Optimization of Maintenance Methods to Improve the Availability of the National Electrical Network

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Abstract

Classical maintenance methods, largely known and used in industrial units, are based on, among others, preventive or provisional operations. It follows from this that stops immobilizing units being maintained are inevitable, which results in the following costly drawbacks.
- Loss of profit due to production stop;
- Decrease in system performance, particularly its operational availability;
- Creation of operating constraints due to stopping and restarting of units;
- Deterioration of the brand image of the body in charge of the system in question and possible customers’ dissatisfaction.

Our work is an analysis of the different interactions between the maintainability functions and the availability of the electrical distribution network in Morocco. This analysis seeks to identify the new approaches to be adopted in the policy of maintenance of the strategic facilities in the said network in view of optimizing their availability as well as the global output and productivity of the system.
The purpose is to minimize global costs arising from the decrease in productivity and loss of profit directly related to maintenance-related stops.

**Keywords:** Availability, maintainability, hot maintenance

1. **Introduction**

The evolution of maintenance concept enabled the various industrial structures to adopt models of maintenance management [1] that meet output and reliability requirements.

However, operating constraints and service continuity requirements, particularly in vital sectors like the production and distribution of electricity, oblige managers to re-examine their maintenance policy in order to reduce systems unavailability through addressing the reliability and Maintainability of facilities.

In fact, in the present article, we plan to highlight the added value of the implementation of a new maintenance policy. This policy lies in the replacement of the classical concepts based on alternating between the different maintenance methods. This will be done using the diagram elaborated to this effect in order to make it possible for decision makers to select the most cost-effective measures availability wise and cost wise.

2. **State of the Art: Classical Typologies of Industrial Maintenance**

The main typologies of maintenance management can be summarized as follows: Corrective maintenance, Systematic maintenance and Predictive maintenance.

In fact, all methods arising from these types of maintenance converge on a standardized definition of maintenance, namely:

“All actions which have the objective of retaining or restoring an item a piece of equipment in or to a specified operable state in which it can perform its required function .” AFNOR, NF X 60-010.

What emerges from this definition is that all the concepts resulting from it are based on the principle of interruption and discontinuance of services provided by the piece of equipment in question [2], during maintenance or servicing periods (remedial or provisional).

J.B MENYE [3] bases his definition of Maintainability, which he defines as « facility and rapidity whereby a system can be restored to an operable state after breakdown or failure, P. 40 », on two concepts, namely intrinsic criteria (demoun-
Optimization of maintenance methods

stability, modularity, accessibility, interchangeability, testability, standardization, etc.) and contextual criteria (Human and material resources, organization, environmental conditions, etc.)

The author specifies that availability increases by decreasing the duration and frequency of maintenance operations. According to him, four indicators can be deduced from this: duration, frequency, labor force and cost, on the basis of which he comes up with process models that are at the heart of his work.

The author, however, states that his thesis suffers from certain shortcomings, which he summarizes in two main points:

- The interactions between components are not taken into considerations.
- The duration of all steps of the maintenance active phase (diagnosis, repair, interchangeability) are not taken into consideration, either.

R. Djeridi [4], on the other hand, seeking to devise approaches which will allow to master availability and take into consideration this parameter in view of elaborating the maintenance policy, puts forward his problem as follows, (p.19): «The definition of operating a system highlights the concept of maintenance which implements all activities permitting the re-establishment of a system following scheduled or unscheduled stops. »Therefore, his approach is based on the identification of not only, but that of modelling methods of operation.

The author explains that (p.29): «apart from inevitable stops due to operation itself, industrial systems should know as few failures or breakdowns as possible, while functioning at full capacity. »He also adds that «…improving equipment maintenance may be result in improving availability».

The solution the author proposes is based on the identification of the sources of unavailability be they organizational, systemic or related to the rescheduling of the maintenance program or the dimensioning of logistics support. This leads us to the same classical schema based on evidence that improving availability requires reducing the duration and frequency of maintenance operations.

Such an approach draws on other research works H. Kafeel [5], F. Turgis [6], M. Dahane [7] and others [8] which postulate that increasing availability of a piece of equipment consists of decreasing both the number of its stops and the time necessary to solve the causes of such stops.

On the other hand, the solution suggested by X. Zwinmann [9], W. I. Soro [10] and M. Demers [11] to reduce the need in terms of maintenance stops and risks of stops following breakdowns is to improve reliability upon design.
Modelling availability, maintainability and reliability concepts relies on similar and classical models compulsorily integrating the time of unavailability in its different forms.

In the rest of the present article, we, through the analysis of the availability indicator of the components of the retained system, examine the impact of maintenance operations, namely those conducted systematically. For the purpose of our study, remedial maintenance operations, related to failures and component reliability are not integrated. History of unavailability shows a preponderance of scheduled stops compared to unpredictable and unforeseeable ones.

3. **Studied System: Electricity Network in Morocco**

![Transformer station view](image)

Fig.1 (Transformer station view)

Being responsible for ensuring proper functioning and safety of the Moroccan electricity network, the management of electricity distribution adopts a power lines and stations maintenance policy that is compatible with the state of equipment, that takes into account the optimal THT configuration and that permits to ensure proper functioning of the national electricity system. All this is done in order to guarantee, among other things, the distribution of electricity in safe and economic conditions. This policy also permits to standardize maintenance methods and ensure effective and efficient practices. In 2015, the studied network covers 230 transformer stations (fig-1) and 23300 km of THT lines.

Account taken of the constant annual growth in demand for electricity, as is indicated in fig-2 below, it appears that improving the availability of facilities and reducing power cuts for maintenance purposes is becoming more and more a strategic and inevitable requirement, directly affecting not only the quality of services but the image of the company as well.
Our study concerns the equipment and facilities of an electricity network (stations and lines), of which the typical schema is the following (Fig-3).

The main electrical components in such a facility (A: primary part/ B: secondary part) are:
1. Primary electrical line
2. Reserve cable
3. Electrical line
4. Tension transformer/Disconnecting switch
5. Disconnecting switch
6. Circuit breaker
7. Current transformer
8. Surge arrestor/protector
9. Power transformer
10. Secondary building
11. Closure
12. Secondary electric line.

3.1 Maintenance Of Electrical Network Facilities

Given the fact that the installation of the different components of the electrical network being studied is carried out in series (continuity of electrical current), we can establish a model for this system, made up of strategic-role subsystems (determining service continuity).
This model can be presented as follows: Higher line (High-tension power lines), Higher circuit breaker, Higher disconnecting switch, Higher bars, Power transformer, Lower circuit breaker, Lower disconnecting switch, Lower bars, Higher lines (Lower tension power lines).

This recap chart shows the different operations of systematic maintenance of the above-mentioned electrical facilities, their periodicity and average execution duration.

<table>
<thead>
<tr>
<th>Facility</th>
<th>Systematic maintenance operation</th>
<th>Intervention duration (hours)</th>
<th>Annual Periodicity</th>
<th>Equivalent Number of hours of unavailability (annual)</th>
<th>Annual Availability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Higher line</td>
<td>Cleaning of insulator chains</td>
<td>8</td>
<td>2</td>
<td>16</td>
<td>99,82%</td>
</tr>
<tr>
<td>Disjoncteur supérieur</td>
<td>type 3 visit (replacing accessories (joints...))</td>
<td>24</td>
<td>0,2</td>
<td>4,8</td>
<td>99,95%</td>
</tr>
<tr>
<td>Higher disconnecting switch</td>
<td>Greasing of joints</td>
<td>4</td>
<td>6</td>
<td>24</td>
<td>99,73%</td>
</tr>
<tr>
<td>Higher bars</td>
<td>Cleaning</td>
<td>4</td>
<td>4</td>
<td>16</td>
<td>99,82%</td>
</tr>
<tr>
<td>Higher bars</td>
<td>Replacing of coupling joints</td>
<td>8</td>
<td>1</td>
<td>8</td>
<td>99,91%</td>
</tr>
</tbody>
</table>
Given customer sensitivity vis-à-vis power cuts due to different periodical operations, the electrical system Operator company should adopt a new approach, aiming at considerably improve the global availability rate, which currently stands at 98.41%. This global indicator $A_{gl}$, closely related to the quality of service of the network, brings into play those of the components listed hereafter. It is assigned the following formula: $A_{gl} = \Pi A(i, k)$

where $A(i, k)$ represents the annual availability of each component.
3.2 Improving Availability: Adopted Methodology

If we define the following indicators: MTTR (Mean Time To Repair): as the mean of the sum of stop time for scheduled repair. Availability will be defined as:

\[
A = \frac{MTBF}{MTBF + MTTR}
\]

In fact, taking into account the following hypotheses: Volume of stops due to insignificant breakdowns and level of reliability of irreproachable facilities.

It follows from this that increasing availability particularly requires decreasing the MTTR factor. [12]

The methodology we suggest can be schematized as follows:
Identification of components Ci

Operation Op(i,k) feasible in live work?

Ci commutation on a similar component?

Possible reduction of Top (I, k) (via improving maintainability)

OP(i,k) achievable in parallel with operation?

Compare Top (i,k) and Top (j,l)

Top (i,k) <= Top (j,l)

A (j,l) = 1

A(i,k) = 1

Calculated Outcome of A(i,k)

Analysis and Proposal of design improving
In fact, if we consider the properties of each piece of equipment, summarized as follows:

<table>
<thead>
<tr>
<th>No.</th>
<th>Equipment</th>
<th>Systematic maintenance operation</th>
<th>Carried out live</th>
<th>Existing redundancy</th>
<th>Carried out in parallel with other operations</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Higher line</td>
<td>Cleaning of insulatorchains</td>
<td>OUI</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>2</td>
<td>Higher circuit breaker</td>
<td>Type 3 visit (replacing accessories)</td>
<td>NO</td>
<td>NO</td>
<td>YES (6-partially)</td>
</tr>
<tr>
<td>3</td>
<td>Sectionneur supérieur</td>
<td>Greasing of joints</td>
<td>YES</td>
<td>NO</td>
<td>YES (2-partially)</td>
</tr>
<tr>
<td>4</td>
<td>Higher bars</td>
<td>Cleaning</td>
<td>YES</td>
<td>NO</td>
<td>YES (6-partially)</td>
</tr>
<tr>
<td>5</td>
<td>Higher bars</td>
<td>Replacing coupling joints</td>
<td>YES</td>
<td>NO</td>
<td>YES (6-partially)</td>
</tr>
<tr>
<td>6</td>
<td>Power transformer</td>
<td>Ten-years visit</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>7</td>
<td>Lower circuit breakers</td>
<td>Type 3 visit (replacing accessories)</td>
<td>NO</td>
<td>NO</td>
<td>YES (6-partially)</td>
</tr>
<tr>
<td>8</td>
<td>Lower bars</td>
<td>Cleaning</td>
<td>YES</td>
<td>NO</td>
<td>YES (6-partially)</td>
</tr>
<tr>
<td>9</td>
<td>Lower bars</td>
<td>Replacing coupling joints</td>
<td>YES</td>
<td>NO</td>
<td>YES (6-partially)</td>
</tr>
<tr>
<td>10</td>
<td>Lower disconnecting switch</td>
<td>Greasing of joints</td>
<td>YES</td>
<td>NO</td>
<td>YES (2-partially)</td>
</tr>
<tr>
<td>11</td>
<td>Lower line</td>
<td>Cleaning of insulatorchains</td>
<td>YES</td>
<td>NO</td>
<td>NO</td>
</tr>
</tbody>
</table>

In fact, recalculating the total availability resulting from the availability outputs $D_{i,k}$, based on the generated properties leads to the following:

$$A_{gl} = \Pi A(i,k) = 99.87\%$$

That is, a gain of 1.4%, equal to 127 hours per year per facility.

**Conclusion**

In light of the different industrial maintenance policies and methods, it emerges that resorting to facility stops to carry out repair operations or scheduled interventions proves to be inevitable at least based on the concepts currently in use. These stops, however, remain very costly for companies and often result in:
- Production shortfall;
- Damage to the company’s brand image and reputation due to the shortage of services provided.
- Additional costs inherent to the changes in state of facilities (sudden and abrupt stops, restarting expenses…)

In fact, considering the economic and industrial context worldwide, it proves to be more necessary than ever to expend considerable efforts in order to reduce the time and duration of system stops, or better yet to remove them completely, through the adoption of a new perspective or vision. Such a perspective may be referred to as « Hot Maintenance » and its fundamental principle is as follows:

« Carrying out preventive or scheduled maintenance operations without altering the functional performance or causing services provided by the facilities in question to be unavailable ».

With regard to the findings of the present work, we have managed to stress the economic contribution of the new methodology suggested, a methodology that is different from the maintenance policies we generally find in users’ manuals elaborated by equipment manufacturers. In our study, an improvement of 1.4% in the availability of a transformer station accounts for at least 29000 cumulated hours (for the 230 existing stations), i.e., an annual shortfall of $145 million.

It should be noted that the model schematized through the selection diagram is likely to be used in other industries, namely those based on the principle of linear transformation chains subject to implementing the necessary changes appropriate to the context concerned.

In this respect, we plan to expand on the analysis of the points raised in the present article, namely at the level of:

- Design of the system (enhancement of its maintainability)
- Development of the mode of operation while preserving availability
- Rational use of functional redundancy

Finally, our objective is to offer to managers in the electricity sector new strategy for the aid decision [13] related to our model above-mentioned.

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References


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