ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

IMPROVING THE AVAILABILITY OF THE NATIONAL ELECTRICITY NETWORK: PRINCIPLES AND CONCEPTS FOR LIVE WORK APPLICATION IN LRSS MAINTENANCE MODEL

Z. Bouzoubaa[1], J. El Alami[1] and A. Soulhi[2]
[1]LASTIMI, University Mohammed V of Rabat, High School of Technology, Sale, Morocco
[2]National School of Mineral Industry, Rabat, Morocco
E-Mail: zakaria_bou78@yahoo.fr

ABSTRACT

In the present paper, we plan to examine the potential of the concept of Live Work in the development of new strategies for the maintenance of electrical facilities in HV transformer stations, in order to protect their operational characteristics from operating-related degradation, while preserving service availability and continuity. For this purpose, we expose the principles of Live Work which incarnates the projection of the concept of Live Work in our LRSS maintenance model; we also illustrate its potential based on concrete examples. This methodology, thus, represents a high operational flexibility in the maintainability of facilities and makes it possible to carry out a wide range of maintenance operations under the best possible safety conditions and with no impact on the system availability.

Keywords: availability, maintainability, live work.

1. INTRODUCTION

An efficient maintenance strategy can be defined as a set of decisions rules that establish the sequence and interactions of maintenance operations to be undertaken depending on the level of facility degradation (depreciation, damage) and the acceptable operating threshold (availability). Each maintenance action makes it possible to maintain or to re-establish the facilities to a specific state by using appropriate resources. Each maintenance action implies an incurred cost, which can be constant or progressive depending on where the facility operating takes place.

In fact, there exist numerous maintenance strategies in the literature. Such strategies can be distinguished based on their typology and the proposed sequence of actions, the retained performance criterion; whether the facility is considered as one entity or as a system composed of constituents and, more particularly, based on the impact of stops on the quality and availability of the service.

However, the progressive complexity of facilities ensures that the new maintenance strategies combine several actions and take account of not only the inherent technical dimensions of the facility, but also of the economic and strategic dimensions of the company operating it.

In our LRSS model [1], the fact of taking into consideration all the important factors likely to have a significant impact on the facility and its performance has led us to examine the potential of live works on the concept of Live Work to increase the availability of the national electrical distribution system.

In fact, the present article introduces the principles of Live Work on HV transformer stations that are elaborated within our organization and illustrates its potential based on concrete examples.

2. LIVE WORK: INTRINSIC PRINCIPLES AND PROPERTIES

One of the major advantages of the LRSS model is certainly Live Maintenance. Such concept includes all the operational modes and maintenance activities that can be carried out by intervention teams and that make it possible to:

- Preserve the working of the maintained facility and prevent stops and removal from operating [2];

- Carry out the different maintenance operational modes that enable the facility to preserve its reliability and extend its overall service life, while respecting periodical or conditional intervention modes [3] & [4]

After that, the general rules to be respected during the carrying out of live maintenance works in our 60 kV, 150kV, 225 kV and 400 kV, alternating current and nominal tension transformer stations belonging to our organizations will be defined [5].

These rules make it possible to carry out operations on stations located at an elevation that is inferior or equal to 1000 m, based on methods of distant work. They equally make it possible to prevent electrical risks likely to jeopardize operators' safety, namely the risk of electrocution and the risk of short circuit.

2.1 Definitions

2.1.1 Operator's volume of work

The operator's volume of work results from their normal movements or actions during the carrying out of their job, except involuntary movements, taking into account of non-insulating parts that they handle and which they are in contact with.

When an operator does not make any movemebt, their volume of work is reduced to its proper volume.

2.1.2 Basic distances (Minimal air insulation distances):

t : Tension distance between phase and ground.
T : Tension distance between phases.
C : Basic distance around chains of insulating columns.

Addition of a suffix' to t or T: Increased tension distance corresponding to the not dampened over voltage.

Empirical results can be summarized as follows:

Un (kV)	**60**	**150**	**225**	**400**
t(m)	0,35	0,95	1,25	2,15
t' (m)	0,45	1,25	1,35	2,75
T(m)	0,45	1,3	1,70	3,10
T'(m)	0,55	1,7	1,90	4,00
C (m)	0,20	0,7	0,80	1,40

2.1.3 Guard distance

The guard distance "**g**" aims at freeing operators up of the permanent concern of respecting basic distances and thus enable them to devote all their attention to the execution of their work, while protecting themselves from involuntary consequences and movements. Such distance is set at 0, 5 m.

2.1.4 Work Distance (Minimum distances from which work is permitted)

Work distances are equal to the basic distances increased by the guard distance "g"

t + g : Minimum approach distance.
t'+ g : Work distance between phase and ground in stations or non-dampened overvoltage.
C+g : Work distance around insulating chains and columns.

Empirical results can be summarized as follows: [1]:

Un (kV)	**60**	**150**	**225**	**400**
t + g (m)	0,85	0,8	1,75	2,65
t' + g (m)	0,95	1,1	1,85	3,25
T + g (m)	0,95	1,3	2,20	3,60
T' + g (m)	1,05	1,7	2,40	4,50
C + g (m)	0,70	1,2	1,30	1,90

2.1.5 Fixed potential conductor part

A fixed potential conductor part is an electrically connected conductor part:

- Either to the ground potential.
- Or to a phase of the live network or considered as such.

In order to apply the above definition, we will consider all the structures supporting insulation equipment as ground potential equipment, whatever their nature.

2.1.6 Variable potential conductor part

A variable potential conductor part is a conductor part that is not electrically connected to a fixed potential conductor part.

2.1.7 Working zone

The working zone is the part of the facility on which live work is carried out. It includes:

- The part of the work on which live work is carried out.
- Operators' work volume.
- The parts and structures movement area.

2.1.8 Insulating part

A part is said to be insulating if it is certified as such in a technical specifications sheet (fact sheet) or if the concern is an insulating element of the network.

2.2 Electrical resistance in the work zone

2.2.1 Basic principles

The contexture of the network and system start up risks can result particularly from handling and /or pollution overvoltage. Prior to deciding to carry live work, it is necessary to take into account the behavior of the facility being operated.
In fact,

- If a facility is subject to frequent actuations, of which the cause is not determined, live work is forbidden in such facility. Thus, we consider that a facility is subject to frequent actuations if we notice several triggers per week on the same facility.
- If a facility is subject to actuation triggered by incidents which occur on specific parts of this facility, live work is forbidden on the said parts. These incidents may, for example, be due to high pollution or to chains or columns including a number of important insulators that are damaged.
- Live work is forbidden on surge protectors or their vicinity and no part should be placed in their sensitive zone defined in the technical specifications file.
- Live work should be preceded by checking insulation in the work zone, i.e., on the chain or column on which interventions take place or on the neighboring chains or columns.

It should be specified that actuations may, for example, be due to specific weather conditions (e.g. fog,

ARPN Journal of Engineering and Applied Sciences

rain, sea spray, frost, etc.) or may occur during certain periods of the day (sunrise).

Furthermore, checking insulation includes:

- A visual check on the neighboring chains or columns.
- Calculation of the electrical resistance to handling overvoltage.
- Calculation of electrical resistance to pollution.

If the visual check:

- Does not reveal any deterioration of the neighboring chains and columns, the examination of the chain's or column's resistance is enough.
- Reveals broken or cracked elements, it is necessary to examine the electrical resistance of the neighboring chains or columns in the same way as for the chain or column on which intervention takes place.

Checking the electrical resistance of a facility aims at determining whether the phase-ground level of insulation of the column in question as well as that of the neighboring columns allows its execution. Live work may be considered if the results of the calculations are compatible with resistance to both over voltage handling and resistance to pollution.

Work preparation requires checking electrical resistance on the insulating columns:

- Located in the work area,
- Switched on or re-switched on during the work being carried out.

2.2.2 Characteristics of an insulating column

Let the following variables:

L : is the length of the column,
b : is the total of the lengths of the pace of the connecting nuts or bolts of columns or column elements,
p : is the length between elements of sane column,
N : is the total number of a column's element,
Cg : is the total of lengths of the projections of the guard parts on the column's axis,
Ld : equal to the total of lenght of deteriorated elements to be taken into account.

An element is an ailette of a column or an element of a column. If an element of a column is cracked or fissured, all the ailettes are considered as deteriorated.

Figure-1 below shows a schematized example of the distances of 225kv circuit breaker installed in a ONEE transformer station.

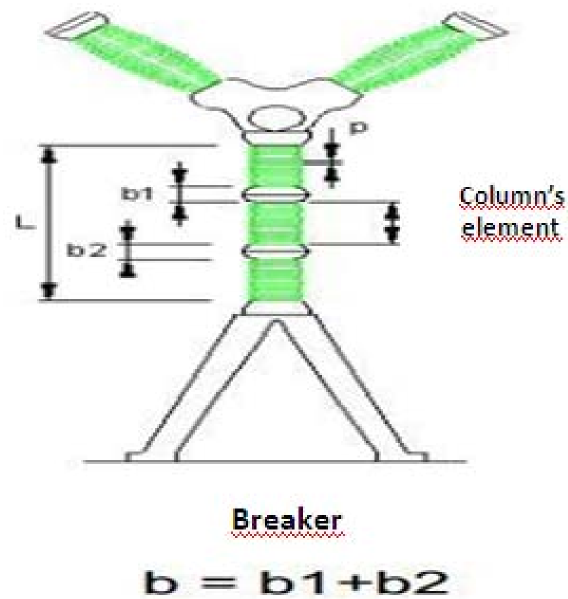


Figure-1. Drawing of 225kv circuit breaker.

2.2.3 Influence of a part inside a volume of revolution

The incorporation of a part inside a volume of revolution may decrease the electrical resistance of the facility. Such influence is expressed in terms of length.

Insulating part

An insulating part has no influence on electrical resistance.

Conductor part

If the part is handled through a guiding and maintenance device, its impact is expressed by an h projection of the part on the axis of the column. If it is guided, its influence corresponds to the highest dimension.

2.2.4 Calculation of electrical resistance to handling over voltage

Electrical resistance to handling over voltage is calculated based on the length L of the insulating column less all the elements reducing its resistance.

The result obtained is a corrected length Lc.

The weakening coefficient of the insulating length K is introduced for the columns containing the device.

Calculation of the corrected length Lc and of k

Lc = L - (Cg + b) - Ld - h

Application to columns not containing a device

Table-1. Limit values to be respected for electrical resistance to handling over voltage.

Un (kV)	**60**	**225**	**400**
L1(m)	0,4	1,4	2,8
L2(m)	0,35	1,15	1,95

ARPN Journal of Engineering and Applied Sciences

- If Lc ≥L1, live work is permitted if handling over voltage in work zones are made compatible with normal or increased distances,
- If L2 ≤ Lc< L1 live work is permitted if handling over voltage in work zones are made compatible with normal distances,
- If Lc< L2, live work is forbidden

Example-2:

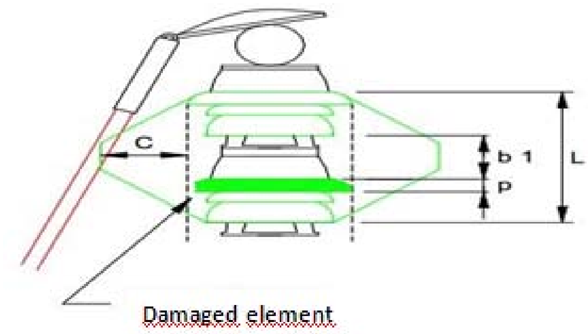
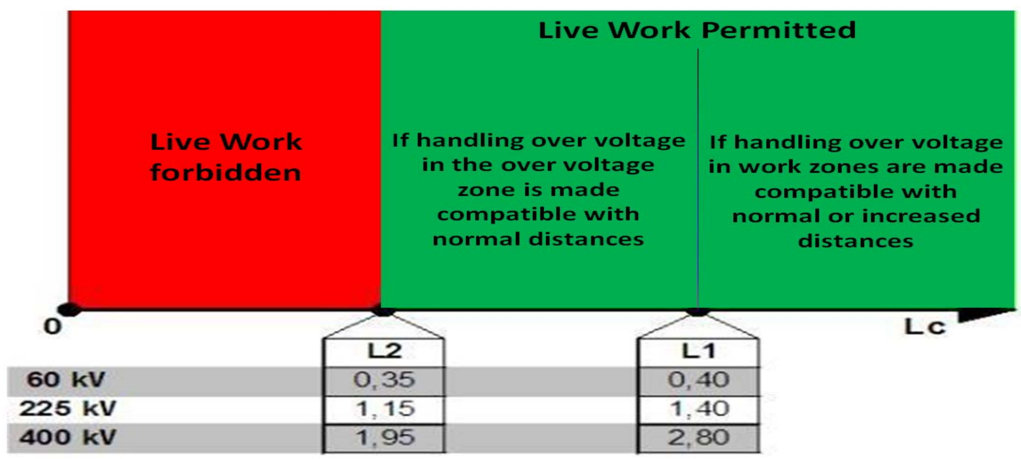


Figure-2. Column composed of deteriorated elements.

In this case, we have:

- **b** = b1 and **Cg** = 0,
- **Ld** = p.1 for the number of deteriorated elements to take into consideration is equal to 1,
- **h** = 0 for no conductor part is inserted in the volume.
- Hence **Lc = L – b1 – p**
  and k= Lc/ (L-(Cg+b)) for columns with a device.



2.3 Atmospheric conditions

The following atmospheric conditions on the working: site:

- Storm,
- Thick fog,
- Important atmospheric precipitations,
- Strong wind,

- Do not permit live work

- If one of the above atmospheric conditions appear on the work site, work should be interrupted. The tools maintaining live parts may be left on site.

- In the event of quite important atmospheric precipitations on the work site, live work should not be undertaken, but the elementary operation in progress may be carried out. The work site should then be abandoned under conditions related to the provisional interruption, and resumption of work.

We consider that there is:

- Storm, if there is:
- Lightening.
- Thunder.
- Thick or dense fog, if visibility is reduced in a way that can jeopardize safety.
- Important atmospheric precipitations, when they disturb operators.

VOL. 12, NO. 7, APRIL 2017 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

- Strong wind, when it prevents operators from using their tools in a precise and accurate way.

These atmospheric conditions may appear either during intervention or during a period in which the work site is abandoned. In both cases, the facility is normally reactivated. Appearance of droplets on tools is similar to important atmospheric precipitations.

For facilities located in highly polluted areas, live work can be undertaken only if the weather is good, dry and without wind.

If, during work, one of the following atmospheric conditions appears, on the work site:

- Fog.
- Atmospheric precipitation, even if not important.
- Sea sprays.

Work should be immediately interrupted, the work site abandoned, and removal of the equipment on site should be done after switching off.

3. DISTANCE CONDITIONS

3.1 Distances to be respected by operators

For the implementation of the conditions below, it is necessary to take into account:

- All the possibilities of movement with regard to fixed or variable potential conductor parts.
- The difficulty to appreciate distances in space.
- The inaccuracy of operators' movements and gestures.

Operators are always at ground potential or are considered as such.

3.1.1 distances to be respected by operators with regard to insulating chains and columns

During work or movement, operators should remain outside the revolution volumes, of which the axes are chains or columns delimited by right segments:

- Making an angle of 50° with axes, and extreme sleeve tangents,
- Parallel to the axes of columns and chains and located at a distance of C + g of the latter.

Distance C + g is given above.

This distance applies except if extreme sleeve tangents right segments (with an angle of 50°) intersect in a point located at a distance that is inferior or equal to C + g. In this case, only these segments lead to the volume to be respected.

- **Intervention on a column**

In order to intervene close to an insulating column, an operator at ground potential may remain at a distance of the other extremity that is inferior to work distance t+g or t'+g. Distance may be reduced to the length L of the column if the checking of electrical resistance satisfies the fixed limits.

When the column is fit with guard parts, the latter constitute the visible limité not to cross.

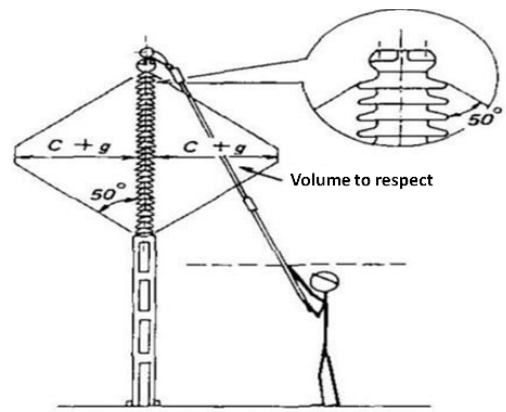


Figure-3. Example of an insulating column extremity constituting a visible limit not to cross in case of dampened over voltage.

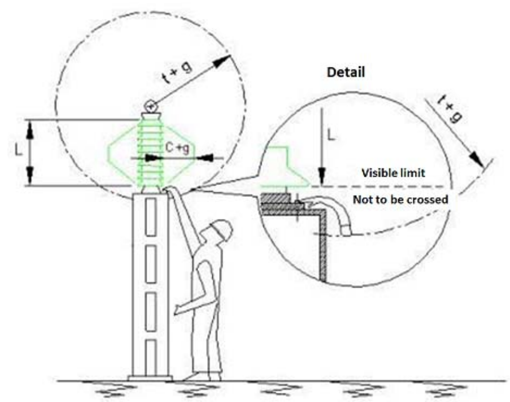


Figure-4. If they respect this limit, operators may enter the area defined by t+g; in this case, however, it is not permitted to shunt the extreme element.

3.1.2 distances to be respected by operators_with regard to live parts

During work or movement, operators should remain at an insulating distance superior or equal to work distances indicated in the table below with regard to live parts.

U (kV)	63	150	225	400
t + g (m)	0,85	1,45	1,75	2,65

- **Particular case**

When work is carried out on a station where over voltage is not dampened, the distance to be respected is distance t' + g given in the table below:

U (kV)	60	150	225	400
t' + g (m)	0,95	1,75	1,85	3,25

3.1.3 distances to be respected between conductor parts and an insulating chain or column

For the implementation of the conditions below, it is necessary to take into account:

- All the possibilities of movement with regard to fixed or variable potential conductor parts.
- The difficulty to appreciate distances in space.
- The inaccuracy of operators' movements and gestures.

Operators are always at ground potential or are considered as such.

3.1.4 distances to be respected by operators with regard to insulating chains and columns

A conductor part, whatever it's potential, should be kept outside the revolution volumes, of which the axes are chains or columns delimited by right segments:

- Making an angle of 50° with axes, and extreme sleeve tangents,
- Parallel to the axes of columns and chains and located at a distance of "C" of the latter.

Distance "C" is given in the following table:

U (kV)	60	150	225	400
C(m)	0,20	0,70	0,80	1,40

This distance applies except if extreme sleeve tangents right segments (with an angle of 50°) intersect in a point located at a distance that is inferior or equal to C. In this case, only these segments lead to the volume to be respected.

However, a non-insulating tool or small part with fixed or variable potential (Figure-5) may enter the volume of revolution surrounding the chain or the column, provided that is made sure in advance that this does not modify the electrical resistance of the chain or column in question beyond the limits indicated above. "Electrical resistance in the work area".

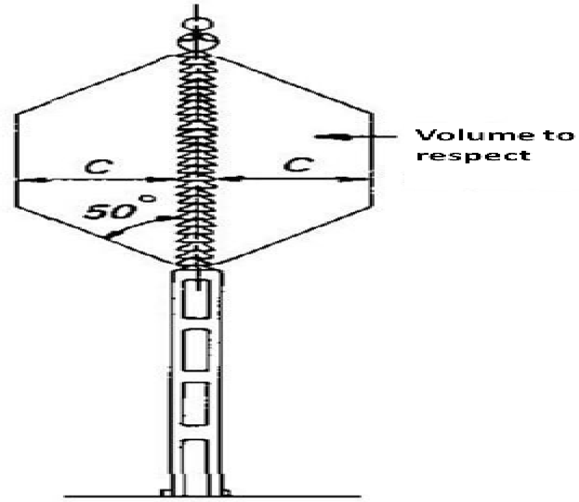


Figure-5. Spring flyweight or metal pole insert**.**

4. CONCLUSIONS

The Live Maintenance methodology proposed in this paper is based on one of the four principles of the LRSS model. It suggests a series of tools and methods used depending on examined criteria [6] and controlled costs.

The present work has made it possible for us to explore live work capacities in order to carry out maintenance operational modes without interrupting service availability [7] & [8], especially that power cuts are usually costly in terms of unavailability and loss of income.

We also plan to develop optimal models [9], which will allow the assessment of the impact of these methods on unavailability, [10] and the overall maintenance cost, over a specific horizon, of any electrical system or facility, particularly concerning the implementation of systematic or conditional maintenance plans.

Current research aims at elaborating a modelling and simulation platform, which will make it possible for us to assess the performance of maintenance strategies in our environment.

ACKNOWLEDGEMENTS

We would like to thank Mr Nourredine ELALAMI, professor at EMI-Rabat for his valuable advice. We also would like to thank Mr. Sadik MALIKI Professor at the faculty of letter, Ain Chock, Hassan II University of Casablanca for the English translation of this article.

REFERENCES

[1] Z. Bouzoubaa1, A. Soulhi, J. El Alami. 2016. LRSS Maintenance Model: concepts and application methods for improving the availability of the National Electrical Network. ARPN Journal of Engineering and Applied Sciences. 11(17).

ARPN Journal of Engineering and Applied Sciences

[2] Z. Bouzoubaa, A. Soulhi, J. Elalami. 2016. Optimization of Maintenance Methods to Improve the Availability of the National Electrical Network, Journal of Innovative Technology and Education. 3(1): 23-35, Hikari Ltd.

[3] D. Ait-Kadi, M.A. Jamali, A. Artiba. 2002. « Optimal periodicreplacement strategies using new and used items». Journal of Decision Systems JDSS-IMRS.

[4] M.A. Jamali, D. Ait-Kadi, A. Artiba. 2002. «Stratégiesoptimales de remplacements périodiques » JTEA 02, 2 : 242-252, Sousse Nord.

[5] C. Bayliss. 1979. Transmission and Distribution Electrical Engineering. 2nd Ed. Manchester: Newnes.

[6] Nkagawa T. 1979. Optimum policies when preventive maintenance is imperfect. IEEE Transactions on Reliability. R-28, 4: 331-332.

[7] Sherif Y.S. and Smith M.L. 1981. Optimal maintenancemodels for systems subject to failure - a review, Navalresearch Logistics Quarterly. 28: 47-74.

[8] H. Elhadaf, R. Benmansour, H. Allaoui, M. Tkiouat et Artiba. 2012. Preventive maintenance scheduling fora multi-component system and spare parts inventory. Asset management and maintenance Journal. pp. 25-27.

[9] R. Barlow *et al*. Hunter. 1960. Optimum preventive maintenance policies. Operations Research. pp. 90-100.

[10] Sukhwinder Singh Jolly, SS Wadhwa, Reliability. 2004. Availability and Maintainability study of high precision. Journal of scientific and Industrial Research. pp. 512-517.