THE RELIABILITY CENTERED MAINTENANCE DATABASE OF URBAN MEDIUM VOLTAGE NETWORKS

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ABSTRACT

The paper is structured in five parts. The first part looks at the reliability centered maintenance (RCM) on urban MV networks opportunity. Also here is presented the database utility for RCM implementation to urban MV networks. The second part is about the database structure and the informational support of database. The indicators evaluation and the intrinsic objective of RCM strategies implementation to urban MV electric networks make the subject of the third part .of the paper. The 4th part contains a brief presentation of the soft used for database administration and indicators assessment used for RCM strategy implementation to urban MV electric networks components. The conclusions and indications looking to urban MV electric network are presented in the last part of the paper.

1. PRELIMINARY APPRECIATION

The reliability centered maintenance (RCM) is a well known method [1÷6] for it's positive impact on costs decreasing and power services quality increasing.

The urban power distribution networks (UPDN) are very important to provide the quality of power supply service to industrial, public and building consumers.

The paper presents the database structure and facilities (characteristics, events, indicators) that intend to make applicable the RCM strategy on UPDN, with application at UPDN of Oradea. It refers to all components, which can affect the reliability level of UPDN.

- Medium voltage underground cables [UGC] and overhead lines [OHL] (6 and 20 kV): 515,5 km totally.
- Power transformers [PT] from substations having 20/0,4 kV and 6/0,4 kV voltage: 637 totally.
- Medium voltage breakers [BK] (6 kV and 20 kV) are 538 in number.
- Medium voltage switches [SW] (6 kV and 20 kV) are 1350 in number.

The materialization trend of RCM strategy:

- The stock sizing depending on reliability level;
- Working planning of preventive maintenance.

The built database has in plus the advantage to offer to the beneficiary:

- Statistics regarding installations/equipments volume;
- Standing out of some hierarchies regarding to the occasion, cause, and failure mode and fault components of the network.

2. DATABASE INFORMATIONAL SUPPORT AND STRUCTURE

2.1. Database Structure

The database comprises information regarding to UGC, OHL and medium voltage equipments (PT, BK, SW) of UPDN structure, Oradea UPDN particularly.

There are two categories of information: technical characteristics and recorded events (table 1÷3).

Table 1 – Recording format structure of technical characteristics of UGC and OHL

ID	Line Name	U_n [kV]	Line Type	UGC
OHL Axis	OHL Tap	OHL Joint	UGC Type	S [mm^2]
L [km]	Initiation Year	OHL Type		

Table 2 - Recording format structure of technical characteristics of PT

ID	Substation Name	U_n [kV]	I_n [A]	S_n [kVA]
Cell No/Name	Type			

The events that develop during analysis period are recorded in standardized tables, for example:

Table 3 - Recording format structure of events of UGC and OHL

ID	Line ID	Event Date	Event Time
Corrective Maintenance Period	Unavailability Period	Occasion	Cause
Failure Mode	Fault Element	Corrective Maintenance Costs	TBF [h]

The recording of events for equipments is the same.
Referring to the analysis purpose there are registered only the states involved in estimating of fundamental reliability indicators: operation (O), fault (F) and corrective maintenance (CM).

The units that can go out of order, causes and failure occasions are taken from standards [7]. The failure modes are specific to analyzed components [3].

For UGC and OHL, that challenge the most failures into analyzed network it provide the registration in database and processing of the next quantities:

- Working period of corrective maintenance;
- Voltage interruption period because failure;
- Working costs of corrective maintenance.

The main facilities offer by database administration system are:

- Very easy introducing, adding, erasing, changing, viewing of all information that set up the database;
- The possibility of changing predefined lists;
- Quickly viewing and searching of data by filter;
- Information typing possibility shown graphic or tabular into a format chose from user;
- Statistical calculus of mean values and dispersions for enumerated variables;
- Establishing of reliability elementary indicators (λ, μ) to components and elements;
- Hierarchic performing, shown graphic or tabular after fault number, or after fault period;
- Establishing of suddenly interruption cumulative number and total interruption period;
- Equipments sizing stock and estimate consumption of elements from their structure and also for UGC and OHL.

2.2. Database Informational Support

Technical characteristics of the components are taken from analyzed installations and equipments technical books operation and constructive.

The reconstitution of input statistical database, that consider the operation behavior it is make on information from ″Shift effective register″ base, completed of effective staff. The set up way of input database is in concordance with methodological rigors [3,4,7].

The characterization of suddenly faults it is made on registered elements from ″Shift effective register″ base and from prophylactic tests reports.
In the future it is stipulate that the effective staff is going to introduce directly the events in program in accordance with database requirements. So the database is going to be functional practical on-line.

3. ANALYTICAL AND INTERPRETATION OF USED MODELS

For statistical data processing in reliability indicators, mean values and random variables dispersions estimation purpose it was used the well know analytical models. The random variables that perform with are:

- Time between failures (TBF);
- Time to restoration (TR)
- Complex variable "time between failures×length (TBF×l)" – for UGC and OHL;
- Corrective maintenance working costs (CMC).

The soft made for database performing has at the base analytical model for statistical data processing that include the sort characteristics, probability distribution parameters assessment, statistical assumptions checking, reliability indicators estimation [2, 3].

3.1. Specific Feature of Reliability Indicators estimation

For equipments (PT, BK, SW) it is record the random variables values (TBF and TR) in the next alternatives:

- On the same functional type assembly equipments;
- On constructive type;
- After voltage level.

For cables it is working with random variables values TBF×l and TR. The estimations are made clear on voltage levels, cable types and cut-set. Referring to splices and terminal boxes from UGC structure there are recorded the random variables values TBF and TR. Referring to OHL, the estimation is going to be made on assembly and on constitutive elements. For OHL conductors the random variables are TBf and TR.
So that, the reliability fundamental indicators are:

$\mu = \frac{1}{MTR}\left[h^{-1}\right]$ - for all network components and for the elements of their structure

$\lambda = \frac{1}{MTBF}\left[h^{-1}\right]$ - for elements and components that quantity is in pieces

$\lambda_1 = \frac{1}{MTBF \times l}\left[h^{-1} \cdot km^{-1}\right]$ - for cables and conductors

Because for equipments in analyzed period the number of failures is small (ν<N), the MTBF indicators are going to establish using the simplify relationship:

$$MTBF = \frac{N \cdot T_A}{\nu} = \frac{1}{\lambda} \qquad (1)$$

3.2. Statistics Regarding the Existing Installations/Equipments Volume

These statistics they are make for the 5 categories of analyzed medium voltage network components, so:

For UGC it spotlights the cable quantity (km) in ratio with technical characteristics as cable type and cut-set for: Mv – UGC assembly; 6 kV UGC; 20 kV UGC.
For OHL it spotlights the volume (quantity) of the next structural elements: conductor (km); poles (pieces); insulators (pieces).

The statistic regarding to all elements it makes like in UGC case, both for OHL assembly and individual for voltage level (6 kV and 20 kV).
For PT it spotlights these volumes referring to the next characteristics: medium voltage rating; power rating; type.

For BK and SW the volume statistic spotlight their number referring to the next technical characteristics: rated voltage and current; type.

3.3. Hierarchies

They are doing referring to:

- the occasion of suddenly fault appearance;
- suddenly failure causes; failure mode;
- the hierarchy of elements from analyzed components structure, after: failures number; failures period.

The hierarchies they are make for an analyzed period (T_A).
Noting: $\nu(T_A)$ - the entire number of failures i T_A;
$\beta(T_A)$ - the entire length of unavailability because intrinsic failure
i - occasion/cause/failure mode/element „i”
They are computing the per-cent relative values of the indicators:

$$\nu_i^*(T_A) = \frac{\nu_i(T_A)}{\nu(T_A)} \cdot 100 \qquad (2)$$

$$\beta_i^*(T_A) = \frac{\beta_i(T_A)}{\beta(T_A)} \cdot 100 \qquad (3)$$

They are represented on paretto diagrams the computed values, clear for those two indicators and obvious for those 4 categories of interest for hierarchy (occasion, cause. failure mode, element).

The indicators upper mentioned and also the hierarchies are referring to:

- UGC on assembly and UGC with the same characteristics (type, rated voltage, cut-set);
- OHL on assembly and OHL with the same characteristics;
- PT on assembly and on power and voltage levels;
- BK on assembly, respective on voltage level and type;
- SW on assembly, respective on voltage level and type.

For each components category it computes the indicator:

$$\nu_r = \frac{\nu(T_A)}{N} \cdot 100[\%] \qquad (4)$$

N - installations/equipments volume (km, pieces)
The estimation of ν_1 indicator it makes on voltage levels and installation type, respective on equipment type.

3.4. Assessment of Equipment Stock and Elements Consuption

It computes faults probable number per year:

- for components administrated on pieces:

$$\nu = 8760 \cdot \lambda \quad \text{[events/year]} \qquad (5)$$

- for cables and conductors:

$$\nu = 8760 \cdot \lambda_1 \cdot l \quad \text{[events/year]} \qquad (6)$$

- for “i” element from UGC and OHL and from equipments structure

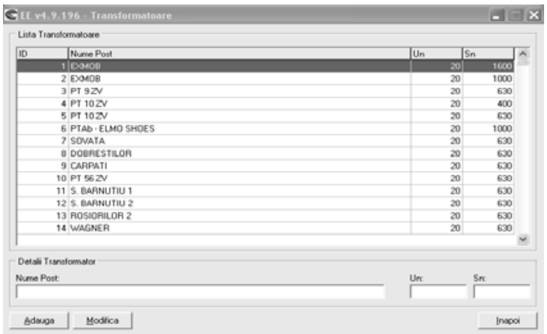
$$\nu_i = 8760 \cdot \lambda \cdot \frac{\nu_i^*}{100} \quad \nu_i = 8760 \cdot \lambda_1 \cdot l \cdot \frac{\nu_i^*}{100} \qquad (7)$$

The indicator ν_i it computes referring to all fault elements that are registered on database during on T_A.
The stock it refers to equipments, and the assessed consumption it refers to elements from equipments, UGC, OHL structure, that are necessary for these corrective maintenance. The stock and assessed consumption it computes for one and five years, through rounding of obtained values (ν, ν_i).

4. SHORT PRESENTATION OF RCM-RMT PROGRAM

The RCM-RMT program it is meant to administrate the database and to estimate the necessary indicators for RCM strategy application to UPDN.

The program it is made on Delphi, and the database it’s made on Microsoft Access. The ADO technology (Microsoft ActiveX Data Objects) from Delphi is providing the access on both ways to the database.
From active window named “Main menu” it appeals the desired submenu, each having a personal working window. In submenus, where were necessary it was introduced combo-box type controls. All posted results react to parameters changing (on-change sensitiveness). Making left click on an element of a scrollbar it can be obtained details. The “Back” buttons establish the coming back on main menu.
The posted graphics has variable size depending on the proportion dispersion of the represented column (the values are treated like “text” data type, so that are sensitive to typing style). The scale is automatic generated from maximal effect of represented values.
Introducing of new data has included completion limitation for some fields so that to respect a standardization of possible values.
EE.mdb database include the specific tables.
For example, in figure 1 it shows the table structure for PT record, and in figure 2 the table structure for recording of lines events.



ID	Nume Post	Un	Sn
1	EXMOB	20	1600
2	EXMOB	20	1000
3	PT 9 ZV	20	630
4	PT 10 ZV	20	400
5	PT 10 ZV	20	630
6	PTAb - ELMO SHOES	20	1000
7	SOVATA	20	630
8	DOBRESTILOR	20	630
9	CARPATI	20	630
10	PT 56 ZV	20	630
11	S. BARNUTIU 1	20	630
12	S. BARNUTIU 2	20	630
13	ROSIORILOR 2	20	630
14	WAGNER	20	630

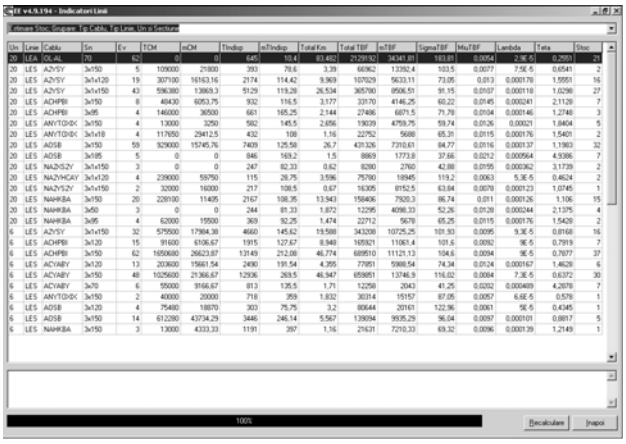
Fig. 1 - Table structure for PT record

5. CASE STUDY RESULTS

The methodology for database set up and the soft meant to administrate (RCM-RMT) was applied referring to Oradea UPDN, meant for power distribution on Oradea and around, administrated from Oradea urban center. The database it was set up through introducing the technical characteristics of Oradea UPDN components and of events recorded between [2000÷2005]. These are in number of 531 for UGC and OHL, 81 to PT and 77 to BK and SW.

In table 4 it is show the synthesis of recorded events to cables, the reliability indicators values and an example regarding the estimated stock for RCM strategy application.

Tab. 4 – Elements for RCM strategy application to UGC and OHL



Un	Linie	Cablu	Sn	Ev	TCM	mCM	TIndisp	mTIndisp	Total Km	Total TBF	mTBF	SigmaTBF	MiuTBF	Lambda	Teta	Stoc
20	LEA	OL-AL	70	62	0	0	645	10,4	83,482	2129132	34341,81	183,81	0,0054	2,9E-5	0,2551	21
20	LES	A2YSY	3x150	5	109000	21800	393	78,6	3,39	66962	13392,4	103,5	0,0077	7,5E-5	0,6541	2
20	LES	A2YSY	3x1x120	19	307100	16163,16	2174	114,42	9,969	107029	5633,11	73,05	0,013	0,000178	1,5551	16
20	LES	A2YSY	3x1x150	43	596380	13869,3	5129	119,28	26,534	365780	8506,51	91,15	0,0107	0,000118	1,0298	27
20	LES	ACHPBI	3x150	8	48430	6053,75	932	116,5	3,177	33170	4146,25	60,22	0,0145	0,000241	2,1128	7
20	LES	ACHPBI	3x95	4	146000	36500	661	165,25	2,144	27486	6871,5	71,78	0,0104	0,000146	1,2748	3
20	LES	ANYTOXIK	3x150	4	13000	3250	582	145,5	2,656	19039	4759,75	59,74	0,0126	0,00021	1,8404	5
20	LES	ANYTOXIK	3x1x18	4	117650	29412,5	432	108	1,16	22752	5688	65,31	0,0115	0,000176	1,5401	2
20	LES	A0SB	3x150	59	929000	15745,76	7409	125,58	26,7	431326	7310,61	84,77	0,0116	0,000137	1,1983	32
20	LES	A0SB	3x185	5	0	0	846	169,2	1,5	8869	1773,8	37,66	0,0212	0,000564	4,9386	7
20	LES	NA2XS2Y	3x1x150	3	0	0	247	82,33	0,62	8280	2760	42,88	0,0155	0,000362	3,1739	2
20	LES	NA2YHCAY	3x1x120	4	239000	59750	115	28,75	3,596	75780	18945	119,2	0,0063	5,3E-5	0,4624	2
20	LES	NA2YS2Y	3x1x150	2	32000	16000	217	108,5	0,67	16305	8152,5	63,84	0,0078	0,000123	1,0745	1
20	LES	NAHKBA	3x150	20	228100	11405	2167	108,35	13,943	158406	7920,3	86,74	0,011	0,000126	1,106	15
20	LES	NAHKBA	3x50	3	0	0	244	81,33	1,872	12295	4098,33	52,26	0,0128	0,000244	2,1375	4
20	LES	NAHKBA	3x95	4	62000	15500	369	92,25	1,474	22712	5678	65,25	0,0115	0,000176	1,5428	2
6	LES	A2YSY	3x1x150	32	575500	17984,38	4660	145,62	19,588	343208	10725,25	101,93	0,0095	9,3E-5	0,8168	16
6	LES	ACHPBI	3x120	15	91600	6106,67	1915	127,67	8,948	165921	11061,4	101,6	0,0092	9E-5	0,7919	7
6	LES	ACHPBI	3x150	62	1650680	26623,87	13149	212,08	46,774	689510	11121,13	104,6	0,0094	9E-5	0,7877	37
6	LES	ACYABY	3x120	13	203600	15661,54	2490	191,54	4,355	77851	5988,54	74,34	0,0124	0,000167	1,4628	6
6	LES	ACYABY	3x150	48	1025600	21366,67	12936	269,5	46,947	659851	13746,9	116,02	0,0084	7,3E-5	0,6372	30
6	LES	ACYABY	3x70	6	55000	9166,67	813	135,5	1,71	12258	2043	41,25	0,0202	0,000489	4,2878	7
6	LES	ANYTOXIK	3x150	2	40000	20000	718	359	1,832	30314	15157	87,05	0,0057	6,6E-5	0,578	1
6	LES	A0SB	3x120	4	75480	18870	303	75,75	3,2	80644	20161	122,96	0,0061	5E-5	0,4345	1
6	LES	A0SB	3x150	14	612280	43734,29	3446	246,14	5,567	139094	9935,29	96,04	0,0097	0,000101	0,8817	5
6	LES	NAHKBA	3x150	3	13000	4333,33	1191	397	1,16	21631	7210,33	69,32	0,0096	0,000139	1,2149	1

6. CONCLUSIONS

The reliability centered maintenance (RCM) is an important example of scientific management, grounded on operational reliability studies and on technical diagnosis subsystems.

For urban medium voltage electrical networks components, structures having an specific impact on quality and efficiency of electrical power supplying servicies, the RCM strategy application it's totaly justified. For making functional the RCM strategy referring to UPDN components (UGC, OHL, equipments) and for increasing the assessments accuracy it's very useful to set up a database dedicated to assessing the operational reliability level of UPDN components and typical elements of RCM strategy.

The database conceived for RCM strategy application to UPDN components, can be characterized so:

- allow on-line bringing up-to-date;
- include the characteristic properties of modern management, inclusive through informational feed-back using;
- it's easy operable and extensible;
- can be applied to alike structure;

The results that was obtained through database using at Oradea UPDN level, underline the next:

- the recording of events to equipments are not complete;
- the operational reliability level of equipments it's higher than that of underground and OHL;
- the reliability level of UGC it's on decreasing given the previous periods;
- the level of components and equipments stock that result on estimations basis is under that is applied now;
- for database capitalization is necessary a more complete and correct recording of events to equipments in concordance with the facilities made through database soft;
- the results that was obtained, underline the fact that it's not justified the application of preventive maintenance strategies on time basis to Oradea UPDN structure equipments.

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