Available online at www.sciencedirect.com
ScienceDirect
Electric Power Systems Research 78 (2008) 566–583
ELECTRIC POWER SYSTEMS RESEARCH
www.elsevier.com/locate/epsr

Estimation of overhead line condition

S.J. Gusavac *, M.D. Nimrihter, Lj.R. Geric

Department of Power, Electronics and Communication Engineering, Novi Sad, Serbia

Received 21 April 2006; received in revised form 29 January 2007; accepted 7 May 2007
Available online 20 July 2007

Abstract

The ranking of old overhead lines with respect to their refurbishment requirements, according to reliability-centered maintenance (RCM) methodology, is based on two values: condition index and importance index. This paper describes a proposed methodology for determining the overhead line condition index by applying fuzzy mathematics. A determination of the overhead line condition index is proposed based on: (1) building elements condition index, (2) condition index of conductors, (3) condition index of protection against lightning impulse, (4) conductor accessories condition index and (5) line route condition index. The value of the indicated indices is determined as a result of detailed inspection of the condition of overhead line components. The inspection is made for the purpose of observing the degree of aggravation of their instantaneous condition in relation to their designed condition. On the basis of the estimation of condition aggravation rate by using fuzzy rules and membership functions, we obtain values for each of the above listed partial condition indices. By combining all the listed partial indices into a uniform grading we get the overhead line condition index. It represents a basis for the objective determination of priorities for taking proactive maintenance actions for the purpose of diminishing the risk of old overhead line operation.

Keywords: Overhead line; Asset management; Reliability-centered maintenance; Condition index; Proactive maintenance

1. Introduction

When approaching the end of the service life of an overhead line, the risks of its use increase. This is a consequence of getting old, which causes more frequent defects, longer maintenance times, a larger number of replaced spare parts, and the requirement for more frequent and detailed inspection of overhead line condition. Altogether, this results in an increase of costs regarding the stated overhead line. Through consideration of the history of events and diagnostic checks of overhead line components (conductors, earth wires, insulators, towers, foundation, earth electrodes, conductor accessories), the condition of the overhead line is estimated and a plan for the elimination of the observed deficiencies made. Papers [1,2] consider the problems of overhead lines getting old in detail as well as the activities to be taken for the elimination of such problems. Paper [3] shows the review of possible strategies for solving the problems of older overhead lines, which are divided into proactive (intensive maintenance, refurbishment, extension of service life, decommissioning) and reactive (fast restoration, insurance, installation of new lines). When the risk is too high due to predictable events, it is to be diminished by the relevant proactive actions, since they lead to reduction of possible defects. If the risk is too high due to unpredictable events, it is to be diminished by reactive actions, which do not influence the possibility of defect appearance, but alleviate its consequences. If the refurbishment of an old overhead line is not foreseen in the near future by replacing some of its components; in order to put its operation within the acceptable limits, it is subjected to an action of intensive maintenance (longer duration of repair, more frequent repair, more frequent inspection of its condition, etc.). Prematurely taking proactive maintenance actions results in an unnecessary increase of investments into new elements, while the delay in taking such actions results in inadequate reliability and increased costs due to the increased number and duration of failures. All this points to the fact that the inspection of overhead line condition and its more reliable estimation are of exceptional importance. Decisions on the time and type of proactive maintenance action, in addition to the overhead line condition index, depend on its importance index. By the overhead line importance

* Corresponding author at: Department of Power, Electronics and communication Engineering, Faculty of Technical Sciences, University of Novi Sad, Fruskogorska 11, 21000 Novi Sad, Serbia. Tel.: +381 21 6 350 650; fax: +381 21 450 028.
E-mail address: straki@uns.ns.ac.yu (S.J. Gusavac).

0378-7796/$ – see front matter © 2007 Published by Elsevier B.V.
doi:10.1016/j.epsr.2007.05.001

index, the consequences of overhead line failure to the electric power system are evaluated.

Ever increasing consideration in the business operations of transmission companies is given to the manner of decision-making on the moment for the refurbishment of overhead line components, since a significant number of overhead lines in operation show the problems which are the consequence of getting old. Frequently, the refurbishment of old overhead line is reduced to the selection of new and qualitative construction of conductors, without necessity for more important refurbishment of its other parts, first of all foundations and towers. This usually results in an increase of transmission capacity and the improvement of reliability parameters for the overhead line. From the point of view of the electric power system as a whole, this may cause less necessity for the installation of new overhead lines as the consequence of risk diminishing, due to fewer situations in which the line is restrictive in the transmission of energy. Since the financial resources required for the refurbishment of conductors, when retaining the existing foundations and towers, are 40–50% of the price for new line installation [4], this leads to a reduction of necessary investment into new overhead lines.

The objective of this paper is to show a procedure for the determination of overhead line condition index by using fuzzy mathematics, which represents the numerical expression of the degree of its condition aggravation and the basis for the selection of the maintenance actions to be taken. The main reason for such an approach is that experts in overhead lines maintenance mostly express the condition of its components in a descriptive way.

2. Methodology for considering overhead line condition and its estimation on the basis of operational data

In order to ensure the long service life of overhead line components, monitoring of their condition should be an activity of high priority. This particularly applies to overhead lines which are near the end of their service life, since that is when the properties of material used in their elements are distinctly aggravated. Hence, the increase of efficiency level in overhead line operation is directly dependent on using statistical data which comes out of the history of their operation. For thorough consideration of reliability problems, due to the abundance of required data in the analysis, and for the successful functioning of the maintenance system, it is necessary to have the relevant information system available. Its fundamental objective is to generate data which enables the execution and monitoring of all works of maintenance for the purpose of increasing the operational reliability of elements and optimisation of maintenance costs [5]. The data on the financial indicators of overhead line connected to its operation, failures, preventive checks, diagnostic checks and repair, make one of the bases for economic evaluation of overhead line maintenance and decision-making on the moment when maintenance actions are to be taken.

Fig. 1 shows the proposed algorithm for overhead lines management. The starting point of the algorithm is made by the estimation of overhead line condition, on the basis of data processing from the operation, from the relevant database on the overhead line. The estimated index value of overhead line condition is obtained on the basis of this data. It represents the rate of condition aggravation in relation to the new overhead line, and is one of the basic values for decision-making on how the overhead line is to be dealt with during the next planned maintenance period. The last 5-year period of operation is, as a rule, a sufficient basis on which the value of condition index can be estimated well.

The estimated value of the condition index has been set to lie within the range from 0 to 100, and depending on its value, the following are carried out on the overhead line:

1. detailed inspection of overhead line condition (estimated value of condition index from 60 to 100);
2. increased level of overhead line maintenance (estimated value of condition index from 30 to 60);
3. usual level of maintenance which corresponds to a new overhead line (estimated value of condition index from 0 to 30).

The main topic of this paper is the determination of overhead line condition on the basis of results of detailed inspection of condition expressed by the so-called overhead line condition index. This is the overhead line rate of condition aggravation and also the base for making the decision on the necessity for taking proactive maintenance actions. Once the lines on which proactive maintenance actions will be taken are determined, it is necessary to determine the sequence of these actions. This decision, according to RCM method, is made on the basis of overhead line condition index and importance index. Finally, when the ranking of lines is made with respect to taking proactive maintenance actions, if changes to the essential parameters of a line occur from the planning aspect (failure rate, transmission capacity, etc.), the process of network planning can begin. In this, the evaluation of the asset manager regarding the sequence of proactive maintenance on overhead lines was taken into account.

2.1. Estimated value of overhead line condition index, based on the data from operation

The initial estimation of overhead line condition index is made on the basis of available information from the history of operation. In order to come to an estimated value of condition index it is necessary to determine the acceptable values of individual values from the operation for the particular overhead line, depending on the conditions of its usage (e.g. existence of pollution) and construction (voltage level, type of conductors, type of towers, etc.). The estimated value of overhead line condition index is determined on the basis of:

1. index of financial aspects of overhead line usage;
2. index of the number of damaged overhead line components;
3. index of overhead line tendency towards failure;
4. index of successful planning of overhead line maintenance.

Increases in financial resources for maintenance, increases in the number of damaged components, increases in failure risk, and longer periods of maintenance (especially corrective), are all indicative of the overhead line condition worsening. These