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Protection Systems in the Integration of Renewable Energy Sources in City Power Supply

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Annotation. *The article addresses the issues related to the protection systems of integrated microgrids, which ensure uninterrupted and high quality power supply to all types of electrical consumers connected to the city power supply system. It elaborates on the technical challenges in microgrids, abnormal operating conditions in the power supply, and potential faults. The analysis highlights both internal and external factors that must be considered when applying protection systems for microgrids supplying electrical energy to city areas. Additionally, recommendations have been developed regarding optimal protection systems for city power supply microgrids.*
Key words: *Protection system, optimal location, integrtion, city power suppy, microgrids.*

Introduction. Renewable energy sources such as solar, wind, and biomass are crucial for transforming the global energy system and reducing carbon emissions. The integration of these renewable energy sources into urban power supply systems can enhance sustainability, reduce environmental impact, and strengthen energy security. However, incorporating renewables into city power networks presents various technological and engineering challenges. Since renewable sources are inherently variable and difficult to predict, maintaining stability within the system becomes a complex task. Therefore, modern protection systems play a vital role in ensuring the successful integration of renewable energy into urban power grids. This article focuses on the safety and reliability challenges encountered in integrating renewable energy sources into city power supplies. By examining protection systems and the requirements they must meet, it aims to provide a deeper understanding of the existing issues and their solutions. Furthermore, it offers recommendations on leveraging advanced technologies to stabilize energy supplies and support the smooth integration of renewable energy into urban power systems. Currently, city power supply systems undergo considerable change in operating requirements – mainly as a result of deregulation and due to an increasing amount of distributed energy resources (DER). In many cases DER include different technologies that allow generation in small scale (micro-sources) and some of them take advantage of renewable energy resources (RES) such as solar, wind or hydro energy. Having micro-sources close to the load has the advantage of reducing transmission losses as well as preventing network congestions. Moreover, the chance of having a power supply interruption of end-customers connected to a low voltage (LV) distribution grid (*in Uzbekistan three phase 380 V and single phase 220 V*) is diminished since adjacent micro-sources, controllable loads and energy storage systems can operate in the islanded mode in case of severe system disturbances. This is known today as a microgrid. The typical Microgrid has the same size as a low voltage distribution feeder and will rare exceed a capacity of 1 MVA and a geographical span of 1 km. Usually more than 90% of low voltage domestic customers are supplied by underground cable when the rest is supplied by overhead lines. The Microgrid often provides both electricity and heat to the consumers by means of combined heat and power plants (CHP), gas turbines, fuel cells, photovoltaic (PV) systems, wind turbines, etc. The energy storage systems usually include batteries and flywheels [1, 4, 18]. The integration of microgrid systems into city power supply networks is becoming increasingly widespread, bringing new opportunities along with certain risks and challenges, particularly related to protection systems. These systems play a critical role in ensuring the efficiency and reliability of microgrids. Microgrids are often based on various energy sources, such as solar, wind, and other renewable resources, making their integration much more complex compared to traditional power distribution systems. As a result, protection systems in microgrids must be adaptive to various operating modes, rapid load changes, and other emergency conditions [2, 16].

Addressing these challenges requires new approaches, including the development of smart protection systems and advanced real time monitoring technologies. Thus, research and advancement in microgrid protection systems are crucial for enhancing the stability and efficiency of modern city power supply systems.

The main part. Currently, it is important that all types of electrical network elements located in the electrical power system of Uzbekistan, and, moreover, in countries independent of the world in the field of electrical energy, work in the normal mode in the long-term.

One of the major challenges is a protection system for microgrid which must respond to both main grid and microgrid faults. In the first case the protection system should isolate the microgrid from the main grid as rapidly as necessary to protect the microgrid loads. In the second case the protection system should isolate the smallest part of the microgrid when clears the fault [15, 20]. A segmentation of microgrid, i.e. a creation of multiple islands or submicrogrids must be supported by microsource and load controllers. In these circumstances problems related to selectivity (*false, unnecessary tripping*) and sensitivity (*undetected faults or delayed tripping*) of protection system may arise.

Some issues related to a protection of microgrids and distribution grids with a large penetration of DER have been addressed in recent publications. Basically, there are two main issues, first is related to a number of installed DER units in the microgrid and second is related to an availability of a sufficient level of short circuit current in the islanded operating mode of microgrid since this level may substantially drop down after a disconnection from a stiff main grid. In [3] the authors have made short circuit current calculations for radial feeders with DER and observed that short circuit currents which are used in over current (OC) protection relays depend on a connection point of and a feed-in power from DER. Because of these directions and amplitudes of short circuit currents will vary. In fact, operating conditions of microgrid are constantly changing because of the intermittent microsources (*wind and solar*) and periodic load variation. Also a network topology can be regularly changed aimed at loss minimization or achievement of other economic or operational targets. In addition controllable islands of different size and content can be formed as a result of faults in the main grid or inside a microgrid.

In such circumstances a loss of relay coordination may happen and generic OC protection with a single setting group may become inadequate, i.e. it will not guarantee a selective operation for all possible faults. Therefore, it is essential to ensure that settings chosen for OC protection relays take into account a grid topology and changes in location, type and amount of generation. Otherwise, unwanted operation or failure to operate when required may occur [4-6].

In order to cope with bi-directional power flows and low short circuit current levels in microgrids dominated by microsources with power electronic interfaces a new protection philosophy is required, where setting parameters of relays must be checked/updated periodically to ensure that they are still appropriate. This report presents a novel adaptive microgrid protection concept using advanced communication system, real-time measurements and data from off-line short circuit analysis. This concept is based on an adaptation of protection relay settings with regard to a microgrid state (*topology, generation and load status*). Further, on the hardware realization (*basic components, communication, etc.*) of this concept and numerically simulated test results are presented and discussed.

The main damage that occurs in the microtars of the urban power supply system is a short circuit. During a short circuit, the current strength increases, the voltage value decreases. At the short junction point, however, the internal resistance approaches the value 0. Short circuit currents are calculated based on each type of network, and protection types are selected [14, 17, 19].

Short circuit currents in electrical networks are calculated using several methods. The most common and widely applied methods are as follows: ***Total impedance method****:* this method is based on determining the short circuit current by taking into account the total equivalent impedance of the electrical network. The resistance and inductive reactance of each component in the network are summed, and then the total impedance is calculated. Using Ohm's law, the short-circuit current is determined; ***Symmetrical components method****:* this method is primarily used for asymmetrical short circuits *(such as phase-to-phase or phase-to-ground faults*). The symmetrical components method separates the asymmetrical currents and voltages in the network into three components: positive sequence, negative sequence, and zero sequence. These components facilitate the calculation of short circuit currents; ***IEC 60909 standard method****:* this international standard provides a method for calculating short circuit currents in electrical systems. It considers various system parameters, including generators, transformers, transmission lines, and loads. The standard is used to determine steady state and dynamic short circuit currents, as well as the duration of the short circuit; ***Graphical method****:* This method involves representing electrical system models through diagrams or graphical illustrations to determine short-circuit currents. It utilizes graphical representations of the system's phase and line voltages and currents; ***Per-unit system method****:* This method employs normalized values (*per-unit*) of the system components for short circuit current calculations. It enables easier comparison of system elements and facilitates faster calculation of short circuit currents; ***Software-based calculation****:* modern short circuit current analysis in electrical networks is performed using specialized software (*such as PSCAD, ETAP, MATLAB, DIgSILENT PowerFactory*). These programs allow for more precise calculations of short-circuit currents by considering the complexity of electrical networks. The choice of method depends on the complexity of the electrical system and the specific requirements of the calculations.

Currently, in modern city power supply microgrids, various protection systems are applied to ensure safety in the process of transmitting and distributing electrical energy. The primary protection systems include the following: ***Relay protection and automation:*** these systems automatically detect malfunctions in power grids and take the necessary actions. Relay protection continuously monitors current and voltage values in the grid, and if they deviate from the norms, it triggers switches or activates other protection devices. This protection prevents high and medium voltage surges from damaging the grid and its equipment [7-9, 13, 18, 20].

These protection systems are applied in a comprehensive manner to ensure the reliable and safe operation of power grids. Regular training of personnel, monitoring the technical condition of protection devices, and compliance with safety regulations contribute to enhancing safety in city power supply microgrids.

As shown in Figure 1, there is a microgrid control center and interface protection in the substation. At each switchboard (SWB), there is microprocessor for unit protection (DER or load).

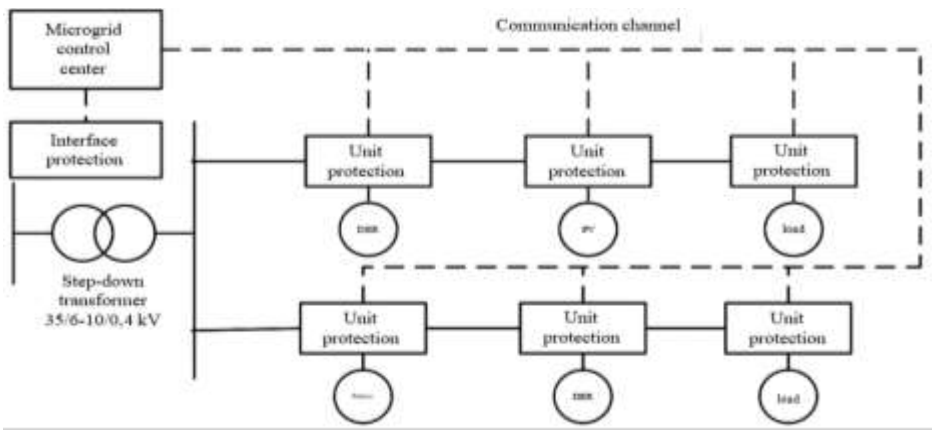

FIGURE 1. Protection system configuration of city power supply microgrid.

The configuration of the protection system is shown in the Figure 1. Detection and isolation of the fault section can be realized using the protection system. The coordination of interface protection and unit protections can help isolate the smallest fault section. There is a control center to control the microgrid. The fault direction signal is exchanged between the interface protection and unit protections via a communication channel [Table 1].

We explored three scenarios with regard to fault position and the status of the microgrid: a) *Grid-connected mode*: utility grid fault; b) *Grid-connected and autonomous modes*: microgrid network fault; c) *Grid-connected and autonomous modes*: microgrid load fault [1, 3, 10-12].

Table 1

Component	Connection Type	Function
Microgrid Control Center	Communication Channel	Controls the entire system
Interface Protection	Protection Section	Connection protection
Step-down Transformer	35/6-10.0.4 kV	Transformation section
Unit Protection (DER)	Through Communication	Protects distributed energy resources (DER)
Unit Protection (PV)	Through Communication	Solar energy system protection
Unit Protection (Battery)	Through Communication	Battery protection
Unit Protection (Load)	Through Communication	Load protection

The configuration of the protection system for city power supply microgrids is a crucial issue because microgrids increase the complexity of the power supply system, and appropriate protection strategies are required to ensure their safe and reliable operation. This topic, from a scientific perspective, includes the following key aspects:

1. ***Basic requirements for the protection system.*** The protection system for city power supply microgrids must meet the following requirements: a) ***High sensitivity:*** Faults or disturbances in smaller microgrids must be quickly detected; b) ***Reliability:*** When faults are detected, the system should reliably disconnect without causing damage to other sections; c) ***Fast response:*** The protection system must respond promptly to faults and ensure the possibility of microgrid reconnection during this process.

2. ***Operational modes of the microgrid.*** **a)** ***Island mode:*** When the microgrid is disconnected from the main grid, it continues to supply electricity through internal sources (e.g., solar panels or backup generators). In this mode, the protection system primarily responds to internal faults; b) ***Grid-connected mode:*** When the microgrid is connected to the main power grid, faults can occur from both internal and external sources. The protection system must protect the microgrid and isolate grid faults.

3. ***Necessary protection systems.*** The following protection systems can be applied to microgrids: a) ***Differential protection:*** Used for transformers and cable lines. This system monitors the current flowing through the line and takes action when deviations occur, particularly during voltage drops or fluctuations in the microgrid; b) ***Short-circuit and overcurrent protection:*** Short circuits and overcurrent situations can cause significant damage to the microgrid. In such cases, the protection system automatically disconnects the microgrid. c) ***Coordination of power sources:*** When multiple sources are working together, coordinated protection systems are required. For example, if faults occur between diesel generators and solar power sources, coordinated disconnection is necessary.

4. ***Automation and intelligent protection.*** Modern microgrids are equipped with ***intelligent automated protection systems***, which offer the following capabilities: a) ***Monitoring and diagnostics:*** The system can detect and record faults within the grid; b) ***Flexible response:*** The system can operate in multiple modes. For instance, when the microgrid is separated from the main grid, the protection strategy automatically adjusts; c) ***Phase-shifting devices:*** These are used to control current direction and safely manage power flow.

5. ***Protection devices and relays.*** The main devices used for microgrid protection systems include: a) ***Protection relays:*** These devices automatically disconnect the grid in case of overcurrent or short-circuit events; b) ***Modern IED (Intelligent electronic device):*** These

devices are installed for monitoring and fault prevention. They monitor voltage, current, and frequency at every point of the microgrid.

Regardless of what type of protection is used for city power supply grids, all types of protection should work reliably and efficiently.

Conclusion. The research highlights the importance of robust and adaptive protection systems in integrated microgrids for city power supply. As microgrids become increasingly integrated into urban power networks, particularly with the rise of distributed energy resources (DER) and renewable energy sources (RES), traditional protection methods prove insufficient. The dynamic nature of microgrids, characterized by rapid load changes, fluctuations in power flow, and varying operating modes (islanded and grid-connected), demands advanced protection strategies. Key challenges, such as the need for selectivity, reliability, and sensitivity in detecting faults, emphasize the importance of modern protection solutions. Adaptive protection systems, real-time monitoring, and communication technologies are essential for ensuring stability and reliability in microgrids. The segmentation of microgrids into smaller, controllable islands during faults, as well as the coordination between interface protection and unit protections, are critical for isolating faults and minimizing disruptions. Ultimately, the development of smart protection systems tailored to the specific operational conditions of microgrids is crucial for maintaining high-quality, uninterrupted power supply to city electrical consumers. Continued research and innovation in this field will be necessary to address the growing complexities of city power supply systems as the integration of renewable and distributed energy sources expands.

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