The management of railway fixed installations maintenance

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ABSTRACT

The paper deals with an important project, which is going to be carried out by the Italian Railways (FS), for the computerized management of the maintenance and all other works done by the personnel on the electric installations.

From a strategic point of view it will be possible to elaborate and simulate plans of activities, helping the negotiation of essential resources and personnel requirements, while from an operating point of view daily and weekly working programmes will be assigned to the maintenance staff, whose activities will be regularly controlled to improve the productivity, measure the results and update health and operating conditions of fixed installations.

1. INTRODUCTION

Nowadays an efficient management of works and maintenance needs the elaboration and the development of the activities planning with the help of computers. This is particularly important in service companies such as Railways, where the reliability of the infrastructures influences the quality of the services offered and the image given to the client.

The Italian State Railways (FS) are very involved in this problem and in its solution, mainly in the field of management of the electric installations, which covers numerous and different areas of specialization. The context we refer to (see fig. 1) can be synthetized in the words "the technical installations are kept efficient by the activities, which take place in the respect of regulations with the rational utilization of resources".

The installations we deal with, consisting in the fixed electric equipment (necessary for feeding the electric traction, for the safety of running, for the information to the public, etc.), are usually managed, maintained and repaired by the direct work of the railway personnel and sometimes by firms that do the works under the strict guide and supervision of the same personnel.
2. ELECTRIC INSTALLATIONS

The railway electric installations can be considered belonging to one of the six specialistic sectors indicated in Tab. 1. This easy classification gives the opportunity to define the necessary maintenance and management strategies, which depend essentially on the type of installation taken into consideration.

In every specialistic field the installations can be divided in apparatus and components. The apparatus are formed by big devices or parts of installations, functionally connected among them or that need a planning of the works quite homogeneous. They can be dealt alone or divided in components, as well as grouped in sections or families so that can be more easily defined.

The word *family* refers to a series of apparatus which have the same function (e.g. the supports of the overhead lines), while *section* distinguishes the apparatus belonging to a part of installation that is well identified geographically and/or functionally (e.g. the HV department of a substation).

Table 1: The electric specialistic sectors

| LP   | = HV and MV lines |
| SSE  | = electric substations |
| TE   | = overhead contact lines |
| LFM  | = lighting installations |
| IS   | = signalling installations |
| TLC  | = telecommunications |

3. PERSONNEL ACTIVITIES

The works done by the FS personnel to manage and to maintain the electric installations can be referred to groups defined as macro-activities (see Tab. 2), of which the first four (A, B, C and D) are those typical of the ordinary maintenance, necessary for technical reasons and/or precise law dispositions.
The macroactivity A "visits and controls on foot" takes into account the operations of easy inspections of the installations' health, without interfering with their normal operating.

In the macroactivity B "tests and measurements" are included periodical works done to check or monitor some physical or functional characteristics of the apparatus or components, which form the installations. These operations have been separated from those of the macroactivity C "controls obliged by law" to distinguish the relevant costs through the evaluation of the occurring personnel, essential and not more compulsory as for other activities, since the Railways must always conform to specific laws.

The macroactivity D "systematic maintenance" includes all the operations which are necessary to be done at specific times for keeping installations in good and efficient conditions. Their execution, along with those above mentioned (A, B and C), has to guarantee (adopting hard time maintenance) the management of the installations at efficient technical levels, as well as their continuity and safety operating as new.

Table 2: The macro-activities of the rail personnel

<table>
<thead>
<tr>
<th>Macroactivity</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>controls and inspections</td>
</tr>
<tr>
<td>B</td>
<td>measurements and diagnostic</td>
</tr>
<tr>
<td>C</td>
<td>controls obliged by law</td>
</tr>
<tr>
<td>D</td>
<td>hard time maintenance</td>
</tr>
<tr>
<td>E</td>
<td>extraordinary maintenance</td>
</tr>
<tr>
<td>F</td>
<td>renewals and improvements</td>
</tr>
<tr>
<td>G</td>
<td>supervision of works done by firms</td>
</tr>
<tr>
<td>H</td>
<td>survey and assistance</td>
</tr>
<tr>
<td>I</td>
<td>on condition maintenance</td>
</tr>
<tr>
<td>L</td>
<td>failures repairing</td>
</tr>
<tr>
<td>M</td>
<td>operating turns</td>
</tr>
<tr>
<td>N</td>
<td>other activities</td>
</tr>
</tbody>
</table>

The macroactivity E "extraordinary maintenance and works" includes the operations considered necessary to be done on the basis of the local programmes, which are planned time by time to re-establish the installations reliability, recovering important times of bad or lack ordinary maintenance.

The macroactivity F "renewals, adjustments and improvements" refers to the operations done for improving (in a concrete way) the operating installation performances, through important systematic works such as:
- renewal of components, replacing them with others of better characteristics;
- adjustment of particular functional aspects, adding new devices to increase the performances or improve the safety and avoid accidents;
- improvements of some operating characteristics, with changes to the structure or to the scheme of the existing installations.
The macroactivity G "supervision and assistance at works done by others to our installations" includes the operations for controlling the quality of the works done and updating the quantity of the installations as well as obtaining the necessary professional knowledge to guarantee a correct management and maintenance. Instead, when the attention is directed to works nearby, for avoiding damages to our installations or to approaching them, the operations are included in macroactivity H "survey and assistance at works done on other installations".

The macroactivity I "works on conditions" includes the operations done immediately after the activities A or B, to remove abnormal situations which are going to compromise the integrity and the reliability of the installations, while macroactivity L "works on failures" refers to the installations repairing and restoration after a damage has occurred. All these operations have to be considered not as a consequence of unjustified events, but as the result of the managing or maintaining strategies obliged or chosen.

In the macroactivity M "turns" is taken into account the work in shifts of the personnel in central control offices as those at sub-stations tele-control.

All the remaining tasks necessary to guarantee the management of the installations, not relevant to the eleven macroactivities above mentioned, have to be included in the macroactivity N "other activities". Among these we remind the management of equipment, materials and other resources, the failures definition, the professional instruction, the diagnostic and statistic data elaboration, the activities planning and the updating of the installations condition.

4. DEVELOPMENT OF THE MAINTENANCE REGULATIONS

Until now the maintenance was managed through the rules and instructions of the General Direction and with the employment of different forms for the relevant specialistic sectors. Besides, owing to the local supervisors experience, many integrations were added to the main rules, that favoured their application to the different territorial realities, but complicated the possibilities to produce homogeneous and comparable plans and reportings.

For instance in the TE sector the general rules requested hard time interventions, whose duration and resources employment were not indicated. For this reason the planning was carried out assigning times fixed from the local supervisors, who took into account the operating situations and the installations health as well as the environment conditions in which they expected to work.

In the IS sector instead, more rigorous rules took into account the operations frequency and duration, but not the working conditions. This prevented the supervisors to shorten or widen the working times on the basis of their evaluations, increasing the difficulties to conform to the main rules, also if the programmes and reportings data were more homogeneous and comparable.

The facts demonstrated that it is much easier to establish rigorous rules for the simple installations, especially if these are not influenced by the environment conditions and not correlated to safety. As a consequence, in the railway electric installations the numerous parameters to be taken into account impose a large flexibility to the rules, which can be applied to the different local
realities, using "ad hoc" corrective coefficients to calibrate the working times, so that the programmes correspond to the real maintenance needs.

The instruments adopted until now, able to elaborate few data in long terms, are inadequate to the needs of an efficient planning, as they limit the possibility to optimize the resources employment and do not allow to produce all the reportings and statistics useful for the analytic evaluation of the costs and productivity. It comes out the necessity to use computers which, having the advantage to elaborate big numbers of data in short times, give the possibility to:
- improve, through simulations, the working organization for obtaining the maximum resources utilization;
- produce reportings and statistics suitable for analysing all the technical and economical aspects at the various responsibility and co-ordination levels;
- keep the files continuously updated.

The resolute orientation towards computerized procedures has requested the previous elaboration of data banks concerning rules, instructions, installations consistency, personnel, means, breaks in the tracks, etc.. So all the existing maintenance rules have been completely reviewed, updated in the substance and homogenized in the form to be adopted for informatic.

The new rules, no more limited to the only maintenance aspects but extended to all types of operations on the electric installations, include:
- the operating forms (schedules) filled for each type of apparatus and component to manage and to maintain;
- the technical and organizing instructions and/or recommendations;
- the references on the main measures to undertake and/or on the special resources to employ in the execution of the maintenance operations.

5. THE OPERATING SCHEDULES

The main data of the maintenance rules are reported on some hundreds of "operating schedules" grouped in six files for the LP, SSE, TE, LFM, IS and TLC specializations. In fig. 2 is reproduced an operating schedule for a SSE apparatus, which gives a useful example for the immediate reference to acquire the notions which are in the present paragraph.

The data shown in the schedules, elaborated for each type of apparatus or components subject or not to maintenance operations, have been distributed in 21 columns (from a to z) in which the schedules themselves are subdivided.

In the first three columns (a, b, c) are reported respectively the code, the description and the frequency of the corresponding operation, remaining implicit that the working methods and organization, the details of micro-operations to do, the control of the works quality and the reliability of the results of measurements and checks compared to the expected values, must be of specific sector knowledge, acquired with experience and professional maturity.

The columns d, e, f, g, and h show the numbers of people usually employed, the duration of the interventions (total and partial times in presence or not of trains circulation) and the whole time expressed in hours and minutes per person. The people and times indicated are those considered necessary for the real development of the operations and for the parallel and contemporary activities as the work-sites protection, earthing, communications, and so on.
### SPECIALIZZAZIONE: SOTTOSTAZIONI ELETTRICHE

#### SSE/5

<table>
<thead>
<tr>
<th>COD. ENTE: 1-40</th>
<th>ENTE: INTERRUUTTORE AT A VOLUME DI OLIO RIDOTTO</th>
<th>COD. COMPONENTI: 000</th>
<th>COMPONENTI:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>n°</strong></td>
<td><strong>DESCRIZIONE</strong></td>
<td><strong>per.</strong></td>
<td><strong>snum.</strong></td>
</tr>
<tr>
<td>a</td>
<td>b</td>
<td>c</td>
<td>d</td>
</tr>
<tr>
<td>AS11</td>
<td>Controllo dell’integrità dell’isolamento, dell’elettricità</td>
<td>ST</td>
<td>1</td>
</tr>
<tr>
<td>BA15</td>
<td>Sostituzione dei fili ampercronometrici</td>
<td>AN</td>
<td>3</td>
</tr>
</tbody>
</table>

Other operations follow.

Figure 2: the top layout of an operating schedule for a SSE apparatus

The column *i* defines the quantity, which gives the possibility to determine if the operation is referred to the whole apparatus or to a measurable and significant part of it, while the column *l* fixes the Technical Unity, competent in carrying out the corresponding operations and responsible in planning, organizing and reporting it.

The notes codified in the column *m* put on evidence some significant aspects connected to the organization and/or to the development of the corresponding operation, which has not to be undervalued in the planning.

### 5.1 The corrective coefficients

On the operating schedules are indicated the specific and generic coefficients to correct the working times, taking into account the installations situation, weather and environment conditions in which is provided to operate.

Four specific corrective coefficients (reported in the columns *n*, *o*, *p*, and *q*) are conceived to take into account, respectively:

- $K_t$, the technology construction and the upkeeping of the apparatus;
- $K_u$, the worn out and age;
- $K_l$, the operating conditions;
- $K_g$, the location in galleries longer than 200 m.

The working times, so corrected and adjusted, are kept in a data bank, together with other characteristic elements of any single device, to be used in the production of the operating programmes.

The three generic corrective coefficients, referring to the external environment conditions (columns *r*, *s*, *t*), take into account, respectively:

- $K_v$, the reduced visibility (rain and fog);
- $K_r$, the uncomfortable outside temperature (cold, hot and sultriness);
- $K_n$, the discomfort for working outside during the night.

In the last three columns (*u*, *v*, *z*) are reported the increasing and reducing coefficients of times and frequencies of the operations maintenance. Without analyzing the $K_m$, that is used in the only IS sector, it is very important to underline that $K_r$ and $K_p$ need to be strictly negotiated.
The reduction of the working times through the application of $K_r$, within the limits fixed by the rules, has to be negotiated, when for shortage of resources it is opportune to leave off a part of the work considered less important. An analogous negotiation is required to reduce the frequency of some operations by the application of $K_p$, always within the fixed limits, because of a contingent situation in the installations and/or of a lack of resources.

6. THE BASIS OF PLANNING

As shown in fig. 3, to plan with efficacy and coherence the personnel activities, it is required a deep and clear knowledge of:
- the installations consistency and characteristics;
- the rules, instructions and recommendations to respect;
- the interfering programmes already prepared;
- the available or negotiable resources;
- the failures statistics.

The process starts from the data of the installations consistency which have to be managed or maintained. So it is necessary a previous census of the elements and components to know their condition and to attribute their codified characteristics, useful for a quick elaboration of the programmes. The main codes refer to geographical position (line, station, track section, locality) and particular location (open air or in gallery) of the apparatus, the time to reach them, the Technical Unity responsible, etc..

In the consistency data bank, the local supervisor has to determine the relating corrective coefficients to apply to the apparatus for each type of installations, conforming to the rules, distinguishing between those obliged and those negotiable with the head staff, within the fixed ranges of application.

To help the supervisor in researching and examining the numerous and complex regulations, either to organize and do the works in the railway environment or to control the work done and its correspondence to the required standards, the present rules suggest the reference data for each specialistic sector. They include law dispositions, operating regulations, safety and protection of staff, technical instructions and constructive characteristics, standards operating and allowed tolerances, maintenance instructions with corresponding procedures and special forms to be adopted for each activity and management of resources that influence the working organization.

The main resources to take into account refer to personnel, means, materials, breaks of circulation, unfeeding times of HV installations and financial availabilities. It is to underline that a coherent programme can be carried out also counting on the resources not available but negotiable with the head staff, who has to guarantee their availability within the times and ways agreed.

The examination of the failures statistic trend and of the installations reliability, compared to the expected results, has to suggest the adoption of the measures to include in the programmes themselves, starting from a simple intensification of the maintenance activities when the operating standards or strategies require it. Of course much attention has to be given to the negative consequences the failures can cause to the regularity of running and to the
quality of the services offered, as well as to the efficiency of the organization carried out for the prompt intervention. In particular, when machineries not directly connected to the trains running are involved in failures, could be preferred their repairing, instead of trying to reduce the number of failures intensifying the maintenance operations and/or the periodic controls.

Moreover it is essential to know the works planned by other Unities on the same installations and, in particular, the programmes and the expectations of renewal and development, that influence the definition of the maintenance strategies. The maximum importance has to be given to all the works requiring breaks of circulation, whose knowledge can in fact help either the planning of the track breaks or promote the synergic use of those planned by others.

7. THE PROGRAMMES ELABORATION

The activities planning requires to be very clear and rigorous, without losing the objective to reach, putting on evidence the necessary data for an easy negotiation of resources. In particular the programmes have to distinguish the personnel employed with the relevant working and additional times:
- line by line;
- with or without breaks of track;
- at daylight or during the night;
- in open tracks or in stations.
Each plan of activities, developed on the basis of logical criteria and of the main lines indicated, has also to have some fundamental qualities to allow objective checks and evaluations at all levels of responsibility, as:
- the congruence with the interfering programmes;
- the clearness of the objectives to pursue;
- the measurement of the expected results;
- the efficiency of the organization and the full utilization of resources;
- the layout suitable for quick and efficacious controls and negotiations;
- the facility of comparison with similar programmes.

Rigorous procedures have been established for the various steps of elaboration, starting from the formulation of the initial programmes conforming to the rules and defining the interventions priority, according to the real conditions of the installations and compatibly to the other needs already planned or known. In particular it is suitable that:
- the local supervisors prepare the maintenance programmes for all the installations of competence, according to the needs expressed by the head technicians, unifying their proposals, verifying the regulations observance, evaluating the maximum utilization of the planned breaks of circulation (also for minor operations) and giving priority to the works in an organic and coordinated way;
- the superintendents and the head staff at any responsibility level coordinate the maintenance needs with those of the planned works, done by the personnel or by contracts, negotiating the relevant resources and reviewing the priorities;
- the management responsible of the production service approves the activities plans, verifying the full utilization of the resources of the dependent Units, according to the available budget and to the prefixed objectives.

7.1 Working and additional times

To elaborate the programmes, optimizing the resources utilization (first of all handwork and track breaks), it is necessary to know, besides the working times, also the additional productive and improductive times.

The additional times to take always into account are those of:
- "preparation and rearrangement", for setting tools, materials and machineries, before and after the execution of the works;
- "moving", from the usual working seat to reach the place where to operate.

Besides, for works carried out during the breaks of circulation, it is necessary to consider the additional times of:
- "protection", to preserve the safety of the worksite and of personnel operating along the track;
- "waiting", either for communicating to the traffic controller for breaking and resetting circulation or to the tele-control centre for earthing and refeeding the electric lines, before the beginning and after the end of the works;
- "moving in intervals", for reaching the apparatus on which to operate, running the track during the circulation breaks.

Fig. 4, gives an idea of the incidence of these times compared with the working ones, showing as for an intervention to the contact line, planned for 16 people during a track break of 110', the working time corresponds to only 21
hours per man, compared to the whole employed handwork of about 70 hours per man.

Figure 4: personnel working on the catenary during a break of track

8. PROGRAMMES AND REPORTINGS LAYOUT

It is suitable to examine the process of planning for the six specialistic sectors and the twelve macro-activities, that the personnel can carry out on the electric installations, through a matrix 12 per 6. Each of the six macro-columns can be studied separately and in a particular form of activities planning and reporting, whose layout is represented in fig. 5.

The sub-columns underline the handwork necessary or employed in the activities planned or done in open tracks or in the stations, with or without breaks of track, at daylight or during the night, distinguishing the working times from the additional ones, while the lines corresponding to the macro-activities have been divided in sub-lines referring to:
- the **theoretic programmes** of the maintenance activities (A-D), elaborated with the medium times according to the regulations (sub-lines a1);
- the **proposed programmes** for the other activities (E-N), elaborated with the times evaluated or expected on statistic bases (sub-lines a2);
- the **approved programmes** re-elaborated with the times established after the resources negotiation (sub-lines b);
- the **reportings** elaborated with the times spent in the activities done (sub-lines c1, c2 and c3), continuously comparable with the programmes data.

From the programmes comes out evident as the content of each cell can become object of negotiation, either to reduce the working times or the additional times with the acquisition of particular resources, as well as object of analysis to correct the organization and/or the strategies.

All the proposals of reducing working times and/or of increasing intervention frequencies, within the limits fixed by the regulations, have to be well justified and approved by the management.
The programmes so reviewed, corrected, and approved, in the process of negotiation at different levels (see fig. 3), have to be put into practice according to the data reported in the sub-lines b.

![PIANO DI ATTIVITA']

|-------------------------|--------------------------|-----------------------------|-----------------------------|

<table>
<thead>
<tr>
<th>PIENA LINEA</th>
<th>STAZIONI</th>
<th>TEMPI</th>
<th>TOTALE</th>
</tr>
</thead>
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<tr>
<td>CON</td>
<td>INTERRUZIONE</td>
<td>SENZA</td>
<td>INTERRUZIONE</td>
</tr>
<tr>
<td>TEM</td>
<td>LAV</td>
<td>ACC</td>
<td>TEM</td>
</tr>
<tr>
<td>GIORNO</td>
<td>NOTTE</td>
<td>GIORNO</td>
<td>NOTTE</td>
</tr>
</tbody>
</table>

| A) CONTROLLI | x1 | b | c |
| B) MISURE | x1 | b | c |
| C) VERIFICHE | x1 | b | c |
| D) MANUTENZIONE ORDINARIA | x1 | b | c |
| E) MANUTENZIONE STRAORD | x1 | b | c |
| F) RINNOVI E MIGLIORI | x2 | b | c |
| G) ASSISTENZA LAVORI | x2 | b | c |
| H) PROTEZIONE | x2 | b | c |
| I) MANUTENZIONE ON CONDITION | x2 | b | c |
| J) RIPARAZIONI GUASTI | x2 | b | c |
| K) TURNI | x2 | b | c |
| N) ALTRE ATTIVITA | x2 | b | c |
| TOTALE ATTIVITA | a | b | c |

Figure 5: layout of the activities plan and reporting

As above mentioned the data reportings can be conveniently summarized in the same forms, for a quick evaluation of the programmes development and of the differences between the activities done compared to the ones planned.

Always referring to the form of fig. 5, the sub-lines c, indicating the times spent, only for the macroactivities I and L have been divided to distinguish the times summarized for the interventions attributed respectively to:
- an insufficient maintenance (sub-lines c1);
- other causes (sub-lines c2).

This layout chosen for the reporting data allows to do further considerations on the opportunity to correct the maintenance strategies and, in particular, intensifying or reducing the operations. In other words if the c1 data
trend show a quite constant diminution of the real or potential failures due to insufficient maintenance, the management can authorize an adequate reduction of the maintenance operations with a consequent partial recovery of the handwork needs for carrying out the macroactivities A, B, and D.

Comparing the data of reportings to those of programmes, it is possible to measure the working productivity and the resources utilization, verifying the quality of the organization and the costs sustained referring to the budget.

At last, it is possible, on the basis of the trend analysis of the reportings data, to re-discuss the improvements to suggest for the elaboration of the following programmes, with the aim to promote the acquisition of the resources not available, also introducing new technologies, and to contribute in a more incisive way to the coordinated development of the synergies.

9. CONCLUSIONS

The computerized planning and reporting of the activities gives the opportunity to improve the reliability of the rail installations, with the essential advantages of:
- developing the working organization and optimizing the resources utilizations, with full responsibility at any level;
- updating the regulations and operation times to the contingent needs and to the employed technologies, comparing the operating results to the expected objectives and to the trend of failures statistic;
- evaluating the dynamic needs of personnel, relating to the consistency of the installations to manage and to the rules to apply, helping the negotiation for the distribution of the necessary resources;
- verifying the costs, the productivity, the possible recovers and the economies according to the objectives to pursue;
- helping the management on the strategic choices referring to the personnel, the investments and the works to do by oneself or to assign by contracts.

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References