Chapter 13
Multi-Criteria Evaluation of Reconstruction Strategies for Distribution Power Networks Designed for Rural Power Supply

Tamara Leshchinskaya
Russian State Agrarian University – Moscow Timiryazev Agricultural Academy, Russia

Pavel Podobedov
Federal State Budgetary Scientific Institution, Federal Scientific Agroengineering Center VIM, Russia

Pavel Maslennikov
Federal State Budgetary Scientific Institution, Federal Scientific Agroengineering Center VIM, Russia

Anton Nekrasov
Federal State Budgetary Scientific Institution, Federal Scientific Agroengineering Center VIM, Russia

Alexey Nekrasov
Federal State Budgetary Scientific Institution, Federal Scientific Agroengineering Center VIM, Russia

ABSTRACT

The rural distribution network has deteriorated. This is due to the high failure rate of electrical equipment, high maintenance costs, reduced power quality, and the increased duration of power outages in agricultural production. This leads to a short supply of electricity, downtime of processing equipment, loss of production or production of low-grade products, as well as excessive energy losses during transmission. The important issue is the development of advanced methods for assessing the feasibility and effectiveness for component replacement of power transmission equipment with newer and more modern, reducing electrical energy loss in the distribution network. To solve these problems, various strategies have been developed and studied to improve the reliability of 10 kV overhead power lines by using modern insulators, wires, and supports.

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INTRODUCTION

Because of high wear level of power distribution networks, particularly that of network equipment (to 75%) and due to the worsening of maintenance quality, duration of power supply outages at sites is as high as 100 h to 120 h per year, while electric energy loss attains 20% to 30%. Voltage deviation is estimated to be in the range of –15% to +15%, at consumer's side. Asymmetry of voltages and currents, as well as harmonic distortion factors of voltage and current exceed essentially their highest permissible values which leads to undersupply of electricity and, therefore, to additional loss of electric energy and to low-quality products manufacture (Gerasimenko & Fedin 2008).

The major direction of reliability enhancement of 10 kV overhead lines is renovation of electric equipment fleet, improvement of operation performance, cost reduction of components, as well as the development of methods making it possible to evaluate the expediency of network components replacement. An important issue is reducing electric power loss, in 10 kV distribution lines, owing to the application of up-to-date equipment.

Recently, concepts and methods have been proposed enabling to optimize performance of power supply systems (PSS) based on the principles of decision analysis and multicriteriality (Knyazev 2005, Leschinskaya & Volkova 2018, Leschinskaya & Knyazev, 2016).

Method of multi-criteria efficiency evaluation of various 10 kV OHL configurations application has been developed, and the most viable re-equipment strategies were selected on its basis.

Purpose of research was to develop multi-criteria evaluation methods for the proposed reconstruction strategies for 10 kV OHLs to define optimal re-equipment options, based on the reliability indicators of electric components used in power distribution network sections.

DATA AND METHODS

Based on results of expert surveys followed by their analysis and on those of sampling statistical data related to 10 kV power distribution networks, reliability levels of currently operated lines have been studied. These studies made it possible to define the most perspective equipment for 10 kV OHL renovation. Multi-criteria evaluation was made for two options of partial criteria combinations followed by their convolution into an entire composed evaluation function. These results were obtained based on Bayes's criterion with the use of fuzzy-set theory. In the frames of multi-criteria model, parameters optimization was performed in accordance with the following algorithm:

- Development of strategies for operation performance improvement of 10 kV power distribution lines with the purpose of power supply reliability enhancement and electric energy quality perfection
- Selection and scientific description of partial criteria for practicability evaluation of electric equipment application designed to enhance power supply reliability and to reduce energy loss, in 10 kV power distribution networks
- Development of mathematical models for partial-criteria-based evaluation including analytical equations for partial criteria
- Selection of uncertainty factor for environment expressed in form of growth factor for perspective load extension (Leshchinskaya & Knyazev 2006)