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ELECTRICAL PROTECTION OF MICROGRIDS

PROTECȚIA ELECTRICĂ A MICROREȚELELOR

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Abstract: *The present work originates from the necessity of evaluating the electrical supply scheme of a bus charging station. Based on this framework, a microgrid model interconnected with the public network was developed, within which the calculations and dimensioning of short-circuit currents and transformer operating voltages were carried out. The determination and analysis of the nominal current capacities and voltage values were performed using the Etap simulation software.*

Keywords: Microgrid, Grounding system, IED, ETAP.

Rezumat: Prezenta lucrare pornește de la necesitatea evaluării schemei de alimentare cu energie electrică a unei stații de încărcare a autobuzelor. Pe baza acestui cadru, a fost dezvoltat un model de microrețea interconectată cu rețeaua publică, în cadrul căruia s-au efectuat calculele și dimensionarea curenților de scurtcircuit și a tensiunilor de funcționare ale transformatoarelor. Determinarea și analiza capacităților nominale de curent și a valorilor tensiunilor au fost efectuate utilizând software-ul de simulare Etap.

Cuvinte cheie: Microrețea, Sistem de împământare, IED, ETAP.

1. Introduction and purpose

Urban electromobility requires the development of reliable and efficient charging infrastructures. In this context, the analyzed scheme illustrates a microgrid dedicated to supplying a charging station for ten electric buses, with emphasis on transformer sizing, the protection systems employed, and energy distribution.

The study highlighted the necessity of investigating a complex system designed to manage the simultaneous electrical supply for a minimum of ten

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electric buses. For this purpose, the essential components and parameters of the system were analyzed, measured, and tested in order to evaluate its performance and reliability (microgrid).

Microgrids are complex power systems of limited size that can operate either connected to the local distribution network or in island mode, ensuring the efficient use of local resources. The electrical protection within a microgrid must be designed to address the specific conditions of islanded operation or connection to the public network. In this study, a microgrid model was developed under the assumption that the microgrid is connected to the public network. Short-circuit currents and transformer bus voltages were calculated and sized. The nominal breaking capacities and setting values were determined based on an ETAP simulation.

2. Methodology

The ETAP software was used for modeling and simulating the analyzed sistem.

The data collection was centralized and interpreted in the conclusions section.

Description of the microgrid and its parameters are described as following:

From the 110 kV busbar, the 20 kV area is supplied through 40 MVA transformers; The medium-voltage network (20 kV, 50 Hz) supplies the two transformers; Each transformer, with a power of 1000 kVA, converts 20 kV to 0.4 kV. On the 20 kV side, there is a 630 A disconnector for protection and maintenance;

On the low-voltage side (0.4 kV), the energy is distributed from 1000 A busbars.

2.1 Electrical Protection in Microgrids

The electrical protection within a microgrid must be designed to address the specific conditions of either islanded operation or connection to the public network.

Microgrid protection coordination involves [1],[2]: avoiding unintended disconnections; ensuring the overcurrent protection operates at values below the set limits; preventing loss of coordination between relays, fuses, and reclosers; and avoiding unwanted disconnection of energy sources.

Isolating the faulty component (installation) from the rest of the unaffected electrical systems while ensuring their continued operation under normal conditions; detecting abnormal (impermissible) operating conditions; selectivity; speed; sensitivity.

The protection system was sized according to the sensitivity factor k_{sens}:

$$k_{sens} = \frac{I_{sc.min.}}{I_{pp}}, \tag{1}$$

which *Isc.min.* represents the minimum value of the short-circuit current in the protected area, while *Ipp* is the starting current of the protection system.

Figure 1 presents the studied microgrid (charging stations for 10 buses); the microgrid is supplied by two transformer substations of 20/0.4 kV, 2 × 1000 kVA.

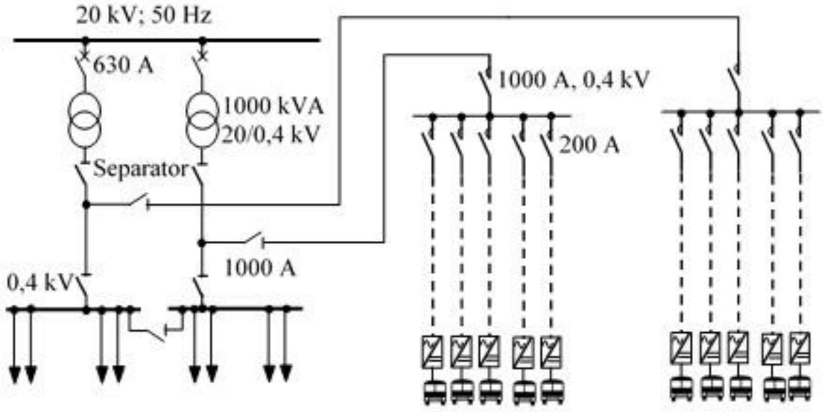


Fig. 1. Basic Diagram for the Charging Station of 10 Buses

The microgrid is supplied from the medium-voltage network (20 kV, 50 Hz) through two 20/0.4 kV transformers rated at 1000 kVA each, providing a total power of 2000 kVA for the charging station. Protection is ensured by a 630 A disconnector on the medium-voltage side, while distribution at low voltage (0.4 kV) is carried out via 1000 A busbars, with a 200 A branch dedicated to consumers. The scheme highlights the coordination of protection elements and the flexibility required for the simultaneous powering of electric buses.

Validation of the scheme requires simulations focused on two essential aspects:

Determination of the short-circuit current on the low-voltage side, to verify the capacity of the protection devices; evaluation of voltage level under simultaneous charging conditions.

2.2 Electronic protections using IEDs

The digital technology used in the protection system, equipped with IED (Intelligent Electronic Device) modules, enables bidirectional information exchange (interoperability) beetwen network operator and the load. This allows the implementation of control logic while considering the various available variables.

The protection-control devices and system allow remote access for maintenance activities, monitoring of transient phenomena (oscillograms), event and fault logging, and protection parameter monitoring [3],[4].

For the protection of each transformer in the charging station, the protection scheme indicated in figure 2 is proposed. In the diagram, the following notations are used:

TC – current measurement transformers

T – medium voltage/low voltage transformer (MT/JT)

51 – maximum current protection

87 – differential protection of the transformer

63 – Buchholz relay signaling/disconnection

71 – oil level absence signaling, Buchholz relay

Annex 1 (Fig. 3) and Annex 2 (Fig.4) present simulations of scenarios for calculating short-circuit currents and transformer bus voltages. Annex 1 presents a Short -circuit Current Calculation using ETAP. Annex 2 presents Voltage Calculation on Busbars Using ETAP.

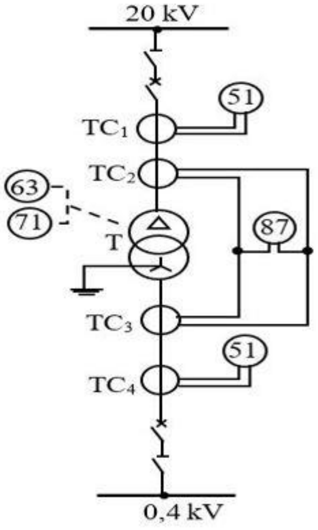


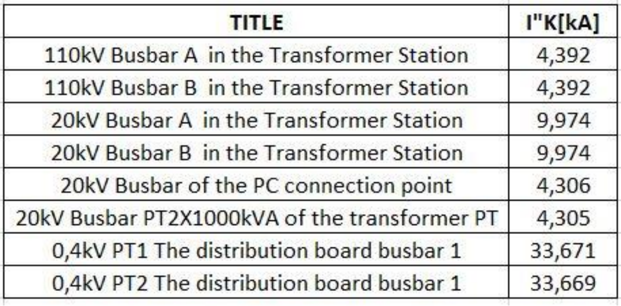
Fig. 2. Transformer protection scheme MT/JT

ETAP Simulation Results:

The short-circuit currents recorded on the transformer station busbars and the transformer substation busbars are presented in tabular form, under the scenario where all equipment installed in the low-voltage switchboard operates simultaneously.

Table 1 shows the results of the calculation of short-circuit currents in the charging station power supply diagram.

Table 1. **Short circuit current values**

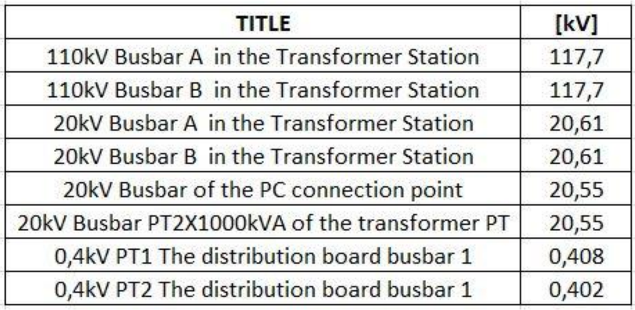


TITLE	I"K[kA]
110kV Busbar A in the Transformer Station	4,392
110kV Busbar B in the Transformer Station	4,392
20kV Busbar A in the Transformer Station	9,974
20kV Busbar B in the Transformer Station	9,974
20kV Busbar of the PC connection point	4,306
20kV Busbar PT2X1000kVA of the transformer PT	4,305
0,4kV PT1 The distribution board busbar 1	33,671
0,4kV PT2 The distribution board busbar 1	33,669

It is observed that the short-circuit current, at the medium voltage busbars, does not exceed the 10kA limit imposed by the Distribution Operator through "Technical Rules regarding Preliminary Verification for Connection to the Public Electricity Network of Generation, Generation/Consumption Installations, Power Increases, and Storage Installations".

Table 2 shows the results of the voltages calculation in the charging station power supply diagram. In normal operation, the voltages at the main busbars of the scheme were within the limits imposed by the distribution operator's standards [5].

Tabelul 2. **Voltage Values**



TITLE	[kV]
110kV Busbar A in the Transformer Station	117,7
110kV Busbar B in the Transformer Station	117,7
20kV Busbar A in the Transformer Station	20,61
20kV Busbar B in the Transformer Station	20,61
20kV Busbar of the PC connection point	20,55
20kV Busbar PT2X1000kVA of the transformer PT	20,55
0,4kV PT1 The distribution board busbar 1	0,408
0,4kV PT2 The distribution board busbar 1	0,402

2.3 Grounding Systems Protection

An essential role in the operation of the microgrid protection system is played by the grounding system of the installation, which ensures the system's reference potential as well as safety conditions for operating personnel.

In the event of lightning strikes on a structure (lightning rod), a transient increase in the grounding potential (CTPP) occurs as a three-dimensional function over time. Determining the CTPP is necessary for studying lightning overvoltages and analyzing electromagnetic compatibility [6],[7].

For the analyzed charging station, the implementation of a concentrated earthing installation in the form of an electrode was considered.

a) Concentrated Grounding Systems in Stationary Conditions

Since the electrical resistance of the concentrated grounding system Rp depends practically only on the soil resistivity, the electrode's electrical resistance can be neglected. For the analysis of these grounding systems, we will consider a hemispherical electrode, as shown in figure 5. The resistance Rp, resulting from the passage of electric current from the hemispherical electrode into the surrounding soil, is:

$$R_p = \frac{\rho}{2 \cdot \pi} \cdot \int_{r_0}^{\infty} \frac{dr}{r^2} = \frac{\rho}{2 \cdot \pi \cdot r_0}, \tag{2}$$

where ρ is the soil resistivity in Ωm and r_0 is the radius of the hemisphere.

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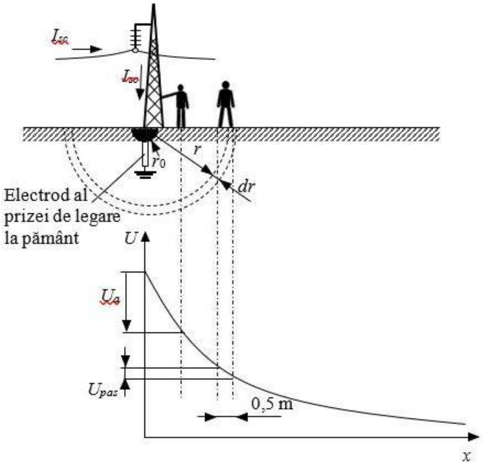

Fig. 5: Touch Voltage (Ua) and Step Voltage (Upas) in Case of a Fault on a Pole of an Overhead Power Line or Lightning Current Passing Through the Pole

The distribution of the electric field in the soil corresponds to a potential distribution of the form:

$$V_{r=x} = \frac{I_{sc} \cdot \rho}{2 \cdot \pi \cdot r}, \tag{3}$$

where *Isc* is the electric current that flows into the ground [8],[9].

b) Concentrated Grounding Systems in Transient Conditions

For transient lightning impulse currents exceeding a certain threshold, a decrease in the electrical resistance of the grounding system is observed. This reduction is attributed to ionization processes occurring in the soil around the electrode.

Figure 6 presents experimental results for the analyzed area, obtained for a conductor with rc = 2.5 mm inserted into organic soil with ρ = 200 Ωm, subjected to an impulse voltage with a front duration tf = (3…10) μs [10],[11].

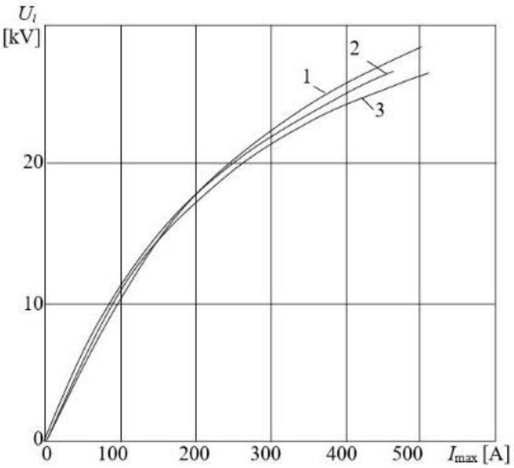

Fig.6: The dependence of the maximum electric current value on the applied impulse voltage and the front duration tf.: 1- t_f = 3 μs ; 2 - t_f = 5 μs ; 3 - t_f = 10 μs

In 6 Figure , it can be observed that the dependence between the applied voltage and the electric current is not linear due to the reduction in soil electrical resistance resulting from ionization processes at the contact between the electrode and the soil.[12,13].

3. Results

To ensure fast charging of the electric buses of the Transport Enterprise, a 10-terminal charging station powered by the public electricity grid was designed and dimensioned. The scheme was designed as a microgrid that can also operate in an islanded mode by powering it from a renewable energy source and connecting an energy storage system.

The calculations performed regarding short-circuit currents and the voltage level in the network, during normal operation, highlighted that the conditions for carrying out the work were met.

The electrical protection scheme with IED equipment provides real-time information to the distribution operator and the charging station operator, and will be adjusted as the station is powered by renewable sources. The proposed scheme for the protection of the 20/0.4 kV transformer that supplies the AC-DC converters was indicated. The evaluations carried out highlighted the fact that at the connection point to the distribution operator's network, the level of distortion of the voltage curve does not exceed the value allowed by the standards.

4. Conclusion

The aggregation of users with specific characteristics into a microgrid is a widely used solution in modern energy systems.The implementation of microgrids, oriented towards the efficient use of local energy sources, requires a thorough understanding of specific operating conditions and the adoption of appropriate protection measures against both internal and external faults.

The present study includes the calculation of fault currents in the power supply scheme by simulating the system on the ETAP platform, emphasizing the need to adapt the protection scheme according to the microgrid’s operating mode.

The study further addresses the calculation of short-circuit currents based on system simulations performed with the ETAP platform, underlining the importance of adjusting the protection scheme in relation to the microgrid’s operational regime. A protection scheme for transformers has been proposed, demonstrating that the proper functioning of the protection system, as well as ensuring workplace safety, depends on the adequate sizing of the microgrid’s grounding system.

The paper highlight that the efficiency of microgrids relies on adapting the protection scheme to the operating mode and on the appropriate design of the grounding system—conditions essential for reliable operation and personnel safety.

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Mihai-Dorel DAFINCA-IONESCU graduated the courses at the University Politehnica of Bucharest, specializing in electroenergetics domain in 2007. In 2010 he graduated Economical Academy Studies of Bucharest, obtaining a master's degree in “ Computerized Project Management “. He is Project Manager of Municipality Lighting Company of Bucharest. He was also involved in several research and development projects. Currently, he develops study in Politehnical University of Bucharest, energy engineering domain.

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