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Feasibility study of the implementation of A.I. automation techniques in modern power distribution networks

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ABSTRACT

Contemporary power distribution networks are no longer regarded as passive power system elements. On the contrary, novel control systems are being constantly developed over the last decade, aiming to achieve reliability improvement and operational optimization by means of power loss reduction, prompt fault detection and power restoration etc. A crucial aspect of the systems developed to achieve these goals will inevitably be their ability to integrate new functions without the need for further investment. In this paper, a multi agent system (MAS) initially developed for fault detection and power restoration is studied with respect to these issues. More specifically, a feasibility analysis is conducted regarding the implementation of the MAS on a segment of the underground 20 kV power distribution network of the city of Thessaloniki, Greece. The analysis focuses on the initial investment cost and the payback of the application, as well as on the additional benefits for the power distribution system operator due to the system reliability improvement. The ability of the MAS to incorporate loss reduction algorithms without further investment is also studied, and the respective benefits of the power distribution system operator are analyzed. Moreover, the feasibility analysis is generalized so as to be able to be applied to any power distribution automation implementation with similar attributes.

1. Introduction

One of the most critical issues concerning contemporary power distribution networks is their classic treatment by the power companies as passive elements within the power systems. This classic treatment can be clearly observed in the traditional configuration of these systems, as in most cases the power companies have no feedback concerning the real time status of their networks at medium voltage (MV) and low voltage (LV) level. More specifically, the power companies usually have at their disposal information concerning real time operation at the level of the high voltage (HV) to MV power substations separating the power transmission from the power distribution networks. Moreover, in many countries including Greece, most switching operations at these voltage levels (except of the ones at the aforementioned HV/MV power substations) are performed manually. Consequently, any power restoration procedure after a fault takes a considerable amount of time, as it basically consists of the dispatch of a technical crew, which conducts a series of manual operations at the MV/LV substations aiming to locate and isolate the fault.

For several decades, this traditional power distribution system configuration worked without presenting significant problems. Over the last decades however, the power consumption has increased dramatically, especially in urban areas. It is estimated that the largest proportion of losses in power networks corresponds to distribution networks; for a typical system in a developing country, distribution losses account for approximately 8% of the total electrical energy produced [1]. Moreover, an additional issue is imposed by the nature of urban power consumption, which is characterized by significant reactive power flow due to the massive deployment of residential air-conditioning units. These issues have demonstrated the importance of concepts such as power distribution automation and power loss reduction.

Automation has been applied to power distribution networks in order to achieve significant service reliability improvement for electricity customers [2–4]. Other approaches investigate reliability improvement and interruption cost minimization based on appropriate switch location or relocation across a distribution feeder [5,6]. Finally, significant research has been conducted on loss reduction in distribution systems via network reconfiguration. These applications are based on the development of algorithms for switching operations utilizing heuristic, fuzzy logic and other approaches [7–9].

An important aspect concerning any investment towards the aforementioned goals is the ability of the deployed system to be

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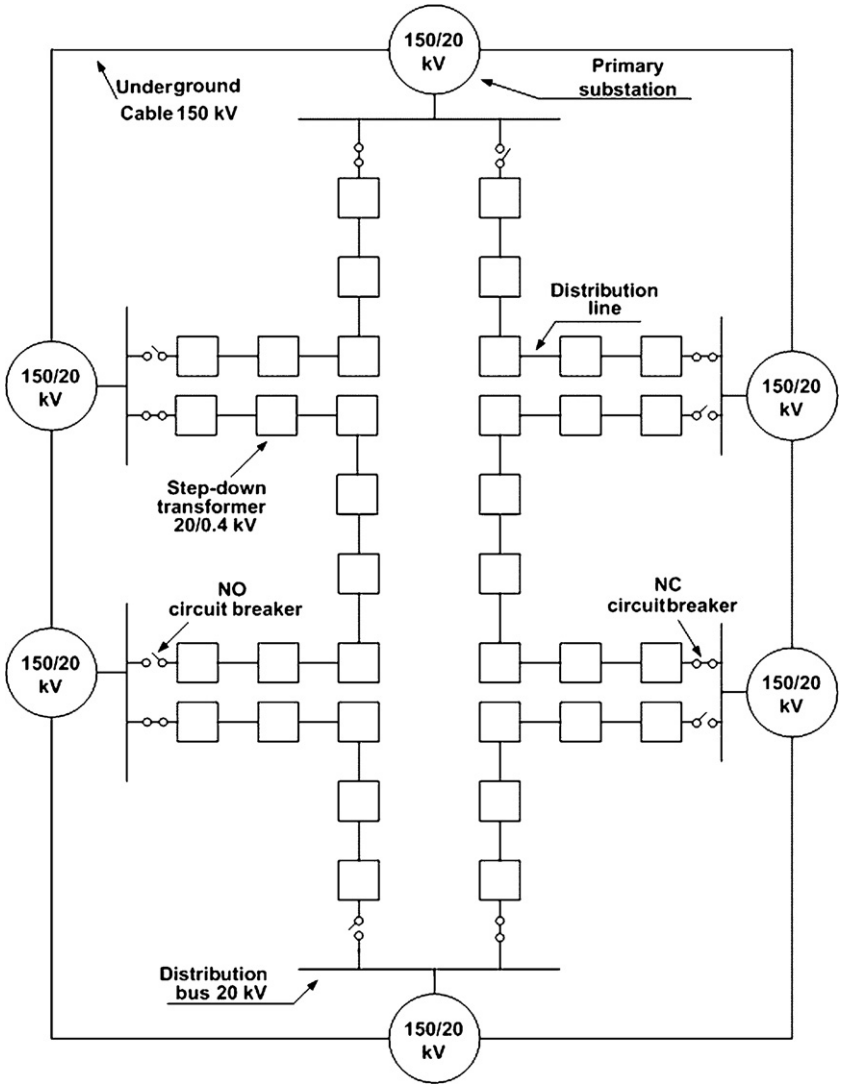

Fig. 1. Typical topology of distribution networks.

enhanced by incorporating additional functions. Moreover, the proposed systems found in the literature are usually based solely on theoretical assumptions, and are seldom tested with regard to data originating from real power distribution networks.

In this context, this paper investigates the economic viability concerning the deployment of a multi agent system (MAS) proposed in Refs. [10–12]. The MAS considered was originally designed for fault detection and power restoration. In this paper, the MAS is considered to be deployed on a real segment of the power distribution network of the city of Thessaloniki, Greece, and its performance is assessed by the use of information regarding the specific segment's actual loading profile. Moreover, the MAS ability to incorporate power loss reduction techniques by means of upgrading its software is studied.

In the second part of the paper, the necessity for the development of a power distribution automation system is analyzed. The operation of the MAS is explained, and techno–economical information regarding its implementation is offered. The techno–economical information is also linked to all power distribution automation systems with similar attributes. In the third part, essential operational aspects concerning power production, transmission and distribution in Greece are presented, and the cost and potential benefits concerning the implementation of automation techniques on power distribution networks are presented. Moreover, the segment of the power distribution network of the city of Thessaloniki used for the assessment of the MAS is presented. Details regarding its topology and the nominal characteristics of its transformers are provided along with the essential investment cost regarding the MAS implementation. In the fourth part of the paper, the payback of the investment concerning the MAS implementation on the specific network segment is specified. Furthermore, additional benefits from the system reliability improvement due to the implementation of the MAS at the specific network segment are presented. The analysis is based on real load curves concerning typical working days. Finally, in the fifth part of the paper the essential algorithms are presented, which will have to be incorporated to the MAS in order for it to provide power loss reduction functionality. In addition, the respective benefits for the power distribution system operator concerning the implementation of these algorithms are presented.

2. Power distribution automation systems

2.1. Necessity of development

Power distribution systems in Greece consist of groups of interconnected radial circuits, as shown in Fig. 1. The power lines