DESIGN AND IMPLEMENTATION A NEW MODEL FOR PREVENTIVE MAINTENANCE OF MEDIUM VOLTAGE ELECTRICAL DISTRIBUTION NETWORKS

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ABSTRACT

The distribution companies in many countries apply Preventive Maintenance method these days. In this method periodic preventive services and repairs are used to decrease the faults. The prominent point in the systematic maintenance and repairing is that because of the limitations in different sections, in many occasions doing these periodical services with the same priority for all of the equipments is not possible and it is not economical in some situations, as a result providing a special time pattern for each equipment on which repairing is done, is so important. In this paper, with incorporating Preventive Maintenance model and Analytic Hierarchy Process model, a pattern is presented that decreases the costs, reduces the time and unexpected outages, then the results of applying the suggested pattern for eliminating loose connections of the medium voltage networks are indicated.

INTRODUCTION

According to the fact that a great deal of whole budget for the current process in distribution companies is spent on maintenance operations, property management in this part can positively affect recognizing and evaluating the decisions which lead to capital turnover and economical beneficiary. Making appropriate decisions in this part needs to have suitable information about the equipment in the network, maintenance and repairing strategies and also statistical evaluation and analysis of errors in the network. Applying the maintenance and repairing program based on Preventive Maintenance (PM) is one of the main methods to increase the reliability of the equipments and their profitable longevity. In this procedure the equipment maintenance is done in specific and pre-determined time periods [1, 2], but in many occasions doing these periodical services with the same priority for all of the equipments is not possible and it is not economical in some situations, therefore in this paper, with incorporating Preventive Maintenance (PM) model and Analytic Hierarchy Process (AHP) model, a pattern is presented that decreases the costs, reduces the time and unexpected outages.
AHP model is based on couple comparisons and it makes it possible for the managers to investigate various scenarios [3].
This model provide decision makers with the capability of defining reciprocal and simultaneous effects of many indefinite complicated situations in different sections such as Preventive Maintenance.
On the other hand, one of the important goals defined in distribution networks is decreasing loss in order to take the most advantage of energy and decrease the undistributed energy. Loose connections are very important parts of faults, so eliminating loose connections in preventive maintenance is considered as one of the priorities to be done in companies.
With this point of view, we simulate our model on the loose connections. At first, all parameters of loose connections in medium voltage network which should be serviced in PM program, have been analyzed with practical and AHP model, then repairing priority on these parameters has been defined, considering some indicators such as the budget, time needed for repairing and plenty of faults. The outcomes resulted from implementation of the present model have led to decreasing costs, saving time and decreasing unexpected outages.

PREVENTIVE MAINTENANCE

Preventive Maintenance means scheduled repairing for equipment and devices which is designed for improving device operation and preventing unscheduled or emergency repairing activities [1, 2, 4]. In this way, the maintenance is done based on a schedule before equipment reach to critical point and in order to prevent outage and to decrease loss. Generally, the goal of PM is summarized as follows:

- Lengthening the useful lifetime of the equipment
- Increasing the reliability of the equipment
- Enhancing the general efficiency of the equipment
- Decreasing the unscheduled and emergency repairing occasions
- Shortening the unexpected outages time and decreasing the undistributed energy

One of the important parameters in developing stable network following increasing its reliability is scheduling for proper usage of human resources and the equipment in order to apply PM program and this indicates the importance of prioritizing faults at the time of preparing PM programs.

LOOSE CONNECTIONS AND ITS RELATED PARAMETERS IN THE MEDIUM VOLTAGE

NETWORK

According to majority of equipment and variety of faults in distribution networks, in this paper the focus is on the effects of the PM applications with AHP model on the loose connections which are of the main causes of energy loss and unexpected outages. Improper assemble of the equipment, contacts with low pressure, inappropriate washer usage, dies and screws working loose and lack of attention to standards in the equipment utilization are of factors which may cause loose connections [5, 6].
Some of the parameters of the loose connections in medium voltage network are such as replacing faulty insulators, renovating jumper and installing clamps, renovating cut-out fuse connections, bounding renovation, electrical panel connections reformation and so on [5].

MULTIPLE CRITERIA DECISION MAKING

Decision making can be considered as choosing a solution from among various available solutions. The process of decision making encompasses four levels of defining the issue and its importance, detecting and describing the issue, specifying solutions, evaluating and selecting one solution. Since World War II improving issues, according to a target function, has been the centre of attention by the managers, but these days more attention is paid to improving issues by considering several criteria. Models of Multiple Criteria Decision Making (MCDM) are divided two general categories [7].

Multiple Objective Decision Making (MODM)

This method is applied in non-linear programming. In this model decision maker has to consider several secondary objectives simultaneously in order to reach to the final goal [8].

Multiple Attribute Decision Making (MADM)

In this method some of the parameters are analyzed and prioritized, in other words the parameters are prioritized based on several indicators for a specific target [8, 9].
Since Multiple Attribute Decision Making (MADM) is utilized in this study, therefore this method is shortly described in the following sections. The MADM is done through two different procedures as compensation and non-compensation methods.

Compensation Methods

In this method, the compensation indicator is considered in decision making in a way that one indicator influences the other indicator's function for instance in the loose connections matter if a great amount of budget is spent in order to eliminate a fault but it can be eliminated in a shorter time, in this condition a kind of making amends is obvious between high amount of costs and short period of time. AHP is the most important model of this method [8].

Non Compensation Methods

The indicators are independent from each other in this method and one indicator cannot necessarily compensate the other [8]. For instance, in the activities related to outages, decreasing the needed time for eliminating outages cannot be compensated by disobeying security rules.

USING AHP IN PRIORITIZING PARAMETERS OF THE LOOSE CONNECTIONS

One of the most efficient techniques for decision making is Analytic Hierarchy Process (AHP) model. This process helps decision makers to arrange the priorities based on the targets, knowledge, and their own experiences; in a way that they consider their own views and judgments. Generally humans apply two main viewpoints in the analysis and evaluation that include analytic viewpoint and systematic one. AHP presents both of these views in one logical and compound framework. The algorithm of AHP model is shown in Figure 1.

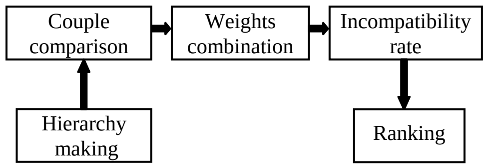

Figure 1. The algorithm of Analytic Hierarchy Process (AHP) model

The infrastructure of AHP theory is based on four principles[7, 8]:

1. The decision maker is capable of couple judgment for an indicator and assumed target.
2. The decision maker never judges that an element is infinite times higher than the other in comparing two elements in relation to an assumed indicator.
3. The structure of an issue can be analyzed to a ranking structure through group arguments.
4. All parameters and effective indicators are pulled together in a decision making process.

In this paper, bellow process has been done to reach to a proper result with the present way of analysis.

First step: Hierarchy production

The models of decision making in eliminating or improving an issue need assumed parameters and decision making indicators. In most cases these indicators and parameters should be specified by proficient experts before and at the beginning of decision making procedure.
First step to accomplish this process is creating an analytic hierarchy or in other words creating a graphical presentation of the issue that the general target of the issue is on top and the indicator and the parameters are in the following levels, as shown in Figure 2.
The analytic hierarchy considered in this paper includes the target, the indicators and parameters. Prioritizing repairing parameters has been defined as the aim and according to the experts' viewpoints of the electricity industry, the budget indicators (the costs spent on eliminating faults) I1, the amount of time needed for repairing I2 and plenty of faults I3 have been considered as prioritizing indicators of repairing parameters in PM programme, and Ps are the faults factors (parameters) or equipments that should be repaired or eliminated. In this study, in order to investigate the model, renovating factors of loose connections of medium voltage network are defined in order as the prune the trees on the network path (tree management), replacing faulty insulators , renovating jumper and installing clamps, renovating cut-out fuse connections, bounding renovation, electrical panel connections reformation, lightning arrester connections reformation, renovating transformers

connections, reforming cable shoes, reforming sectionalizing switch connections, renovating the terminations connections, repairing wire, renovating disconnector switch and circuit breaker connections as the parameters (P1....P14).

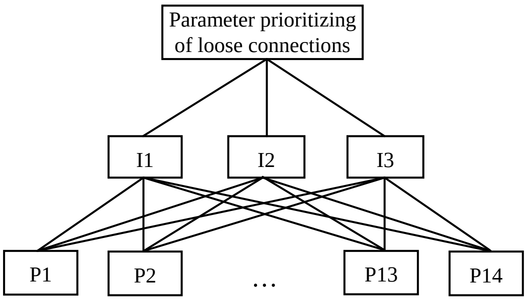

Figure 2. Parameters prioritizing Hierarchy of loose connections (The letter I refers to the scale and P refers to the parameter)

Second step: decision making matrix and couple comparisons

After defining the parameters and indicators, first of all the couple comparison between indicators has been done and this procedure has been repeated for parameters based on each indicator till the priority of one parameter over the other become obvious, then the scores given by the evaluation group are brought together in Decision Making (DM) matrix and the results have been inserted into the decision making model in order to give more understanding of the whole system. According to I1,I2 and I3 definition as three indicators and P1,P2,….and P14 as the parameters of loose connections modification, it is clear that the DM matrix for 3×3 indicators and 14×14 parameters have been defined based on each indicator.

It should be stated that for completing matrix of the couple comparisons based on AHP model, 1 to 9 weight measurement is used for determining the relative importance of one option to the others [8]. After couple comparison, by numeral average, the skilled experts' opinions have been considered as the main matrix. The arithmetic mean of all matrixes should be calculated in order to obtain the main matrix relative weight.

In the matrix tables I and II in order, based on the AHP pattern, the normalized results of indicators couple comparing to each other and the parameters versus the indicators for the loose connection factors are shown.

Table I. The normalized matrix results of couple comparing indicators and relative weights

Indicators	I1	I2	I3	relative weights
I1	0.14	0.14	0.15	0.14
I2	0.29	0.29	0.75	0.44
I3	0.57	0.57	0.10	0.42

Table II. The normalized matrix results of couple comparing parameters versus indicators and relative weights

Indicator / parameter	I1	I2	I3
P1	0.07	0.09	0.04
P2	0.10	0.08	0.11
P3	0.05	0.06	0.03
P4	0.07	0.08	0.05
P5	0.06	0.06	0.08
P6	0.03	0.05	0.03
P7	0.07	0.05	0.02
P8	0.04	0.06	0.04
P9	0.06	0.08	0.09
P10	0.17	0.08	0.04
P11	0.02	0.03	0.07
P12	0.05	0.06	0.04
P13	0.07	0.08	0.28
P14	0.17	0.15	0.09

Third step: weights combination

After defining relative weights using AHP model process, pure weight and based on that the parameter prioritizing has been obtained.

Fourth step: incompatibility rate

In this stage, the incompatibility rate should be calculated in order to clarify whether there is compatibility between couple comparisons; therefore Weight Sum Vector (WSV) should be calculated using equation 1 [8]:

$$\mathrm{WSV} = \mathrm{D} \times \mathrm{W} \quad (1)$$

Which in this relation D is as matrix of the couple comparisons and W as relative weights, then the Compatibility Vector (CV) which is obtained based on the division of factors of the weight sum vector on the relative weights vector should be calculated.

Incompatibility Index (II) is calculated from equation 2 [8]:

$$(2)\ \mathrm{II} = \frac{\lambda \max - \mathrm{n}}{\mathrm{n} - 1}$$

In this relation n presents the number of indicators and $\lambda_{\max}$ presents the greatest amount of couple comparisons matrix which equals the arithmetic average of the CV elements. The stated outcomes based on the AHP model in this paper have been resulted with the incompatibility rate of 0.057.

ANALYSIS OF AHP MODEL RESULTS COMPARING WITH THE PRACTICAL RESULTS

The results of investigating the activities done in 12 months in Guilan Power Distribution Company in the field of loose connections in medium voltage network and comparing it with the results from AHP model which have been explained in the previous section all are shown in Figure 3. The comparison outcomes show that the parameters prioritizing of loose connections modification should be changed in some cases. For instance, as the results show, at this moment, fault elimination is done in jumper modification, faulty insulators replacements, tree management, cut out fuse modification in order. While based on the results of the AHP model, it is deduced that these priorities should relatively change according to the local conditions, for instance AHP model states that the parameter of tree management is of greater importance comparing to other parameters in places such as Guilan state. This parameter is at the third level of importance in the practical model. According to the outcomes of AHP model should act with higher priority for fault elimination of parameters of transformer, electrical panel and cable shoes connections to which less attention is paid at the moment in comparison with other parameters of loose connections. The investigations also has been shown that the volume of actions done for bounding renovation and cut-out fuse modification in respect of other loose connections parameters is relatively compatible with the results of AHP model.

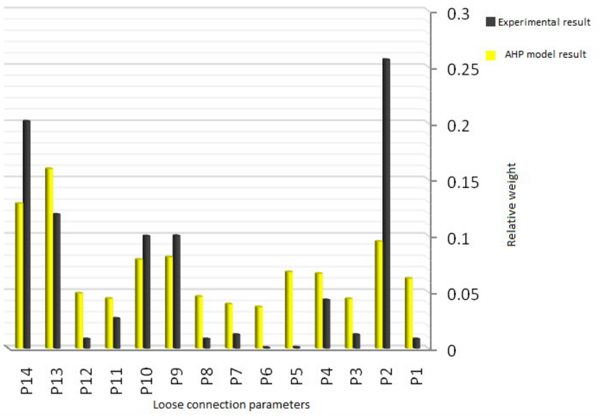

Figure 3. results comparison of AHP and experimental models

CONCLUSION

The PM employment which is nowadays a powerful tool for improving the productivity of organizations and factories all over the world can become a useful means in order to decrease the production costs and increase effectiveness and efficiency of equipment in power industry, so that appropriate preparation and spreading the maintenance culture in power industry are of main prerequisites of proper application of PM and more attention is needed to this matter. According to the broadness of power distribution installations, defining a priority in scheduling for visiting and doing preventive maintenances is of great importance. According to the indicators of budget, time and plenty of faults, the investigations on AHP results and comparing them with practical results show that the priorities of activities in the loose connection modification part which is partly done subjectively and based on the current conditions of branches of the company, should be modified in some of the parameters based on the scientific outcome and also some of special local conditions, in defining these priorities, should be considered. It is obvious that this model can be used for all systematic repairing models.

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