

INSTALLATION AND OPERATION EXPERIENCE IN WRAPPING OF OPTICAL CABLE AROUND PHASE CONDUCTOR TECHNOLOGY

Filip Reiskup, Vratislav Štěpka, Filip Girszewski, Petr Úšela; all from EG.D, a.s.

The article sums up the present experience from pilot projects with Access wrap technology (wrapping of optic cable around the phase conductor). This technology raises another possibility in optic fibre installation on medium voltage overhead lines. In comparison to the standard technologies utilised in EG.D is beneficial mainly from the side of usage of the current infrastructure (lines), speed of the realization process and mitigation of the authorisation procedure. On the other hand, it brings some complications in the daily operation/maintenance of the line. This technology implies usage for special applications such as short branches or lines with high residual value. This article sums up the experience from the installation process as well as the maintenance in a daily operation.

1. INTRODUCTION

The development of decentralized power sources, especially renewable energy sources, and the connection of an ever-increasing number of smart devices requires the power network to be monitored and managed in a reliable way, which also entails increasing demands on data transmission. To ensure effective network management, it is necessary to build a high-quality and sufficiently dimensioned network that will manage communication between network elements and transmit current measured data. One of the important pillars for achieving this is building our own optical infrastructure at the high voltage level.

Important communication tasks are performed via the optical network. These include SCADA, emergency telephony, and walkie-talkies (DMR). The aim of building optical networks is to interconnect distribution networks and thereby achieve independence from external communication providers. In addition, interconnection via optical cable offers increased communication speed. The optical networks at the high voltage level are built with a view to connecting remotely controlled elements and distribution substations, which is why sufficient reserves of optical cable are wound on branch lines and remotely controlled elements (reclosers, remotely controlled sectional disconnecting switches) for the future connection of these elements.

Certain priorities for the development of optical networks have also been defined within the company. In particular, they involve densifying the optical network at the very high voltage and high voltage levels. Further development is planned at the high voltage and low voltage levels in the access section for smart grids, which includes optics in municipalities with more than 500 inhabitants, connecting selected remote controlled sectional disconnecting switches, REC, and Smart DTS type K1.

1.1. CURRENTLY USED METHODS OF INSTALLING OPTICAL ROUTES ON OVERHEAD HIGH VOLTAGE LINES IN EG.D

The implementation of the smart grids is closely linked to the development of proprietary optical infrastructure. The goal is to build a total of 1,400 km of optical routes in the EG.D, a.s. (EG.D) distribution area by 2030 for the overhead high voltage lines. To achieve this goal at the high voltage level, two or potentially three methods of implementation are used. They include all-dielectric self-supporting cable (ADSS) suspended from a support point under high voltage brackets or on a four-conductor bracket, and the method of wrapping the optical cable around the phase conductor.

The most common solution is to hang the ADSS directly on the support point under the high voltage conductors. The optical cable is attached approximately 0.5m below the high voltage bracket in accordance with the conditions of PNE 33 3301. In practice, this location allows high voltage and ADSS systems to operate independently of each other, with minimal high voltage line shutdowns. The high voltage conductors also protect ADSS from damage caused by falling trees. From a security point of view, it is necessary, according to the EG.D concept,

to meet the requirement for the minimum height of the optical cable above ground, which is 6 meters. This is the most commonly used method of installing optical fibers on the overhead high voltage lines.



Fig. 1 – All-dielectric self-supporting cable

Another possible installation method is to use the four-conductor bracket. The bracket is similar to claw or six-conductor brackets for high voltage lines, with the difference that there is one extra arm for attaching an optical cable (see Figure 2). Four-conductor steel brackets are designed for the construction of simple overhead high voltage lines up to 35 kV with suspended ADSS, also referred to by manufacturers as All Dielectric Self Supporting Fiber optical cable, and other structures for attaching optical cable onto support points on the overhead high voltage lines.

The four-conductor brackets have been assessed by the Czech Agency for Nature Conservation and Landscape Protection (AOPK) as safe for wild birds of prey and other birds. The brackets are designed so that they do not contain any horizontal elements, thus preventing the birds from landing thereon.

The four-conductor brackets are particularly suitable for the following cases:

- An optical self-supporting cable placed under a high-voltage line would no longer meet the minimum permitted height above ground between the support points.
- There are other structures for high voltage cable feeders and high voltage branch lines, including connecting conductors, at the support point, and the self-supporting optical cable must therefore be diverted to a safe distance from live high voltage parts.
- Another special application includes construction of a disconnecter under the “PPN” (live working) line and an overhead switch (recloser).

The advantage of the four-conductor bracket is that it offers a full-fledged replacement for most existing high voltage support points fitted with Flat, Delta, CLAW-I, CLAW-II, and CLAW-III support brackets (taking into account the interphase spacing, field span, all types of AIFe cables used, and the relevant frost and wind

area), and in addition, it permits installation of the self-supporting optical cable on the remaining fourth arm. Thanks to the higher placement of the optical self-supporting cable above the ground (compared to placement below high voltage on low voltage brackets), the support point can be settled simply by replacing the bracket at the top of the pole without having to replace the pole with a taller one.

Installing four-conductor brackets on the support point changes the width and, thanks to the asymmetrical placement of the conductors, also the shape of the high voltage line protection zone. The disadvantage of using these brackets is, on the other hand, a wider protection zone (the same as for flat brackets, i.e., approx. 0.7m wider than delta or claw brackets) and lower design loads on the support points (limited to 20kN for corner poles).

One continuous stretch of the VN35 is currently in operation in the Hodonín region, covering a length of 4.5 km. Otherwise, they are used individually or in selected anchor stretches, in individual cases as solutions for the restoration of overhead high voltage lines.



Fig. 2 – Four-conductor bracket

As an alternative, a combined ground cable (KZL) can be used instead of ADSS on four-conductor brackets, similarly to the tops of lattice towers in a continuous row, on substation feeders, or on lines connecting substations (e.g., on the Tábor–Náchod line).

The third method used at EG.D is to wrap the optical cable around the phase conductor. This technology is mainly used on newly modernized lines, which also have a high residual value. More information about this installation method is provided in the following sections of this paper.

2. WRAPPING OF THE OPTICAL CABLE AROUND PHASE CONDUCTOR

2.1. PILOT INSTALLATION

There are currently two locations in the EG.D territory where the method of wrapping optical cable around the phase conductor is used. In 2020, the first pilot project was implemented on a stretch of the line between the municipalities of Hrušovany and Hostěradice (Znojmo district). The stretch is 5km long. This is a stretch without terrain complications and with a minimal frost zone of I-0. This part of the line was reconstructed in 2011 and did not allow for the suspension of a self-supporting optical cable and the connection of the intended optical route along the entire length of the line. For this reason, this stretch was selected as suitable for pilot testing of AccessWrap technology (wrapping optical cable around the phase conductor). The Claw II brackets are located on this stretch of the line.

The first pilot project was implemented with the aim of gaining experience with the technology in question, both in terms of installation and operation. Due to a lack of knowledge about the technology, training took place at a training ground three days before the real installation, with the aim of training the participants in the technology and providing them with an elementary summary of the work procedures. The subsequent implementation took place over five days without any significant complications. In addition to gaining experience from the implementation, the pilot project also resulted in a list of operational issues and open points that the project was unable to address due to the nature of the line.

In view of these open issues, it was decided to implement a follow-up pilot project. A 30 km line connecting the Telč and Počátky substations was selected for the follow-up pilot project. In this case, the ground is significantly more challenging (rugged elevation profile, overcoming water obstacles, ravines, frost zone I-8 and higher, etc.) than it was for the first pilot. Due to the nature of the line, the spans in this case are also shorter than in the first installation. This line was chosen with a view to gaining experience with winding older lines, where there are numerous wire connections, for example, and often on flat brackets. An important goal of the implementation was also to verify the behaviour of the wrapped conductor in a frost area and its resistance during defrosting.

In January of this year (2023), the installation took place on a 1.5 km stretch near the municipality of Studená. This implementation was carried out primarily with a view to verify the behaviour of the wrapped conductor in the frost area up to I-12. The project documentation for the remaining part of the line is currently being finalized, and implementation is planned for 2024.

2.2. INTRODUCTION TO THE TECHNOLOGY

According to the manufacturer's website (AFL (UK)), AccessWrap technology is a fast and cost-effective solution for installing optical networks. Its special design, lightweight installation equipment, fittings, and unique cable construction allow it to be wrapped around phase conductors with voltages up to 50 kV. The AccessWrap technology is designed to withstand the harsh environmental conditions found on power lines while creating minimal additional load on the conductor after installation. This allows installation without the need to modify the existing infrastructure, making it ideal for all types of poles [1].

This technology involves wrapping a thin optical conductor (diameter approx. 5.6mm) around an AlFe phase conductor (see detail in Fig. 3 below). It is possible to use 48 fibers or, if necessary, 96 (SkyWrap technology).



Fig. 3 – Detail of the wrapped conductor

The installation of the optical fiber is made using a special wrapping machine. The wrapping machine is pulled along the cable by a worker, and the optical cable is wrapped around the conductor by rotation within the appropriate span (Fig. 4). At the given distance, the wrapped conductor is secured with a clamp that prevents it from coming loose. An aluminum profile with an internal channel, through which the optical cable is routed, is used to cross the insulator. To prevent the cable from falling out of this profile, it is secured in the profile with plastic snap-on clips after being threaded through. For the transition across the insulator, refer to Fig. 5.



Fig. 4 – Installation of the optical cable



Fig. 5 – Detail of the transition over insulator

A special case is transitions across elements that can disconnect the line at a given point, specifically sectional disconnectors or sectional switches – reclosers. In this case, it is necessary to route the optical cable using a special protective insulated tube (grounded at the lower end) to the support point where the optical cable is terminated in an optical connector. From this connector, it is then routed back to the line in the same way and continues in the usual manner in the following span. This transition is referred to by the technology supplier as PTG (phase-to-ground). The optical cable itself is all-dielectric and does not contain any conductive parts. However, due to operational factors (dirt, moisture, weather conditions, etc.), it cannot be ruled out that the surface of the cable may become conductive. Therefore, it is necessary to use this special down conductor for each transition from the wrapped conductor to the support point structures. The PTG transition is a significant item in the budget for the entire project, and special training (certification) is required for the installation. In the course of the installation, it is also necessary to take into account that it will be more time-consuming than crossing a conventional support point. The PTG transition via the recloser is shown in Fig. 6.

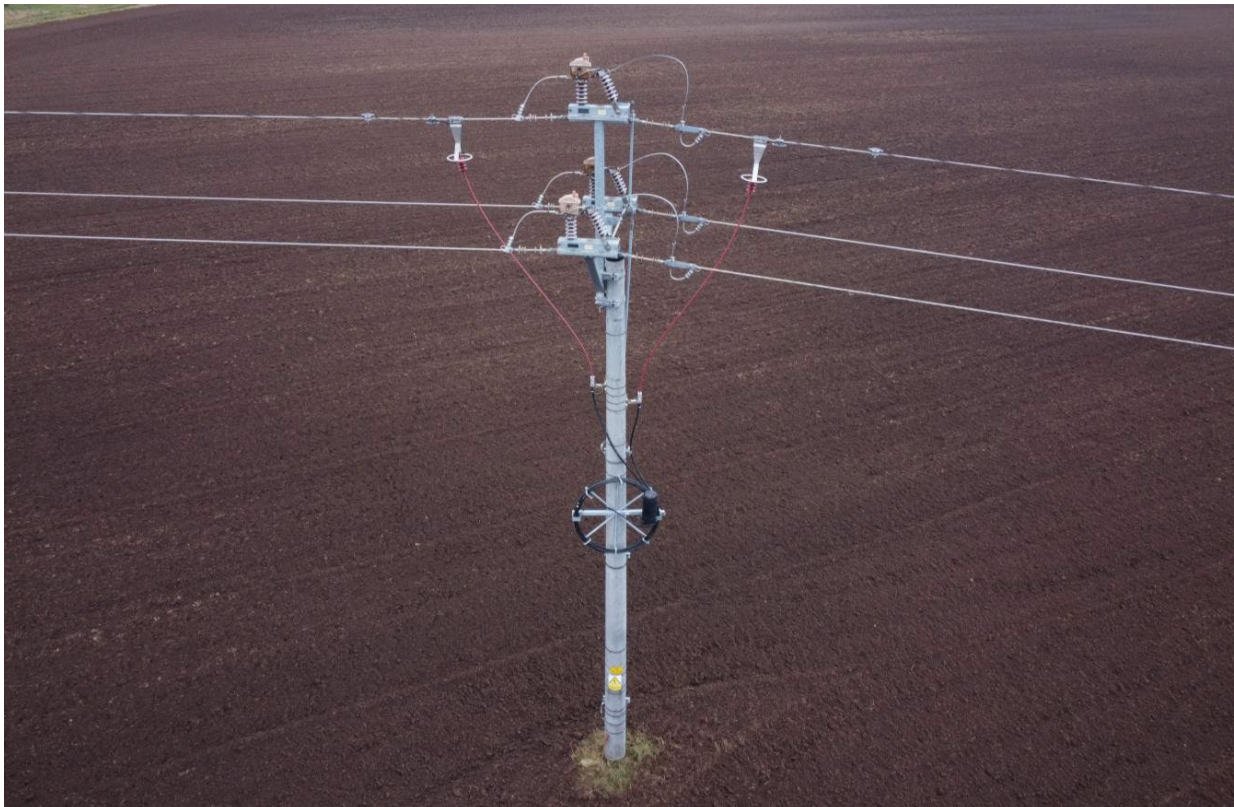


Fig. 6 – PTG (phase-to-ground) transition

The disadvantage of this technology is that it creates a higher number of connectors. A maximum of 700 m can be wound onto the drum for the wrapping machine. When two drums are unwound, each from a specific point to a different side, it is possible to achieve a maximum length of approximately 1.4 km without the need to install an optical connector. As mentioned above, the optical connectors must also be created at each transition through a recloser or sectional switch. After guiding the optical cable to the support point using PTG, the second option is to create a connector directly on the given span at the top of the conductor. When sufficient cable reserve is created, an optical connector is created on the ground and then attached to the conductor using a disk structure, as shown in Fig. 7.



Fig. 7 – The disk connector attached directly to the conductor

2.3. SUMMARY OF EXPERIENCE FROM THE INSTALLATION

As mentioned above, approximately 7 km of cable was deployed as part of two implementation projects in EG.D. In the course of these events, experience was gained for further possible installations, which are summarized below in several points. The following points relate exclusively to the installation.

- Only one platform can be used for the installation. The machine is relatively light (approximately 50 kg), so it can be handled by two workers from a single platform to transfer it over the support point. Two platforms can be used for easier handling.
- Wrapping is possible on the middle phase and on the outer conductors regardless of the type of bracket. It is more appropriate to wrap the outer conductor. Most connections between anchor sections are routed under brackets, where it is easier to fix the optical cable.
- Creating optical connectors on each recloser or sectional switch.
- Longer waists of the anchor support points can be bridged over using a pair of aluminium structures that can be flexibly shaped.
- Wrapping over the conductor connectors is possible as well. Here, the connector must be modified before installation (alignment of transitions at the edges of the connectors). The high voltage conductor is fitted with a protective spiral at the connector, which provides additional protection for the optical cable against damage, especially at the edges of the connector structure.
- It is not possible to wrap wires that are equipped with bird strike barriers.
- Complications during possible repairs (connecting wires) or relocations (replacement or shifting of the support point). Two additional connectors will be installed in association with the removal of the optical cable in the given section, in connection with the risk of damage, placement on adjacent

support points out of reach of freely moving persons, and reinstallation.

- It is possible to wrap up to 2 km per day on average with experienced workers (6-8 people).

2.4. OPERATION OF THE LINES WITH WRAPPED OPTICAL CONDUCTORS

The wrapped optical cable around the phase conductor inherently introduces a number of operational limitations. When handling the phase conductors, it is necessary to take into account the presence of optical cables, for example when troubleshooting the power section. EG.D agreed on a procedure whereby priority would be given to the operation of primary technology (high voltage lines) and the restoration of electricity supply.

In the event of a simultaneous fault of the primary part of the high voltage line and the optical network, the power supply (primary part of the high voltage line) is restored first in fault mode. The optical network is installed on site in such a way that it does not compromise the safe and reliable operation of the primary part of the high voltage line and does not pose a risk to pedestrians or vehicles. For example, winding up and securing a broken optical cable under the support point bracket at a height inaccessible to the general public. The subsequent repair of the optical route is being addressed in the form of a planned high voltage shutdown.

To subsequently restore the optical route, it is necessary to either re-wrap the entire stretch between the two nearest connections or to wrap only the given section. In the latter case, however, this results in the creation of two additional optical connectors in the given route.

The presence of the wrapped optical cable on the line imposes certain operational restrictions. The most significant of these restrictions are mentioned in the list below.

- A short-circuit kit cannot be placed on a wrapped AIFe conductor. The short-circuit kit must be installed in designated locations. These are arcing horns or the AIFe line points where the optical cable is not wrapped. For the arcing horns, see figure below.



Fig. 8 – The arcing horns on the line

- It is not possible to remove frost from the wrapped conductor using conventional methods (wiping or knocking). Damage to the optical cable is imminent. The frost can be removed from other AIFe conductors (without wrapped optical cable) in the usual manner.
- This technical solution makes it impossible to perform selected work under voltage (PPN VN crews).
- Flexi body cannot be placed on the wrapped line.
- If it is necessary to physically disconnect the high voltage line for operational reasons (e.g., by disconnecting the waist), then it is necessary to cut the optical cable, remove the aluminium profile carrying the optical cable, and wind up each end of the interrupted optical cable into a bundle and fix in a suitable way to the wound up phase conductor (out of reach of the general public). Subsequent

repair of the optical route is managed according to the procedure mentioned above (fault removal).

- Higher OPEX costs due to the presence of two workers or a platform for certain activities on the line.

2.5. FURTHER DEVELOPMENT AND OPEN ISSUES

There are still several open issues related to the use of the technology that involves wrapping optical cable around a phase conductor. One of the main reasons for implementing the second pilot project was to verify the behaviour of the conductor in frost areas and the defrosting. With this goal in mind, the stretch around the village of Studená was also given priority. However, due to the mild winter, there was no frost on the power lines. However, the line will continue to be monitored and the pilot project will subsequently be updated with the findings. Another question is the durability of the cable when the conductors are heated to remove frost. The maximum operating temperature of the optical cable used is specified at 85 °C. During the heating, the AlFe conductor may heat up to 170 °C, and in some cases up to 250 °C cannot be ruled out. We plan to test the effects of the heating on the optical cable.

In the course of the planned implementation of the remaining stretches, the route will cross water obstacles (ponds) and ravines. We have established a theoretical procedure for overcoming these obstacles, which will subsequently be verified in practice. For installations abroad, a larger machine with its own drive was used to install 96 fibers. The disadvantage of the larger machine is significantly higher weight (up to 250 kg) of the machine and the associated more complicated handling.

Within the scope of discussions, this technology appears to be a possible add-on to already standardized procedures (suspension on support points under the high voltage brackets and on four-conductor brackets). One option could be the use for the branches from the high voltage short branches. In rash terrain (forest clearings, etc.), there is a significantly higher risk of the cable breakage and the associated more complicated repair of the optical cable. For this reason, other options for installing the optical cable appear to be more advantageous, especially in forest clearings. Considering the need for minimal modifications to the line (renovation), minimization of the risk of damage and additional costs during reinstallation, the wrapping technology is suitable for use on the stretches with high residual value (after renovation on the claw brackets) that are in good technical condition and are not scheduled for renovation in the near future.

3. COMPARISON OF OPTICAL INSTALLATION OPTIONS ON THE OVERHEAD HIGH VOLTAGE LINES

In the course of the evaluation of the pilot projects and implemented parts thereof, a basic comparison was made between individual standardized types of optical cable installation on the overhead lines in EG.D. The basic comparison of these technologies is provided below for each type of installation.

3.1. SUSPENSION (ADSS)

This is a standardized technology that is already in common use. It is currently the most common installation option.

Advantages

- A lot of experience from operating the stretches already installed
- Minimal operational restrictions on the

power section Disadvantages

- When installing on the existing lines, modifications are necessary – usually line renewal, increasing lengths of the support points
- More time required for designing due to necessary modifications
- The need for thickening and increasing the number of the support points (in frost zones I-5 and above) and the associated need to go through the permitting process

3.2. FOUR-CONDUCTOR BRACKET

This is a standardized technology that is currently used mainly on an individual basis or in selected anchor stretches. Only the VN35 pilot project, with a length of 4.5 km, has been implemented for the entire line. Further construction projects are currently in the planning stage.

Advantages

- Ideal in terms of operation
- More suitable for longer spans, uneven terrain, bridging the complicated support points, and stretches with frequent frost around I-3 to I-5.

Disadvantages

- Higher capital expenses
- More time required for designing due to necessary modifications
- The protection zone is the same as for the flat brackets.
- The need for thickening of the support points (in higher frost zones I-8) and the associated need to go through the permitting process
- Replacement of the claw/delta pole in compact sections means another approval process (extension of the protection zone).

3.3. WRAPPING AROUND PHASE CONDUCTOR

This is currently a pilot technology. Currently, two stretches of total length of approximately 7 km are in operation. No decision has yet been made regarding further use at the time of writing.

Advantages

- Does not require major modifications to the line
- Lower capital expenses than previous types (approximately 15% compared to ADSS)
- Faster installation and design
- No approval process required

Disadvantages

- Higher OPEX maintenance costs
- Significant operational restrictions on the power section (refer to above, e.g., flexi bodies, securing the workplace, inserting elements in the line route)
- Problematic fault removal – more extensive outages (SAIDI, SAIFI)
- A larger number of the optical connectors
- Technology in the testing phase

4. CONCLUSION

The pilot projects that have already been implemented and the subsequent operation of the given stretches significantly helped to increase knowledge of the technology, including its preparatory phase and the production of the design documentation. Thanks to the pilot projects, we know what to focus on, how to use the technology correctly, how to determine costs, and we have the necessary knowledge to implement the technology in other potential projects. The experience from the projects will be important in deciding whether the technology will be used as a standardized solution.

In general, the wrapping method appears to be a faster and cheaper option for installing optical cable on the overhead high voltage lines compared to standardized methods (ADSS and four-conductor bracket). The advantages include that no major changes to the power lines are necessary, such as raising the poles or expanding the protection zone. However, the impact on operations is a significant negative factor. Due to the intrinsic nature of the technology, it is not possible to perform live work on the live lines, install FLEXI bodies, and troubleshooting is also problematic. This may result in a slight increase in SAI-DI/SAIFI in the given area. Another negative point is the higher operating costs for maintenance of the high voltage lines.

The technology of wrapping optical cable around a phase conductor can support the construction of optical networks at the high voltage level, especially in the area of special applications such as modernized stretches of the lines, problematic terrain (elevation, ravines, water obstacles) or short branches of the lines to distribution substations. Its potential use in frost-prone areas remains an open issue.

5. BIBLIOGRAPHY

- [1] AccessWrap AFL [online]. Duncan (UK), 2022 [date of access: 2023-09-27]. Available from : <https://www.aflglobal.com/emea/Products/Fiber-Optic-Cable/Aerial/Skywrap/AccessWrap>



Ing. Filip Reiskup

In 2020, he completed his master's degree at the Faculty of Electrical Engineering and Communication Technologies (FEKT) at the Brno University of Technology in the field of electrical engineering. He devoted his final thesis to the topic of non-frequency support services in a territory of a distribution company. In the course of his studies, he completed several professional internships (ČEPS Invest, EG.D). Since the beginning of 2020, he has been working as a project manager at EG.D, where he focuses on pilot projects for new technologies in the Innovation Projects department, particularly in the area of smart grid components.

Contact to the author: Phone: +420 703 467 641, e-mail: filip.reiskup@egd.cz



Ing. Filip Girszewski

He joined EG.D, a.s. (formerly E.ON Servisní, s.r.o.) in 2017 as a high voltage, low voltage, and ZP technician. In 2022, he completed a distance learning master's degree in Electrical Engineering at the Faculty of Electrical Engineering and Computer Science (FEI) at the VŠB-Technical University of Ostrava (VŠB-TUO). He devoted his final thesis to the problem of using reclosers for automatic frequency relief systems (SAFO). Since 2022, he has been working as Chief Engineer of High Voltage and Low Voltage Network Operations, where he focuses primarily on methodological management of operations, occupational health and safety issues, and technical administration of public tenders in the High Voltage and Low Voltage Network Operations Department.

Contact to the author: phone: +420 603 420 999, e-mail: filip.girszewski@egd.cz



Ing. Vratislav Štěpka

He was born on June 9, 1960. After graduating from the apprentice school in Hluboká nad Vltavou with a degree as Electrician and from the Secondary Technical School with a degree in Heavy Current Electrical Engineering, he successfully completed his studies at the Faculty of Electrical Engineering of the University of West Bohemia in Pilsen with a degree in Applied Electrical Engineering. On August 1, 1995, he began working with E.ON Česká republika s. r. o. in the Standardization Department, where he is involved in the standardization of overhead line technologies and materials, among other things. He continues to work in this department within EG.D, a. s. (formerly E.ON Distribuce a. s.).

Contact to the author: Phone: +420 607 544 627, e-mail: vratislav.stepka@egd.cz



Ing. Petr Úšela

In 1998, he completed his master's degree at the Faculty of Electrical Engineering at the Brno University of Technology in the field of Communication Technology. He had been working with T-Mobile for 18 years in several positions in network development and optimization. He has been working as the secondary technology development manager since 2019 at EG.D and he is involved, among others, in the development of optical and radio network.

Contact to the author: Phone: +420 735 144 989, e-mail: petr.usela@egd.cz