CONSIDERATIONS ON THE MAINTENANCE STRATEGY OF THE ELECTRICITY TRANSMISSION GRID AND THE NEED TO PROMOTE LIVE WORKS TO OVERHEAD LINES

Marian FLOREA[1], Aurelian LECA[2]

Prin restructurarea sectorului energetic, pentru societăţile/companiile rezultate au fost necesare noi standarde/ reglementări/prescripţii, şi în mod special, pentru funcţionarea şi menţinerea în functiune a reţelelor electrice de transport şi distribuţie.

În vederea realizării -de către CNTEE „Transelectrica" SA, Operatorul de Transport şi de Sistem (OTS) a unor servicii de calitate pentru participanţii la piaţa de energie electrică, Compania s-a preocupat de introducerea conceptului de management performant în activitatea sa.

Integrarea Sistemului Electroenergetic Naţional (SEN) în cadrul UCTE şi functionarea integrată a Reţelei Electrice de Transport al energiei electrice (RET), implică atât respectarea condiţiilor tehnice de funcţionare integrată, cât şi organizarea şi desfăşurarea proceselor de mentenanţă prin aplicarea şi utilizarea concepţiilor şi a tehnicilor larg folosite în ţările membre UCTE.

În conformitate cu reglementările Autorităţii Naţionale de Reglementare în domeniul Energiei (ANRE), CNTEE „Transelectrica" SA a elaborat Programul de asigurare a mentenanţei (PAM).

Concepţia de organizare a lucrărilor de mentenanţă sub tensiune la liniile electrice aeriene (LEA) este integrată în prevederile PAM.

Lucrarea prezintă câteva consideraţii privind activitatea CNTEE „Transelectrica" SA în domeniul mentenanţei, cu referire la lucrările de mentenanţă sub tensiune la LEA..

New standards/regulations/prescriptions were needed by the resulting companies/firms and mainly by the sustained operation of transmission and distribution networks, as a result of the power sector restructuring.

C.N.T.E.E. "Transelectrica" SA, the Romanian transmission and system operator (TSO) has been concerned with implementing the state-of-the-art management concept in its activity in order to provide high quality services to the electricity market participants.

The National Power System (NPS) integration into UCTE (Union for the Coordination of Transmission of Electricity) and the integrated operation of Electricity Transmission Grid (ETG), involve both observing the technical conditions of integrated operation and organising the maintenance activities by means of applying the widely utilised conceptions and techniques of UCTE member countries.

[1] Eng., C.N.T.E.E. Transelectrica S.A., Bucharest, Romania, e-mail: marian.florea@transelectrica.ro

[2] Prof., Depart. UNESCO, Universitatea POLITEHNICA of Bucharest, Romania

C.N.T.E.E. "Transelectrica" SA has drawn up the maintenance insurance programme used for its maintenance activity, in accordance with the regulations of the National Regulatory Authority in the energy field (ANRE).

The organisation of live maintenance works to overhead lines (OHL) complies with the provisions of the maintenance insurance programme.

The paper describes a few considerations on "Transelectrica's activity in the maintenance field, referring also to live maintenance works to OHL.

1. Introduction

In the context of sustainable development, asset management is the set of methods and procedures that contribute to increased profitability, enhanced competitiveness of services provided by such assets and improved continuity and quality of their operation.

Asset management is the manner in which asset utilisation is improved by gathering and processing relevant data from maintenance, refurbishment, investment decisions and performance monitoring. Also risk management supervises and controls risk levels in the operation of assets in accordance with the utility's objectives of service quality, safe operation of installations and their security.

New challenges occur permanently that require solutions for various problems such as [4]:

- Developing infrastructure investments- long-term investment trends; re-investment strategies; developing the Electricity Transmission Grid (ETG) in response to increased demands, and optimising the efficiency of the existing network;
- Risk management, ensuring the quality and quantity of primary data, data conversion into knowledge and of knowledge into decisions; management and maintenance of aged assets, providing operational safety; classifying investments by priority degrees taking into account the risks; cost forecast and control during the entire life cycle; integrating cost fluctuations into the long-term planning; management of aged assets using the least cost principle; justifying the maintenance costs for such assets; managing the high risks associated to these assets; developing a strategy for the entire life of new assets and for their maintenance;
- Benchmarking - comparative analysis of performance - a need for consistent comparisons and for methodologies measuring the asset performance;
- The need to elaborate or update certain standards in the field;
- New maintenance techniques in order to provide proper services during maintenance activities; providing external communication under the

relationship to the public; justifying the investments based on cost-benefit and risk analyses;

- Issues for the future- future electricity networks- challenges for managers; new technologies; industry – research – education relationship;
- Regulatory problems; cost control mechanisms; price rise management; long-term forecasts, regulatory periods; how can the regulator to facilitate an efficient planning.

The decision-making process involves developing and implementing integrated strategies and coherent decisions derived from various activities, all of which are leading towards an efficient safe operation of the ETG and of the National Power System (NPS) in its whole.

The basic function of asset management can be described as an uninterrupted decision-making process with respect to all the activities carried out within and in relation to the ETG during all the stages of asset life cycle:

Planning (process)➔Purchase (data, technologies)➔ Operation (performance management, strategy)➔ Maintenance (strategy, organisation and personnel)

Asset management is an iterative and evolutionary process (Fig. 1), with strong feedback connections that facilitate the decision-making process.

Fig. 1. Asset management process

Therefore, a balance is aimed at between performance, cost and risk by a maximum utilisation of installations (Fig. 2) [1]-[4], [7].

INVESTMENTS AND CAPEX PROJECTS

- DESIGN AND PURCHASING : LIFE CYCLE COSTING
- PROJECT PRIORITISATION AND COST / RISK EVALUATION
- REPAIR VERSUS REPLACE OPTIONS
- OPTIMAL REPLACEMENT TIMING
- LIFE EXTENTION / REFURBISHEMENT PROJECTS

OPERATING AND MAINTENANCE DECISION

- MAINTENANCE INTERVALS
- INSPECTION / MONITORING INTERVALS AND ALARM POINTS
- SAFETY TESTS AND FAILURE FINDING TESTS
- SHUT DOWN AND OUTAGE PROGRAMMES
- WORK OPPORTUNITIES AND CLUSTERING

RESOURCES AND PURCHASING DECISIONS

- SPARES AND MATERIAL STOCKS SUPPLIER AND PURCHASING STRATEGIES

Fig. 2. Resolving the apparent conflict

2. Maintenance activity – a component of the asset management

2.1. Maintenance Ensuring Program

In CNTEE “Transelectrica” SA the maintenance activity is developed based on its own Maintenance Ensuring Plan (MEP) drawn up based on ANRE provisions.

MEP is thus based in prescriptions, recommendations, procedures, technological sheets etc. to ensure that the maintenance policies are determined and understood within and outside CNTEE “Transelectrica” SA - to the maintenance service providers -, implemented and kept on country - wide. The activities stipulated in MEP are procedure-shaped. The procedures have requirements including roles and responsibilities, personnel qualification, change management. MEP consists in and preserves (by ensuring the framework for elaboration, review, update the documentation on maintenance, if the case) all the documentation referring to the maintenance activity. This documentation justifies

in an efficient manner the implementation and functioning of each stage of MEP and makes the key results of this process as well as the decisions made to be traceable and applicable. MEP is applied to all the components of the maintenance activity (technical, economical, financial, relational, and organizational) undertaken at all the fixed assets within the ETG.

2.2. Maintenance strategy

The maintenance strategy defines the objectives of the Company needed to carry out this activity.

In order to organize, plan, schedule and conduct the maintenance activity, general and specific objectives are determined through the provisions in MEP which should be reached for increasing the performance.

The maintenance strategy is meant for planning and scheduling the long term activities, organizing the activities on clearly stated bases, purchasing maintenance services based on contracts from specialized entities (economic agents), from outside CNTEE "Transelectrica" SA and by observing the determining the performance criteria. Organizing the activity ensures the needed interfaces (relations, communication, coordination) between the departments on CNTEE "Transelectrica" SA and contractors, work execution survey, work acceptance tests.

2.3. Coordination of the maintenance work

The schedules of the preventive maintenance are correlated with the investment programs (transforming substations rehabilitation programs constructed on scientific bases, on ranking criteria which lead to making ranking decisions on performing the maintenance work or investments).

Based on the annual maintenance and investment plans the annual program on equipment and facilities retirement from exploitation is constructed.

The maintenance program are constructed in such terms that all activities to be performed at an equipment or facility of the ETG should be executed within a single retirement from exploitation period.

At the same time, the work at OHL-s should be correlated with the work at the end bays, the work at transformers, autotransformers, shunt reactors will be correlated with the work at the related bays, the work at the primary equipment with the work at the secondary one or between various equipment managers etc. including neighboring power systems partners.

2.4. Information feedback used to improve the maintenance strategies

In order to justify the decisions on enhancing the reliability and maintenance activity based on the information feedback, the following issues have to be considered: analysis of the defect occurrence frequency and analysis of the

equipment operation features evolution to state the technical condition; analysis of the of equipment importance within the NPS; cost analysis.

All the aforementioned are included in the general philosophy of Reliability Centered Maintenance (RCM), a systematic decision making process and a process of standardized approach of the maintenance activity currently applied within the ETG. The RCM is capitalizing the classical theory of reliability which directs the maintenance actions towards the vulnerable spots in the installations and where these activities are justified by the economic efficiency. Therefore it was progressively change from the time-based maintenance activity to the condition-based maintenance work, namely the reliability-based maintenance activity.

The main maintenance philosophy objectives based on reliability are as follows: maintenance undertaking at the optimum time and in the optimum amount; cutting down the maintenance costs; diminishing the decommissioning periods of time; providing the requirements on the investment work promotion; correlating the maintenance and rehabilitation programs.

Priority of the preventive maintenance work is set function of the technical condition of equipment/facilities quantified based on statistically processing the information on the operational behavior: frequency and duration of the accidental failures, evolution of parameters and operational features, maintenance history, costs and considering their importance for the NPS.

Integrating the results related to the technical conditions of all functional equipment/ facilities owned by each transmission branch and the importance of facilities for ETG, it results the program on annual maintenance activities required at the level of each functional category unit, split by the four levels stipulated in MEP as well as suggestions for the rehabilitation/investment plan.

The final maintenance program, followed by the one on the retirement from exploitation is the result of an annual iterative process as per the specific operational procedures.

3. Live line works' technical and economic benefits

3.1. General view

Presently, most of the minor or major maintenance works in NPS from Romania involves the retirement from exploitation of the installations on which they intervene. Any retirement represents a deviation of regular scheme with direct bearings over transported energy costs or of the undelivered energy [6].

The new imposed conditions of the energy market regarding the energy supply with its exigencies regarding the labor providing quality and continuity, the penalties for the contracts inobservance and all the social bearings grew the necessity for some modern techniques and equipments for the energy supply

activity.
On the other hand, from the transmission activity's point of view, the interlinkage terms with UCTE and the need of lining the technologies used in Romania to the UCTE system requirements have led Transelectrica to develop a strategy for the implementation of live working. The internal clients' requirements are continuously growing along with the restrictions concerning supply continuity, and therefore live working seems to be the single alternative.

Therefore, it is necessary to test that the practice of Live Working does not involve an increase of the costs. [6]
The criteria on which live working are applied are:

- Necessity
- Utility
- Efficiency

It is necessary to see how all these are achieved.

3.2.Deviations from the normal scheme (DNS) at „Transelectrica" SA

Strictly referring to Transmission Grid, it's been demonstrated that live working offers yet another advantage–an economical one: a lower technical consumption.

The increase of technical consumption due to deviations from the usual scheme is influenced by several factors:

- The amount of power carried through the system parameter outages;
- The time of the installations' unavailability;
- The load degree of the networks adjacent to that which has been withdrawn from exploitation.

The analysis took into the consideration a subsystem which consists of the western and south-western area of the Romanian Transmission Grid.

The program that was used was called POWER. The software determines the power flow through, the buses' voltage value and phase angle, the active and reactive power generated in the slack bus, as well as the losses distribution on components.
Two operation conditions were considered:
a) operation on maximum load in the most significant day of 2001
b) operation with 25% bigger active and reactive loads compared to the previous condition

The operation conditions have been analyzed in two different situations.
Losses were determined for each of the conditions disconnecting the mentioned lines in order to perform the maintenance works.

The conclusions go as follows:

- Considering the present network load in the power system presented, the effect of the additional technical consumption caused by deviations from the normal scheme is insignificant (in quantity and value).

- Even in the current situation, the withdrawal from operation for some main lines highly increases the technical consumption thus justifying the live line works.
- A 25% increase of the local consumption leads to a 2.3 times increase of the additional technical consumption due to deviations from the normal scheme.
- In double contingents operating conditions (one line withdraw for planned maintenance and another accidentally disconnected) the technical consumption increase due to further due to deviations from the normal scheme, is highly amplified (roughly 4.5 times in the presented case).

3.3. Concise respects regarding the congestions

The transport network represents understructure which makes the existing of the electrical energy market possible. The transport and system operators are forced to make this understructure available for all market participants.

The actual performing of the required works and transactions may require the use of certain parts of the power network beyond the limits which allow the operation in safety conditions.

The Technical Code of Transmission Grid defines “congestions” as “running situations in which the energy transport between two junctions or system areas leads to NPS safety parameters in observance”.

As defined by the CE 1228/2003 regulation, article 2, section 2c, “congestion” represents the situation where the transport networks cannot apply the requested international transactions of the market participants, due to the insufficient capacity of the interlinks or resp. National Power Systems.

In a different approach, the congestion can be ranked as being the networks’ disability to power the users from the cheapest sources, due to some capacity constraints (thermal limits, stability or safety limits).

The Romanian approach associates congestions with the providing of transport in safety conditions, while the European regulation stresses on the technological restrictions that appear in the fulfillment of some commercial requirements. Obviously, the congestions’ management must insure safety, but the costs must be reflected on and assigned to the network users.

The Romanian Commercial Code considers the Transport and System Operator (OTS), meaning C.N.T.E.E. “Transelectrica” S.A. as being the only one responsible and also the one that has to integrally cover the increases of costs that arise from the disposed measures for removal to those, including this cost in procedure clothed costs structure of the transport rate, whichever the causes what they generated congestion.

The extreme registered costs to the year level 2007 for the congestions management have pointed out existing of some problems in the running to those and the find necessity of some decay solutions of those.

The congestions management, appoints the adaptive measurements unit of the

energy market requirements to the technical and function limits of the networks. The step is imperative when OTS observes as the transactions actively had been concluding, without the network embargos regard, cannot be laid in work. The congestions management must to apply the integrating problematic of the system preparation for the running behavior whereupon refers: permanent behavior, stability, safety.

3.4. The main causes of the congestions

For a correct substantiation we must see the double cause of the congestions:

-Financial: the modification of some commercial preferences of the participants to energy market;

-Structural - dynamics: the wiring to network of new users, in unfavorable locations for network and without the suitable appliance of this.

The main causes which may lead to congestions are the following:

-The self dispatch existing principle, pursuant to which each producer schedules running of the groups so to increase the profit, the consequences over total costs on which must to pay to the end users;

-The optimizing of the dimensions of generating units and of the scheduling to those, having as goal the profit enlargement,

-The consequences of one such behavior, correct from point of view of the market rules, in addition to the costs increase is the congestion appearance in the transport networks;

-The outage and the closing of the thermo power-plants from certain red areas, which leads to abnormal behaviors for the transmission installations,

-The failures of some production installations, of some repair works and revisions,

-The increase of the power consumption in certain urban areas, correlative with unavailability and faults in the distribution local installations (110kV);

-Accidental incidences and unavailability in the transport networks, which overlap across the maintenance and investments programs;

- The increase of the power consumption to ventilation installations, of frost and of conditioned air;

- Prolonged drought preys the availability of the hydro power plants.

3.5. The database presentation [6]

The National Transmission Grid scheme was extracted from National Dispatching Energetic (DEN) data base. The result was an electro energetic system (Fig. 5) with the following elements:

-Total node number -145, of witch 46 with generators (31 actual, 15 equivalent) and 89 consumption nodes;

-Network side number- 193, of witch 133 OHL, 54 transformers and autotransformers, 6 couples and 7 coils.

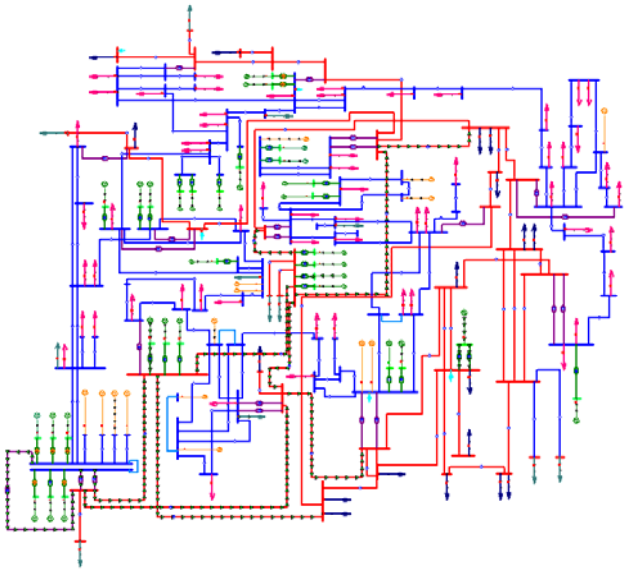

Fig. 3. The structure of National Power System

They were considered, basically the voltage levels of 400 and 220 kV.
In these conditions we took all measures as the running behavior for the subsystem to coincide, in reasonably limit, with one supplied by DEN for the summer behavior evening - winter.
All databases were implemented on the rated program Powerworld the version 8.

3.6.Case study regarding the influence of congestions

Controlled section = a group of certain 400 kV & 220 kV OHLs under control of National Dispatch Centre (NDC) in order to keep the load flow up to a certain value based on steady state stability or transient stability computations results.

Controlling this section at every moment of the day, NDC ensures a reliable and adequate level of the stability margins in the involved area system.
Dispatch Actions: if a congestion is detected, the generation level can be re-dispatched using the availabilities on the Balancing Market.
The generation program changing can be performed on the Balancing Market by selection of the right amount of generation in adequate location, but from outside of the Merit Order as a means to reduce the load flows under limit value.
This kind of action is a regulated one but involves a payment done by the “Transelectrica” to the called producers**.**

According to the common yearly maintenance schedule agreed by both TSO-s, the 400kV tie-line Rosiori - Mukachevo between Romania and Ukraine was out of operation 10 days.

At a planning daily level was detected[3] a several days and hours when the stability of the North-West part of the Romanian Power System could have been jeopardized. The right decision of the National Dispatch Center was to order the start-up in addition a new unit in TPP Iernut and for several peek hours a first unit in HPP Mariselu. So, the traded energy for congestion management involves an important payment to the called producers on behalf of Transelectrica.

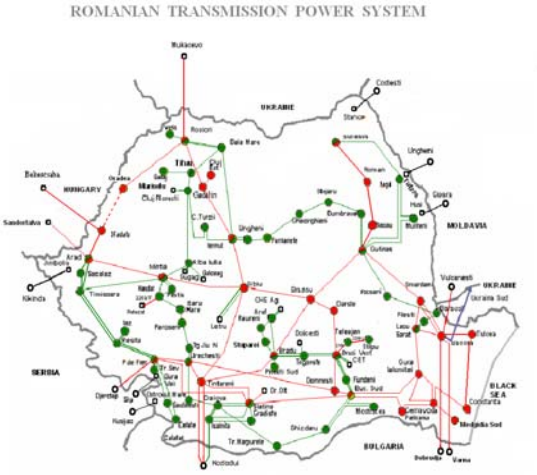

Fig. 4. Romanian transmission power system

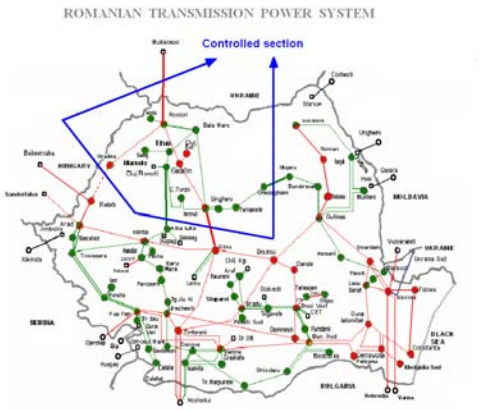

Fig. 5. Controlled section

[3] All the analyses are performed in respect with N-1 criterion

For all traded energy on the Balancing Market to remove the congestions, the cost was around 100.000 EUR (for 10 days).
During this network topology a further scenario[4] showed that in case of:
- unavailability of the 400kV Rosiori-Mukachevo due to a stand-by time over 48 hours;
- hypothetically requirement of emergency works (insulator replacement for instance) on the second OHL 400kV belonging to the same controlled section (400kV OHL Iernut-Sibiu);
-new costs for congestion removing could be necessarily: 180.000 EUR (per day of outage).

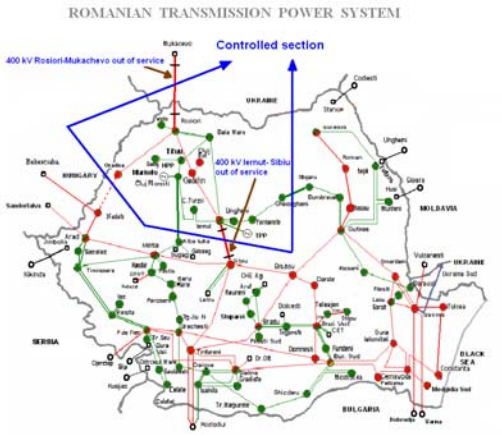

Fig. 6.The controled section and the second unavailability

In such a case, take into account the huge amount of the possible traded energy on Balancing Market, the usage of the live working on the second line represents an important option for the company because it allows to:
-maintain the congestion costs at same low level and consequently no-additional financial pressure level against the company;
- keep the last two units in HPP Mariselu at the National Dispatch Center disposal as available units for system reserves (such as Area Generation Control).

The presented studies demonstrate, against general current which considers that LIVE WORKING is performed with higher costs than the work on deenergised line, Live Working has an important economic advantage.

In the distributors case can be generate collateral gains, such as:
- the decreasing of maneuvers number (in other scale can discuss a re-structure of this activity);

[4] based on both a further steady stability computation and an average cost of the congestions for new involved units belonging to TPP Iernut and HPP Mariselu

- reduced requirements imposed to the distributor for the network continuity in ideal conditions (no maneuver needed in different network areas);
- smaller requirements imposed to the company for the redundancy for the customer.

One must notify that Live Working has a larger importance when:

- life span of the installations is large and can impose a large frequency of the maintenance works (preventive and corrective)
- the increase of power request generates a load of the installations;

In the transmission companies case Live Working has also other advantages:

- insures the service execution possibility as it was it planned;
- entails the commutation processes reduction and so of the events number;
- leads to the simplifying of the procedures referring to the works set up and deploy;
- confines the impact over environment.

It leads to the safety increase (is proved statistical that the accidents number during Live Working is much smaller than one during the works on deenergised installations).

There are other gains of keeping the power on, heavier to quantify: client satisfaction, mediate image, company image, stock-market quotation, social impact.

Regarding the congestion, Live Working is not only recommendable, it is mandatory in congestion management.

4. Conclusions

- On the internal market "Transelectrica" provides the needed infrastructure and the non-discriminatory regulated access to network for all participants on the electricity market.
- Although the sector has been separated in many entities in commercial and legal terms, "Transelectrica" provides the functional unity of the National Power System, its safety and best operation.
- "Transelectrica" continues the tradition and experience gathered in 50 years of operation and maintenance of the NPS.
- The informational feed-back based on operational behaviour monitoring results in higher operational safety, both by means of specific maintenance and operation activities and by taking joint action with equipment supplier with a view to improving its reliability.
- "Transelectrica" is concerned with providing maintenance using live work techniques and with implementing specific working conditions, taking into

account both the impact of electricity sector restructuring and the new conditions occurring in this situation.

- The Romanian electricity sector integration into the European and regional market is provided by interconnecting the transmission grid to the UCTE member power systems.
- "Transelectrica" will further provide the development and operation of the transmission grid at highest technical levels for a safe operation of the regional and domestic electricity market and in order to participate to the zone and continental projects extending the interconnection of transmission networks under a sustainable development and EU integration.

The issues the paper presents summarize the authors' concept for a new maintenance strategy in the ETG, framed in the broader concept of asset management. Moreover, in an in-depth case study live work efficiency is presented from a new point of view, that of congestion occurring in the NPS.

REFERENCES

[1] *C. Diaconu and C. Bărbulescu*, "Fixed asset management within the electricity transmission grid - a determining factor for operational safety", in Energetica nr. 6/2004, pg. 293 – 299

[2] *P. Wester*, "General outlook on the utilisation of feedback methods in the domain of electric equipment" in Electra nr. 204, October 2002, pg. 41 – 47, Papers from Conference Proceedings (Published)

[3] *S. Bartlett*, "Asset Management in a Deregulated Environment", in Proc. CIGRE 2002, rap. 23-303

[4] ***Managing Infrastructure Assets, in Documents of Adam Smith Institute- Conference, Amsterdam, 5-6 June 2007

[5] *C. Diaconu, M. Florea and C. Bărbulescu*, "Current aspects of asset management within Romania's electricity transmission grid as critical infrastructure" in Proc. Regional Energy Forum – FOREN 2008, Neptun, June 15 – 19, 2008

[6] *M. Oltean, M. Florea and I. Ardelean*, "Technical and economical arguments for live working", in Proc.CIER, Buenos Aires, May, 2009

[7] *I. Hațegan, C. Diaconu, C. Barbulescu and M. Florea*, "Monitoring the Operational Behaviour of Installations from the Electricity Transmission Grid – Source of Information for Maintenance Strategies", in Proc. International Conference of Modern Power Systems MPS, Cluj, May, 2010

[9] *J. Kabs, X. Tao*, "Asset Management Concepts for Electricity Networks" in Proc. Marcus Evans Conference -Increasing Grid Reliability for Transmission and Distribution Networks, Vienne, 27-28, Sept. 2007

[10] *E. Goddard*, "Transmission Network Reliability in a Competitive Electricity Market" in Proc. Marcus Evans Conference -Increasing Grid Reliability for Transmission and Distribution Networks, Vienne, 27-28, Sept. 2007