,
- years backwards unreal price of the electricity,
- low economy standard,
- lack of awareness of the decision makers and citizens,
- lack of appropriate legislative and regulative which would offer long-term support, strategic determination and devotion,
- lack of long-term financial support ,
- lack of regulations and mechanisms for maintenance and control of the installed solar systems quality.
- lack of mechanisms to register the newly installed capacities and their operability,
- incompetence in designing and installation of the solar systems,
- un-aesthetic integration of the solar systems [9],
- lack of good business practice (agreements for long-term regular maintenance and service, warranties, etc.).

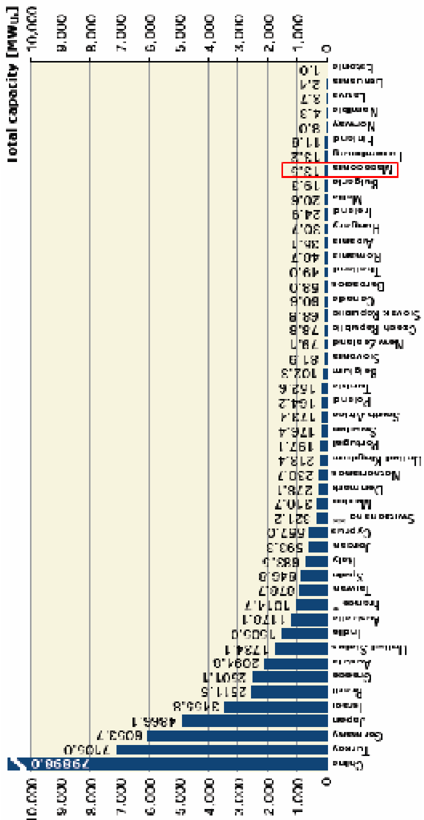

Fig. 3 - Total operative capacity in flat plate and vacuum solar collectors by the end of 2007 [5]

3. CONDITIONS FOR WIDER PENETRATION

Necessary conditions for wider penetration of the solar energy application are logical conclusion from the formerly listed reasons, and could be summarized in few important factors mutually related and dependent:

- ambitious targets
- research and development
- awareness raising
- obligations
- financial support
- demonstration projects
- trainings.

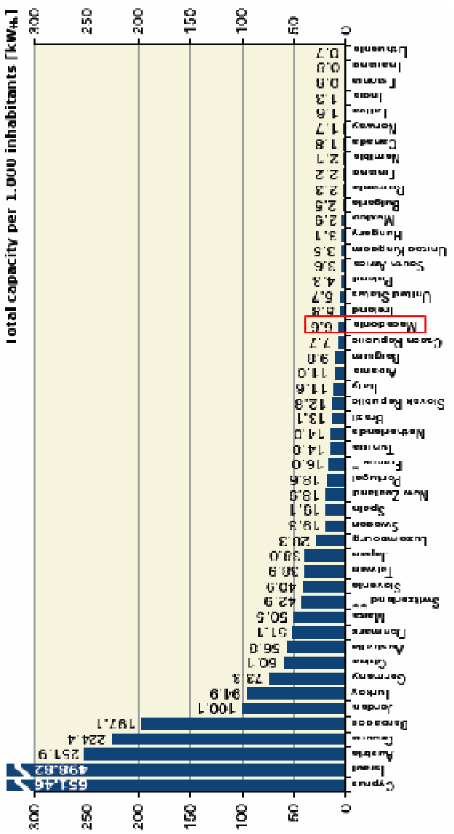

Fig. 4 - Total operative capacity in flat plate and vacuum solar collectors per 1000 inhabitants by the end of 2007 [7]

Ambitious targets – in Macedonia, considering the solar energy, it is obvious that priority is given to the power generation, i.e. the one is supported by preferential tariffs depending on the installed capacity. But due to high feed-in tariffs, and the power grid capacity, the maximum total installed capacity is limited to 10 MW, of which 2 MW are reserved for small capacities with max. nominal power of 50 kW (first preferential tariff 460 □/MWh, changed to 380 □/MWh, last change 300 □/MWh), and the rest is for larger capacities but up to 1 MW (first preferential tariff 410 □/MWh, changed to 340 □/MWh, last change 260 □/MWh). [7] Not anticipated limitations in terms of solar thermal power plants.

It is foreseen total installed capacity of 10-30 MW by 2020 with generation of 14-42 GWh per year, and 20-40 MW by 2030 with generation of 28-56 GWh per year. Upper limits are feasible in the case of considerably higher market price of electricity and development of cheaper solar technologies for power generation.[1,4]

Concerning the solar thermal energy, the one is treated as "hearsay" potential, where in the most recent document the following is stated:

The heat energy from the solar is foreseen to be used mainly in households. By 2020yr. 60,000 to 90,000 installations in households are planned, making the total utilization of solar energy (along with commercial and service sector and industry) about 60-90 GWh per year. By 2030 80,000 to 150,000 installations are planned in households. Thus, the utilization of solar energy as heat in all sectors would be 83-155 GWh per year.[1,4] In other words, the expected installed area by 2030 would be 160-300,000 m^2, which is going to be achieved even without support and additional efforts (current installed capacity is about 20.000 m^2). The EU target is $1m^2$ per inhabitant by 2020 and 3 m^2 per capita by 2030.

In overall, there are no ambitious targets, neither there are intentions to be set; for the power generation due to real barriers – the targets are limited, while for heat production there are no limitations, but no support either (despite the fact that considerable power energy might be saved).

Research and development – In Macedonia there are already many technical faculties in the frame of the state or private universities. In the study programs of the first and second cycle at some faculties the RES, their technologies and plants are covered with appropriate subjects. There are also information for involvement in projects related to RES and solar energy, too, but most of them are dealing with transfer and dissemination of experiences, knowledge and technologies. At the Faculty for Electro and Informatics Technologies research is going on for producing low cost organic PV cells. In other words, as time has shown integral approach is necessary otherwise nothing can penetrate and be accepted successfully.

On the other hand, there have been initiatives from the business sector to develop its own products and optimization of system concepts. Such initiatives have resulted in several development projects financed by the Ministry of Science and Education of the Republic of Macedonia, organized in cooperation with the technical universities and the private sector.

Awareness raising - several times within a project funded by the EC or bilateral, campaigns have been conducted to raise public and administration awareness. In principle, positive results have been achieved expressed with increased interest in solar thermal systems, but it cannot be stated that larger application has been obtained. The reasons for this are the same as listed in section 1, of which nothing is done to mitigate or eliminate.

Financial support – as it has been previously said, the power generation from solar energy is supported by preferential tariffs, long-term, through 20-year contracts.

As for solar thermal energy (for households), from 2007 there have been four short-term programs for financial support in level of 30% of the installed system costs or a maximum 300 euros per system. Each program had available 150.000,00 euro or they were spent in less than month. The total result is approximately 2000 systems for domestic warm water with approx. 4000 m^2 installed collector area.

In 2007 a preferential VAT of 5% for solar thermal components has been introduced.[6]

Despite these recently introduced measures for financial support, not significant increase in the use of solar thermal systems can be observed. Obviously short-term programs for support (as is stressed in the global information literature and pointed out repeatedly) not only that are not positive but draw many negative consequences, such as opening of phantom companies which quickly benefit from the support; causing the stop-go effect to the solar thermal market – most of the people expect the next cycle of financial support to purchase a

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solar system; no criteria applied to guarantee the minimum required quality of the installed systems, therefore, soon a wave of dissatisfaction is expected from the users or anti-campaign. Also, the preferential tax rate is not recommended supporting measure, because the results are not visible and principally interventions in tax liabilities are not encouraged. Notably, neither in Macedonia this measure resulted in greater use of solar thermal energy.

Demonstration projects – considerable numbers of demonstration projects have been realized mainly for sanitary warm water preparation, but the need for medium and large size demonstration is obvious (space heating and cooling, industrial applications, etc.). The ones should be open for the public to allow abstraction of experience.

Obligations - Obligations in relation to solar energy can be viewed from two aspects, namely:

1. Obligations of the state in terms of increasing the participation of RES in the energy balance. The goal of EC is 20% RES participation in the total energy needs by 2020.
2. Obligations in terms of providing a minimum quality that will provide guaranteed energy gains from the solar systems and their minimum durability of 25 years (it is estimated that it takes 12 to 13 years only to recover the energy invested in the system production).

Not long ago the RES in Macedonia had been treated as hearsay and non-worthwhile, especially for production of thermal energy. The relevance of joining the EC changed this treatment, but only declaratively because no any concrete steps are taken to increase the RES participation considerably. As previously explained, attention is paid only on power generation from wind, solar and small hydro facilities. But even here the results are negligible. Apparently it is not sufficient to have only legal background, but the ones should be based on extensive analyzes to determine the real and ambitious targets whose achievement requires legal background, and enforcement mechanisms, financial support, promotion etc. Also, the results of each measure should be carefully monitored to determine its success!

Countries that experienced tremendous growth in the use of solar energy, accepted responsibilities gradually achieved through:

- Obligations for mandatory coverage part of the total energy needs of new residential and commercial buildings with their own system employing RES (in principle among them solar energy is inevitable resource in urban areas).
- Prohibition to use power for heating sanitary water (China). Drastic but effective measure.
- Obligations for mandatory installation of solar thermal systems in the new residential buildings (Spain). At the beginning this measure had proved quite unsuccessful since the quality preservation and guaranteed energy gains had not been foreseen, but with the introduction of these aspects the result is tremendous growth.
- Attract financial support, i.e. for example 30-50% return of funds invested in solar thermal system (for natural and legal persons) or an exemption from paying property tax or income tax in the amount of 30-50% of the system costs. Of course, this support is tied to evidence of observed quality and energy gains of the system.

Concerning the obligations for minimal quality provision of the solar thermal components and systems, in Macedonia such mechanism doesn’t exist. In the frame of a project financed by the Austrian Development Agency, a solar test laboratory has been provides for testing solar thermal collectors and tanks, with vision for future testing of solar thermal systems, too. The initial purpose of the test station has been to enable examination, improvement and optimisation of the Macedonian products, and at appropriate time to become accredited laboratory as indispensable part of the quality assessment and certification (e.g. – Solar Keymark). Unfortunately already forth year the solar laboratory is out of operation due to incompetence, lack of funds, lack of legal background etc.

4. CONCLUSIONS

Solar energy might be important energy resource for Macedonia. There is no doubt that the solar resource is plentiful, but dedicated work is required to ensure suitable conditions for its widespread use. The examples which can be followed are numerous, showing that it is worth investing in this ecological resource. Figure 5 shows the installed capacity of flat-plate and evacuated tube collectors from 2000 to 2008. At the same graph the economic growth rate can be observed. No other industrial sector can praise with such large growth rate. Therefore, there are no doubts that it is economically viable to develop the solar market.

Is the solar viable energy source? The assessed price for 1 kWh produced thermal energy is 0.017 euro [3]. No any thermal plant can even come close to such characteristics. Obviously solar thermal capacities are energy viable.

The ecological influence is definitely positive since the solar systems’ operation is not connected with emission of dangerous gases.

However, probably the most important attribute is the social benefit since the development and growth of the solar market creates new jobs in different sectors. It can be estimated that if the necessary conditions are provided to install 700 MW capacity in solar thermal systems, minimum 3000 new employments will be opened in research and development, education, trainings, production, design, installation, service, maintenance, trade, etc.[10] This fact must not be neglected and will for sure contribute in decreasing the indigence, reviving of the economy and increasing of the life standard.

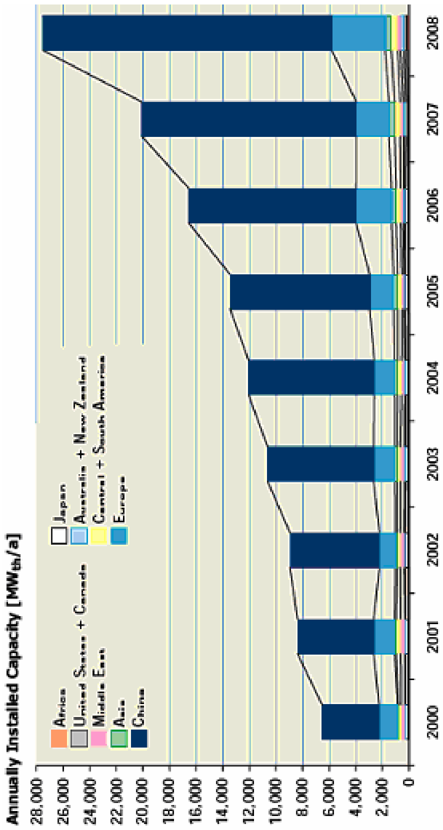

Fig. 5 - Annual installed capacity of flat-plate and evacuated tube collectors from 2000 to 2008 [2].

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INFLUENCE FACTORS ON COST IN DESIGNING OF THE HYBRID POWER SYSTEMS

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Abstract Renewable resources are considered to be a cost effective alternative for providing electricity to remote rural areas, still designing a hybrid power system (HPS) is not an easy task. A lot of factors influences on the initial and the total life cycle cost of a HPS. In this paper we analyze the following one: installed power of the bulbs for inside and outside lightning, c.c. bus voltage, fuel used by Diesel groups, the choose between individual and common HPS in rural insulated area electrification and cost distance dependence factor.

Keywords: hybrid systems, rural electrification, initial cost, total life cycle cost

1. INTRODUCTION

Recently statistics shows that about 33% of the world population does not have access to electricity [1]. There are entire areas that are situated far from national grid and most of them are in developing countries.

Electrifying these insulated regions can be done either by extension of an existing grid, or designing and operating hybrid power systems which used renewable resources. The abundant energy available in nature can be harnessed and converted to electricity in a sustainable way to supply the necessary power demand and thus to elevate the living standards of the people without access to the electricity grid. There is a huge potential for utilizing renewable energy sources, for example solar energy, wind energy, or micro-hydropower to provide a quality power supply to remote areas.

Nevertheless, using a standalone power system based on renewable resources rise some difficulties:

- availability of these resources has daily and seasonal patterns;
- regulating the output power to cope with the load demand;
- a very high initial capital investment cost is required.

This paper focused on this last disadvantage of the HPS, trying to identify aspects that influence that costs.

2. DESIGNING A COST EFFECTIVE HYBRID POWER SYSTEM

To find and underline the factors that have an important influence in HPS initial and final costs, we consider a calculus example.

It is needed to electrify a hamlet of five cottages in a remote insulated area of Bihor country, Borod –Auseu area. The renewable resource considered is solar and wind. Daily solar irradiance is took from [2] and annual average of the wind speed from [3], in both cases we used latitude and longitude of the site. Daily and seasonal profiles of the load are modeling with HOMER program as shown in Figure 1.

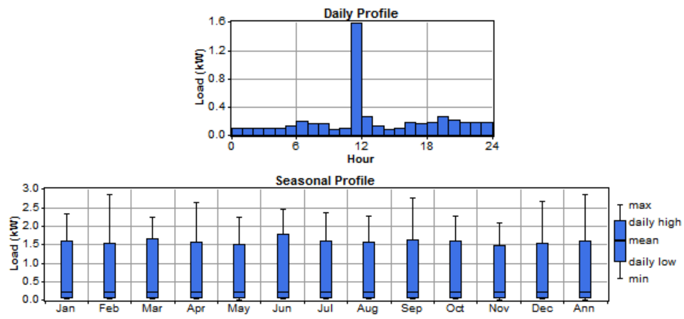


Fig. 1 - Daily and seasonal profile of the load

For system sizing we used [3] and we choose a configuration with c.c. bus for the HPS, the same with the system chosen in worksheet no.9, as shown in Figure 2.

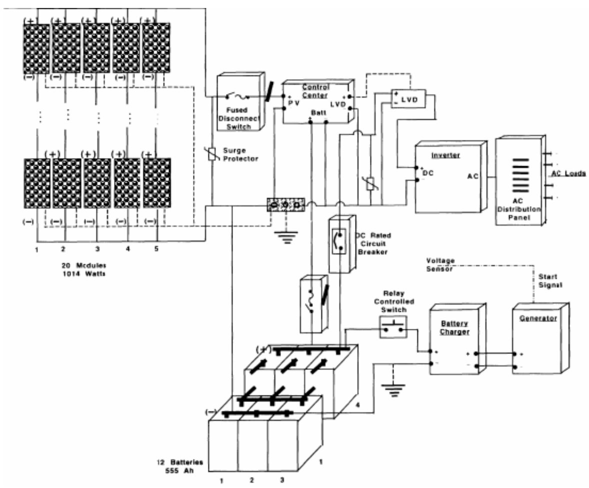
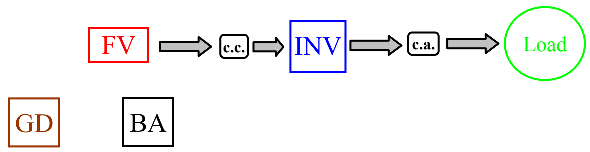


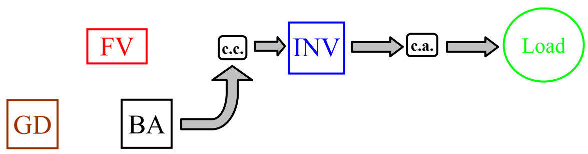
Fig. 2 - HPS chosen configuration

The dispatch strategy consists in:

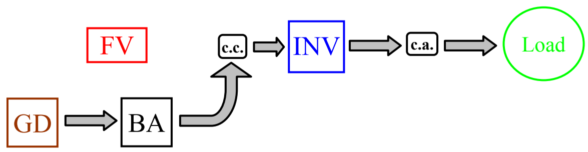
- for daylight and renewable resource (rr) available the load will be cover from PV system (Figure 3a);
- for night or rr not available, battery system will cover the load (Figure 3b);
- for night or day without rr or battery (battery discharged) the load will be covered by genset(GD), simultaneously the battery will be recharged (Figure 3c).



(a)



(b)



(c)

Fig. 3 - Dispatch strategy of the HPS

If it is suitable to add or not a wind turbine the HOMER simulation program will pointed out, depending on the chosen system configuration, Figure 4.

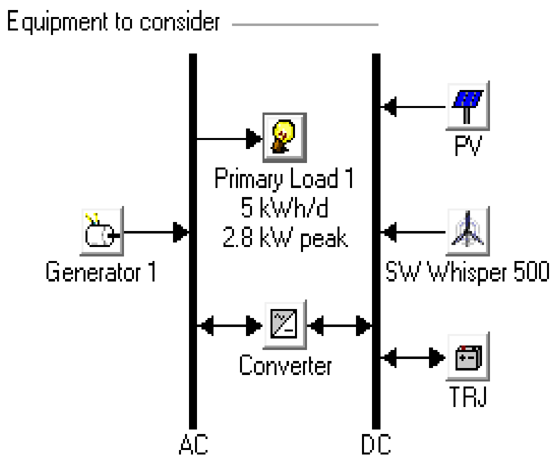


Fig. 4 - HPS configuration in HOMER

3. FACTORS OF INFLUENCE ON TOTAL COST OF A DESIGNED HYBRID POWER SYSTEM

Whatever the variant is chosen for a HPS, designing a cost effective system is not an easy task. Some factors have an important impact on the system initial investment cost and also on the total cost of the system during its lifetime.

a) the bulbs for inside and outside lighting: to a standalone HPS, installed power of the bulbs it is important because these it finally resume in amp hour loads that must be covered from PV or battery bank systems: a greater Ah-load must be covered from a greater PV panel or battery, hence the initial capital cost increase. The implication goes further in the size of the genset: a large diesel group is needed, hence the fuel consumption is rising.

Making a calculus for the same HPS configuration shown in Figure 2, but with different type of bulbs we obtained the results shown in Table 1.

Table 1 - Influence of the bulb types on costs

Type of bulbs	AC load power [W]	Daily loads [Ah/day]	Initial HPS investment [$]	Theoretic consumption [l/yr] GPL*
LED 9W	2314	90	11831	1397
Economic 24W	2429	106	12424	2224
Normal 100W	2769	176	15929	2870

* rounded up values

It is important to notice, when using 9W LED bulbs results a substantial economy from normal 100W bulbs, moreover the consumption of Diesel genset reduces more than twice. It results also a substantial economy from 24W economic bulbs.

In consequence, when it is design a hybrid power system it is necessarily to consider the lowest wattage for the lighting bulbs to obtain a cost-effective price of the HPS initial investments.

b) nominal voltage of .c.c bus: this is an important factor to consider, because it appears in early stages of the HPS design. Most of the common home appliances work on 220V tension and for our example we consider the following (Table 2):

Table 2 - Loads to consider for an insulated hamlet

Load description	QTY		Load Current [A]		Load Voltage [V]		AC Load Power [W]
Lightning – LED 9W	5	x	0,041	x	220	=	45
Refrigerator	1	x	0,8	x	220	=	176
Hydrophore	1	x	3	x	220	=	660
Washing machine	1	x	6	x	220	=	1320

Table 2 - (continuation)

Load description	QTY		Load Current [A]		Load Voltage [V]		AC Load Power [W]
Tv	1	x	0,4	x	220	=	88
Radio	1	x	0,113	x	220	=	25
Total AC power (W)							2314

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A calculus has been made for these ordinary a.c. loads of 220V taken into account the 24V, 48V, 60V and 120V bus. The results are shown in Table 3.

Table 3 - c.c. bus nominal voltage influence

c.c. / [$]	24V	48V	60V	120V
FV	2982	2982	4473	4970
BA	3300	1600	2000	3720
GD	4500	3900	4500	4500
INV	3905*	2700	3905*	7623*
CTRL	378	378	378	420
BAB	-	271	-	-
CHRG				
Initial investment [$]	15065	11831	12256	21263

* INV+CHRG included

Table 3 shows that the 48V c.c. bus is the best option for 220V appliances in terms of initial investment costs. Any other value leads in increasing genset and inverter size, number of batteries and in case of 60 and 120V c.c. bus the increase number of PV panel.

c) Influence of single or common design: it is obvious that a HPS for a single hamlet needs a certain amount of capital but when it has to consider more hamlets the cost multiplies. In this case we consider five 5 hamlets needed to be electrify, all of them on a radius of no more then couple of hundred meters. The question is which design is more cost effective: electrifying with one HPS for each hamlet or making a single common HPS to supply all 5 hamlets?

In Table 4 and 5 we present the results on two designs, individual and common HPS. Net Present Cost represent the total cost of the system to entire life duration (in this case 25 years) and it is are simulated and calculated with HOMER from the same loads and the same renewable resources on site.

Table 4 - Cost for individual HPS for 5 hamlets

Value [$] / System	GD on Diesel		GD on GPL	
	Initial investment	NPC	Initial investment	NPC
SHSD 50%FV 50%GD 9W bulb	11,182 (55,910)*	41,896 (209,480)	9,532 (47,660)	30,182 (150,910)

*Between parentheses we calculate the cost for all five hamlets.

Table 5 - Cost for common HPS supplying 5 hamlets

Value [$] / System	GD on Diesel		GD on GPL	
	Initial investment	NPC	Initial investment	NPC
SHSD 50%FV 50%GD 9W bulb	47,180 (90,491)	181,056 (224,367)	47,180 (90,491)	154,816 (198,127)

The components of the HPS are the same: solar, Diesel and batteries (SHSD).

In Table 5 we have to ad the value of 1 Km low voltage cable and the value of the connectors needed, which is: 26069$+17242$=43311$ So the total value are presented between parentheses.

We can see that the initial investment capital for common system on GPL of 47,180$ is smaller than individual system of 47,660$, but when we ad 43,311$ became grater.

Summarizing, it is cheaper to design five individual HPS to supply the five hamlets (150,910$) than to make a single common HPS for the same five consumers (198,127$).

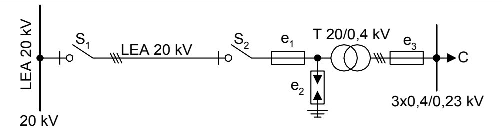
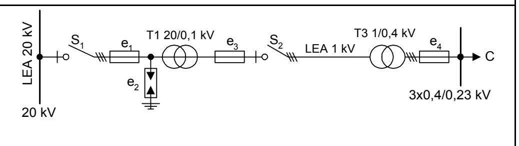
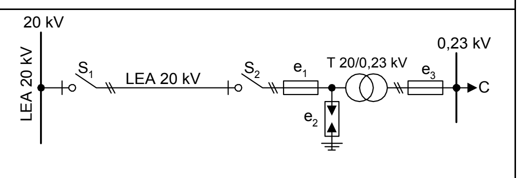
From these two table above we observe another influence factor, which is:

d) fuel used for Diesel group: Because the GPS is cheaper than Diesel, it is obvious that the cost of HPS running on GPL will be cheaper, considering the same operating hours of the GD. As a thumb rule it is better to choose the genset GD running on cheapest fuel.

e) the distance-cost dependence factor: The insulated region can be electrified either by extending the grids of the existing power system or by constructing new remote power systems based on renewable resources. In general it is preferred to go on the variant of extending the power grid, but it is not always affordable due to some factors: rough terrain, poor transport infrastructure, etc. Further more, power grid extension is primary distant depended: the investment cost increases whenever the site is further away. On the other hand, the investment cost of hybrid power systems does not depend on distance but only on generation capacity of the source: for a small demand, a small investment is needed, and for a large demand, a large investment is needed.

Having the calculus for the classical solution to electrify a consumer of 15KW from national grid [4] it can be taken into consideration three variants represented in Table 6. Cost distance depencence of the three variants are pictured in Figure 4.

Table 6 - Variant of connection the 15KW from national grid

Nr. crt.	Var iant	Connection to the National Power Grid
1.	I.1.	
2.	I.2.	
4.	I.4.	

From Table 4 we have the net present cost of individual HPS to supply 5 hamlet of 2,3KW (5X2314=11570W), in total 11,57KW, the results are represented also in Figure 4.

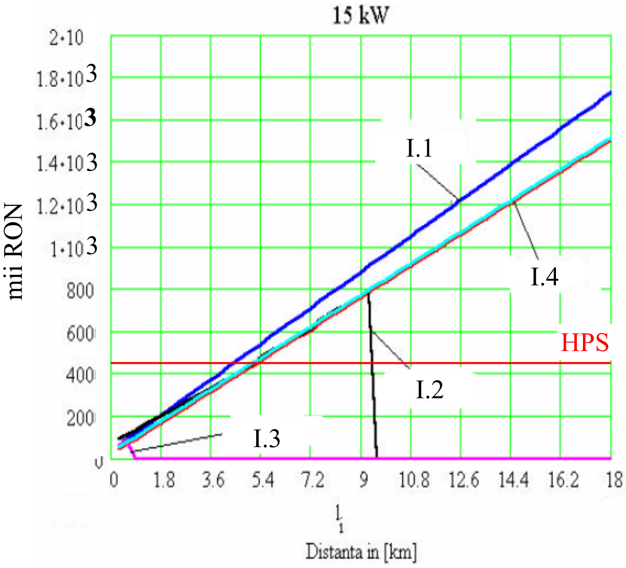


Fig. 4 - The distance - investment cost dependence

For the 11,47KW HPS from Table 4 the NPC of 150,910$ we multiply with 2,8 = the value of USD in 2005. The 422,548 mii RON are represented with red line.

We can easily see that an extension of the power grid within 4 kilometers for a 15kw consumer is a cost effective solution for I.1 variant, but if it is necessary to supply the same consumer situated above 5,4 kilometers, a hybrid power system is more suitable than the I.2 and I.4. variant.

4. CONCLUSIONS

Designing a cost effective hybrid power system to electrify an insulated rural area it's not an easy task. However it could be used a few solutions that can reduce the overall cost of that kind of systems. In this paper we identify some of them:

1. always using a smaller bulbs for lighting, LED technology is available and affordable, a relatively small investment in the initial phase of the design could lead to significantly economy of the hole project;
2. if the ac loads is the common 220V , 50HZ, it is better to choose 48V cc bus of the HPS;
3. to electrify a smaller number of insulated hamlets, the solution of individual HPS for each house is cheaper than a single common HPS due to the additional cost of low voltage grid and connectors;
4. Diesel groups running on cheaper fuel, such is GPL, leads in reducing the total net present cost of the HPS, usually this kind of genset is cheaper than one running on Diesel for the same KW installed;
5. always take into consideration the distance of the insulated hamlet from the connection point of the national grid. Not always a HPS is the cheapest solution, even if the renewable energy resource on site is attractive.

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ISSN 2067-5534 © 2012 JSE

SIMULATION AID TO THE SUSTAINABLE USE OF GEOTHERMAL PRODUCTION WELLS

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Abstract - This paper presents results from a research project aimed at the study of the chemical characterization of waters from production geothermal wells. Two low-temperature geothermal wells were selected for this study. Damage of the equipment used for the production and distribution systems has occurred for these production wells. The purpose of this work was to study the relationship between the chemical composition, the temperature and the types of scales which can appear when different geothermal waters are used for heating. Firstly, the chemical composition of geothermal waters was determined in order to classify them. Based on chemical analyses of these waters, geothermometry was used for the determination of subsurface temperatures by assuming equilibrium between specific minerals and the geothermal fluids at depth. The silica-enthalpy mixing model was applied in order to calculate the temperature of the hot water component in the reservoirs. An interpretation of geothermal water compositions has been performed using a speciation program that allows evaluation of how changes in the temperature of geothermal waters affect mineral saturation and scaling tendencies. The structures of the solid deposits formed during utilization were analysed. The results were compared to those obtained by the simulation program.

Keywords: mixing model, geothermometry, scaling evaluation

1. INTRODUCTION

Geothermal is energy available as heat emitted from within the earth, usually in the form of hot water. As a recoverable energy resource, geothermal one is very site specific. The geothermal industry worldwide grew rapidly in the later half of the last century. As competition grows and as the drive to improve reliability and performance with fewer resources continues, new maintenance techniques and technologies will be ever more important. As an integral part of any reservoir exploitation, a monitoring system must be set up, the main purpose being to provide information on the fluid produced and to allow long term monitoring of the physical and chemical changes that occur. Interpretation of this data and reservoir modeling is necessary for understanding the reservoir behaviour. The proper utilization of heat from the produced geothermal fluid is possible if scaling can be prevented for all temperatures.

In Romania, the main exploited area is located in the western part of the country. In this paper emphasis was placed on geothermal fields of Oradea and Felix. In the Felix Spa resort there are natural hot springs with temperatures between 35^o and 50ºC. These waters have special therapeutic properties and have been used in treating degenerative and inflammatory rheumatism. Geothermal water from Felix, well 4003, was taken for study. The Oradea aquifer is exploited by 12 wells with wellhead temperatures of 70-105ºC [1]. Well 4797 from Nufărul is one of the production wells which supplies the space heating for several blocks of flats in Oradea town. In order to maintain the pressure in the reservoir, the waste geothermal water is reinjected into well 4081.

2. PHYSICAL-CHEMISTRY ANALYSIS OF FLUIDS AND SCALES

Geothermal waters from two low-temperature geothermal wells: Felix-4003 and Nufărul-4797 were sampled and preserved according to their particular conditions [2], [3]. The chemical analyses were performed by analytical methods [1], [3-6]. The pH was electrometric determined. The carbon dioxide was analysed by the use of a titrator 716 DMS Titrino. The silica content was spectrophotometric determined, the absorption being read at 410 nm. Boron content was also spectrophotometric determined, the absorption being read at 420 nm. Sodium potassium, calcium and magnesium were analysed by atomic absorption spectroscopy by direct aspiration. Absorptions were read at 589.6nm, 766.5 nm, 422.7 nm respectively at 285.2 nm at a Perkin Elmer 1100 B AAS. Aluminium and iron were detected by atomic absorption spectroscopy with graphite furnace. For aluminium, samples were dried 30s at 125ºC, ashed 30s at 1500ºC, atomized 3s at 2400ºC; for iron the samples were dried 30s at 140ºC, ashed 30s at 1200ºC, atomized 3s at 2100ºC. Purge gas was Ar. Absorptions were read at 309.3 nm, respectively at 248.3 nm. The fluoride content was determided by potentiometric analysis with selective electrode and the chloride and suphates anions were chromatographic determined at a Dionex DX-500 ion cromatograph. The total dissolved solids were gravimetric determined.

The solid deposition samples were ground using a mortar and pestle, and transferred to an aluminium sample holder with glass backing. The samples were identified using a Philips PW1710 Diffractometer. The raw data from the solid samples were handled using EVA software from Bruker AXS.

3. RESULTS AND DISCUSSIONS

Classification of the studied geothermal waters was established based on their chemical composition. The results of the analyses are summarized in table 1.

The ionic balances for the samples calculated using the WATCH program [7] gave values acceptable for equilibrium calculations; therefore the data could be used for interpretation. As seen from table 1, the mineralisation of the water from Felix is very low and the chloride content is low for both Romanian wells. The carbonate content of water from well-4003 is high. The highest anion concentration is recorded at well 4797 for sulphates. The geothermal water from well-4003 can be classified as calcium-bicarbonated water and that from well-4797 as a calcium-sodium-sulphated type.

Table 1 - Chemical composition of geothermal waters, in mg/l

Component	well 4003	well 4797
pH	7.8	7.5
CO_2	275	172
BO_2^-	1.6	0.03
SiO_2	28.2	49
Na^+	31	296
K^+	3.2	24.2
Mg^{2+}	24.3	51
Ca^{2+}	134	320
F^-	0.4	1.1
Cl^-	9.3	8.1
SO_4^{2-}	117	1207
Al^{3+}	0.001	0.006
Fe^{3+}	0.015	0.092
TDS	522	2170

The calculation of geothermal reservoir temperatures with the aid of chemical geothermometers involves various assumptions.

Chemical geothermometry, when applied to specific sites, can be expected to reveal the temperature of the aquifer feeding the respective well. One of the basic assumptions is that a temperature-dependent equilibrium is attained in the geothermal reservoir between specific solutes and minerals. It is further assumed that the respective solutes are not affected by chemical reactions in the upflow where the cooling occurs. Several geothermometers have been developed to estimate reservoir temperatures in geothermal systems. The results of the chemical analyses obtained in this study (table 1) were used to calculate temperatures based on these geothermometers using the WATCH aqueous speciation program. The results of the geothermometry calculations [7] are shown in table 2.

The temperatures of the reservoirs indicated by the calculated chalcedony geothermometer are close to the production temperatures of the waters.

Table 2 - Geothermometry calculations

Well	Wellhead temperatures, ºC	Chemical geothermometers, ºC		
		Quartz	Chalcedony	Na/K
4003	42	80.6	48.8	222
4797	71	97.7	67	172.5

The silica-enthalpy mixing model [8] was used in order to estimate the reservoir temperature. Because the cold ground water was not sampled and analysed, the cold water point was assumed to represent the hypothetical cold ground water (temperature: 10ºC and SiO_2: 20ppm) in the study area. The intersection point of the “cold water - geothermal water” line with the solubility of chalcedony curve gives the silica content and the enthalpy of the deep hot water component, and its temperature is obtained from the steam tables [9].

Based on this model, a temperature of 85ºC is obtained for the deep geothermal water from well-4003 and 93ºC for the hot geothermal water from well-4797 (figure 3). The temperatures obtained using this method are significantly higher than both those calculated from the chalcedony geothermometer and those measured at the wellhead. These differences of temperature are due to mixing with cold water in the upper layers. Colder water from the shallow feed zones can mix with hotter water from the deeper ones.

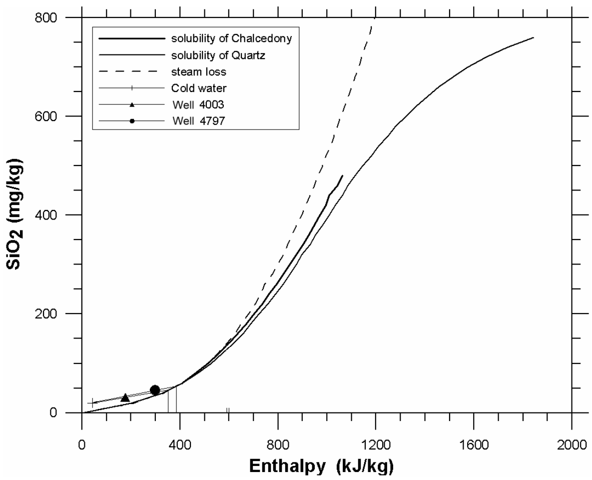

Fig. 3 - Dissolved silica-enthalpy diagram

Scaling prediction is useful for forecasting the behavior of the reservoir for different production scenarios. The potential scaling problems for geothermal well utilization depend on the type of water. Therefore, a reliable analysis of the water and a simulation of the changes occurring during the utilization were needed to predict possible scaling.

The WATCH program is commonly used for interpreting the chemical composition of geothermal fluids. In this paper, the program was used to compute the concentrations of resulting species, activity products and solubility products when the equilibrated fluid is allowed to cool conductively from the reference temperature to some lower temperatures, which can be reached during utilization. The scaling potential is estimated by calculating log Q/K, where Q represents the ionic activity corresponding to different minerals in the brine, and K the theoretical solubility of the respective minerals.

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The WATCH program was used to calculate the solubility indexes [7] for several minerals for wells 4797 and 4003.

The diagram for well-4003 (figure 4) indicates a supersaturation for calcite, talc, chrysotile and quartz at the wellhead temperature of 42ºC. There is an equilibrium with chalcedony at all temperatures which were used, assuming conductive cooling during utilization. There is undersaturation with respect to the other minerals.

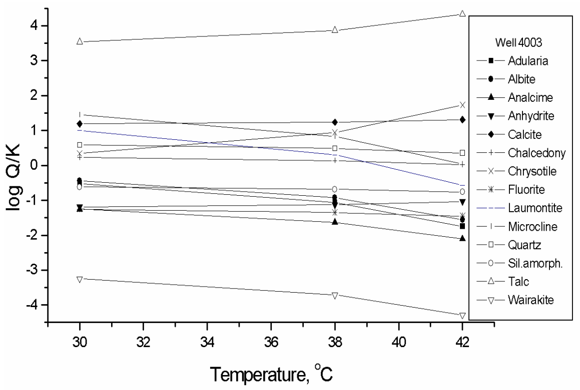

Fig. 4 - Log Q/K vs. temperature for geothermal water from well 4003

The diagram for well-4797 (figure 5) shows a possible scaling with respect to calcite at the wellhead temperature. There is also supersaturation for talc, quartz, microcline and laumontite, and anhydrite is close to the saturation line. There is equilibrium with respect to chalcedony. Most of the minerals tend to be fairly close to saturation at temperatures exceeding 60ºC. Most of the lines intersect between 45 and 55ºC, with the minerals in equilibrium at different temperatures within this interval.

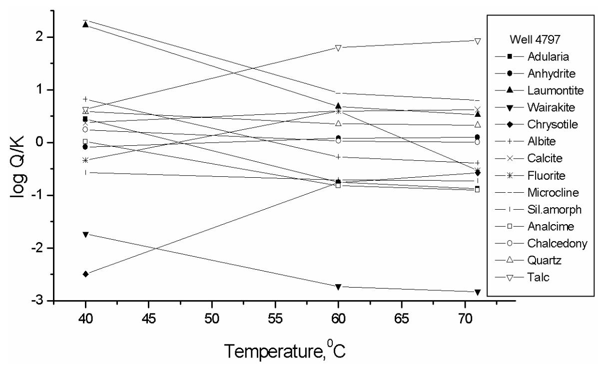

Fig. 5 - Log Q/K vs. temperature for geothermal water from well 4797

An assessment of potential scaling was obtained by using the WATCH program, problems due to scaling being expected in the system. Deposition had occurred in the well-4797 distribution system and in the pipeline casing of well-4003 after a period of four months of utilization. In order to determine the crystal composition of the solid deposits, fine grain samples were prepared and analysed by X-ray diffraction. The solid sample from well-4003 consists mainly of calcite ($CaCO_3$). The amorphous phase has a high Fe content due to the corrosion of the pipe, and for this reason the scan has an elevated baseline on the XRD diagram (figure 6). Even though the chloride content of the water is low, it is possible that some oxygen entered the system and caused corrosion. The solid sample from well-4797 (figure 7) consists of calcium carbonate in the crystalline forms of calcite and aragonite and traces of calcium sulphate.

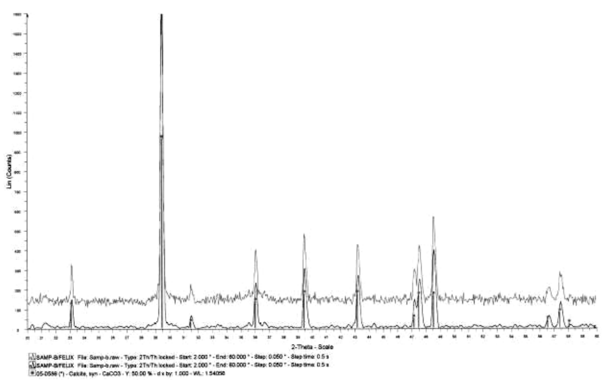

Fig. 6 - The XRD diagram for depositions from well 4003

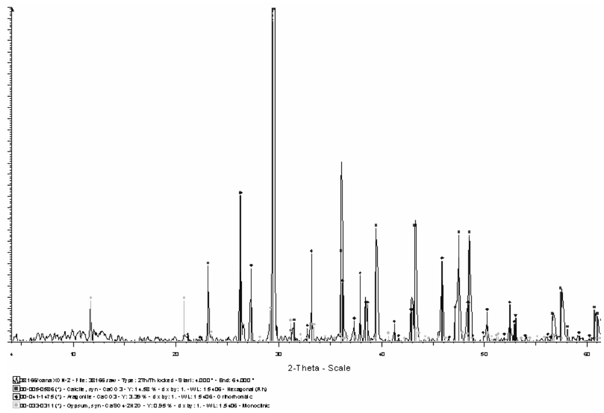

Fig. 7 - The XRD diagram for depositions from well 4797

4. CONCLUSIONS

The geothermal waters from the study areas can be classified as calcium-bicarbonate with a low mineralisation at Felix and calcium-sodium-sulphate at Nufărul.

The results from the silica geothermometers indicate that chalcedony controls the silica concentration in the studied reservoir waters, since for these low-temperature geothermal waters they give better values than the quartz geothermometers. The temperatures obtained from chalcedony geothermometers are very close to the measured temperatures. Temperatures calculated using Na/K equations deviate significantly from the measured temperatures for the two wells studied.

The dissolved-silica-enthalpy diagrams for determining the temperature of the hot water component mixed with cold water indicate higher temperatures than the results given by chalcedony geothermometers. This suggests a mixing of the hot water from the reservoir with infiltrating cold water before discharge from the well.

Chemical equilibrium calculations for the geothermal waters from the two production wells performed with the speciation program WATCH give the saturation indexes for minerals occurring in the reservoirs. At well-4003 and well-4797, there is an equilibrium with chalcedony at the temperatures which can be reached assuming a conductive cooling during utilization. The saturation index for calcite has a value more than one at well-4003, which indicates that calcite will precipitate. At well-4797, there was recorded supersaturation for calcite at the wellhead temperature, the saturation indexes in respect with calcite being lower than for the other studied well. The values of the saturation indexes for microcline, laumontite, quartz and talc are not high, except for talc, but this does not create problems.

Solid deposits formed during the utilization of wells 4003 and 4797 were XRD analysed. It was proved that the scale deposits from Felix is formed by calcite in the crystalline phase. At geothermal production conditions, from water from the well-4797 calcium carbonate was precipitated, calcite form being recorded as main. The scale products predicted using the simulation program were confirmed by the experimental results.

It is recommended that the geothermal waters be sampled at least twice a year. Based on good analytical results and thermodynamic data for the minerals that could precipitate, the scale potential can be predicted before problems occur.

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THE IMPACT OF THE CONSUMPTION FORECAST ON VARIATION OF THE BAND OF REGULATION IN TERMS OF DEVELOPING THE WIND ENERGY MARKET

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Abstract – At the National Dispatch Center (NDC) one of the parameter monitored daily is RM (the Average Regulation) that can be defined shortly as being an hourly average error. This average regulation is particular to the secondary regulation band and it has to fit between ± 20 MW. Because the RM has to have the values between the limits (inferior and superior) mentioned above, this becomes a factor of evaluation of the activity of the chief dispatcher.

In the paper it is analyzed how the consumption forecast can influence the RM. Will be considered the contribution brought by the wind farms on system functioning and, more precisely, it is being studied the effect that it has the wind power forecast in what concerns dispatching in safe conditions of the National Power System.

Keywords: average regulation (RM), secondary regulation band, load forecast, forecast of the wind power production.

1. INTRODUCTION

Factors as the liberalization of the Energy Market in 2005, the accession of Romania at the Europe Union (EU) at January 1st 2007 helped to a strongly development of the National Power System and, in the same time, to the growth of the economic and social level of Romania. The accession of Romania to EU implied assimilating certain principles and implementing some development projects on medium and long periods of time. Thus, according to "Energy – Climate changes" settled by EU for 2020, Romania and the National Power System implicitly, must insure a growth with 20% of the renewable energy share in the total energy production nationally.

Since always, the operative management of the National Power System represented a basis activity and a very important one in what concerns the safety and the continuity of supply the consumers with electric energy. However, amid new challenges appeared as a result of the accelerated development of the society and because of the high requirements of the people, this activity of operative management of an energetic system became increasingly complex and complicated.

In Romania, National Dispatch Center is responsible of the operative and operational management of the National Power System. Among the attributions of the NDC we can include: the control of the power flows in the electric grid, the management of the capacities on the interconnections lines, the compliance of the criteria "N-1" of safe functioning of the National Power System, the scheduled energy generation for the next day and, not least, operating the system in real time. [1]

Speaking administratively, in NDC we find the Central Dispatch Center (CDC), represented by the chief dispatcher and the power dispatcher that have to operate in real time the system to ensure a safe and correct functioning of the National Power System.

Because NDC is an interconnected system, within it must be maintained the frequency between the limits that are imposed by ENTSO-E (European Network of Transmission System Operators for Electricity). For this, within NDC there is the central controller of frequency that has the role of maintaining the frequency and the power on the interconnection lines at the programmed values. [2]

2. DEFINITION OF THE AVERAGE REGULATION (RM)

The power systems work interconnected, which implies maintaining the balance between the production and the consumption of electric energy at a programmed frequency and respecting the schedule of the cross-border exchanges on the interconnection lines.

Maintaining the frequency at the reference value is made through the regulations of a power system (primary regulation, secondary regulation, tertiary regulation), more precisely through the modification of the power generated by the electric generators. For monitoring the system performances in what concerns maintaining the frequency between the established limits, it is used an indicator like error signal which is called ACE (Aria Control Error) and has the next formula [2]:

$$ACE = \Delta P_{sch} + K \cdot \Delta f \qquad (1)$$

where: ΔP_{sch} – the cross-border exchanges;
K – balancing factor;
Δf – frequency deviation.

While for ΔPsch and for Δf are registered values per second, the balancing factor K has a fixed value that for

2012, for Romania, is 534 MW/Hz. The working group "System Frequency" from ENTSO-E is responsible for calculating the value of the K factor, value that is valid a year and it is characteristic to only one country. For calculating the balancing factor is taken into account the annually average consumption from the last year. For example, the value of 534 MW/Hz for 2012 it was obtained considering the average value of the consumption in 2010.

The integral on an hour of the average value of the ACE in that hour represents the so called hourly average error, symbolized by RM (average regulation). The RM values must fall between ± 20 MW (limits that are established after system calculations), and the exceeding of these limits marks the fact that, within the National Power System, it couldn't be maintained the secondary regulation band at an optimum level.

3. THE INFLUENCE OF THE LOAD FORECAST ON RM

The realization of the load forecast in the National Power System helps, on one side, to program the hourly needed power for the next day and to determine the variation of the prices on the Energy Market [3], and on the other side, by forecasting the energy consumption is intended to simplify and to improve the activity of the chief dispatcher.

Performing a load forecast is made taking into account the next aspects:

- ✓ The average temperature of the forecasted day;
- ✓ The nebulosity level of the forecasted day;
- ✓ The type of the day;
- ✓ The religious character of the forecasted day;
- ✓ The operational structures of the National Power System in the forecasted day (switch on/switch off the big consumers that can influence the variation of the consumption).

As we mentioned, RM can become a parameter in the dispatching activity at NDC, activity that wants to be facilitated through the realization of good load forecast, close to what happens in reality. In this paper is wanted to highlight the connection between RM and the load forecast, or better said the influence that the load forecast has it on RM.

Thus, there are situations when RM exceeds either the superior limit or the inferior limit, and the load forecast is similar to reality.

3.1. Case study

- December 16th 2011

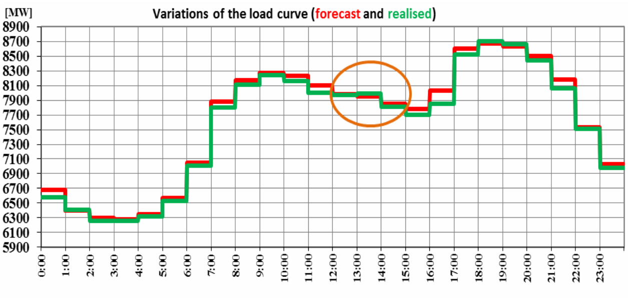

Fig. 1 - Chart of the load curves (forecast and realized) from 12.16.2011

In table 1 are presented the recorded values for the energy consumption (forecast and realized) and for RM from December 16th 2011.

Table 1 - Recorded values

Time interval	NDC Consumption forecast [MW]	Realized consumption [MW]	RM [MW]
1	6680	6575	**6.2**
2	6400	6411	**-9.4**
3	6300	6260	**-8.5**
4	6280	6257	**-29.5**
5	6350	6320	**5.9**
6	6570	6532	**-11.4**
7	7050	7008	**-17**
8	7880	7802	**-11.9**
9	8170	8112	**-8.8**
10	8270	8241	**-19.7**
11	8230	8159	**9**
12	8100	7998	**-9.2**
13	7980	7967	**2.1**
14	7950	7990	**-19.1**
15	7850	7807	**-28.8**
16	7780	7701	**-5**
17	8030	7850	**-7.7**
18	8600	8528	**1.2**
19	8670	8701	**0.3**
20	8630	8668	**-5.5**
21	8500	8447	**10.6**
22	8180	8064	**-24.8**
23	7530	7506	**8.8**
24	7030	6982	**15.9**

- January 10th 2012

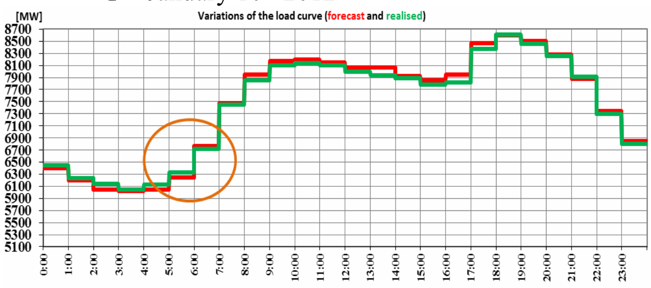

Fig. 2 - Chart of the load curves (forecast and realized) from 01.10.2012

Table 2 - Recorded values

Time interval	NDC Consumption forecast [MW]	Realized consumption [MW]	RM [MW]
1	6400	6448	**3.2**
2	6200	6232	**-1.2**
3	6050	6142	**-64.2**
4	6020	6039	**-11.8**
5	6050	6124	**-27.2**
6	6250	6323	**-21.6**
7	6770	6718	**-24.1**
8	7470	7450	**-3**
9	7950	7849	**-0.5**
10	8170	8096	**-0.6**
11	8200	8134	**-11.8**
12	8150	8100	**4.6**
13	8070	7998	**-7**
14	8070	7933	**10.3**
15	7930	7890	**-7.4**
16	7850	7783	**1.4**
17	7950	7812	**-7.3**
18	8470	8377	**-2.4**
19	8600	8609	**-2.4**
20	8500	8457	**2.6**
21	8280	8259	**0.3**
22	7880	7912	**8.8**
23	7350	7302	**11.3**
24	6850	6801	**-31.1**

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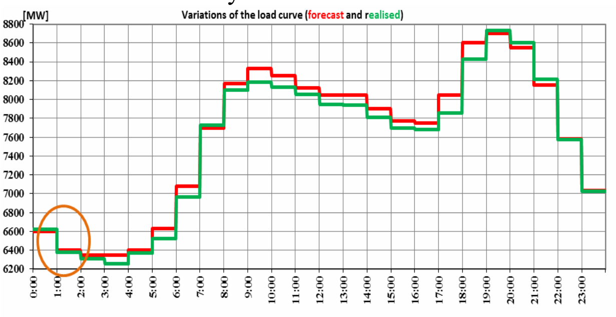

Fig. 3 - Chart of the load curves (forecast and realized) from 02.28.2012

Table 3 - Recorded values

Time interval	NDC Consumption forecast [MW]	Realized consumption [MW]	RM [MW]
1	6600	6623	**74,5**
2	6400	6382	**-34,4**
3	6350	6310	**10,1**
4	6350	6253	**-5,4**
5	6400	6374	**-30,7**
6	6630	6527	**-1,5**
7	7080	6965	**-11,9**
8	7700	7729	**1,4**
9	8170	8097	**-0,9**
10	8330	8180	**12,8**
11	8250	8128	**-13**
12	8120	8053	**4,8**
13	8050	7947	**10,4**
14	8050	7938	**-7,9**
15	7900	7808	**0,1**
16	7770	7697	**2,8**
17	7750	7680	**-5,2**
18	8050	7853	**-10,6**
19	8600	8425	**10,2**
20	8700	8732	**2,6**
21	8550	8602	**-6,7**
22	8150	8218	**1,4**
23	7580	7573	**-4,3**
24	7030	7028	**-20,7**

3.2. Observations

Studying the influence that the load forecast has it on RM, has been noted that the situations in which RM is exceeded are either those in which exist considerable differences between the forecast and the realized consumption, or those in which the differences between the two curves are not so high, but the curves are crossing each other.

When big differences appear between the forecast and the realized energy consumption (due, for example, to a surplus of power in the system), the RM values are influenced and can exceed the imposed limits. The surplus of power appears when the realized consumption of energy is smaller than the forecasted consumption of energy. A particularity of the RM exceeding is that it happens, usually, at night when is the “off-peak hours” (the consumption of energy has the smallest values). On the “off-peak hours”, most of the power plants, which can realize the regulation in the National Power System, function at the power of minimum technical and on them it cannot operate on the downside of the generated power, for bringing the production at the consumption level. The power produced additionally in those hours must be consumed because there are no energy storage devices with large capacity in our country. So, this power must be exported. Therefore, appears a modification of the balance on the cross-border interconnections that leads automatically to variations of the secondary regulation band

More difficult is the situation when the load curves (forecast and realized) are crossing each other (there are successive passages above or below of a curve compared with the other), the numerical differences between the two curves being small. The activity of the chief dispatcher is being made harder on that hour because he must increase and decrease successively the same power generator so he can maintain the production at the consumption level.

Given the last observation, in the study case, from the previously subparagraph, there were presented the days when it was reached a similar situation (the curves are crossing each other and by default the RM is exceeded).

4. THE INFLUENCE OF THE WIND POWER GENERATION ON RM

According to the European Union standards concerning the renewable energy in an electric power system, by 2020 each EU country member must produce at least 20% from the total needed power to cover the energy consumption in renewable sources. Therefore, in Romania have appeared many projects of developing the renewable sources of energy, most projects aiming the wind power.

Nowadays, the power installed in wind farms in Romania is 1140 MW. As a percentage, the highest value recorded was of about 10% from the total produced energy in the National Power System (the daily average value was 620 MW, and on an hourly interval was recorded in SCADA about 1000 MW).

The power obtained by wind sources is a priority power, defined in “Regulation from 12-13-2006 for qualification the priority production of electric energy from renewable sources” published in Official Journal, no. 1041, first part, from 12-28-2006 by the National Authority for Energy Regulation, as a uncontrollable priority production, meaning that it cannot be managed in an active way by the producer so it can be ensure the compliance with the contractual obligations notified. [4]

In the study case below was shown how RM was exceeded in days that the wind production was high, but the error between the forecast and the realized consumption was small.

4.1. Case study

December 23th 2011

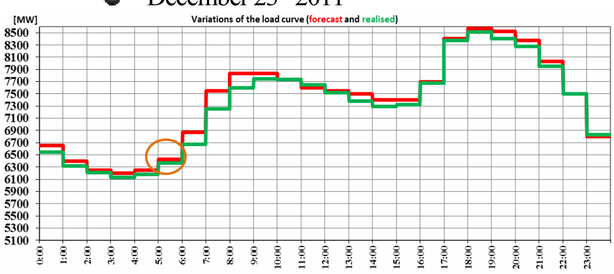

Fig. 4 - Chart of the load curves (forecast and realized) from 12.23.2011

In table 4 are presented the recorded values for the energy consumption (forecast and realized), for RM and the recorded values of the wind generation from December 23th 2011.

Table 4 - Recorded values

Time interval	NDC Consumption forecast [MW]	Realized consumption [MW]	Wind power production [MW]	RM [MW]
1	6650	6543	559	**14.5**
2	6400	6319	561	**11.7**
3	6250	6211	515	**2.6**
4	6200	6132	532	**5.3**
5	6250	6177	517	**-5.7**
6	6430	6364	539	**-88.2**
7	6870	6670	563	**-12.6**
8	7550	7257	575	**0.1**
9	7830	7601	500	**-6.3**
10	7830	7749	467	**-3.1**
11	7730	7732	476	**1.9**
12	7600	7650	558	**-9.2**
13	7550	7522	617	**3.3**
14	7500	7384	600	**-0.6**
15	7400	7290	581	**-3.1**
16	7400	7323	624	**-0.4**
17	7700	7674	587	**-4.8**
18	8400	8373	606	**-4**
19	8570	8517	516	**-6.6**
20	8520	8408	432	**-3.4**
21	8370	8278	434	**6.4**
22	8030	7948	418	**2.9**
23	7500	7494	356	**10**
24	6800	6825	380	**5.5**

To visualize better the situation of the renewable sources from that day, in the next chart is outlined the wind generation curves (forecast production and realized production).

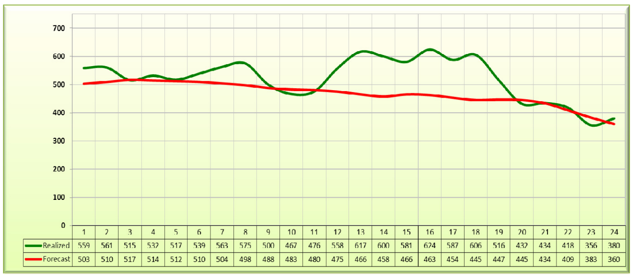

Fig. 5 - Chart of the wind generation (forecast production and realized production) from 12.23.2011

- January 31st 2012

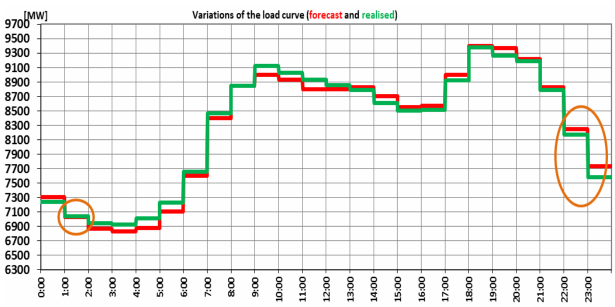

Fig. 6 - Chart of the load curves (forecast and realized) from 01.31.2012

Table 5 - Recorded values

Time interval	NDC Consumption forecast [MW]	Realized consumption [MW]	Wind power production [MW]	RM [MW]
1	7300	7242	655	**-7.8**
2	7030	7034	643	**-26.6**
3	6870	6945	643	**10.3**
4	6830	6926	635	**-9.4**
5	6880	7006	636	**-14.2**
6	7100	7231	655	**-18**
7	7600	7657	661	**4.4**
8	8400	8466	651	**-0.3**
9	8850	8842	659	**3.5**
10	9000	9119	647	**-3**
11	8930	9030	613	**-1**
12	8800	8930	607	**2.2**
13	8800	8857	588	**-1.9**
14	8830	8787	568	**0.4**
15	8700	8608	551	**-3**
16	8550	8505	557	**-15.8**
17	8570	8509	588	**-7.9**
18	9000	8921	618	**-10**
19	9400	9384	599	**7.8**
20	9370	9267	592	**0.7**
21	9220	9193	571	**0.1**
22	8830	8790	580	**-16.7**
23	8250	8170	578	**-23.8**
24	7730	7576	581	**-21.8**

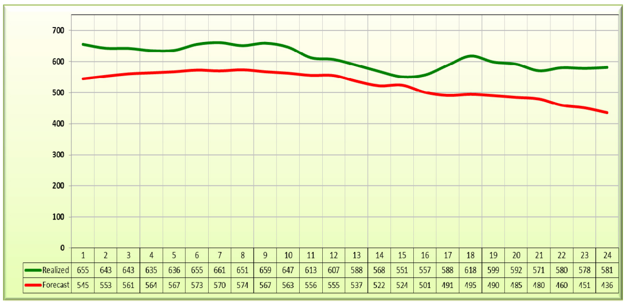

Fig. 7 - Chart of the wind generation (forecast production and realized production) from 01.31.2012

- January 25th 2012

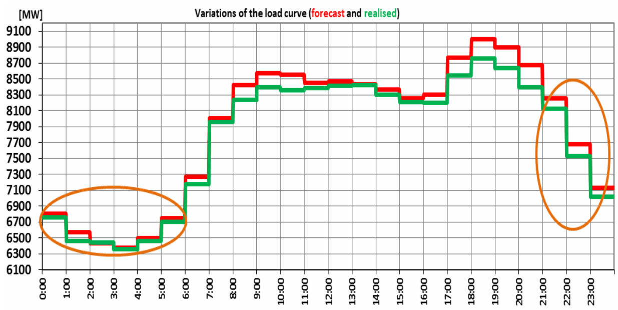

Fig. 8 - Chart of the load curves (forecast and realized) from 01.25.2012

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Table 6 - Recorded values

Time interval	NDC Consumption forecast [MW]	Realized consumption [MW]	Wind power production [MW]	RM [MW]
1	6800	6760	664	**-235.6**
2	6570	6464	653	**-41.3**
3	6430	6438	660	**-135.4**
4	6380	6359	676	**-40.7**
5	6500	6463	659	**-203.1**
6	6750	6706	663	**-24**
7	7270	7174	681	**3.3**
8	8000	7960	713	**1.1**
9	8420	8234	713	**1.3**
10	8570	8395	708	**1.6**
11	8550	8355	724	**-3.7**
12	8450	8388	792	**-1**
13	8470	8416	801	**0.3**
14	8430	8419	810	**-6.2**
15	8370	8297	817	**-10.2**
16	8250	8207	817	**-12.8**
17	8300	8202	817	**-9.1**
18	8770	8539	817	**-5.6**
19	9000	8754	803	**-0.7**
20	8900	8637	803	**9.3**
21	8670	8397	800	**4.9**
22	8250	8120	804	**-23.6**
23	7680	7532	802	**-122.3**
24	7130	7021	805	**-401.2**

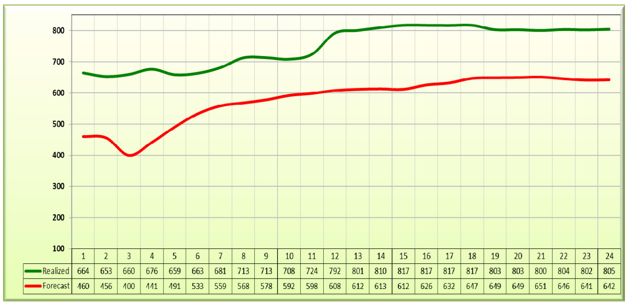

Fig. 9 - Chart of the wind generation (forecast production and realized production) from 01.25.2012

4.2. Observations

Analyzing the days in which RM was exceeded and there weren't observed situations like those mentioned in the previous paragraph, was noted that the functioning of the wind farms influences the variation of the secondary regulation band. The explication is that, because of the priority character that it has the wind power, this must be taken in the transmission grid before other types of produced energy, the compensation for this power being done using the other generators that are in the list of generator units that can make secondary regulation or fast tertiary regulation. The problem that appears is that, for our electric power system, the secondary regulation band consists, almost equal, both in thermo units whose functioning is slow down by the high start time, and in hydro units that are characterized by a fast load variation at the increasing or decreasing the power at generators. If, in what concerns the thermo units, the difficulty appears because of the high start time, at the hydro units it can be mentioned two special situations:

- ✓ The situation when the hydraulicity is reduced and so, there is no regulation reserve. Practically, at some point, the wind farms begin to function (the wind speed has grown sufficiently to produce energy) and the dispatcher has to compensate that power through the decreasing of the production in other zones, at other power generators. Most commonly used for these kinds of actions are the hydro units, but in this situation is not possible because the reservoirs are empty. Appear modifications of the balance and automatically variations of the programed values (power on the interconnection and frequency) that are registered in the central controller of frequency, whose final result is the exceeded of RM.
- ✓ The situation when the hydraulicity is increased may lead to a violation of the current standards that aims the production of energy from hydro sources which is considered an energy produced from renewable sources. Same as the previous case, at some point of time the wind farms begin to function and the dispatcher has to compensate this power. The thermo units have a high start time and therefore, they usually are not disconnected. If it would operate on the hydro units, it would mean that is necessary to reduce the production on hydro plants. This fact can be realized only by spilling the water, meaning that the renewable sources are being wasted.

In what concerns the fast tertiary regulation band, the problem concerns the fact that the increase of the power generator unit must be done with 15 minutes before the actual time interval. These 15 minutes, most of the times, are big enough to not be able to compensate the quantity of wind power produced and entered in the transmission grid.

Also, another reason why appear RM exceeds is the wind production forecast, more exactly the notified values send by the producers at NDC. The dispatchers encounter often with the situation in which the wind production notifications are smaller than the realized of wind production.

5. CONCLUSIONS

The maintaining and the safety functioning of the consumers is the main goal for which the power systems are developing continuously by using the most modern and the most efficient devices. The National Power System is managed operative and operational by the National Dispatch Center, where the chief dispatcher and the power dispatcher are those who monitor the good functioning of the system.

According with the analyze that has been made in this paper, we have reached to the conclusion that it is very useful both for facilitating the dispatcher activity and for obtaining correct results, that the load forecast must have a similar allure with the realized consumption (it must be avoid the situations in which there are interconnections between the two curves).

Nowadays we must take into consideration the impact that the wind power has it on the system, aspect that it was treated in this paper. The conclusion we have reached was that, because of the priority character of the wind power, this must be taken into the grid before other types of produced energy, and this situation, mostly, makes harder the activity of the dispatcher. It is very important that the producers of wind power to provide to NDC better forecasts of wind production, so that the differences between the forecast and the realized wind production decrease.

All of these exceeds of RM that appear when the central controller of frequency registers changes of the programmed values of the frequency and of the power on the interconnections, mean costs that the Transmission and System Operator – Transelectrica must incurs. In terms of the Commercial Code of the Energy Market, in the National Power System there is a BRP (Balance Responsible Party) which is called "Transelectrica – Inadvertent Deviations" which is responsible for the modifications of the power on the interconnection lines. These modifications are known as imbalances and they can be positives (when BRP "Transelectrica – Inadvertent Deviations" wins money because, inside this BRP was produced an surplus of power which was sold on the Day-Ahead Market) or negatives (when BRP "Transelectrica – Inadvertent Deviations" loses money because, inside this BRP was produced a power smaller than the notified power and so, the difference was bought from the Day-Ahead Market, to can honor the agreements closed with others BRP).

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ISSN 2067-5534 © 2012 JSE

DG ALLOCATION AND SIZING USING MSFLA TO REDUCE LOSSES AND IMPROVE VOLTAGE PROFILE IN DISTRIBUTION NETWORK

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Abstract-- The Distributed Generation (DG) has created a challenge and an opportunity for developing various novel technologies in power generation. The proposed work discusses the primary factors that have lead to an increasing interest in DG. DG reduces line losses and increases system voltage profile. The proposed work finds out the optimal value of the DG location and capacity to be connected to the existing system using modified shuffled frog leaping algorithm (MSFLA) thereby maximizing the system voltage profile and reduces line losses. Benefits of employing DG are analyzed using Voltage Profile Improvement Index (VPII) and Line Loss Reduction Index (LLRI).The proposed method is tested on a standard IEEE-70 bus radial distribution system and the results of the simulation carried out using MATLAB7.0 are found to be encouraging. The method has a potential to be a tool for identifying the best location and rating a DG to be installed for improving voltage profile and reduces line losses in an electrical power system.

Keywords-- Distributed Generation (DG), Line Loss Reduction Index, Modified Shuffled Frog Leaping Algorithm (MSFLA), Voltage Profile

1. INTRODUCTION

Distributed power generation is a small-scale power generation technology that provides electric power at a site closer to customers than the central generating stations. A distributed power unit can be connected directly to the consumer or to a utility's transmission or distribution system to provide peaking services .Distributed generation (DG) provides a multitude of services to utilities and consumers, including standby generation, peaks chopping capability, base load generation.

The key element of this new environment is to build and operate several DG units near load centers instead of expanding the central-station power plants located far away from customers to meet increasing load demand. Distributed generation technologies can enhance the efficiency, reliability, voltage profile, and operational benefits of the distribution system. DG can be powered by both conventional and renewable energy sources [1].Several DG options are fast becoming economically viable [2-3].Technologies that utilize conventional energy sources includes gas turbines, micro turbines and else engines. Currently, the ones that show promises for DG applications are wind electric conversion systems (WECS), geothermal systems, solar-thermal–electric systems, photovoltaic systems (PV) and fuel cells [4-5]. This paper presents a modified shuffled frog leaping algorithm (MSFLA) for Distributed Generation Allocation and sizing to Reduce Losses and Improve Voltage Profile processes. The SFLA is a meta-heuristic search method inspired from the memetic evolution of a group of frogs when seeking for food. It consists of a frog leaping rule for local search and a memetic shuffling rule for global information exchange. In this paper, a new frog leaping rule is proposed to improve the local exploration of the SFLA. The main idea behind the new frog leaping rule is to extend the direction and the length of each frog's jump by emulating frog's perception and action uncertainties. The modification widens the local search space, thus helps to prevent premature convergence and improves the performance of the SFLA. The proposed method is easy to implement and program with basic mathematical and logic operations. It can also handle objective functions with stochastic nature and does not require a good initial solution to start its iteration process.

2. APPROACH TO QUANTIFY THE BENEFITS OF DG

In order to evaluate and quantify the benefits of distributed generation suitable mathematical models must be employed along with distribution system models and power flow calculations to arrive at indices of benefits. Among the many benefits two major ones are considered: Voltage profile improvement, line loss reduction.

2.1 Line Loss Reduction Index

Another major benefit offered by installation of DG is the reduction in electrical line losses [6]**.** By installing

DG, line currents can be reduced, thus helping to reduce electrical line losses. The proposed line loss reduction index (LLRI) is defined as

$$LLRI = \frac{LL_{W/DG}}{LL_{WO/DG}} \qquad (1)$$

where, LLw/DG is the total line losses in the system with the employment of DG and LLwo/DG is the total line losses in the system without DG and it can be

$$LL_{W/DG} = 3\sum_{i=1}^{M} I_i^2 \times R \times D_i \qquad (2)$$

where, I_i is the per unit line current in distribution line i with the employment of DG, R is the line resistance (pu/km), D_i is the distribution line length (km), and M is the number of lines in the system.
Similarly, LLwo/DG is expressed as

$$LL_{Wo/DG} = 3\sum_{i=1}^{M} I_i^2 \times R \times D_i \qquad (3)$$

where, I_i is the per-unit line current in distribution line i without DG.

Based on this definition, the following attributes are:
LLRI <1, DG has reduced electrical line losses,
LLRI =1, DG has no impact on system line losses,
LLRI >1, DG has caused more electrical line losses.

This index can be used to identify the best location and sizing to install DG to maximize the line loss reduction.

2.2 Voltage Profile Improvement Index

The inclusion of DG results in improved voltage profile at various buses. The Voltage Profile Improvement Index (VPII) quantifies the improvement in the voltage profile (VP) with the inclusion of DG [6]. It is expressed as,

$$VPII = \frac{VP_{W/DG}}{VP_{WO/DG}} \qquad (4)$$

Based on this definition, the following attributes are:

VPII < 1, DG has improved the voltage profile of the system,

VPII = 1, DG has no impact on the system voltage profile,

VPII > 1 DG has not beneficial.

Where, $VP_{W/DG}$, $VP_{Wo/DG}$ are the measures of the voltage profile of the system with DG and without DG respectively. The general expression for VP is given as,

$$VP = \sum_{i=1}^{N_{bus}} \left| V_i - V_{i,ref} \right| \qquad (5)$$

Where, V_i is the Magnitude of voltage of bus i. $V_{i,ref}$ is the Magnitude of voltage of slack bus that for VP provides an opportunity to quantify and aggregate the importance, amounts, and the voltage levels at which loads are being supplied at the various load busses in the system. This expression should be used only after making sure that the voltages at all the load busses are within allowable minimum and maximum limits, typically between 0.95 p.u. and 1.05p.u. In this case all the load buses are given equal importance. In reality, DG can be installed almost anywhere in the system. Therefore, VPII can be used to select the best location for DG.

3. LOAD FLOW

On account of the some inherent features of distribution systems such as; radial structure, unbalanced distributed loads, large number of nodes, a wide range of R/X ratios; the conventional techniques developed for transmission systems generally fail on the determination of optimum size and location of distributed generations. In this study, The proposed methodology is based on the equivalent current injection that uses the Bus–Injection to Branch-Current (BIBC) and Branch-Current to Bus-Voltage (BCBV) matrices which were developed based on the topological structure of the distribution systems and is implemented for the load flow analysis of the distribution systems. The details of both matrices can be found in [7].The methodology proposed here requires only one base case load flow to determine the optimum size and location of DG. Detailed description of BIBC and BCBV matrix's building algorithm is omitted due to the lack of space and can be found in [7].

4. THE PROPOSED MSFLA BASED OPTIMIZATION OF DG LOCATION AND CAPACITY IN A RADIAL DISTRIBUTION SYSTEM

4.1 The Objective Function

The proposed work aims at minimizing the combined objective function designed to reduce power loss and also improve voltage profile system for various values of distributed generations. The main objective function is defined as

$$\min F_{total} = P_{loss} + \sum_{p=1}^{n} \lambda_p \left(V_p\right)^2 \qquad (6)$$

where, λ_p is the penalty factor of bus voltages and is heuristically taken as 1,P_{loss} is the real power loss obtained from the load flow solution at the base case, V_P is the voltage profile of the buses and n is the total number of buses in the distribution system.

4.2. Constraints

The constraints are listed as follows:
• Distribution line absolute power

$$\text{limits} \left| P_{ij}^{Line} \right| \le p_{ij.\max}^{Line} \qquad (7)$$

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$\left|P_{ij}^{Line}\right|$ and $p_{ij,\max}^{Line}$

are the absolute power and its corresponding maximum allowable value flowing over the distribution line between the nodes i and j, respectively.

• Bus voltage limit Bus voltage amplitudes are limited as

$$V_{\min} \le V_i \le V_{\max} \tag{8}$$

where V_{min} and V_{max} are the minimum and maximum values of bus voltage amplitudes, respectively.

• Radial structure of the network

$$M = N_{bus} - N_f \tag{9}$$

where M is the number of branches, N_{bus} is the number of nodes and N_f is the number of sources.

• Power limits of DG

$$Q_{DGi}^{\min} \le Q_{DGi} \le Q_{DGi}^{\max}$$
and (10)
$$P_{DGi}^{\min} \le P_{DGi} \le P_{DGi}^{\max}$$

where P_i and Q_i are the injected active and reactive power of DG components at the ith bus.

• Subject to power balance constraints

$$\sum_{i=1}^{N_{sc}} P_{DGi} = \sum_{i=1}^{N_{SC}} P_{Di} + P_L \tag{11}$$

where: N_{sc} is total number of sections, P_L is the real power loss in the system, P_{DGi} is the DG real power generation at bus i, P_{Di} is the power demand at bus i.

4.3 Modified Shuffled Frog Leaping Algorithm

4.3.1Shuffled frog-leaping algorithm

The SFLA is a meta-heuristic optimization method that mimics the memetic evolution of a group of frogs when seeking for the location that has the maximum amount of available food. The algorithm contains elements of local search and global information exchange ([8], [9]).The SFLA involves a population of possible solutions defined by a set of virtual frogs that is partitioned into subsets referred to as memeplexes. Within each memeplex, the individual frog holds ideas that can be influenced by the ideas of other frogs, and the ideas can evolve through a process of memetic evolution. The SFLA performs simultaneously an independent local search in each memeplex using a particle swarm optimization like method. To ensure global exploration, after a defined number of memeplex evolution steps (i.e. local search iterations), the virtual frogs are shuffled and reorganized into new memeplexes in a technique similar to that used in the shuffled complex evolution algorithm. In addition, to provide the opportunity for random generation of improved information, random virtual frogs are generated and substituted in the population if the local search cannot find better solutions. The local searches and the shuffling processes continue until defined convergence criteria are satisfied. The flowchart of the SFLA is illustrated in Fig.1. The local search block in the flowchart is shown later in Fig. 5.

The SFLA is described in details as follows. First, an initial population of N frogs $P = \{X_1, X_2, ..., X_N\}$ is created randomly. For S-dimensional problems (S variables), the position of a frog i^{th} in the search space is represented as $X_i = [x_1, x_2, ..., x_{is}]^T$. A fitness function is defined to evaluate the frog's position. For minimization problems, the frog's fitness can be defined as,

$$fitness = \frac{1}{[f(x)+c]} \tag{12}$$

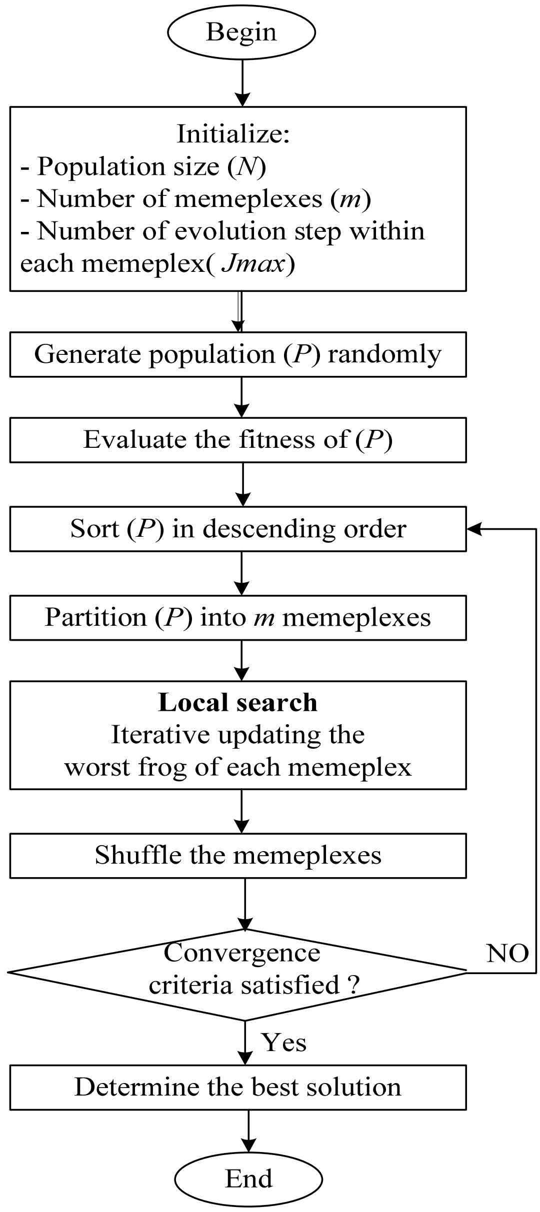

Fig. 1 - Flowchart of the SFLA

and for maximization problem, the frog's fitness can be simply defined as,

$$fitness = f(x) + c \qquad (13)$$

where $f(X)$ is the cost function to be optimized, and C is a constant chosen to ensure that the fitness value is positive. Afterwards, the frogs are sorted in a descending order according to their fitness. Then, the entire population is divided into m memeplexes, each containing n frogs $(i.e. N = m \times n)$, in such a way that the first frog goes to the first memeplex, the second frog goes to the second memeplex, the mth frog goes to the mth memeplex, and the (m+1)th frog goes back to the first memeplex, etc. Fig.2 illustrates this memeplex partitioning process.

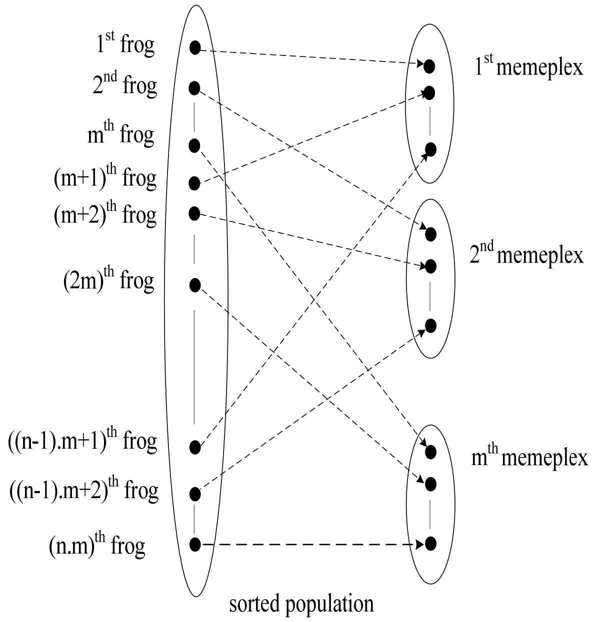

Fig.2 - Memeplex partitioning process

Let M_k is the set of frogs in the kth memeplex, this dividing process can be described by the following expression:

$$M_k = \{X_{k+m(l-1)} \in P | 1 \le l \le n\}, (1 \le k \le m) \qquad (14)$$

Within each memeplex, the frogs with the best and the worst fitness are identified as X_b and X_w, respectively. Also, the frog with the global best fitness is identified as X_g. During memeplex evolution, the worst frog X_w leaps toward the best frog X_b. According to the original frog leaping rule, the position of the worst frog is updated as follows:

$$D = r \times (X_b - X_W) \qquad (15)$$

$$X_W(new) = X_W + D, (|D| \le D_{max}) \qquad (16)$$

where r is a random number between 0 and 1; and D_{max} is the maximum allowed change of frog's position in one jump.

Fig. 3 demonstrates the original frog leaping rule. If this leaping produces a better solution, it replaces the worst frog. Otherwise, the calculations in (15) and (16) are repeated but respect to the global best frog (i.e. X_g replaces X_b).

If no improvement becomes possible in this case, the worst frog is deleted and a new frog is randomly generated to replace it. The calculations continue for a predefined number of memetic evolutionary steps within each memeplex, and then the whole population is mixed together in the shuffling process. The local evolution and global shuffling continue until convergence criteria are satisfied. Usually, the convergence criteria can be defined as follows:

i. The relative change in the fitness of the best frog within a number of consecutive shuffling iterations is less than a pre-specified tolerance;

ii. The maximum user-specified number shuffling iterations is reached.

The SFLA will stop when one of the above criteria is arrived first.

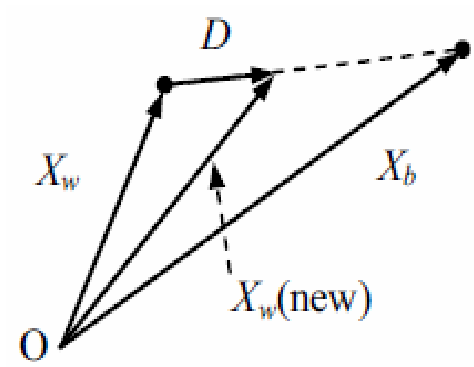

Fig. 3 - The original frog leaping rule

4.3.2 Modification of the frog leaping rule

In the natural memetic evolution of a frog population, the ideas of the worse frogs are influenced by the ideas of the better frogs, and the worse frogs tend to jump toward the better ones for the possibility of having more foods. The frog leaping rule in the SFLA is inspired from this social imitation, but it performs only the jump of the worst frog toward the best one. According to the original frog leaping rule presented above, the possible new position of the worst frog is restricted in the line segment between its current position and the best frog's position, and the worst frog will never jump over the best one (see Fig. 3). Clearly, this frog leaping rule limits the local search space in each memetic evolution step. This limitation might not only slow down the convergence speed, but also cause premature convergence. In nature, because of imperfect perception, the worst frog cannot locate exactly the best frog's position, and because of inexact action, the worst frog cannot jump right to its target position. Considering these uncertainties, we argue that the worst frog's new position is not necessary restricted in the line connecting its current position and the best frog's position. Furthermore, the worst frog could jump over the best one. This idea leads to a new frog leaping rule that extends the local search space as

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illustrated in Fig. 4 (for 2-dimensional problems).The new frog leaping rule is expressed as:

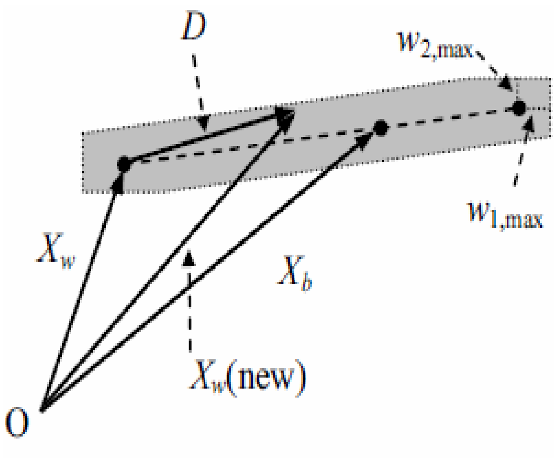

Fig. 4 - The new frog leaping rule

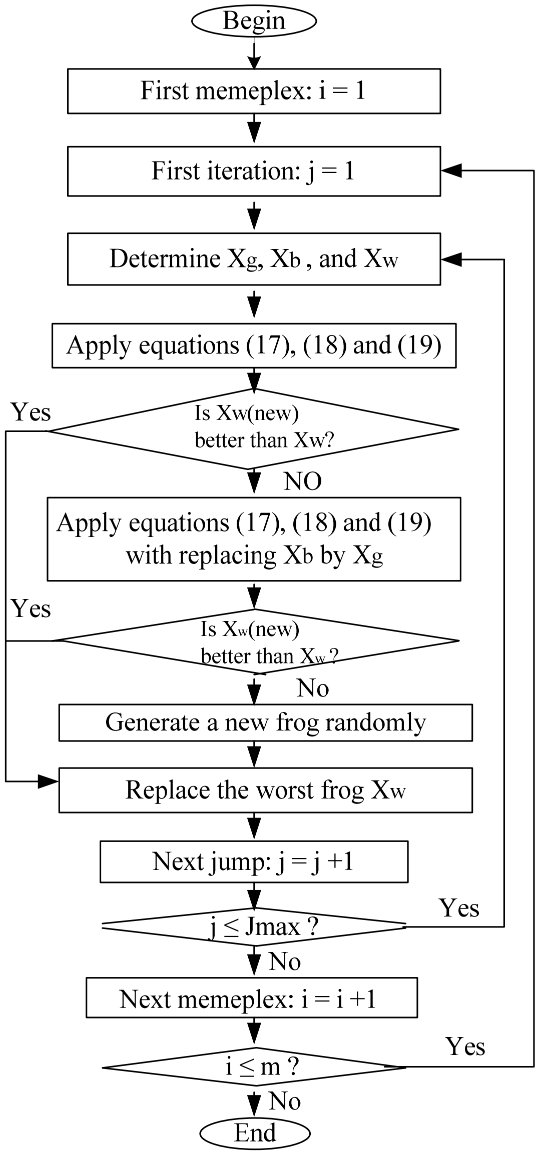

Fig. 5 - Flow chart of the local search using the new frog leaping rule

$$D = r \times c\left(X_b - X_W\right) + W \qquad (17)$$

$$W = \left[r_1 w_{1.\max}, r_2 w_{2.\max}, \ldots, r_S w_{S,\max}\right]^T \qquad (18)$$

$$W_W(new) = \begin{cases} X_W + D, if |D| \le D_{\max} \\ X_W + \dfrac{D}{\sqrt{D^T \times D}} D_{\max}, if |D| \ge D_{\max} \end{cases} \qquad (19)$$

where r is a random number between 0 and 1; c is a constant chosen in the range between 1and 2; r_i $(1 \le i \le S)$ are random numbers between -1 and 1; $w_{i,max}$ $(1 \le i \le S)$ are the maximum allowed perception and action uncertainties in the i^{th} dimension of the search space; and D_{max} is the maximum allowed distance of one jump. The flow chart of the local memetic evolution using the proposed frog leaping rule is illustrated in Fig. 5.

The new frog leaping rule extends the local search space in each memetic evolution step; as a result it might improve the algorithm in term of convergence rate and solution performance provided that the vector $W_{\max} = \left[w_{1.\max}, w_{2.\max}, \ldots, w_{S,\max}\right]^T$ is appropriately chosen. However, if $|W_{max}|$ is too large, the frog leaping rule will loss its directional characteristic, and the algorithm will becomes more or less random search. Therefore, choosing a proper maximum uncertainty vector is an issue to be considered for each particular optimization problem.

4.3.3 MSFL algorithm for optimizing DG location and capacity for reduce losses and voltage profile

The sequential steps are as follows:

1. Begin;
2. Generate random population of *P* solutions (frogs);
3. For each individual $i \in P$: calculate fitness (*i*);
4. Sort the population *P* in descending order of their fitness;
5. Divide *P* into m memeplexes;
6. For each memeplex;
7. Determine the best and worst frogs;
8. Improve the worst frog position using Eqs. (17) , (18)and(19);
9. Repeat for a specific number of iterations;
10. End;
11. Combine the evolved memeplexes;
12. Sort the population *P* in descending order of their fitness;
13. Check if termination = true;
14. End;

5. RESULTS AND DISCUSSIONS OF STANDARD IEEE 70 BUS SYSTEM

The tested system is a 11-kV radial distribution system having two substations, four feeders, 70 nodes, and 69 branches as shown in Fig.6.The load data and branch data are given in Table1.Data for this system are given in the Appendix [10].

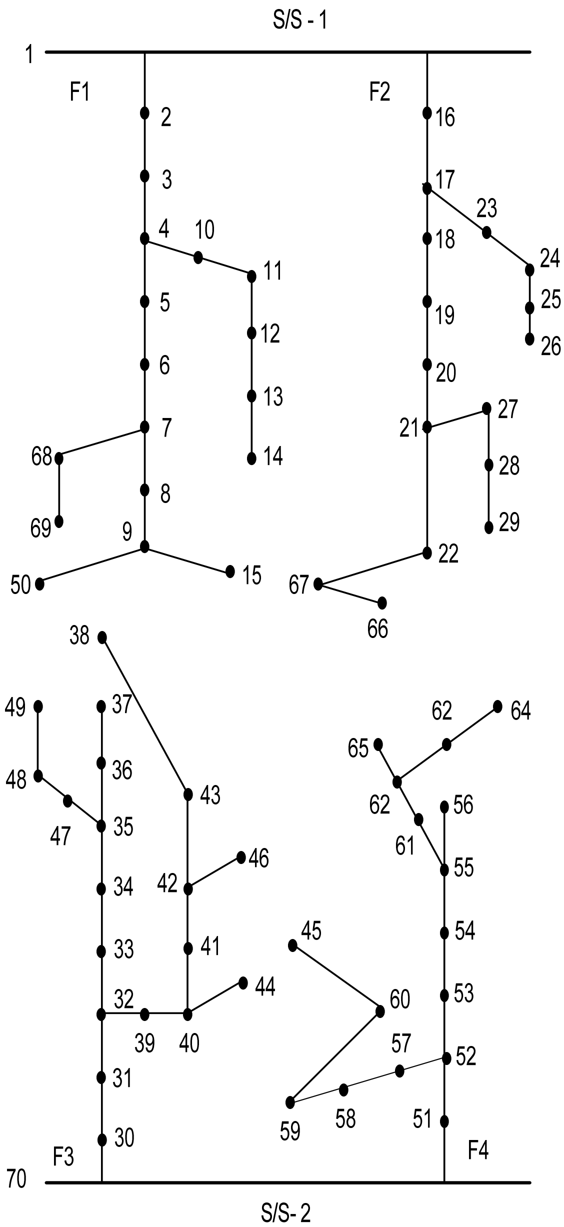

Fig. 6 - Standard IEEE 70 bus system

Table 1 - Line and load data

Line no	From bus	To bus	R ^{ohm}	X ^{ohm}	PL^{kW}	QL^{kVAR}
1	1	2	1.097	1.074	100	90
2	2	3	1.463	1.423	60	40
3	3	4	0.731	0.716	150	130
4	4	5	0.366	0.358	75	50
5	5	6	1.828	1.790	15	9
6	6	7	1.097	1.074	18	14
7	7	8	0.731	0.716	13	10
8	8	9	0.731	0.716	16	11
9	4	10	1.080	0.734	20	10
10	10	11	1.620	1.101	16	9
11	11	12	1.080	0.734	50	40
12	12	13	1.350	0.917	75	60
13	13	14	0.810	0.550	25	15
14	14	15	1.944	1.321	40	25
15	7	68	1.080	0.734	80	50
16	68	69	1.620	1.101	40	30
17	1	16	1.097	1.074	60	30
18	16	17	0.366	0.358	40	25
19	17	18	1.463	1.432	15	9
20	18	19	0.914	0.895	13	7
21	19	20	0.804	0.787	30	20
22	20	21	1.133	1.110	90	50
23	21	22	0.475	0.465	50	30
24	17	23	2.214	1.505	60	40
25	23	24	1.620	1.110	70	65
26	24	25	1.080	0.734	75	65
27	25	26	0.540	0.367	75	60
28	26	27	0.540	0.367	80	55
29	27	28	1.080	0.734	85	70
30	28	29	1.080	0.734	95	70
31	70	30	0.366	0.358	70	50
32	30	31	0.731	0.716	60	40
33	31	32	0.731	0.716	13	8
34	32	33	0.804	0.787	16	9
35	33	34	1.170	1.145	50	30
36	34	35	0.768	0.752	40	28
37	35	36	0.731	0.716	60	40
38	36	37	1.097	1.074	40	30
39	37	38	1.463	1.432	30	25
40	32	39	1.080	0.734	75	45
41	39	40	0.540	0.367	60	35
42	40	41	1.080	0.734	65	50
43	41	42	1.836	1.248	60	30
44	42	43	1.296	0.881	18	10
45	40	44	1.188	0.807	16	10
46	44	45	0.540	0.367	80	50
47	42	46	1.080	0.734	60	40
48	35	47	0.540	0.367	80	65
49	47	48	1.080	0.734	65	40
50	48	49	1.080	0.734	75	60
51	49	50	1.080	0.734	70	45
52	70	51	0.366	0.358	60	40
53	51	52	1.463	1.432	20	11
54	52	53	1.463	1.432	40	30
55	53	54	0.914	0.895	36	24
56	54	55	0.914	0.895	30	20
57	55	56	1.097	1.074	43	30
58	52	57	0.270	0.183	80	50
59	57	58	0.270	0.183	85	60
60	58	59	0.810	0.550	65	45
61	59	60	1.296	0.881	25	10
62	55	62	1.118	0.807	10	5
63	61	62	1.118	0.807	90	60
64	62	63	0.810	0.550	125	110
65	63	64	1.620	1.101	30	20
66	64	65	1.080	0.734	130	120
67	65	66	0.540	0.367	75	60
68	66	67	1.080	0.734	25	15
69	9	50	0.908	0.726	-	-
70	9	38	0.381	0.244	-	-

5.1 Optimal allocation and sizing of distributed generation

For the 70 bus radial systems, in Tables 2, results optimal allocation and sizing of distributed generation by SFLA and Proposed Method(MSFLA) .For MSFLA and SFLA parameters, population size=300, The maximum iteration for the MSFL algorithm is 5.The number of memplexes is 15. The number of frogs in memplex is 20. The LocalIter number of iterations in each memeplexes is 5.The GlobalIter Total number of algorithm iterations is 5.The number of DG(DG is capable of supplying only real power) for Optimal allocation and sizing is 13 (thirteen). The maximum real power of DG is 50kW.

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Table 2 - Optimal DG allocation and sizing for DG

By MSFLA		By SFLA	
Bus no	DG_{size}(kW)	Bus no	DG_{size}(kW)
26	48.7225	54	42.7448
67	38.0563	14	41.5201
44	29.1158	68	15.0686
59	44.6827	6	45.6470
28	41.7856	45	35.9678
68	25.0144	16	45.5061
39	47.9189	18	49.1392
64	42.6504	27	43.1954
50	47.0747	35	43.4727
33	47.3473	66	27.9072
61	38.2382	25	46.9886
14	46.4518	40	39.8541
27	41.3904	43	44.4546

5.2 Results of power Loss Reduction and Improvement in Voltage Profile of the system

The reduction power losses is evident after connecting thirteen DG as shown in Table 3 and Table 4.It indicates the reduction power losses with installation of DG for rating of 50 kW. The power loss for the base case without DG installation is calculated by load flow solutions and is found to be 205.0669 kW. For DG rating of 50 kW the values of power loss considerably reduces as indicated in Table 3 and Table 4.The percentage of power loss reduction is by means of (LLRI) and a reduction of 17.91 % is obtained with SFLA and a reduction of 18.35 % with MSFLA respectively.

Table 3 - Power losses reduction results for a DG rating of 50 kW by SFLA

Method	DG rating (50 kW)		
	Power losses (kW)	LLRI	Reduction (%)
Base case	205.0669	-	-
SFLA	168.3249	0.8208	17.91

Table4 - Power losses reduction results for a DG rating of 50 kW by MSFLA

Method	DG rating (50 kW)		
	Power losses (kW)	LLRI	Reduction (%)
Base case	205.0669	-	-
MSFLA	167.4329	0.8164	18.35

Table 5 and Table 6 indicates that for the SFLA and MSFLA methods considered, the values of the voltage profile of the system have improved considerably by connecting a DG of 50 kW capacities. The voltage profile of the base case was calculated to be 0.5157kV when a DG rating of 50 kW were connected for case study by SFLA and MSFLA. The voltage profile of the system has improved which clearly indicates the need of a DG. The percentage of voltage profile improvement is by means of (VPII) and a improvement of 6.61 % is obtained with SFLA and a reduction of 7.09 % with MSFLA respectively.

Table 5 - Voltage profile improvements for a DG rating of 50 kW by SFLA

Method	DG rating (50 kW)		
	VP(kV)	VPII	Improvement (%)
Base case	0.5157	-	-
SFLA	0.4816	0.9338	6.61

Table 6 - Voltage profile improvements for a DG rating of 50 kW by MSFLA

Method	DG rating (50 kW)		
	VP(kV)	VPII	Improvement (%)
Base case	0.5157	-	-
MSFLA	0.4791	0.9290	7.09

Figure 7 and Figure 8 shows variation of improvement in voltage profile at bus 70 for a DG rating of 50 kW.

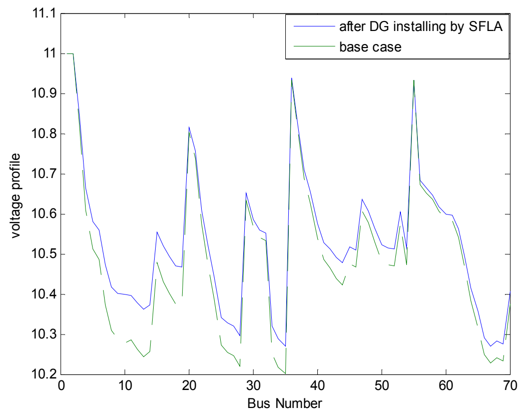

Fig. 7 - Voltage profile improvement results by SFLA

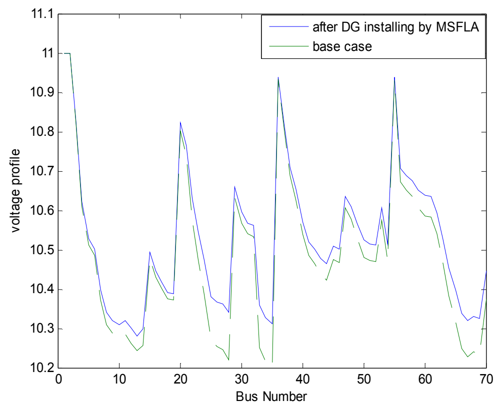

Fig. 8 - Voltage profile improvement results by MSFLA

Before optimal placement and sizing of distributed generation, the minimum bus voltage is $V_{min}=V_{35}=10.2001kV = 0.9272p.u.$ After optimal placement and sizing of distributed generation by SFLA and MSFLA, the minimum bus voltage of the system has improved 10.2924kV=0.9356p.u. and 10.3106kV=0.9373 p.u respectively.

5.3 Comparison of objective function of SFLA and MSFLA

The problem is to determine allocation and size of the DGs which minimizes the distribution power losses and improve the voltage profile for a fixed number of DGs and specific total capacity of the DGs. Therefore, in this paper the objective function for the optimal placement and sizing of DG in distribution network problem is to minimize the real power losses and improve the voltage profile. The reduction objective function is evident after connecting thirteen DG by SFLA and Proposed Method (MSFLA) as shown in Table7.It indicates the reduction objective function with installation of DG for rating of 50 kW. The objective function for the base case without DG installation is calculated by load flow solutions and is found to be 102.7913 kW. The percentage of objective function reduction of 12.76 % is obtained with SFLA and a reduction of 16.25% with MSFLA respectively.

Table 7. Comparison objective function results by SFLA and MSFLA

Method	After optimal allocation and sizing of DG	
	F_{total} (kW)	Reduction (%)
Base case	102.7913	-
SFLA	89.6709	12.76
MSFLA	86.0798	16.25

Table 7 shows the reduce in maximum objective function of the system after connecting DG at buses using the modified shuffled frog leaping algorithm.

6. CONCLUSION

The Distributed Generation (DG) in a distribution system offers several benefits such as relieved transmission and distribution congestion, voltage profile improvement, line loss reduction, improvement in system, and enhanced utility system reliability. This proposed work has presented an approach to quantity some of the benefits of DG namely, real power loss reduction and voltage profile improvement of system.

The results of the proposed method as applied to IEEE-70 bus system clearly show that DG can improve the voltage profile and reduce real power losses. Both ratings and locations of DG have to be considered together very carefully to capture the maximum benefits of DG. In this study shows the better capability of modified shuffled frog leaping algorithm (MSFLA) scale in shuffled frog leaping algorithm (SFLA) is to reduce the objective function by optimizing the DG allocation and capacity.

APPENDIX

Other data: current carrying capacity of all tie branches are 234.0 A. The current carrying capacity of branches 1 to 8, 17 to 23, 31 to 39, and 52 to 57 is 270 A. For branches 9 to 16, 24 to 30, 40 to 51, and 58 to 68, it is 208 A (see Table 1).

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 ISSN 2067-5534 © 2012 JSE

POSSIBLE TECHNICAL SOLUTIONS IDENTIFICATION IN INDOOR LIGHTING SYSTEMS DESIGN

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Abstract - The paper presents the appropriate way to be followed for a systematic assistance of indoor lighting systems design that means the choice of optimal economical solution from the whole acceptable technical solutions, for a given electrical equipment offer. After the complete specifications of solutions in offer (SO) significances and their quantitative determination, it reiterates the theoretical basis of the solutions predetermination phase. Until now, the included conditions in the electrical equipment predetermination phase are the followings:
- luminaires choice according to the room destination and its environment;
- accurate color rendering by including in SO only those luminaires of which lamps respect color rendering index or color temperature;
- illumination uniformity by fulfilling the luminaires plane placement conditions;
- minimum average illumination;
- limitation of glare phenomenon by considering the maximum suspension height.
The developed program is presented, witch the first part is represented by indoor lighting database, followed by the calculation part, with the scope to select those of SO who fulfill a exposed minimum lighting conditions.
It is considered the fact, shown in the general designing chart, that the possible technical solutions, to be further subject of a complete lighting and economical analysis, using professional design programs.

Keywords: luminaires, general designing chart, solutions in offer, possible technical solutions.

1. INTRODUCTION

Computer aided design programs dedicated to indoor lighting installations, in general made by the companies producing the electrical lighting equipment, invite the designers to choose the types of luminaires, with the equipment recommended when more variants are possible. Even the programs (Dialux) commanded by an association of European concerns start from the same point, having only the advantage that present a more developed a database. In this situation, any lighting systems designer, regardless of his professional experience, will be content to find some acceptable technical solutions, from which will choose a solution that satisfies the priority criteria.

Given the complexity of a lighting system, with many involved factors, it is unlikely that an unsystematically approach could led to the economically optimal solution. For this reason, opening an initial as large perspective on the SO and shaping a selecting methodology for the optimal solution, from the economical point of view, represent the essential requirement of the actual indoor lighting design.

Developing the relative databases to the luminaires of their equipment the flexibility to the technological improvements are always current desiderates for a performance work design. On the other side, should take of the fact that the manipulation of the extensive databases and to identifying the SO becomes the extremely laborious.

A consequence, it was considered useful and necessary to carry out a program to facilitate the identification a minimum number of solutions that satisfy some of the lighting conditions, fulfilling the goals of the offer analysis phases for determining the possible technical solutions.

2. METODOLOGICAL BASIS

2.1. The economical optimization phases

The correct approach to an indoor lighting project, by using the available computer programs and compliance with the conditions that the proposed solution satisfying the completely lighting, and economically to represent the optimum desired by the customer, requiring the following phases according to the diagram shown in Figure 1.

The initial phase of the *application defines*, requires a detailed description of there, identify the appropriate values for photometric sizes and restrictions explanation on the placement on vertical or in plane luminaires.

The *offer analysis* is the generic name for the second phase, which selects the types of the luminaires after the recommended destination by the manufacturer and types the lamps after the fitting set of luminaires and color rendering index R_a (or color temperature).

The *electrical equipment predetermination* can be based on the analytical methods which take into account a few lighting characteristics to fulfill by the lighting installation: illumination uniformity by fulfilling the luminaires plane placement conditions; minimum average illumination; limitation of glare phenomenon by considering the maximum suspension height. In the paper uses the utilization factor method, in original form, matrix.

The fourth and the fifth phases are solving with the computer assistance, supposing that it has a program that can cover the calculation requirements for the both aspects.

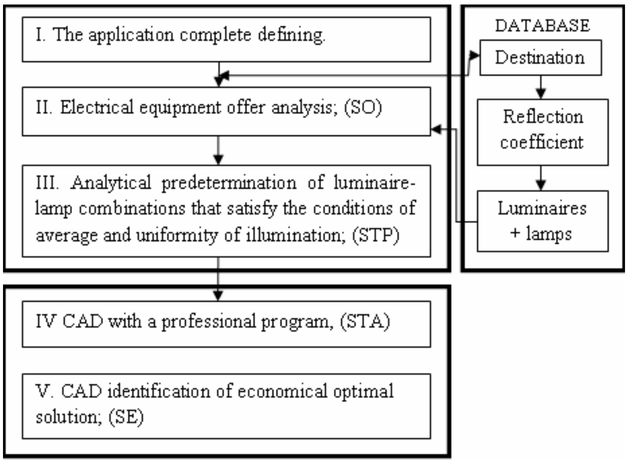

Fig. 1 - The program structure and position of the design methodology for economical efficiency of indoor lighting installations.

The solutions pyramid proposed in [2] accompanying the phases presented in the chart, which including the following solutions levels:

- solutions in offer (SO), representing the part of the offer which corresponding the application and also the solutions base of the pyramid;
- possible technical solutions (STP), selected after following the predetermination phase of the electrical equipment;
- acceptable technical solutions (STA) is the result to pass through the STP solutions verification phase on the computer, of which are selected only those which fulfill the lighting conditions;
- economical solution (SE), in fact the optimum economic of the STA.

2.2. Analytical bases

Concerning the luminaires of SO, we need to consider the accurate color rendering by including in SO only those luminaires of which lamps respect color rendering index or color temperature. Also, for the hanging height, the domain defined by the minimum and the maximum hanging heights will be considered.

The minimum hanging height is determined in terms of the limitation of glare phenomenon, defined form the accepted correlations between the mounting height by the eyes H_o and room dimensions (L_1, L_2), in the horizontal plane, according to the luminance of luminaires.

For the luminaires of luminance L_c < 5000 nt, to determine the minimum hanging height requirements H_{min} in the form:

$$h_{\min 1} = \frac{L_1}{6} + h_{om} - h_u \quad (1)$$

$$h_{\min 2} = \frac{L_2}{4} + h_{om} - h_u \quad (2)$$

and the minimum height, h_{min}=max(h_{min1}, h_{min2}), where h_{om}-the average human height, up to eye level, h_u-the height useful plan.

The maximum hanging height resulting from the condition of the minimum length of the pendulum h_{cmin}, representing the distance between the ceiling and the optical center of the luminaire when this would be mounted directly on the ceiling:

$$h_{Max} = H - h_u - h_{c\min} \quad (3)$$

and H is the height of the room.

If choose the incremental step Δh (eg. 5÷20 cm), which cover the range (h_{Max}-h_{min}), then it can calculate the number of options N_{sh} that multiply the solutions on offer, due to changes the hanging height above the utilization plane:

$$N_{sh} = \frac{h_{Max} - h_{\min}}{\Delta h} + 1 \quad (4)$$

The luminaires plane placement is solved based on the relative distance between two luminaires d*, [3] of which the recommended maximum values should be concordantly with the illumination uniformity conditions. It considers only relations on the linear sources placement, which are the types selected in the offer. So, for the number N_1 of the luminaires number on a row is used the double inequality:

$$\frac{L_1}{h \cdot d_{1*M}} + (1 - 2k_{p1}) \le N_1 < \frac{L_1}{L_c} - 2k_{p1} \quad (5)$$

where h represents hanging height, d_{1*M}=0.7 is the maximum value recommended for the relative distance on the luminaires within the same row [3], L_c - the luminaire length equipped with the linear source, $k_{p1} \in (0,25...0,5)$ the coefficient taking into account the luminaires distance from the wall and the utility given of the wall space.

The number of rows, denoted by N_2 is limited inferior, according to the relation:

$$N_2 \ge \frac{L_2}{h \cdot d_{2*M}} + (1 - 2k_{p2}) \quad (6)$$

where d_{2*M}=0.6 is the maximum value recommended for the relative distance between two side by side rows, k_{p2}-the coefficient similar to k_{p1}, but corresponding the distances from the wall as L_2 dimension.

From an economical perspective, is better to start the calculations with the minimum number of luminaires:

$$N_{c\min} = N_{1\min} \cdot N_{2\min} \quad (7)$$

following that the number of luminaires incrementing be done of nearby, until the exhaustion of all possible technical solutions, limited to the minimum flux lamps

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for each type of luminaire.

If considered N_{nc} the number of all variants of numbers of luminaires, ranging from the minimum number calculated with (7) and the maximum number defined above, then the number of initial variants is:

$$N_{VI} = N_{Oc} \cdot N_{sh} \cdot N_{nc} \tag{8}$$

where N_{Oc} is the number of luminaires types identified in the offer.

Detailed the design phases and highlighting how to shape the corresponding solution is done in the following.

2.3. Predetermination of electrical equipment

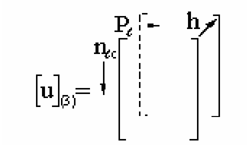
The electrical equipment predetermination phase, solved by the utilization factor method is laborious, imposing its realization by a computer program.

The photometric value on which to sort the solutions on offer to get the STP, is represented by the luminaires lamps flux.

After determining the range of values for the hanging height, first the room index is calculated for each of the values set of the hanging height:

$$i = \frac{L_1 L_2}{h(L_1 + L_2)} \tag{9}$$

Knowing the way of luminous flux distribution for each luminaire type selected, the reflection factors of ceiling and walls and the room index, can be determined the utilization factor u, corrected by the real value of luminaires efficiency. Because the luminaire efficiency depends on the power P_l and the number of lamps from a luminaire n_{lc}, the utilization factors corresponding to a luminaire type can be organized in a three-dimensional matrix form:



(10)

the third variable is represented by the hanging height h.

Becomes STP those lighting systems, characterization by the combination of luminaire-lamps, hanging height and number of luminaires, that fulfill the double inequality written in condensed form, matrix:

$$\frac{E_{med} \cdot A}{k_{Mt} \cdot N_c}\left[u^{-1}\right]_{(2)} \le \left[\Phi_{lc}\right]_{(2)} < \frac{E_{medM} \cdot A}{k_{Mt} \cdot N_c}\left[u^{-1}\right]_{(2)} \tag{11}$$

where $A=L_1L_2$ is the room area, E_{medM} - the upper limit of average illumination, set according to the following value E_{med} of the illuminations scale, k_{Mt} –the total maintenance factor, by the lighting installation, $N_c=N_1 \cdot N_2$ – the number of luminaires and Φ_{lc} – the luminaire lamps flux.

Writing the matrix relation is conventional and index (2) shows that two-dimensional matrix is treated having organized rows and columns, as variables n_{lc} and P_l.

3. THE PREDETERMINATION PROGRAM FOR STP

3.1. Databases

The evolution of methods and techniques of data organization was determined by the necessity to have as quickly and easily the access to a volume of increasingly more information. A programming environment that allows the creation, the database management and construction the applications is Visual FoxPro with other programming languages such as: MySQL, ORACLE, SQL SERVER etc.

In Visual FoxPro a database is assigned a special file (.DBC) where is stored data relating as a whole database, such as: the components tables, the permanent relations between tables, etc.

It creates a database that contains more tables:

- the destination room (libraries, offices, schools, textile industry, machine building industry, metallurgy and steel, food, electricity plants, printing, etc..) of the types rooms that will be illuminated. These rooms are characterized by the overall evaluation glare index (UGR), maintained illumination (E_m), color rendering index (R_a), color temperature (T_c), height useful plan (h_u);
- luminaires, characterized by the type of luminaire, luminaire dimensions, lamp type, lamp power, the number of lamps from a luminaire, the flux lamps of luminaire, the lamp color temperature, color rendering index, the lifetime of the lamps, the luminaire hanging height, the safety degree, socket type, applications of the luminaire;
- reflection coefficients for different categories of materials: painting, building materials, metal surfaces, textiles and paper;
- the utilization factors for luminaires with fluorescent lamps, characterized by the ceiling reflection index, the wall reflection index, the room index which is calculated according to room dimensions;
- offer solutions, possible technical solutions that contain information about the solutions obtained from the offer solutions browsing, and selecting those that correspond our application, the characteristics listed in the luminaires plus the number of luminaires, the number of luminaires in a row, the number of rows, the room index, total flux of the luminaire and height which is mounted the luminaire above useful plan.

The offer of luminaires and lamps can generally be extended much as want the designers and the beneficiaries.

3.2. Description of application

The program is realized in Visual FoxPro 9 this is an environment for working with databases. The application is structured on database "database.dbc" which includes several tables: luminaires.dbc, schools.dbc, offices.dbc, offer_solution.dbc, possible_technical_solution.dbc, utilization_coefficients.dbc, textile_industry.dbc, etc.

The communication between user and the application is made easier with a graphical interface. This interface is made in Visual FoxPro with the forms, form1.scx, Fig.2.

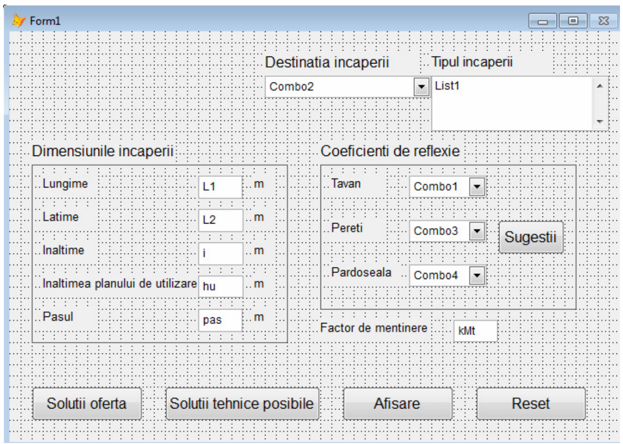


Fig. 2 - Program main form.

From the field *room destination* is choose a general category of the destination which materialize in the aside list, *room type*, then is defined the room where is inserted from the keyboard length, width, height and height of the work plan, the incremental step of hanging height. The reflection coefficients fields for ceiling, wall and floor reflection is selected the refection index of light according to the color of the ceiling, walls and floor. To select the correct coefficient is pressed suggestions, which contains four buttons: painting, building materials, metal surfaces, textiles and paper, which include different materials and appropriate reflection index.

It denotes and maintenance factor value, then press the *solutions offer* (*Soluții ofertă*) stage is selected only luminaires which corresponding the application. For the luminaires selected will be calculated: the minimum hanging height; the maximum hanging height; the minimum respectively maximum luminaires recommended on a row; number of rows and the room index.

Clicking the button *possible technical solutions* (*Soluții tehnice posibile*) will select of the solutions on offer, these luminaires which correspond and terms of luminous flux. The *Reset* button is to start a new application.

The information obtained can be processed by applying them in another program the lighting, the program will continue to run and will display a graphical solution of the luminous flux distribution and location of luminaires in the room.

4. CONCLUSION

A first contribution of this paper is to define more clearly and complete the notion of Solutions in Offer (SO). For the designer who understands and appreciates the proposed methodology, as a sure way to identify the optimal economical solution, it is clear that electrical equipment options are multiplied by the number of hanging heights and number of combinations of the luminaires numbers. The opening of "perspective" initial is essential in order to reach the best solution a view agreed by the designer and should not be necessarily always the criterion of total costs, updated.

For the first design “filter”, it proposes an electrical equipment predetermination, a step which includes: the luminaires choice according to the room destination and its environment; the accurate color rendering by including in SO only those luminaires of which lamps respect color rendering index or color temperature; the minimum average illumination; the illumination uniformity by fulfilling the luminaires plane placement conditions and the limitation of glare phenomenon by considering the maximum hanging height.

The predetermination phase of electrical equipment, solved in the paper in an original form, matrix, of the utilization factor method is quite laborious, which could discourage some designers. Therefore it is considered necessary Computer aided design, conceiving a calculation program, which was included the relative database to luminaires, applications, reflection coefficients, etc.

ACKNOWLEDGMENT: This paper was supported by the project "Doctoral studies in engineering sciences for developing the knowledge based society-SIDOC” contract no. POSDRU/88/1.5/S/60078, project co-funded from European Social Fund through Sectorial Operational Program Human Resources 2007-2013.

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COMPARATIVE ANALYSIS BETWEEN CONVENTIONAL VOLTAGE REGULATION USING REACTORS AND CONTINUOUS VOLTAGE REGULATION USING TCR IN DYNAMIC OPERATION STATE

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Abstract – In this paper a diffrent approach for voltage regulation strategies is taken into consideration. At the National Power Dispatch Centre one important voltage regulation method is done by connecting/ disconnecting reactors in order to compensate the voltage variations. Each reactor has 100 MVAr, and it's fully connected/disconnected in the Electric Power System grid when needed, leading to voltage spikes in the power system which stresses the nearby equipments. By replacing the reactors with thyristor controlled reactors (TCR) the "on/off" regulation method is changed into a continuous regulation process and voltage spikes are eliminated. Dynamic simulations have been realised to show these differences using Eurostag simulation software and the National Power System database. Results are shown in the chapters below.

Keywords: thyristor controlled reactor modelling, voltage regulation, reactor, electric power system.

1. INTRODUCTION

Presently in the National Power System, reactors are used to regulate voltage in the connection nodes and nearby area by connecting and disconnecting them in certain time intervals, in order to maintain voltage values within normal thresholds. At any moment, due to their fixed inductive reactance, their full reactive power is connected or disconnected to the grid producing high voltage variations inversely proportional with the short-circuit power of the node in which they are connected. In this paper the opportunity of modifying the fixed reactance of the reactors by creating a variable reactance with the purpose of making a reactive power regulation band is studied. In this case, voltage regulation will be continuous not in steps. At the moment there are 16 reactors operating in the system, adding up to 1600 MVAr, inductive reactive power.

By design there are two types of reactors, single phased and newer models three-phased. Reactors are used to locally regulate voltage by connecting them in the off-peak hours and disconnecting them in the peak hours to keep voltage within normal limits. The method implies connecting/disconnecting all available reactor capacity of a reactor to deal with voltage regulation. In an area with a low short-circuit power connecting a reactor leads to up to voltage swells, which stresses the equipment in the area, like the reactor's circuit breaker. As shown in the figure below high voltage spikes can be seen when connecting and disconnecting the 100 MVAr reactor in Suceava substation (SS). Up to 30 kV voltage spike was recorded on disconnection in the and up to 25 kV spike on connection.

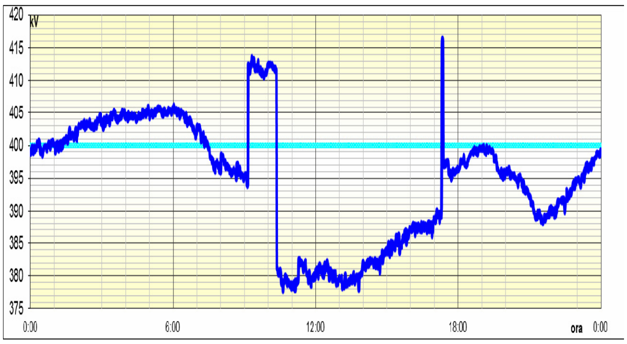

Fig. 1 - Measured voltage curve in 400 kV Suceava Substation (SS).

In this paper an alternative voltage regulation method is addressed, by using the reactors in a different mode. Fixed capacity reactors are replaced with variable capacity reactors, controlled by an automatic voltage regulator. This is technically possible by connecting in series the reactors with static bidirectional switches(fig 2). These static bidirectional switches are composed of valves formed of two thyristors connected in antiparallel one for each voltage alternation period. Thyristors continuously regulate the reactor's reactive power. By using them the reactive power supplied by the reactors is not fixed, either 0 or 100 MVAr, but varies between 0 and 100 MVAr. The electric current through the reactor can be continuously modified from maximum amplitude to zero, by using a phase regulation method. Electric current variation $i_{BC}(\alpha)$ is obtained by controlling the moment when the thyristors conduct, thus the duration time in every period. If the thyristors conduct when the voltage is at it's highest values, maximum conduction will result in the reactor, equivalent with bypassing the thyristor blocks. Thus the reactor compensates 100 MVAr, its nominal power [1].

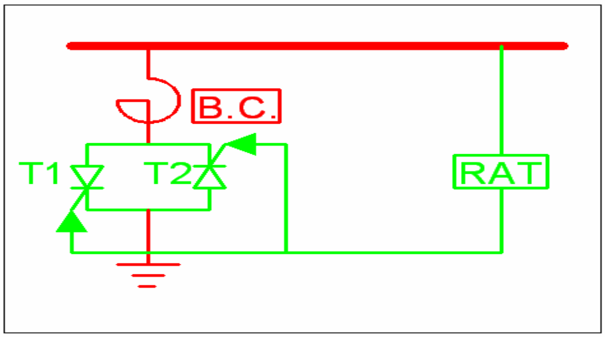

Fig. 2 - Basic design scheme of a thyristor controlled reactor

If the circuit from Figure 2 is supplied with a voltage $v(t)=\hat{V}\sin\omega t$, $\hat{V}$ being the maximum magnitude, the current can be calculated from the following differential equation: $L\dfrac{di_{BC}}{dt}=\hat{V}\sin\omega t$.

After calculating the integral, it results that $i_{BC}(t)=C-\dfrac{V}{\omega L}\cos\omega t$, where C is the integration constant. By adopting the following condition, $i_{BC}(\omega t=\alpha)=0$ it results that:

$$i_{BC}(t)=\frac{V}{\omega L}(\cos\alpha-\cos\omega t) \qquad (1)$$

Depending on the conduction angle α, of the thyristors we can determine the reactor's admitance $B_{BC}(\alpha)$:

$$B_{BC}(\alpha)=B_{\max}\left(1-\frac{2}{\pi}\alpha-\frac{1}{\pi}\sin 2\alpha\right) \qquad (2)$$

where $B_{\max}=\dfrac{1}{\omega L}$.

The thyristor controlled reactor can operate within a defined V – I characteristic, with borders determined by the maximum values of admittance, voltage and current (Fig. 3).

By defining σ as the conduction period, the relation between α and σ is the following:

$$\alpha+\frac{\sigma}{2}=\pi \quad or \quad \sigma=2(\pi-\alpha) \qquad (3)$$

and considering that: $X_{Bc}=\omega L$ we can calculate the reactive power output of the TCR with the following formula [2]:

$$Q_{BC}=\frac{\sigma-\sin\sigma}{\pi X_{BC}}V^2 \qquad (4)$$

Using phase regulation we can continuously control the inductive reactive power from 0 to 100 MVAr, according to the characteristic shown in figure 3.

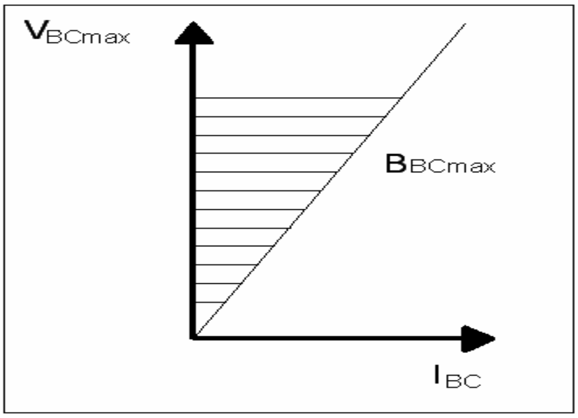

Fig. 3 - V – I operation characteristic of a thyristor controlled reactor [2]

Considering his continuous reactor voltage regulation concept, an analysis of the effects of this phenomena has been done using a database of the National Power System topology (NPS) modeled in Eurostag software [3].

2. MODELLING OF THE REACTOR AND THE TCR

For the simulations the 400 kV Suceava node was chosen due to it's small short circuit power, radial configuration and low active and reactive power flows on the Substation's 400/110 kV transformer.

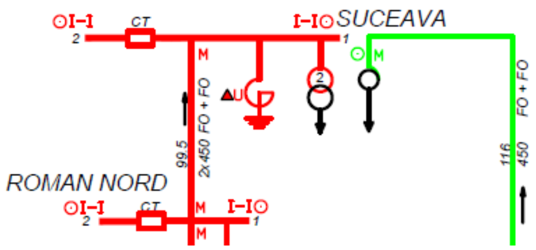

Fig. 4 - Suceava substation and overhead line connection to Roman Nord substation.

Using Eurostag the reactor was modelled as a Reactor bank connected to the Suceava 400 kV node.

The TCR was simulated in a different mode. Instead of replacing the 100 MVAr reactor with a 100 MVAr TCR to the existing configuration an 100 MVAr purely capacitive SVC has been added to the original configuration which uses a PI (proportional integrative) – regulator (fig 5). Thus the 100 MVAr inductive reactive power of the reactor can be varied from 0 MVAr to 100 by increasing the capacitive reactive power of the SVC. This method has been chosen because if the reactor were to be replaced with a TCR it will not load at 100 MVAr capacity in the initial operating conditions, making the comparative analysis difficult to realise.

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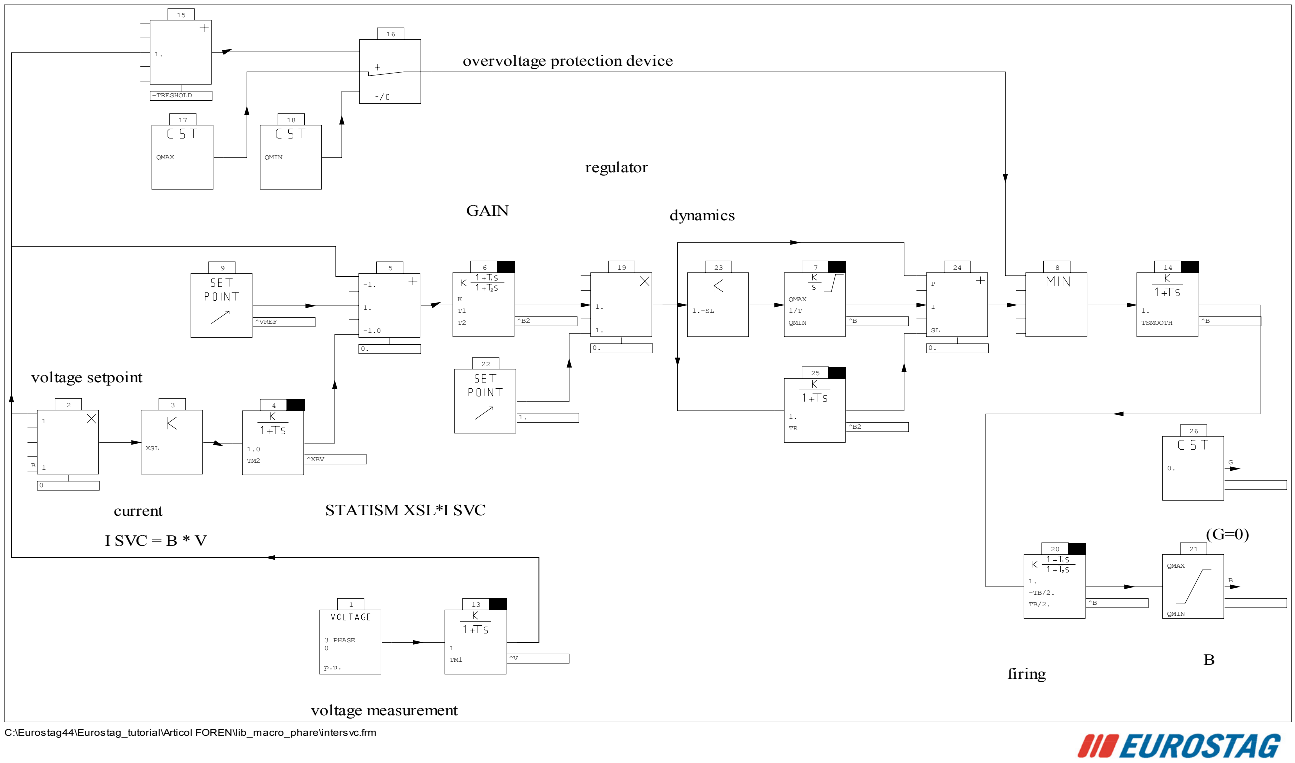

Fig. 5 - P-I regulator structure belonging to the SVC, used in the simulations* [5]

In normal operating conditions (all lines operational), on a winter generation schedule (9905 MW), the following simulations have been run:

- Load variation on the 110 kV node of Suceava substation, the load was varied from 100 MW and 20 MVAr to 130 MW and 60 MVAr.
- Successful auto-reclosure of the line 400 kV Roman Nord - Suceava
- Connection/disconnection of the 100 MVAr reactor in Suceava Substation
- Progressive reactive power decrease of the TCR from 100 MVAr to 0
- Progressive reactive power increase of TCR from 0 to 100 MVAr.

3. SIMULATION RESULTS

a) Load variation on the 110 kV node from Suceava substation, the load was varied from 100 MW and +20 MVAr to 130 MW and +60 MVAr. Both normal reactor operation and TCR were simulated. Results are shown below:

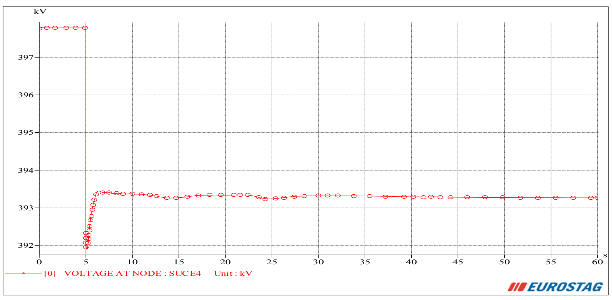

Fig. 6 - Voltage variation on Suceava node on t = 5 sec using a reactor

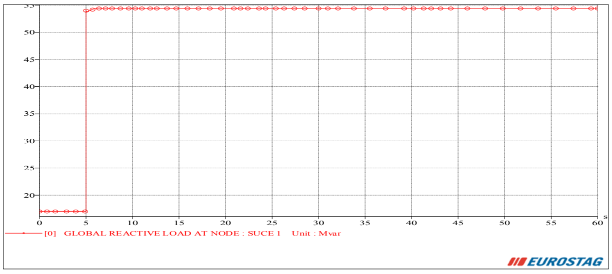

Fig. 7 - Reactive power variation at t = 5 sec using a reactor

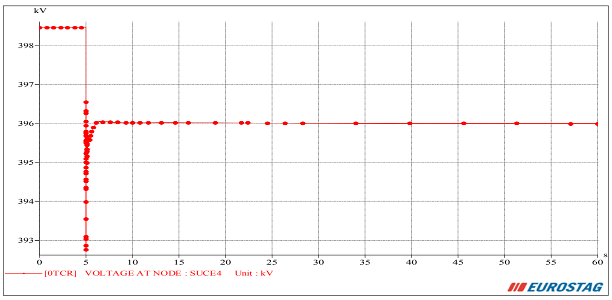

Fig. 8 - Voltage variation on Suceava node at t = 5 sec using TCR

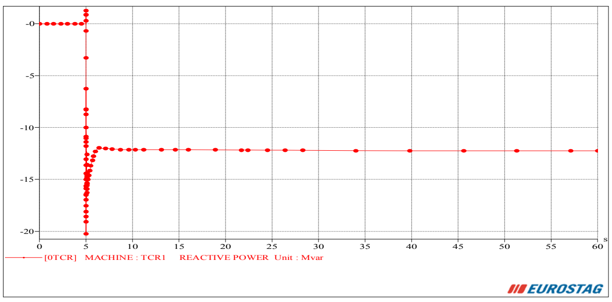

Fig. 9 - Reactive power variation on Suceava node at t = 5 sec using a TCR

Comparing the two simulations it can be said that using the reactor the voltage drops from 398 kV to 393.5 kV when the load increases while using a TCR the voltage drops from 398 to 396 kV, a higher value, than using the reactor, measuring the reactive output of the capacitive SVC and making a reactive power balance it results that 85 MVAr are being absorbed in the node, instead of 100 MVAr in the conventional case. It can be said that using a TCR, which has a reffrence voltage, when the load increases in the node its reactive power output decreases, to mantain the voltage close to the reffrence value.

b) Successful auto-reclosure of the line 400 kV Roman Nord – Suceava

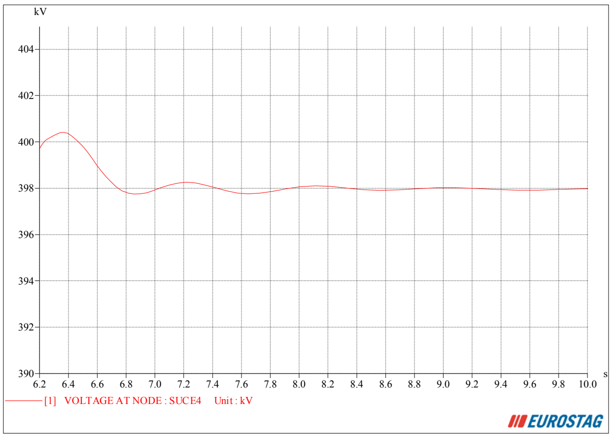

Fig. 10 - Successful auto-reclosure of the line 400 kV Roman Nord – Suceava when reactor is connected

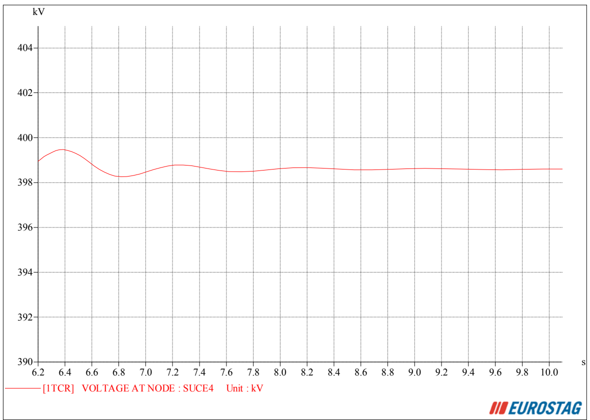

Fig. 11 - Successful auto-reclosure of the line 400 kV Roman Nord – Suceava when TCR is connected

In this case the difference is not great, but it can be noticed that when a TCR is used the wave oscillations are reduced from 9 seconds to 8 seconds by 1 second, due to the P-I regulator.

c) Connection/disconnection of the 100 MVAr reactor in Suceava Substation

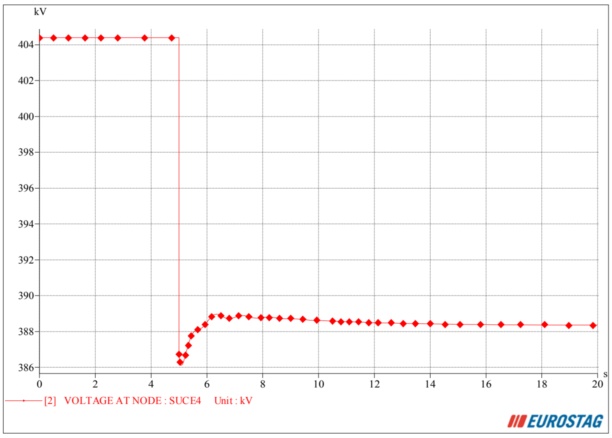

Fig. 12 - Connection of the 100 MVAr reactor in SS Suceava

In the studied simulation it can be noticed that connecting the reactor produces a 20 kV voltage surge in the connection node, this surge also propagates in the nearby 400 kV nodes Bacau Sud, Roman Nord and Gutinas (fig 12):

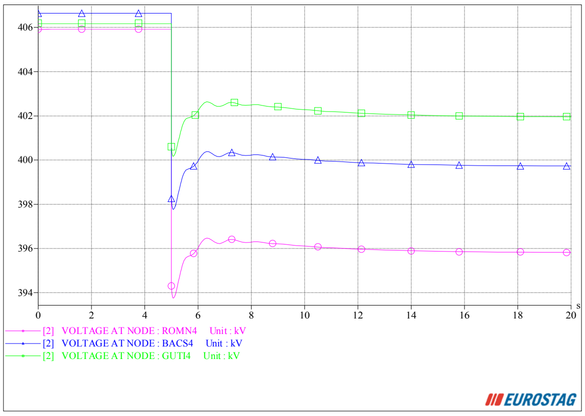

Fig. 13 - Voltage surge in SS Roman Nord, Gutinas and Bacau Sud produced by connection of the 100 MVAr reactor Suceava

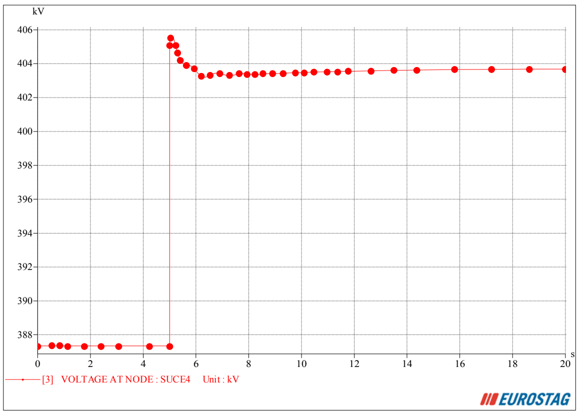

Fig. 14 - Voltage surge produced by disconnection of the 100 MVAr reactor in SS Suceava

Considering the same operation parameters disconnection of the reactor produces a 18 kV voltage decrease in the connection node, also propagated in the nearby nodes (fig. 14).

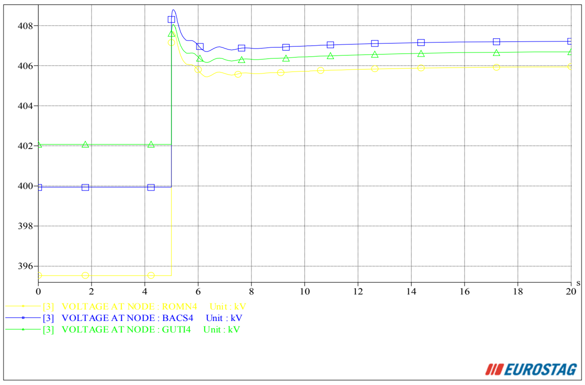

Fig. 15 - Voltage surge produced in in SS Roman Nord, Gutinas and Bacau Sud by disconnection of the 100 MVAr reactor in SS Suceava

d) Progressive reactive power decrease of the TCR from 100 MVAr to 0.

In order to eliminate the potentially harmfull situation created when operating the reactor, a diffrent approach has been simulated using the TCR. A variable increase/ decrease of the reactor power has been simulated. The increase/ decrease speed was determined to be 2 MVAr/sec. The following graphs have been obtained:

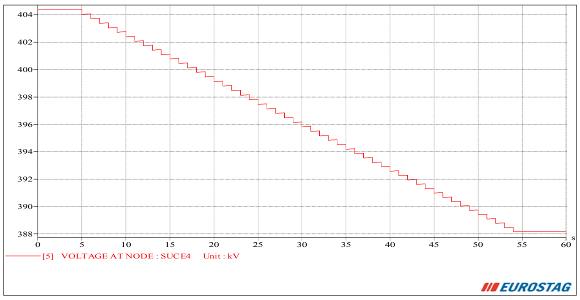

Fig. 16 - Voltage variation due to progressive reactive power increase of the TCR from 0 to 100 MVAr

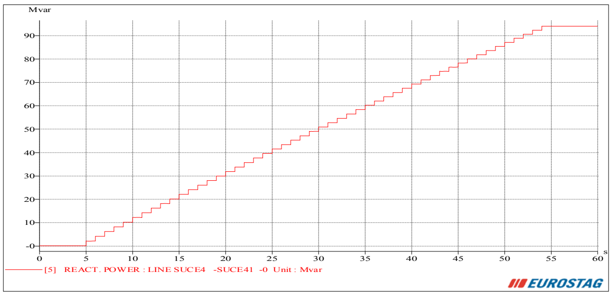

Fig. 17 - Progressive reactive power increase of the TCR from 0 to 100 MVAr

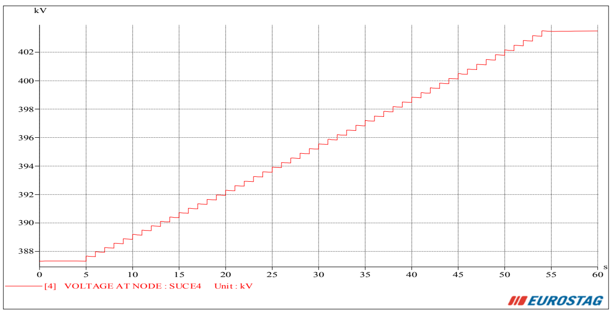

Fig. 18 - Voltage variation due to progressive reactive power decrease of the TCR from 100 MVAr to 0

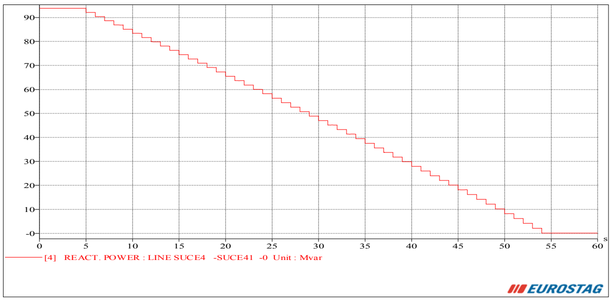

Fig. 19 - Progressive reactive power decrease of the TCR from 100 MVAr to 0

In this method voltage is droped in steps, every step is controlled, therefore the surge is eliminated.

4. CONCLUSIONS

In this paper a comparative analysis between a conventional reactor and a thyristor controlled reactor has been realised, in the National Power System topology, and it has been shown that a TCR can be safer to use for the equipment in the area. Due to its proportional integral regulator the amount of reactive power absorbed from the system can be controlled to adapt to the variable working conditions and also, during fast dynamic events, like when the line auto-recloses oscilations are dampened. Therefore the security in the area is improved.

In case of load increase the reactive power consumption is reduced in order to maintain a stable voltage, as close to the initial voltage as possible. Also by setting a reffrence voltage in the selected node, the voltage in the surrounding area is also controlled. Therefore the voltage variation curve has smaller swells. In case of connection/disconnection of the devices, while the reactor induces a voltage variation up to 30 kV, a TCR can gradually control the voltage variation, in order to maintain power system security and steady operation in the area.

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