Sectionalized Reinforced Concrete Power Transmission Poles for Reducing Overhead Lines Cost, and Modern Projects of Power Transmission Poles as a Basis for Digital Network Space Formation

The paper is devoted to the erection of modern reinforced concrete poles to power transmission lines. The durability of those poles is comparable to the service life of metal poles while the cost is half. Sectionalization of spun concrete poles simplifies their transportation. New solutions for erecting power transmission poles on foundations raise the height of conductors' suspension. Thus, new reinforced concrete poles are capable to replace metal structures effectively in more than 60% of cases. Modern typical projects for overhead transmission lines can be incorporated into a single digital space of power line design, where necessary information will be present for all interested units throughout the entire life cycle of the facility.

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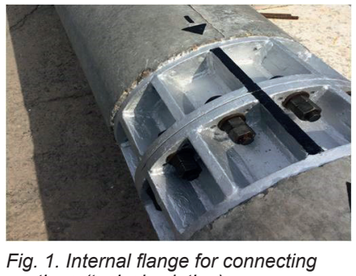

Fig. 1. Internal flange for connecting sections (typical solution)

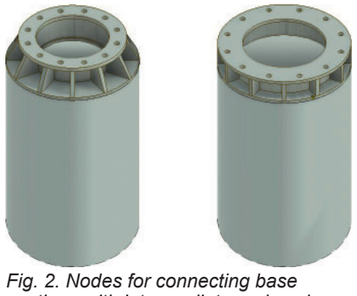

Fig. 2. Nodes for connecting base sections with intermediate and anchor and angle reinforced concrete power transmission poles

Almost half of the length of all overhead lines in Russia was built using reinforced concrete power transmission poles from spun concrete. Thus, the task of reducing metal consumption and power lines cost was solved in the middle of the last century. Spun concrete allows engineers to achieve a high degree of material compaction. In its turn, prestressing of concrete provides increased rigidity of the poles. According to the data on power transmission poles failure rate processed by JSC "Firma ORGRES" for more than 40-year period, metal and reinforced concrete structures demonstrates an equal reliability.

In 2013, the first samples of the poles from two sections with an internal flange (the flange is placed in the concrete form before centrifugation) were manufactured and tested (Figure 1).

As before, modern poles are made in conical or cylindrical concrete forms with a length of 26 and 20 m, respectively. Short sections solve logistical problems and have increased rigidity. Also, they are not damaged during transportation and are easily interconnected with bolts on the erection site.

By now, recommendations on the use of sectionalized reinforced concrete power transmission poles for 110-750 kV power lines have been included in the PJSC "Rosseti" Regulations "On a unified technical policy in power grids". It was done through the joint efforts of the Rosseti Group of Companies and creators of the design.

For the replacement of old power transmission poles and the creation of an emergency reserve, PJSC "Rosseti" recommends using sectionalized analogues of SK 22 and SK 26 reinforced concrete poles. Systematic work on the new poles erection has been in progress since 2015. Sectionalized poles are manufactured at the factories of "PO "Energozhelezobetoninvest", LLC in Rybinsk, Volgograd and Gulkevichi (Krasnodar Territory). All afore-mentioned manufactures are certified at PJSC "Rosseti".

New sectionalized power transmission poles are selectively erected to replace poles taken out of service. New poles are formally designed for the same loads. Except easy transportation without damage, separate rigid sections have a significant advantage: cable reinforcement is used in all constructions. It increases the crack resistance by means of pretension. Moreover, the use of concrete characterized by enhanced strength class (B60 instead of B40 or B30), waterproofness (W14 instead of W8) and frost resistance ($F_1$400 and above instead of $F_1$200) increases power transmission poles service life up to 70 years. Thus, there is no need for poles repair during the operation.

For a wide use of reinforced concrete poles in the new construction, a series of unified designs for 110 kV overhead lines was developed. A full-fledged standard project includes design documentation for 23 types of power transmission poles, including 8 intermediate poles and 15 anchor poles in single-circuit and double-circuit design.

Intermediate power transmission poles are made on the basis of conical pillars 26 m long (from two sections with a length of 13 m each), the lower diameter of which is 650 mm. For more loaded anchor poles, cylindrical pillars with a diameter of 800 mm, manufactured in concrete forms with a length of 20 m (with a length of 10 m each) are used.

A significant achievement was erecting poles on the foundation sections of cylindrical reinforced shell-type concrete piles of 800 mm diameter. The proposed design of the flange joint between poles and foundations (Figure 2) made it possible to raise the height of conductors' suspension, to increase the spans and to reduce the total number of poles per kilometer of overhead lines. Thus, reinforced concrete power transmission poles became comparable to metal ones. The load-bearing capacity of the poles was enhanced by choosing a reinforcement system and using high strength concrete. It allowed power transmission poles to carry increased loads.

In order to use power transmission poles within new construction, a series of regulatory documents has been developed. The documents included process charts for erection and operating instructions for sectionalized structures.

Fig. 3. 2SPB500-3V power transmission poles on 500 kV "Donskaya AES – Staryy Oskol 2" overhead line

All types of 110 kV poles were tested at the facility of "Firma ORGRES", JSC in Khotkovo. All manufacturing plants were certified at PJSC "Rosseti".

A technical and economic comparison of the cost for 110 kV overhead line section built using new reinforced concrete poles with overhead line on metal poles showed that the new poles reduce the construction costs by half, saving at least 900,000 rubles per kilometer for single-circuit power lines and 1300,000 rubles for double-circuit power lines.

In addition to standard designs for 110 kV overhead lines, more than 20 types of sectionalized reinforced concrete poles were developed as a part of real projects for 35, 110, 220, 330, 500 kV overhead lines. In January 2019, one of the anchor spans of 500 kV overhead transmission line "Donskaya AES – Staryy Oskol 2" was built using 2SPB500-3V portal concrete structures (Figure 3).

A feature of these structures was erection of poles on reinforced concrete foundations, which made it possible to raise the height of conductors' suspension and to increase the spans up to the level of 2MP500-3V multi-faceted power transmission poles, installing on other sections of overhead line. At the same time, the cost of poles and foundations decreased by 1.5 times compared with metal poles.

Individual projects of new designs, providing optimal solutions in specific conditions, place high demands on developers' qualification and require tests and regulatory documents. Due to this, time and funds for developing overhead lines project are often not enough.

The solution of the problem in modern conditions can be found through the integrated development of basic series for 220, 330 and 500 kV power transmission poles, planned for release as a part of PJSC "FGC UES" R&D.

Real optimization of design decisions can be achieved through providing designers with the necessary auxiliary programs for calculating the bearing capacity of power transmission poles and foundations, taking into account real conditions of overhead lines route. The availability of new generic projects to a wide range of specialists will allow them to quickly carry out all necessary calculations for erecting poles in specific conditions. Also, it will provide required reliability of overhead lines projects, while minimizing construction and operation costs.

In addition, the availability of a proven design options will allow engineers to quickly modify power transmission poles for other conditions regarding to the conditions for main series. Thus, it is possible to obtain the optimal (almost individual) design for specific overhead lines.

3D-models of the poles will allow engineers to avoid mistakes in the development of structures, to reduce the time for overhead line projects development, to guarantee the absence of problems in the factory production and field assembly and to make informed decisions relating to repair volume in operation.

To guarantee delivery of quality structures to the line route, power transmission poles will be equipped with electronic markers using radio frequency identification technology. The radio-frequency identifier contains the initial information about the pole, which can be expanded with the data stored on the factory server. In such a way, it is possible to clarify the parameters of power transmission poles manufacture. Information on all products supplied to PJSC "Rosseti" facilities will allow the customer to control overhead line during construction phase and entire service life. As a result, data on power transmission poles installed on line route will be linked with the geographical coordinates of the area (GIS model) and will be used in the common CIM model of electrical grid (Common Information Model) for solving production and technical management problems. P

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