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New trend on Transmission Power Lines and related Stringing Equipment Development

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SUMMARY

Electricity demand is increasing worldwide, and the great challenge is to increase the transmission efficiency and the transmission distance.
The demand for conductor with higher diameter and for increased number of multiple bundle conductors power lines is required on major transmission networks & UHV Power Lines, both AC & DC.
During the last years, new generations of conductors, especially HTLS (High Temperature Low Sag) conductors became more popular to raise the current capacity of an existing transmission line.
Due to the aging of existing power lines and the limitations on obtaining new right of ways for transmission lines, reconductoring stringing operations are more frequent all around the world.
The new trends require machines specifically designed: objective of manufacturers is to design and manufacture transmission stringing equipment able to face the new demand in large crossing stringing operations, without damaging the conductors of new generation and maintaining at the same time the maneuverability of the machines.
Innovation has been carried out also in materials: the use of hard materials for the bull-wheels grooves surface does not affect the conductor's surface allowing a smooth stringing behavior of the conductor.
Easier transportation on public road and fast and flexible positioning of the equipment at the job-site is a must when stringing operations are performed in hard environment areas, such as mountain areas and those with difficult access.

KEYWORDS

Transmission Stringing Equipment
Reconductoring
Large Diameter Conductors
HTLS Conductors
Large Crossing Stringing Operations
Bull-wheels material
Detachable Machines
Modular Stringing Machines

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Background

With several regions of the world facing severe pressures on transmission line infrastructure, with modern societies becoming increasingly dependent on reliable and secure electricity supplies in order to support the economic development and the industrial growth, nowadays the great challenge is to increase the transmission efficiency and the transmission distance.

When improvements and additions to the transmission system have been required in the past, several methods to increase the available transmission capability have been used.

These methods can be classified between the ones which involve upgrades or replacements to the existing transmission lines and the ones involving the installation of new lines but they have in common the demand for larger and increased number of multiple bundle conductors power lines on major transmission networks & UHV Power Lines, both AC & DC.

When the construction of a new line is possible, the recent trend of countries with the higher rate of energy development for reducing energy losses is to give priority to extra high and ultra high voltage power lines, many of which designed to operate in direct current.

When economic concerns and limitation on obtaining new right of ways for transmission lines limit the growth of new lines, the solution is to increased the need for additional power transfer on the existing equipment.

Typically, the amount of clearance between energized conductors and other objects limits the capacity increase of most existing overhead transmission lines.

As the load on a line increases, the temperature of the conductor increases causing the conductor to elongate. The increased elongation results in additional sag in the conductor, thereby reducing the clearance to the conductors and objects. Moreover, the amount of sag for a given current loading is directly affected by the weather conditions including ambient temperature and wind speed.

For this reason, reconductoring operations became more frequent all around the world involving both the renewal of the old conductor (line refurbishment) and the replacement of standard conductors with those of last generation (line improvement).

New generation HTLS (High Temperature Low Sag) conductors are becoming more popular to raise the current capacity of an existing transmission line.

These new conductors help in solving transmission bottlenecks, especially power flow restrictions concerned with operating lines at high temperatures; extensive rebuilding is avoided by using existing right of ways and all the existing tower infrastructure.

Objective

Power transmission system owners and operators need new solutions to maintain the transmission efficiency over time or to increase the capacity of existing lines. These solutions have to be acceptable to the public, reliable and economical.

Objective of manufacturers is to design and manufacture transmission stringing equipment able to feed the new demand, in terms of:

- Stringing conductors with larger diameter
- Stringing new generation HTLS conductors avoiding any damage to them
- Large crossing stringing operations
- Easy transportation of stringing equipment

Stringing machines with larger bull-wheels diameter
The increasing of the diameter of the conductors requires machines with larger bull-wheels diameter.
A new generation of tensioner and puller-tensioner has been developed with bull-wheels diameter up to 2400 mm/95 inch, in different shapes and configurations.

The diameter of the bull-wheels is historically prescribed by two International Standards:

- IEC TR 61328 [1]
- IEEE 524std [2]

Both of them requiring a bull-wheel diameter that is at least 35 times the diameter of the conductor.

The trend of the market along the years is the increase of the typical dimension of bull-wheels: from 1200 mm/48 inch to 1500 mm/60 inch while in the last years the request of larger diameter bull-wheels arises up to 2400 mm/95 inch.

The driving factors of this increase are basically three:

- The increase of the diameter of traditional ACSR conductors up to 52 mm/2.0 inch
- The introduction of new generation HTLS conductors
- The need for large crossing power lines with conductors' diameter out of standard range

The **increase of diameter of traditional ACSR conductor** is a trend due to the need to increase the power transmitted by the HV and UHV Power Lines, both in AC and DC configuration.
Conductor diameters are moving from a typical maximum diameter of 42 mm/1.65 inch to a range between 46 mm/1.8 inch and 52 mm/2.0 inch.
For this reason the bull-wheel diameter need to be enlarged: typical values of bull-wheels diameter manufactured in the recent years are 1600 mm/63 inch, 1700 mm/66.9 inch, 1800 mm/70.9 inch, 1850 mm/72.8 inch.

Puller-Tensioner
1200 mm/48 inch bull wheel's diameter

Puller-Tensioner
1500 mm/60 inch bull wheel's diameter

Puller-Tensioner
1700 mm/66.9 inch bull wheel's diameter

The **introduction of new generation HTLS conductor** is becoming more popular due to their enhanced properties which can address demanding applications: the resistance at High temperature loads, the possibility to operate continuously above 100°C without loss of tensile strength or permanent sag-increase, the low sag at high temperature are some of the peculiar characteristics of these new generation conductors.

Compared to traditional ACSR conductors, HTLS conductors are made with different materials and have a different behavior during stringing operations. Therefore, most of the manufacturer of HTLS conductor are evaluating or prescribing a larger ratio between the diameter of conductors and bull-wheels, moving from the traditional 35 towards to 40, 42 and in some cases 45.
According to the new demand, stringing equipment's manufacturers expanded the range of their products with stringing machines with increased bull-wheels diameter.

Puller-Tensioner
ACSS conductors on 1800 mm/70.9 inch bull wheel's diameter

Puller-Tensioner
ACCR conductors on 1500 mm/60 inch bull wheel's diameter

The **large crossing power lines with conductor diameter out of the standard range** is a niche of the power line construction scenario, because so large conductor's diameter requires special equipment dedicated to this activity.
Stringing equipment's manufacturers developed machine specially dedicated to this operation, with typical bull-wheels diameter ranging between 2000 mm/78.7 in and 2400 mm/95 in.

Puller-Tensioner
2000 mm bull wheel's diameter

Puller-Tensioner
2400 mm bull wheel's diameter

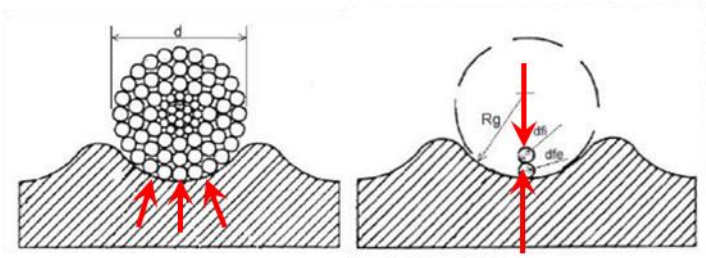
Bull-wheel's grooves made by hard material
The tradition of stringing equipment is based on the aspect that soft bull-wheels surfaces need to avoid damages to the conductors. For a long time the tensioner machines have been made with soft material, as adiprene, urethane or similar, as per the IEEE Std524 [2]:

"The material and finish of the grooves must be such as not to mar the surface of the conductor. Elastomer-lined grooves are recommended for all conductors, but are particularly important for nonspecular conductors. When a semiconducting elastomer is used for lining the grooves, it should not be relied upon for grounding."

The high friction that such materials apply to the conductor surface requires the winding of the conductor on the bull-wheel to respect a typical condition:

"For normal conductors having a right-hand direction of lay for the outer wires, bull-wheels should be arranged so that, when facing in the direction of pull, the conductor will enter the bull-wheel on the left and pull off from the right side. For any conductors having a left-hand direction of lay for the outer wires, the conductor should enter on the right and pull off from the left. This arrangement is necessary to avoid any tendency to loosen the outer layer of strands as the conductor passes over the bull-wheels."

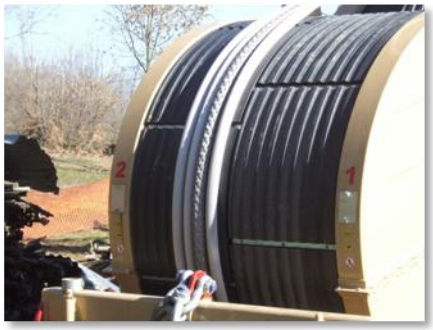
Along the years, machines with different materials for bull-wheels lining have been introduced on the market.
Even if harder than the conductor material, the use of grooves made of hard materials, as steel with thermal and chemical protection or hard polyamide, allows a smooth stringing behavior of the conductor when passing on the bull wheels, preserving the conductor from any possible stress therefore reducing the possibility of damages and defects.
Grooves with hard surface have no influence on the conductor because the contact pressure between them and the conductor is lower than the internal pressure between elementary wires of the conductor. Moreover, low friction involves self-alignment of the conductor on the bottom of the groove and no influence related to the right-hand or left-hand formation of the conductor; the main consequence is that machines are simple to use and the conductor loading procedure is faster than before.



The benefit of the harder material applied for years to traditional conductors became more evident when HTLS conductors have been introduced into the market.
Such conductors are normally made by soft material on the outer layers, typically annealed aluminum, with a stronger core in the center made in different materials such as composite core, carbon core, high tensile strength Invar steel.
Most of them are also made with trapezoidal wires, to fill up all the available space on the cross section, instead than traditional rounded wires.

Puller-Tensioner
ACSS conductor on 1500 mm/60 inch
bull wheel diameter interchangeable nylon linings

Puller-Tensioner
ACSS TW conductor on 1700 mm/66.9 inch
bull wheel diameter interchangeable nylon linings



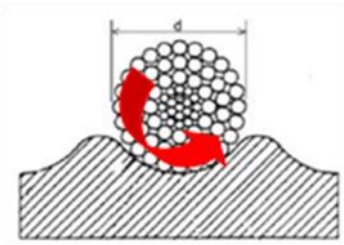
Puller-Tensioner
Hollow G(K)TAL conductor on
1800 mm/70.9 inch bull wheel diameter steel interchangeable lining

Puller-Tensioner
ACCC conductor on 2000 mm/78.7 inch bull wheel diameter steel interchangeable lining

The new material and shape of such conductors has become an issue when using traditional machines with soft bull-wheels material because, when passing on the bull-wheels, the high friction between conductor and bull-wheels groove generates a torsional stress on the conductor which results in:

- breaking of the core of the conductors when wound in line with the right hand or left hand direction
- easy bird caging when the conductor is wound in opposition direction to the right hand or left hand direction

In such a situation, machines with hard material's grooves were the optimal solution, because the low friction minimizes the torsional overstress on the conductor and allows a smooth and regular stringing operation thus preserving the conductor integrity.



Easy transportation machines
Whenever the logistic of the jobsite is the key factor the trend is to have less equipment to be moved; in this case, the best solution is to have all equipment stored together on the same truck

Truck installed machines
Typical stringing machines are designed to be towed by traction units just on the job-site area for positioning operations, and normally transported with auxiliary trucks on public road and in case of large distance to be covered.

To allow easier transportation on public road and fast and flexible positioning in the job-site situation, a new generation of stringing machines is required:

- Truck installed machines
- Machine equipped with DOT trailers able to be towed by a proper truck on public roads.

Truck installed machines are normally large machines with big mass; this for having a versatile solution in which a dedicate truck is part of the whole product.

Truck mounted Puller-Tensioner

Truck mounted Puller-Tensioner

Machine with DOT trailer are generally requested for small or medium size machines, to be towed by regular vehicle or small truck, as well as large machine, to be towed by dedicate trucks.

Puller-Tensioner on DOT low-bed trailer

Puller-Tensioner on DOT trailer

Puller on DOT trailer

Puller mounted on DOT trailer

Detachable machines

Dimension of machines is becoming larger along the time, as per the increase of the bull-wheel diameter or the large number of bundle conductors per phase to be strung at the same time with the same machines. In some case, they are so large that need to be divided in sections to be transported by regular truck on public road without the need of special permissions.

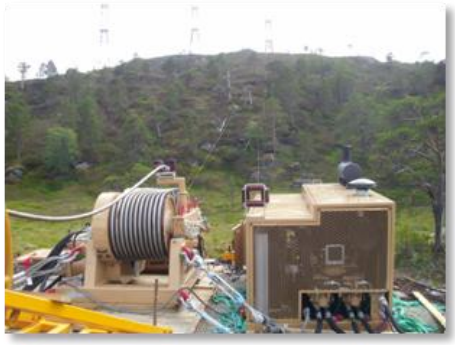
If places like rivers, fjord, lakes and mountains are difficult to reach with common transport vehicle and are placed along the way, then power transmission lines have to face natural obstacles. Technology used in large fjord-crossing operation and UHV power lines construction with large crossings and becoming popular on the market.

In such situation, when the working area of the job-site doesn't have any access road or doesn't have permission to made a temporary access road, the only solution is to fly the machines by using helicopter, that require to respect certain values of max weight allowed to be transported, such as 1200 kg or 3000 kg, depending on the typology of the helicopter.

Therefore equipment manufacturer reply at the request by promoting machines able to be split in separate units reaching a modular design, where the single module can be able to work in the proper way both assembled or separate but properly connected.

Detachable 160 kN Puller
Single element mass < 1200 kg

Detachable 160 kN Puller
Detail of element assembling/disassembling



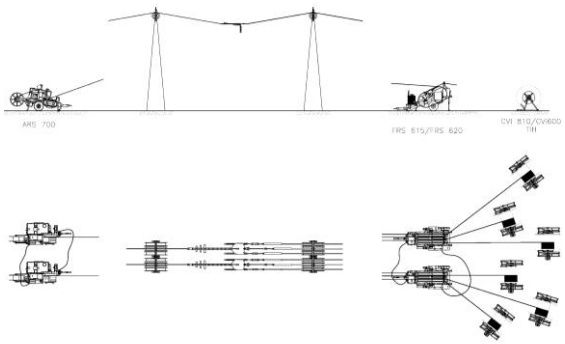
Detachable 360 kN Puller
Work Units and Power Units
Single element mass < 3500 kg

Detachable 140+140 kN Tensioner
Work Units and Power Units

Modular machine concept

The modular machine concept is based on the possibility to link a series of stringing machines, both at the puller or tensioner side, allowing the stringing of a large number of ropes or conductors.
The machines on each operational side are linked in parallel and electronically connected and synchronized; however, they are operated by one operator from one main control.

Tensioner in modular configuration



Sketch of the modular stringing method

Findings and Conclusion

The changes occurring in the power markets have been profound and significant, showing the signs of the sector's transformative efforts to design reliable transmission stringing equipment able to face the demand arising from the variety of the developing projects.
Next years will see the spread of the demand for reliable stringing equipment, able to address the need for new generation of conductors and the easy transportation.

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