

Analysis of a diagnostic system for railway overhead line automatic regulation

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Abstract - The increase number of high speed trains needs an high reliable and available railway overhead line. Because of the elevated train speed [1] increases the wear failures, with possible railway track interruptions. Therefore it's necessary to identify failures modes and correlated effects to improve the railway network availability and safety features as well as maintenance and renewal costs. This strictly depend on the appropriate use of diagnostic methodologies: the traditional approach of cyclic maintenance needs to be replaced by more efficient approaches, such as on-condition and predictive maintenance.

I. Overhead line RCM analysis

The methodologies, like RCM analysis (Reliability Centred Maintenance) [2], should implement the continuous monitoring of the railway components status and should also realize predictive diagnostic functions in order to optimise the maintenance works planning by means of an on-condition maintenance strategy.

In the national railway structure an automatic overhead line regulation system has been implemented and, in this work, it has been analysed and tested. In case of not correct system behaviour it's possible a wrong overhead line alignment. This determines an increase of line wear and stress.

The system, placed in a gallery, is characterised by constant temperature with small thermic changes on the line. Furthermore, the gallery is a critically railway track point for maintenance activity and in case of a train stop.

The most important overhead line characteristics to meet are:

- constant contact conductors height compared to the railway track;
- the height must be constant when a train transits. For this reason the same ratio between contact line lifting (mm) and pantograph contact shoe strain (kg) it's necessary;
- constant contact conductors position in comparison to rail track axis;
- the structure must be strong enough mechanically to support the full weight of the span of conductor, as well as loads due to ice accumulation, and wind.

It's evident from the characteristics analysis as the overhead line geometry is important to consider.

For guarantee an appropriate railway track activity it's fundamental therefore the role of the maintenance.

Usually the traditional maintenance has as resulted the following points:

- often the maintenance tasks aren't defined clearly;
- it's possible needless maintenance;
- it can be ineffective and harmful.

For these reasons, the RCM analysis can be considered as a good solution with the following benefits:

- system availability and integrity can be increased using appropriate and detailed maintenance activities;
- maintenance costs can be reduced through a series of planned and more efficient maintenance activities;
- a revision process fully documented for future maintenance management improvement;
- the maintenance managers have a management tool that improves the process control and guide;

- the maintenance department has a best know-how of its objectives, purposes and planned maintenance activities.

This analysis is suggested if the system under examination is subject to wear failures. In fact, if it isn't possible to connect a component failure mode with a degradation, thus there are only random failure (as in the case of the electronic components), it's impossible to foresee, with specific chemical-physical models, direct monitoring or the experience, when it's necessary a maintenance action. In this case let's carry out only corrective maintenance after a component failure. Such maintenance type can be preventive type if we are able to observe the real component condition otherwise we can consider a particular event (km travelled, operation time, etc.) for a planned maintenance. Under these conditions, that are indeed those related to overhead line, an RCM analysis can be performed.

This analysis can be implemented by mean of the following steps:

- let's divide the system in physical-functional subsystems;
- let's define system and subsystem functions;
- identification of functionally significant item (FSI) or structurally significant item (SSI) (see Figure 1);
- detailed reliability analysis and failure modes, effects and criticality analysis (FMECA) of the FSIs and SSIs [3]:
 - identification of failure modes and causes of the FSIs;
 - prediction of failure modes correlated and respect of their occurrences;
- fault tree analysis (FTA);
- definition of a preventive and planned maintenance program.

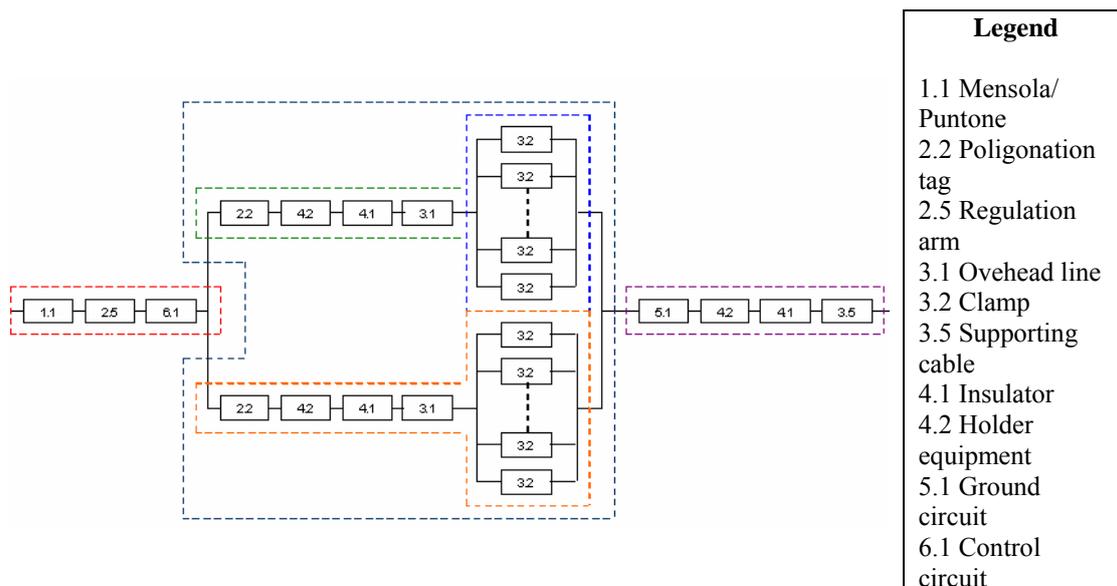


Figure 1: structurally significant item (SSI)

In this case, there are more random failures than those due to wear failures, RCM analysis has allowed to verify the necessity of frequent periodic inspections on the same overhead line and the impossibility to reduce corrective maintenance activity.

A different maintenance type when the system has an increase number of wear failures, it's efficacious only after 5 years of overhead line operation from extraordinary maintenance.

Let's complete the overhead line study with an availability analysis, considering the historical data from corrective and planned maintenance activities.

The Achieved Availability (A_A) is defined as follows:

$$A_A = 1 - \left(\frac{DT}{t} \right) \quad (1)$$

where DT denotes the Down Time (in minutes) defined as:

$$DT = \text{Maintenance Time} + \text{Restore Time} \quad (2)$$

with maintenance time is the intervention time during which the components aren't in operation. The estimated availability is 99,7%, if the extraordinary maintenance, with which the complete overhead line is replaced every seven years, isn't considered. Such great value is due to the fact that the maintenance operations by direct observation and also usually planned maintenance operations don't decrease the line availability for the normal railway traffic.

II. Analysis of diagnostic system strain data

The presence of a diagnostic system in perceptible points of overhead line, as in the gallery, could be an excellent prevention tool, because it receives and analyses data in real time. The monitoring system values the overhead line strain [4]; we define two threshold: a maximum limit and a minimum one, so the software automatically finds, in real time, the possible alarm signals, being therefore able to consider the presence of false alarms too.

Even if there isn't a monitoring system on the mooring of supporting cables, the presence of its critical situation could be equally localized through great improvements of strain data. In fact a possible breaking of the supporting cables could induce itself to touch the overhead line increasing its weight and consequently the values of acquired data.

The control system is made up by 52 sensors, loaded cells (LC), placed in the gallery, where the uneven loaded cells are referred to the north-south direction line, instead the even ones are referred to the south-north binary.

Compared the nominal value of the strain with the acquired data, as shown in figure 2, we can note that the range of $\pm 100\text{kg}$ is exceeded in so as to underline an alarm situation.

Considering the LC14 and the LC16, we can observe that the range $\Delta_{LC14-LC16}$ is 376,02kg, but in figure 1 we can note that the strain on the two parts of overhead line by mooring is roughly the same, moreover both the line parts show a range of $\pm 50\text{kg}$, that can be acceptable if the $\Delta_{LC14-LC16}$ value could not be so high. In this case we can deduce that, for the LC acquired data, the line of LC16 has a correct behaviour, instead the line of LC14 shows an alarm signal that could indicate a partial break of the pulley or an anomaly of the numbers of counterweight.

If we analysed carefully the acquired data is it possible to see that the parts of line that present a too low range are on the even binary (south-north direction), apart from referring to adjacent regulation parts.

The underlined values can be the effect of the presence of an abnormal but not critical situation or in the worst case the consequence of a failure on the overhead line.

For these reasons we have singled out the possible causes of the irregular strain values.

The difference of strain between two parts of overhead line could be caused by:

1. irregular inclination of the mooring balance respect to the rail,
2. potential break of the automatic regulation pulley,
3. wear of cables,
4. wrong acquisitions by the diagnostic system.

For example, in the first case, to award the irregular behaviour to the balance, we can do a mathematical evaluation; in fact added two strain values relative to two wire and calculated the mean, then we can do a comparison between the obtained value and the nominal one; if the last values are equal we can say that there is a high probability that the balance is the cause of the out of specific data.

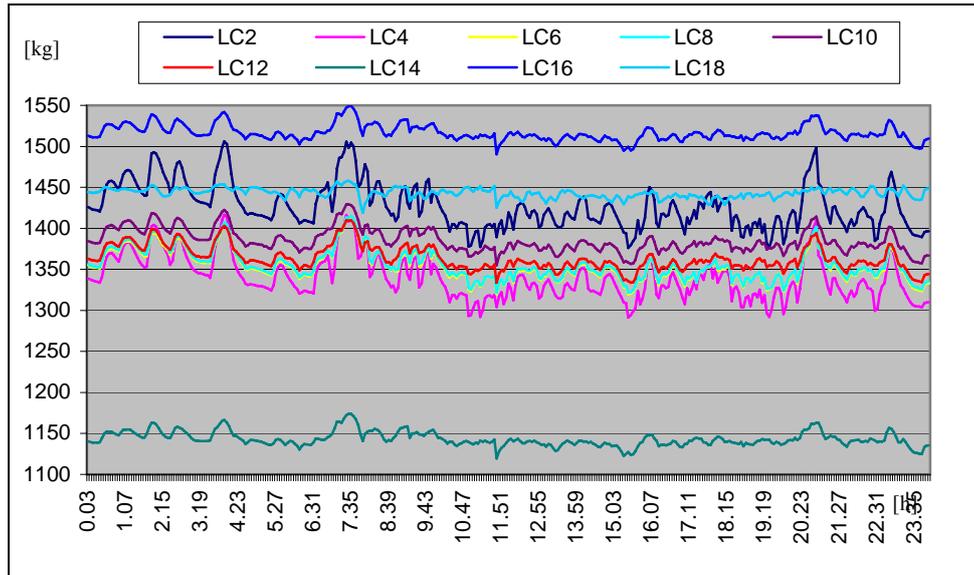


Figure 2: strain values relative to the south-north direction acquired by the diagnostic system

III. Conclusions

The made measures and the RCM analysis have confirmed the adequate maintenance plan, but, after 5 years of work after a extraordinary maintenance, we have recommended to improve the inspections from monthly to biweekly. At the same time we have verified that the measurement system can give useful information for the diagnostic and allows to implement preventive maintenance for gallery overhead line, the most critical point of the railway line.

The shown analysis allows to located some abnormal values in the automatic regulation of the overhead line strain due to the partial break of its own pulley, to an irregular inclination of a mooring balance respect to the plane of rail and the wear of the same overhead line.

References

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