# QUANTIFYING THE SIGNIFICANCE OF ELEMENTS FROM ELECTRIC GRIDS WITHIN THE ROMANIAN POWER SYSTEM – A USEFUL TOOL IN THE DECISION-MAKING PROCESS

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## *ABSTRACT*

*The paper describes the technical criteria and the categories of data & information required in order to define the significance of elements- nodes and sides- from electric grids within the Romanian Power System (RPS) in terms of provided safety and of their importance. The quantifying tools and the hierarchy-setting in terms of significance are also submitted. Such aspects provide the items needed in order to assist the decision-making process under asset management and to issue objective maintenance or investment (upgrading) options, with also a description of decision-making methods.*

## INTRODUCTION

In the context of sustainable development the assets management is a set of methods and procedures contributing to increased profitability, competitiveness of services with such assets as well as the continuity and quality of their operation.

Asset management is the manner to optimise the use of such assets by collecting and processing relevant data from maintenance, refurbishment, investment decisions and from the monitoring of asset performance.

The basic of asset management can be described as a continuous decision-making process regarding all activities performed under and in relation to the Electricity Grid.

Applying a sound asset management can bring about- adaptation to institutional changes; maximising the availability of the transmission network; substantiation of refurbishment decisions; reliability of equipment and increased operational safety; extension of the operational lifecycle of fixed assets from the electricity grid, as well as optimisation of information flows.

Asset management requires assistance to the decision-making process in order to allow selecting the best solution among several possible options. Taking into account the policy aiming at installations retrofitting, implementation of new technologies as well as modern tele-management and tele-control systems, multi-criteria processes are required for decision-taking where the quantification of electric installations significance within the Romanian Power System (RPS) is an important item that has to be supported by feedback.

## TECHNICAL CRITERIA DEFINING THE IMPORTANCE OF GRID ELEMENTS WITHIN THE ENTIRE RPS

The criteria used in determining the importance of network equipment take into account 2 items, namely- the level of safety such equipment means for the RPS and their significance for the network.

Therefore to define the importance of network elements several kinds of criteria have to be taken into account:

- structural criteria;
- functional criteria.

The main **structural criteria** start from:

- operational voltage level,
- level of rated capacity defined in construction,
- line length, simple or double circuit,
- the amount of transmitted power corresponding to peak loads in the studied year,
- number of current paths,
- importance of users provided,
- number of system services performed for the RPS,
- service to an international interconnection.

The **functional criteria** are generated by means of indicators assessing the contribution of each structure to the good operation of the RPS:

- contribution to maintaining the quality parameters of transmitted power within normal limits,
- contribution to enhanced operational safety of the interconnected assembly.

Thus the significance of a current path (line or transformer) or that of a substation (bus bar or network node) is determined using two components corresponding to the two classes of criteria defined above.

The two fore-mentioned components contribute equally to determining a final indicator of the significance.

The component elements of the electric network are regarded as:

- Connections (OHL, transformers, autotransformers)
- Nodes (substation bus bars)

Assessing the functional importance takes into account:

A) <u>Criteria assessing the importance of a connection</u>:

a) **stationary regime** criterion (for peak load);

b) **static stability** criterion

a) general contingency analysis featuring the successive disconnection of all connections (line, transformer, autotransformer)

◆ The outcome of disconnections is assessed using:
- the changes of **loads** upon RPS connections;
- the **voltage** levels variation within nodes

A global indicator including such outcomes is calculated using the following relation:

$$J_l = \frac{1}{2}\sum_{1}^{NL}\left(\frac{I_j - I_{j0}}{I_{j\max}}\right)^2 + \frac{1}{2}\sum_{1}^{NB}\left(\frac{U_i - U_{i0}}{U_{inom}}\right)^2 \quad (1)$$

where:

$I_j$ - current resulting onto connection **j** following disconnection of connection **l**

$I_{j0}$ - current onto connection **j** under the reference regime

$I_{j\max}$ - maximum admissible current onto connection **j** (thermal limit)

$U_i$ - voltage module resulting in bus bar **i** after disconnecting connection **l**

$U_{i0}$ - voltage of bus bar **i** under reference regime

$U_{inom}$ - rated voltage of bus bar **i**

NL – number of connections of RPS grid

NB – number of bus bars of RPS grid

◆ If disconnecting a connection leads to the failure to supply certain consumers or to blocking power within a power plant or to the failure to transmit from an area to another of the RPS (non-connected network), the importance criterion will result from the relative value of the non-supplied/blocked/non-transmitted power.

b) static stable operational analysis against each electric network connection; global indicator- **static stability reserve** of the RPS sections including the studied line / transformer / autotransformer;

◆ The static stability reserve of a section is determined. Sections are identified, generators are grouped on both sides of each section into REI – Dimo equivalent generators, the stability reserve is calculated for each section.

◆ The stability values of the stability reserve are obtained for each section of the RPS.

◆ The section with the lowest reserve is searched for each connection.

**RESULT**: a single qualifying item characteristic to the significance of lines.

Two coefficients are mediated corresponding:
- a) – the greatest value of disconnections (current – voltage) from stationary regimes (with contingencies) is 100% and the others proportionally;
- b) – the lowest value of the stability reserve is 100% and the others proportionally;

Similarly the greatest value is 100% for the non-supplied / blocked / non-transmitted power.

B) <u>Criteria assessing the importance of **nodes**</u>:

- **transient stability** criterion (**time limit to disconnect** three-phased **short circuits** to which the operation is still stable regardless of the short circuit location).

This indicator uses the fact that, for any short circuit location there is always a span of time during which, if the fault is removed, no generators lose their stability.

Therefore the shorter such time limit the higher the risk for the substation to produce system failures and consequently a greater significance has to be assigned it.

**RESULT**: a single qualifying item characteristic to the significance of nodes.

Two coefficients are mediated corresponding:
- the importance of each line and transformer connected onto the respective bus bar;
- the time limit to disconnect short circuits

– the lowest value is 100% and the others proportionally.

Considering the above therefore, the **importance ($I_{mp}$),** for instance of a substation (bus bar or network node) is determined using two components:

- The **safety** level it has for the RPS **(Sig**);
- The **significance** of the substation for the transmission network **(Îns**).

Each magnitude can range between 0 ÷ 100.

Thus, the **importance** of node « i » comes from the relation:

$$I_{mp}^{i} = \frac{(1-p)S_{ig}^{i} + (1+p)\hat{I}_{ns}^{i}}{2} \le 100$$

where:

- p - is a possible share that can be assigned to one or the other of the magnitudes;

If for instance there is a wish to outline the significance, one might take p = 0.2; automatically the value of safety is reduced by 0.2 so that the final result of $I_{mp}$ cannot exceed 100.

- The value of $S_{ig}^{i}$ is determined as shown above.

- The value of $\hat{I}_{ns}^{i}$ will be determined by summing up some magnitudes as follows:

- Power plant or consumption node with:

| | |
|---|---|
| P ≥ 500 MW | $T_1$= 40 |
| 500 > P ≥ 200 MW | $T_1$= 30 |
| 200 > P ≥ 40 MW | $T_1$= 20 |
| P< 40 MW | $T_1$= 10 |

- Node with a number **C** of current paths (lines or transformers connected to the respective bus bar):

| | |
|---|---|
| C > 4 | $T_2$ = 40×u |
| 4 ≥ C > 2 | $T_2$ = 30×u |
| 2 ≥ C | $T_2$ = 20×u |

**u** depends on the bus bar voltage level at a level of:

| | |
|---|---|
| 400 kV | u = 1.25 |
| 220 kV | u = 1 |

110 kV u = 0.75

- Node providing system services:

$$T_3 = 10$$

One can notice the maximum summed up amount:

$$\hat{I}_{ns} = T_1 + T_2 + T_3 = 100$$

$T_4$=10×u can be added for international interconnection nodes; however if $\hat{I}_{ns}$ exceeds 100 values are reduced proportionally, so that the highest value of $\hat{I}_{ns}$ =100.

Electric substations included in the analysis have been assigned a score ranging 1 ÷ 100 for each criterion.

The same procedure is applied to connections (lines or transformers / autotransformers).

Classifying the scores for the importance of power transformers, collector bus bars and lines, scores are further assigned to each piece of equipment in accordance with the codes developed by the software. This means for instance that the importance of each piece of equipment (circuit breaker, disconnector, metering transformers etc.) of a line is of equal value as the importance of the respective line.

## MAKING THE HIERARCHY OF SUBSTATIONS AND LINES WITHIN THE RPS IN TERMS OF THEIR IMPORTANCE

The importance of installations and outfits within the electricity grid in terms of each one’s safety provided to the RPS comes from the processing operations performed using a *specialised computation software* based on stationary regime (current and voltage levels, power blockages within power plants, power not supplied to consumers, power not transited between system areas), static and transient stability calculations as well as on algorithms devised to this purpose and described above.

Therefore the computation software uses as inputs only such information regarding the RPS network structure and the results from a calculation of a peak load within the studied network.

When accessed the software opens a series of dialogue boxes:

- **Name of network data file**

When running is over the software displays the following information and results:

**- Significance of nodes within the grid ($INS_N$)**

The nodes of the transmission network are submitted (one on each line), respectively the significance of each node. These are ordered by their significance value from the most to the least important.

**- Significance of lines within the grid ($INS_L$)**

The lines of the transmission grid are submitted (one for each row), respectively its significance. Similarly to nodes, they are ordered by their significance value.

**- Significance of transformers within the grid ($INS_T$)**

The transformers (autotransformers) of the grid are submitted, respectively each one’s significance.

The results obtained are also submitted into 2 files:

- file **“TIE”** where the significance of connections can be seen within the transmission network non-differentiated by lines or transformers, but ordered by their significance value;
- file **“NOD**” where the significance of substations can be seen.

## DECISION-MAKING PROCESS IN ASSET MANAGEMENT

Asset management requires assistance for decision-making in order to allow selecting the best solution between several possible options.

The **decision-making** process involves:

- evaluating the condition and the risks
- decision-making algorithm.

Decision-making can be considered as a continuous process based on technical, economic and sociological data.

Such data categories are:

- **tehnical** data: characteristics, operational parameters, condition, importance;
- **economic** data: assessing costs for the entire life cycle (investment, operation, maintenance, taking out of operation), costs of failure results;
- **sociological** data: social and environmental aspects (impact of hazards, criticality: number and period of hazards), thus the social impact being obtained: the image for the public and the feeling of ‘security’.

The decision-making algorithm develops by hierarchical levels:

**Level 1: component (asset)**

It consists of assessing the equipment condition based on the technical data and information. Many scenarios can be found to influence the assets performance in terms of reliability and availability**.**

**Level 2: network (RET)**

When technical information is combined to the economic and network ones, costs are quantified. These are also expressed in terms of reliability, consequences of events, risks.

**Level 3: corporation (Company)**

The costs and advantages of various scenarios are combined with the risks of each one in order to take the best decision.

Quality, coherence and validity of data and information have to be ensured in the decision-making process.

## UTILISATION OF HIERARCHY IN TERMS OF IMPORTANCE WITHIN THE DECISION-MAKING PROCESS

The establishment of the electricity market and the significance of the transmission network in terms of infrastructure requires concerns to increase the operational safety and the economic efficiency of Transelectrica's specific activities sustained by means of activity organisational models and of specific software applications as IT technical support of asset management.
One of the important aspects in assisting the decision-taking process of asset management is the IT determination, analysis and use of the importance of installations within the network for various purposes such as- **substantiating the maintenance schedule or justifying the maintenance or investment options (refurbishment), the sizing and hiring the personnel needed etc**.
Thus by integrating the results on the technical condition of all operational equipment/assemblies under the management of each branch and the importance of such installations at grid level, the result is the annual maintenance schedule as required by each category of functional assembly, as well as proposals for the retrofitting/investment plan.
The final maintenance programme is obtained by means of an iterative process which is carried out each year in accordance with the specific operational procedures.
The methodology and the IT application described here allows determining during quite a short interval the importance of grid components using directly the information existent in the Company's databases as well as making the hierarchy of electric lines and substations under such criterion- useful for multiple purposes.

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