Intensification of Emergency and Restoration Maintenance of Overhead Lines of Distribution Networks Using UAVs

Oleksandr KOZLOVSKYI
Department of Electrical Systems and Energy Management
Central Ukrainian National Technical University
Kropyvnytskyi, Ukraine
0000-0001-6885-5994

Dmitro TRUSHAKOV
Department of Automation and Control in Technical Systems
Central Ukrainian National Technical University
Kropyvnytskyi, Ukraine
0000-0003-0326-2383

Oleksandr SAVCHENKO
Department of Power Supply and Energy Management
State Biotechnological University
Kharkiv, Ukraine
0000-0002-6401-0852

Serhiy RENDZINYAK
Faculty of Electronics and Computer Technologies
Ivan Franko National University of Lviv
Lviv, Ukraine
0000-0003-4544-4871

Vasyl KORUD
Institute of Power Engineering and Control Systems
Lviv Polytechnic National University
Lviv, Ukraine
0000-0002-1289-3534

***Abstract*—The problem of organizing emergency and restoration maintenance of overhead power lines of distribution networks 0.4–10 kV and ways of intensifying response to failures using unmanned aerial vehicles (UAVs) are considered. A stochastic parallel cluster model of emergency maintenance is developed, in which the UAV is considered not as an additional repair channel, but as an asynchronous information resource to support dispatching decisions. An analytical criterion for choosing a rational dispatching strategy is formed and parametric modeling is carried out to determine the limits of the effectiveness of the parallel algorithm depending on spatial-logistic and meteorological factors.**

Keywords—overhead power line, aerial inspection, UAV, information channel, stochastic model, parametric simulation

I. INTRODUCTION

Modern distribution grids operate in conditions of increasing electricity consumption, accelerated integration of renewable and distributed energy resources, and increased requirements for the safety and reliability of electricity supply [1]. An additional risk factor is the progressive aging of the grid infrastructure. The European Commission notes that about 40% of the EU distribution grids have been in operation for more than 40 years, which necessitates their large-scale modernization. A similar problem is typical for Ukraine: the Energy Security Strategy of Ukraine states that the wear and tear of electrical grids is more than 50% of their total volume, and the wear and tear of individual electrical grid facilities in individual companies reaches more than 70% [2, 3]. Under such conditions, the failure rate of electrical grid elements becomes non-stationary, in particular due to aging and wear processes, and can be described by reliability functions based on the Weibull distribution [4]. This complicates the planning of repair resources and reduces the effectiveness of purely deterministic approaches to the operation of power grids.

A significant limitation of existing algorithms for emergency and restoration maintenance is the organizational and logistical delay [5], [6]. The elimination of stochastic damage is usually implemented as a multi-phase sequential process, in which one of the most lengthy and uncertain components is the ground search for the location of the damage to the overhead line (OHL) by the Mobile Operations Crew (MOC) [7, 8]. The duration of this stage increases for long sections, branched networks, hard-to-reach areas and in conditions of mass failures [8].

One of the technological means of reducing the time for damage localization is the use of UAVs [9, 10]. In the practice of operating power grids, UAVs are most often considered as a tool for scheduled inspections, monitoring the technical condition or additional visual inspection of overhead lines [11]. A separate area of research is related to assessing the effectiveness of different types of aircraft for overhead line inspection [12]. At the same time, the issue of using UAVs as an information resource in the emergency response algorithm remains insufficiently formalized.

To describe the processes of servicing requests in power systems, the apparatus of the theory of mass service is used, in particular for modeling the work of operational on-site crews as channels for servicing emergency requests [13, 14]. Existing models are mainly focused on assessing the load of repair crews, the waiting time for requests or the required number of service channels or routing crews for known damage locations [13]-[15]. In modern studies, the problems of emergency and restoration of distribution networks are also formalized as problems of stochastic routing of repair crews and network reconfiguration under conditions of uncertainty of repair time and workload [15]. At the same time, the stage of operational obtaining of information about the location and nature of the damage, in particular with the use of UAVs, is mostly taken outside of the mathematical model.

Thus, it is relevant to develop a stochastic model of dispatching decision support that allows assessing the technical feasibility of using UAVs in emergency and restoration maintenance of overhead lines of distribution networks. Such a model should take into account the time of visual search for damage, the availability of MOC and UAVs, the probability of obtaining useful diagnostic information, and additional logistical delays that arise during the use of an unmanned complex.