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SPECIFICITIES OF RELIABILITY ANALYZING OF AUTOMATION AND PROTECTION SYSTEMS OF ELECTRIC NETWORK

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Abstract: *The paper has 4 parts. The first part presents the current methodology of automation and protection system reliability (APS) of electric networks structure (EN) that justifies the authors concern and the contribution raised towards the APS reliability analyze. In the second part are defined the special reliability indices of APS, that are intrinsic also for EN. The synthesis of analyzing model of APS global performance is given in the third part and in the last part there are described the conclusion of analyze.*

Key words: *electric networks, automation and protection systems, reliability, indices*

1. INTRODUCTION

The reliability analyzes of APS of EN structure, are subordinated to the objectives of maximizing the electricity availability (EE electric energy) by consumers and of EN safety. By availability maximizing of the energy is obtained the maximizing of the EN economic efficiency.

Sometimes, there is a tendency to minimize the importance of APS onto the EN performance, precisely because they are more reliable than primary equipment (PRE), treating their reliability inappropriate (Anderson 1990, Billinton et al., 1987). In fact, as shown analytically (Yaguchi et al., 1984, Yip et al., 1984), APS and its elements are in an upper plane as PRE and its elements, a position from which is "followed" and if it necessary "occurred" within the meaning of correct operation of all the PRE and of EN ensemble.

As a schematic suggestive form, the APS integration to EN may be represented such as in fig.1 (Felea et al., 2010).

Although APS, by its position in EN implies some features and treatment reliability approach, by making this analyzes must be considered the interference between the components of PRE and APS (fig.1) and the decisive impact of realities onto the performance of EN.

The reliability study of APS supposes the complex approach of the problem. The reliability is treated from the simple to the complex (Albut-Dana, 2010). This approach is also the object of this paper where the authors have contribution in direction to define and express the specific reliability indices of APS, respectively, in direction to elaborate the global performance model pf APS.

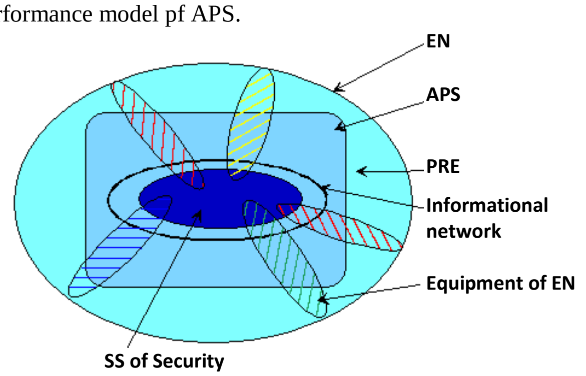


Fig. 1. Structural subsystems of EN

2. SPECIFICAL RELIABILITY INDICES OF APS

2.1 The specific reliability indices to APS components

There are two categories of indicators recommended to APS components:

a.) **Classical indicators (established) (**Billinton et al, 1987, Felea, 1996):

- Probability of good service (safety time)
- Mean time between the failures
- The probability of rejection (risk of not responding to the request)
- Average number of unanswered requests during the "T":

b.) **Complementary indicators**

Intensity of incorrect operation (EN) of APS:

$$\lambda_{ER} = \lambda_{\overline{RC}} + \lambda_{INT} \quad (1)$$

where, $\lambda_{\overline{RC}}$ - intensity events "refusal response to commands" ($\overline{RC}$);

λ_{INT} - intensity of transmission of unexpected orders (false).

The risk of events appearing ($\overline{RC}$, INT):

$$q_j(t) = 1 - e^{-\int_0^t \lambda_j(t)dt}, \quad j = \{\overline{RC}, INT\} \quad (2)$$

- The statistics made about of the reliability of APS and its components, will refer on variables:
  t_j – operating time without the variables "j"

$\nu_j(T)$ – number of events of "j" type during "T", period, where, j={$\overline{RC}$, INT, ER}

2.2. Indicators to characterize the overall reliability

Taking into account the classical indicators of PRE and APS and complementary indicators of APS, it is explained the fundamental of the ensemble (ANS).

- Probability of good service (R_{ANS}) and the risk of failure for "T" period (q_{ER}):

$$\begin{cases} R_{ANS}(T) = e^{-\lambda_{EPR} \cdot q_{ER} \cdot T} = 1 - Q_{ANS}(T) \\ q_{ER} = q_{\overline{RC}} + q_{INT} - q_{\overline{RC}} \cdot q_{INT} \end{cases} \quad (3)$$

- The probable average number of wrong operation:

$$\begin{cases} R_{ANS}(T) = e^{-\lambda_{EPR} \cdot q_{ER} \cdot T} = 1 - Q_{ANS}(T) \\ q_{ER} = q_{\overline{RC}} + q_{INT} - q_{\overline{RC}} \cdot q_{INT} \end{cases} \quad (3)$$

$$\nu_{ANS} = N_{SOL} \cdot q_{ER}; \ N_{SOL} \text{ – no. of requests} \quad (4)$$

- Intensity of failure of the ensemble:

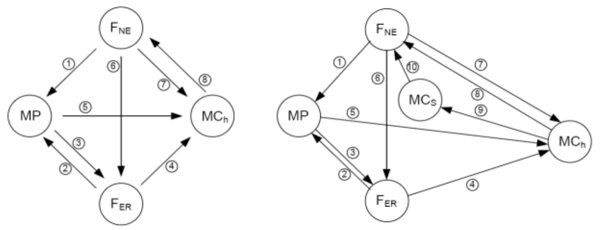
$$\lambda_{ANS} = \lambda_{EPR} + \lambda_{\overline{RC}} + \lambda_{INT} \quad (5)$$

3. THE MODEL OF GLOBAL PERFORMANCE APPLIED TO APS OF EN

To characterize the technical capacity of APS from the EN to satisfy the pre established functions, will be used the concept of global performance (PG) – a size vector with components of: reliability [R(t)], availability [A(t)], maintainability [M(t)], security [S(t)] and credibility [C(t)].

$$PG = PG[R(t), A(t), M(t)\ S(t)\ C(t)] \quad (7)$$

The last generations of EN APS near the elements of hardware includes also elements of soft (fig. 2).



a) Case of APS without software   b) Case of APS implemented with hard and software

Fig. 2.Graph of an APS

Modeling SAP requires on the one hand, knowledge of the functions they fulfill and the possible states (fig. 2). The principle states of APS are:

- Operational state without failure (F_{NE}), includes the cases with failures that not lead to wrong answers;
- Wrong operational state (F_{ER}), includes situations when the system transfers wrong answers;
- State of preventive maintenance (MP);
- State of corrective maintenance of the hardware (MC_h). By automat reconfiguration is identified and eliminate from the system.
- State of corrective maintenance of the software (MC_s), by this are corrected or reconfigured the programs and the date.

Realistic transitions between states are marked in fig.2:

- Moving from F_{NE} into MP and from F_{ER} into MP is made basing on MP;
- Moving from F_{NE} into F_{ER} is the occurrence of undetected failures, that leads to wrong answers;
- Moving from F_{ER} into MC_s is made when there is detected a failure followed by a wrong operation;
- Moving from the state MP into F_{NE} is made when after MP operation isn't detected any failure;
- Moving from MP into F_{ER} is made when after MP operation isn't detected failures that leads to appearance of any wrong answers;
- Moving from MC_h into MC_s is made when the hardware failed and the consequences appears in the software;
- Moving from MC_h into F_{NE} is made when after the MC operations are eliminated the failures of the hard that leads to wrong answers;
- Moving from MC_s into F_{NE} is made when by MC operation of the software were eliminated the failures of this level

The model of PG is concretized by assessment of vectors components of APS, thus:

- Reliability, R(t), is the probability as APS is in the state of FNE in (0, t) interval.

$$R(t) = Prob\ (F_{NE}) \quad (8)$$

- Availability, A(t), is the probability as the system is in the operation state in t moment:

$$A(t) = Prob\ (F_{NE} \cup MP) \quad (9)$$

- Security, S(t), is the probability to not exist undetected faults that leads to wrong answers in (0,t) interval:

$$S(t) = Prob\left[F_{ER}; \forall t \in (0,T)\right] \quad (10)$$

- Credibility, C(t), is the probability to not exist undetected faults that leads to wrong answers at t moment:

$$C(t) = Prob\ (\nu_{ER} \equiv \nu_{MC}) \quad (11)$$

ν_{ER} – no. of total faults (wrong operation);
ν_{MC} – no. of moves in state of MC.

- Maintainability (of the hardware, software) $MC_h(t)$, $MC_s(t)$ is the probability that APS may not be in state (MC_h, MC_s) at t moment, if in the moment of 0 was in this state.

$$M_i(t) = 1 - Prob\left[MC_i; \forall t \in (0,T)\right];\ i \equiv \{h, s\} \quad (12)$$

4. CONCLUSIONS

1. Modelling and evaluating the provisional reliability of APS from EN structure is made taking into account the following specifications:
- The purpose of APS in REUMT;
- Necessity to make the analyses from simple to complex;
- The differential application in the two modes of operation (continuous and intermittent);
- The necessity to operation with specific indicators (complementary) and classical indicators (established);
2. The complementary indicators of APS follow the way to quantify the effects of unexpected operations of the components from APS and it is based in expression on conditional probability.
3. To characterize the technical capacity of APS from the structure of EN is recommended to utilize the notion of "global performance" - a vector size with components of safety, availability, maintainability, security and credibility.

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