Continuous Linear Puller: a Highly Efficient Reconductoring Process

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SUMMARY

TSOs are looking to enhance or upgrade existing routes, by the use of larger conductors, improved conductivity alloys, higher operating temperatures, novel conductor systems and raised voltage levels. Investment into providing green energy from wind, off-shore and solar farms need potential modification to the network hence the demand for more outages to provide these new connections.

Every TSO will have 10's of 1000's of repairs to make on their network each year and as a direct result will have to manage a series of outages or de-energization of numerous circuits to facilitate the maintenance work to be completed. It is therefore extremely important that wherever practical outage work is kept to an absolute minimum which is managed by the planning teams as it is often practical to offer a range of repair works to the same assets during one outage period.

Conventional methods for replacing OHL conductors involve hauling a replacement conductor between the towers using the existing conductor as a lead/pilot bond, by using conventional machinery for over 40 years, only seeing incremental changes as technologies in electronics advances.

The Continuous Linear Puller (CLP) recently developed has proven to be a new concept in the replacement of OHL conductors in the energy sector. The advantages of the CLP in providing efficiencies for the power utilities (System Operators) will encourage further benefits of a new concept to reduce outages time and either reduction of site resource and increase of operational safety.

The CLP project targeted a key deliverable as it highlighted these as key issues that when addressed could have the potential to substantially reduce the process of changing existing conductor for a new replacement item.

The benefits of the Linear Puller fall into different categories as some are related to direct costs whereas others are classified as indirect. What is apparent and is the largest key benefit is the time reduction in the outage period from the client/Utility whilst the contractor performs the refurbishment process in a timelier fashion.

KEYWORDS

conductors, stringing equipment, reconductoring, reducing outages

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Introduction

There is a requirement from the TSO to keep customers on supply every second hence, to maintain the high standard of reliability the TSO must plan repair schedules to ensure the equipment or assets are fully maintained and in full working order.

Every TSO will have 10’s of 1000’s of repairs to make on their network each year and as a direct result will have to manage a series of outages or de-energization of numerous circuits to facilitate the maintenance work to be completed. During this period of outage work the network will have to be temporarily re-configured which may also affect the vulnerably of the supply.

It is therefore extremely important that wherever practical outage work is kept to an absolute minimum which is managed by the planning teams as it is often practical to offer a range of repair works to the same assets during one outage period.

The Continuous Linear Puller (CLP) recently developed has proven to be a new concept in the replacement of OHL conductors in the energy sector. The conventional machinery albeit having passed through various iterations and additional benefits has in terms of the base principle not changed since it was first utilised more than 50 years ago.

The advantages of the CLP in providing efficiencies for the power utilities (System Operators) will encourage further benefits of a new concept to reduce time deficiencies and either reduction of site resource or the removal of highly skilled resource replaced by lower skilled and more cost-effective labour.

The need for change conductors

The limited number of new power lines constructed over the past 20 years has resulted in the TSO looking at ways to enhance or upgrade existing routes. Circuit rating have increased dramatically, using larger conductors, improved conductivity alloys, higher operating temperatures, novel conductor systems and raised voltage levels.

Recent years have also seen an investment into providing green energy from wind, some off-shore, and solar farms all which need potential modification to the network to provide turn-ins and teed circuits hence the demand for more outages to provide these new connections and the resulting increased capacity on the same route requiring upgraded conductor systems.

All overhead line conductors perform as part of a system, in dynamic and onerous environments, the combination of which tends to affect the condition of the asset over time. All conductors are susceptible to a similar degradation, the general causation being prolonged exposure to the weather or exposure to pollution in the atmosphere. Over time, the corrosion of the conductor components has been established as a primary failure mode however, the rate of corrosion can depend on several factors notwithstanding the general premise of exposure to the weather. Such factors which may affect the quality of the conductor, the quality of the installation, or more commonly a combination of two or more of the aforementioned. Experience within the industry combined with the knowledge and empirical evidence does indicate that conductors are more susceptible to failure due to corrosion from the age of circa 50 years. Conductors can so fail earlier with common failure modes beign vibration, lightning damage, windblown debris, bird impact, degradation of conductor fittings or in rare instances poor installation. In view of this the 50 years criterion as a yardstick for longer term planning purposes is commonly used, but then supplemented by condition and risk assessment to define strategic replacement plans.

As stated, aluminum conductor with galvanized steel reinforced core (ACSR) has been utilized on OHL for more than 80 years. The design of this type of conductor, with its differing metallic components, is susceptible to galvanic corrosion between the strands which is heavily influenced by the weather and pollutants in the atmosphere attacking the galvanizing on the steel core. In early 1960’s this issue began to be addressed with the application of grease to the steel core of conductor to delay the onset of corrosion. Original application techniques were poor (manually by hand), and quality issues were common where gaps in the grease application were observed on installed conductor producing a visible bulge of installed conductors.

Since the 1990’s the industry has been moving away from ACSR towards All Aluminum Alloy Conductors (AAAC) which does not suffer from these galvanic corrosion issues.

The Conventional Reconductoring Process

The method of conductor replacement and associated costs of doing so will depend on the residual strength of the conductor. If the conductor is badly corroded (i.e., the residual strength of the steel core cannot be assured) other more expensive options will have to be considered such as dropping the conductor to the ground and then re-stringing however with so much infrastructure built beneath the circuits this could be a very costly and difficult process to manage safely hence all efforts should be utilized to ensure the conductor does not go beyond its usable life.

The current method for replacing OHL conductors involves attaching a new conductor to the existing conductor, placing conductor blocks at each intermediate structure, and then winching in the existing conductor and coiling it onto an old drum. New conductor is fed in off a factory wound drum, reeved around a large tensioner, and then released at a continuous tension to maintain clearance to any underlying obstacle/road crossing/railway infrastructure.

Existing conductor is collected onto drums and then transported to a recycling depot where the conductor strands are separated so as not to mix the steel strands with the aluminium. Both products are then processed into re-useable material where the impurities are removed, and they can either be treated as standard material or a lower grade that can be used for low technology/importance components.

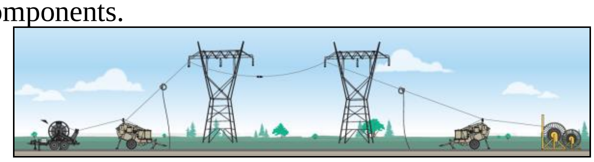

Fig. 1. Conventional Reconductoring Process

The existing machines designed to haul the conductor through have to stop each time a joint in the old conductor arrives. This joint may be one of the following:

- Existing mid-span splice that was installed during the main conductor construction phase partially caused by having stock drum lengths and not bespoke to the contract
- Repairs of conductor following areas where the outer strands have been damaged by externally mounted fittings such as spacers, fittings, etc.
- Repairs where the conductor has been struck by lightning and strands may have been broken
- Line diversions/turn-ins where there have been modifications to the network and the conductor has been re- used.

At every intermediate pull-through tower where tension insulators are replaced with a short section of conductor, four stockings, a 'C' connector and a swivel.

All such joints or connectors are not designed to travel around the surface of the bull-wheel on the winch. In fact, the design of the grooves in the outer diameter of the bull-wheel is very sensitive to any discrepancy or variation in the circumferential size of the conductor or joint. The bull-wheel, in order to achieve the pulling force, requires approximately 6 complete revolutions of the conductor. There is an exponential variation of force as it passes across the bull-wheel grooves with the residual load lowest on the end two grooves. It is important to recognize that once the length of the conductor has been accepted onto the bull-wheel each revolution is fixed in length and any fluctuation in the diameter causes an increase in tension in that revolution concentrated adjacent to the point where the conductor increases. This can have the effect of producing a stress point and possibly resulting in joint/strand catastrophic failure. Therefore, the risks of joints & connectors being passed around the bull-wheels has the potential to damage or fail the conductor hence methods have been developed to avoid the risk. This method includes stopping of the winching process on both entry and exit of the machine to connect and remove a temporary joint incorporating and large manual resource to perform these tasks.

Fig. 2. Mid-span joint replacement operation

The analysis can be split between different projects as the technology can be utilized on anything from 132kV single conductor up to large capacity EHV networks 220kV and above, usually in bundled conductors configuration ranging from 2 to 8 sub-conductors, having drums arranged at the tensioner site and a similar arrangement at the puller site. This requires a considerable area of land and multiple numbers of drum stands to hold the new and old conductor drums; moreover, the project durations will vary tremendously as larger conductors require a disproportionate time to prepare and remove joints. On bundled conductor phases it is worth noting that the connectors & joints may not always be aligned therefore this entire removal process may be replicated many times during a single conductor pull.

The New Reconductoring Process

Starting from an existing proprietary technology used for pulling continuous cables, a new type of machine has been developed, for the safe collection and disposal of the existing conductor. In developing this solution, it has the potential to provide cost and time savings against the conventional processes as summarized below:

- Reduction in circuit outage (circuit de-energized)
- Less contract resources required
- Reduction in number of temporary platforms (EPZ) to contain pulling machinery
- Health and Safety benefits due to less operators working at height and substantially fewer tripping hazards
- Environmental savings across the entire operation

The solution is to provide a machine that can haul the conductor at a continuous speed without the requirement to halt when a joint or connector approaches. The pulling operation is to proceed at a constant momentum so as not to stress any intermediate support, but it must have the facility to retain the tension in the conductor during the entire process, even when a joint pass through the winching mechanism. Furthermore, the possibility of collecting the conductor in a way that is required by the re-cycling without the need to recover it in separate coils has been implemented.

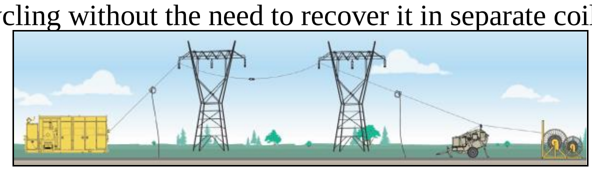

Fig. 3. The new Reconductoring Process

The new puller has now successfully been designed and manufactured in line with the exacting specification prepared, to have a “four machines in one” concept; the design incorporate the following key features:

- Containerized module easily transported/shipped around from site to site
- Ability to utilize ISO twist-lock mechanisms on a RO/RO delivery platform
- Fully enclosed machinery avoiding ingress from airborne particles
- Screened protection to reduce 3rd party interference when the machine is not in use
- Simple single conductor entry point accessible from ground level
- Direct spooling winch located on the front of the machine to assist the conductor loading
- Self-adjusting multiple pinch wheels pulling module to never stop the process when the joint arrives and to grant the self-loading of the conductor line

- Cutting module to cut the old conductor in small parts, including mid-span joints and similar devices
- Conveyor system to collect the chopped conductor parts into a proper container skip

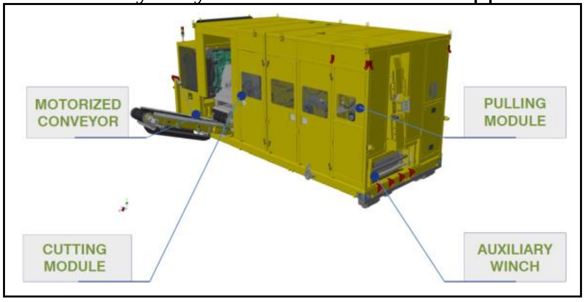

Fig. 4. “Four Machines in One” concept

The Benefit of Using the CLP

The CLP project targeted a key deliverable as it highlighted these as key issues that when addressed could have the potential to substantially reduce the process of changing existing conductor for a new replacement item.

The benefits of the Linear Puller fall into different categories as some are related to direct costs whereas others are classified as indirect. What is apparent and is the largest key benefit is the time reduction in the outage period from the client/Utility whilst the contractor performs the refurbishment process in a timelier fashion.

A. Outage Planning and Associated Resources

The analysis provided have highlighted substantial savings in site time both as direct and indirect costs.

A case study based on 50 km of twin line single circuit, with a total of 128 mid-span joints and 26 intermediates joints, generate a figure of 28% of time saving, moving from 120 days to 86 days of outage; the distribution of such saving is 4% related to Set-Up or Strip-Down operation at puller site and 24% related to pulling operation.

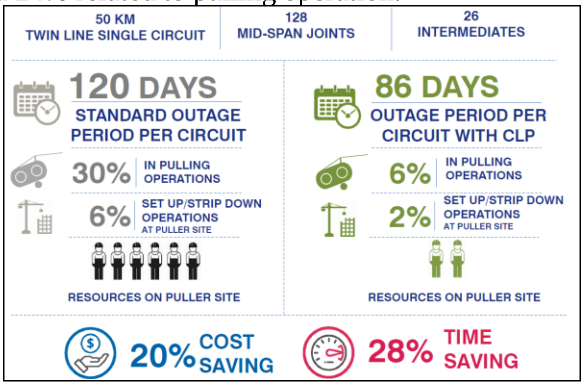

Fig. 5. Outage and Resources Saving

B. Site Resources

The CLP machine will dramatically reduce personnel levels required at the puller/winch site.

On the previous case study there is an evidence of site personnel reduction at the puller from 6 to 2, a saving of 66%.

C. Equipment: Equi-Potential Zone

The purpose of the EPZ is to protect the operatives as they potentially handle the conductor from the winch onto the cable drums. In performing this task there could be a fault or an inadvertent re-energization of the conductor that would cause an instant increase in the conductor voltage and thus cause an electric shock to any personnel in contact with the conductor as their feet will be at zero or of a lesser voltage level than the conductor UNLESS they are all bonded together. The purpose of the

EPZ is to connect all the parts that may be accessed by these operatives so in the event of unplanned re-energization all the items rise to the same voltage level.
The CLP is a machine that essentially processes the conductor without the need for all the collection of the conductors onto drums resulting in the operatives not being able to come into contact with the conductors and thereby potentially eliminating the need for the EPZ provision. Excluded from this is the operator who could simply have the option of either standing on a designated footplate or operating the machine via radio remote control and be in close proximity of the machine but not in direct contact.

D. Equipment: Drum Stands

The CLP is designed to eradicate the need for conventional drum-stands hence there is no requirement on site for these items at the winch site. To replace the drum-stands there will be a requirement for a large waste disposal skip that will collect all the dis-used conductor from the CLP as it hauls the sub-conductor into the machine.

E. Equipment: Platforms, Clamps, Slings, Pull-lift

Associated with the process of removing the joints prior to entering the machine the CLP is a continuous process and thereby will not require the use of the equipment that temporarily takes the tension of the conductor whilst the joints are being removed.
Moreover, the CLP has eradicated the need to have personnel working on height, thus improving the operational safety.

F. Equipment: Stockings, Connectors

It is planned to replace the conventional method of connecting two sections of conductor with a novel connector that can be installed by the operatives as simply as the conventional equipment. These will then have the ability to pass through the CLP without stopping hence these are classified as consumables.

G. Equipment: Other Equipments

During the stringing process in order to set-up the site, place old drums at the puller for scrap conductor removal requires multiple visits to site by a truck/tractor complete with hydraulic lifting arm. The CLP can reduce the frequency of truck visits as the machine is self-contained and only requires a suitable container to collect the scrap conductor. Site access restrictions will require rigorous planning to ensure the scrap conductor is handled in an efficient way.

H. Working at Height

The current process involves restraining the conductor between the tower and the puller involves operatives working at height to position clamping devices onto the sub conductors. This can be achieved either by accessing the platform suspended from the tower cross-arm or the use of a portable platform positioned adjacent to the machine. This process for the removal of the conductor joints, as well as any intermediate strain towers where the conductor has been made continuous with temporary connectors, is then repeated once temporary connectors have passed through the machine to avoid disposal of re-useable temporary connectors.

Fig. 6. Reduction of Working at Height

I. Environmental: Air Pollution

The process of recovering old/aged conductor can often generate many particles of aluminium oxide that in certain conditions can cause potential issues to site personnel, the area around the machine and also the actual pulling machinery as these particles are very abrasive. The CLP device has been designed to collect these dust particles during the recovery of the conductor and remove them at source hence removing the issues of allowing the particles to become airborne

J. Environmental: Pollution from Transport

The job site set-up for the CLP will be a change from the conventional set-up due to the types of equipment and personnel required on site for the pulling operation. On a conventional job site you would expect to see a range of equipment associated with each pulling machine or winch such as:

- Powered drum stand (2) per sub-conductor
- Kentledge/ballast weights
- Equipotential zone to support all the machinery
- This equipment is used as follows:
- A truck delivers and installs the EPZ as required dependent on the size of the winch and the number of drum stands.
- Drum stands and kentledge weights are delivered onto the EPZ and then assembled by the site operatives.
- Drums of coiled scrap conductor are either removed one at a time by truck/tractor and taken back to the depot or stored on site and removed by a large truck

The CLP may not require any other supplementary equipment apart from the removal of scrap conductor hence there will be a variation in the number of delivery vehicles that have to travel to the job site to deliver/collect these items of equipment.

Fig. 7. Standard truck vs skip loader truck

A Light Alternative Solution

Having in mind all the benefits of the new proposed technology, a special activity has been the implementation of a solution that combines some of the advantages of the CLP system with the logistic organization of a traditional reconductoring jobsite.

So, a new solution, called Continuous Linear Puller Light (CLPL), has been developed and will be proposed to the market.

Fig. 8. The Continuous Linear Puller Light (CLPL)

The solution implements the Pulling Module developed for the CLP in a traditional machine layout, eliminating the cutting and conveyor system, thus providing a working solution similar to the traditional puller-tensioner stringing machines, with the big advantage of allowing the old conductor to pull continuously, without stops when mid span or repair joints arrive in front of the machine.

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The old conductor is then wound in a traditional reel winder and scraped as a series of coils as per the normal reconductoring operation.

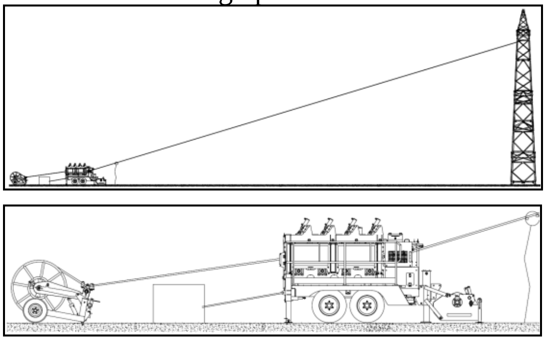

Fig. 9. CLPL layout use and detail of the job-site arrangement

The new CLPL solution allows to reduce the logistic impact of managing multiple skip units on the job-site area, also reducing the occupation of land of the puller station compared with the CLP solution.

Conclusions

The developed Continuous Linear Puller has proven to be a new concept in the replacement of OHL conductors in the energy sector.
The CLP machine can be complimented by new items to potentially introduce further advancements from the conventional tension stringing system, moving from the CLP to a concept we call “Continuous Pulling System” (CPS); new items are currently under feasibility evolution or prototype phase, in order to:

- Minimize the pulling tension value to prevent conductor damages
- Maximize the collection of the scrap conductor
- Minimize the dead time at the tensioner station when replacing old reel to new reel of conductor
- Minimize the time of execution of mid-span joints or temporary connection
- Minimize the clipping operation time after the stringing operation

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