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Exploring the World of Aluminium Conductors

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Abstract: The sustainability of the economic growth of any country depends on the continuous and safe availability of Electric Energy. In general, Electric Energy is produced in a dedicated power station that can be thermoelectric, hydroelectric or wind farm and must be transported and distributed to the utilization centres.

The growing of the industrialization and the improvement of the living standards require more and more Electric Energy to be sustained. The industry of electrical conductor has spent tremendous efforts for studying new conductors that, with the same or similar weight per linear meter or linear km, are able to transport more current, therefore more electric power. Consequently, during the years we are noticing that the worldwide industry is gradually switching from the basic ACSR aluminium conductors to the AAAC (All Aluminium Alloy Conductors) or to the sag resistant conductors, just to make an example.

The aim of this paper is to illustrate how Continuus-Properzi has contributed and contributes, with its equipment and technology, to the development of new alloy rod to be served to the cable industry to follow or to anticipate the growing demand of Electric Energy.

1- Electric Energy – A Vital Lymph for Growth and Development

Available data indicates world population reached seven billion during the year 2012 while approximately 900 million people had very scarce access to food and more than 2.1 billion people were considered overweight. According to some research made available by ONU, in 27 years from now the world population will reach nine billion growing at an average rate of 1.4% per year.

It goes without saying that a country's economy, and by that, the welfare of its people, depend among the others, on secure, reliable and up-to-date energy and communication networks in addition to access and availability of natural resources. Electric energy (EE) plays a fundamental role.

The chart below displays the growth of EE consumption during the past 20 years (more precisely from 1990 through 2012) with reference to the main macro-geographic areas.

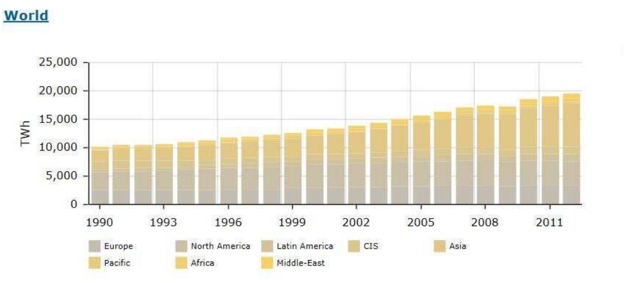

Fig. 1 – Chart of EE Consumption 1990-2012

As we can see, during this period of observation (1990-2012) the demand/supply of EE has continued growing despite a minor setback in 2009 as a consequence of the global crisis of the last quarter of 2008, jumping from 10,000TWh (1990) to approximately 19,000TWh in 2012; we could say that in 22 years it has almost doubled.

Referring to the data available relevant to 2012, China – 1.35 billion people – has been the largest consumer of EE with an aggregated demand of approximately 4,300TWh, followed by the USA – 310 million people – with approximately 3,800TWh. It is important to note the modest demand of India – 800TWh for 1.2 billion people – when compared with the demand of China since the two huge countries are comparable in population. Why so? Evidently this is due to the different levels of industrialization and urbanization and, among the others, we should not forget the fact that currently about 400 million people in India live without access to EE. However, several years ago, India instituted the Electricity Act 2003 that has liberalized the production of EE. In the sector of aluminium, this circumstance has encouraged the big players, Vedanta and Hindalco, to add an astounding aggregated amount of 800,000tpy of rod to their existing production capacity.

Although we have now focused our attention on India, we should not forget that approximately 20% of the world's population currently has no access to EE.

According to the forecast of ExxonMobil, in the next 27 years the aggregated demand of EE will reach 32,500TWh with a growth of approximately 80%. It will take time but the portion of population without access to EE will diminish remarkably in the coming years. We all hope that this growth will be environmentally and socially sustainable and, in our capacity as a supplier dedicated to this sector, we will have the tremendous responsibility and the unique privilege of contributing, with our equipment, products, technologies and services, to the success and swift realization of the dream…"*electric power for everybody*".

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2- The Nonferrous Rod; the Backbone of EE Transmission and Utilization

Continuus-Properzi started this mission more than six decades ago bringing its technology and its equipment for producing nonferrous rod – mainly aluminium rod at that time – to the major players of the Cable Industry worldwide. Picture 2 displays the Properzi Rolling Mill Mod. 6B. We could say that this machine contributed to the electrification of our world during the period 1950-1965. Just to put some reference numbers on the table, in that period the aggregated demand of EE worldwide went from 1,850TWh in 1950 to 3,700TWh in 1965. In 1960 the overall production of aluminium was in the range of five million tons and there were approximately 50 Properzi Al rod lines in operation in 19 countries. The total annual output of those 50 lines, optimistically, was in the range of 500,000 tons; five modern Lines of 15tph each give the same output today!

Fig. 2 – The Historical Rolling Mill 6B

Over the years, aluminium rod and copper rod have remained the basic semi-finished products concerned with the various utilization of electric energy (production, transportation, distribution, motors, transformers, etc.).
At the end of 2012 we estimated the aggregated annual production of aluminium rod worldwide to be approximately 6.0 million tons, whereas the total production of primary aluminium was in the range of 45 million tons. Considering these figures, on a global basis the portion of aluminium transformed into rod is in the range of 11% of the total.
Although the above analysis concerning the use of aluminium for electrical applications might be affected by minor imprecisions or discrepancies, nonetheless this will give a reliable idea about the utilization of copper worldwide.

3- The Electric Power – An Expensive Utility

It is commonly well-known that the electric power is generated in power stations that can be thermoelectric or hydro and then is transported and distributed through the wire network. During the years, the industry has worked towards the minimization of the power loss associated to the power transportation and the increase of the intensity of current per square mm of cable and conductors.

If we consider a single conductor the power loss is completely transformed into heat according to the Joule Law, expressed by the following equation:

i) $P = RI^2$

Where:
- P is the dissipated power expressed in [W]
- R is the resistance of the conductor depending on material, length and shape, expressed in [Ω]
- I is the current intensity expressed in [A]

Yet, the resistance R depends on several parameters according to the equation:

ii) $R = \rho\, l/s$

Where:
- ρ is the resistivity of the material [$\Omega mm^2/m$] -
- l is the length of the conductor [m]
- s is the cross section area of the conductor [mm^2]

For many years, the power transmission lines have been designed using ACSR (Aluminium Conductors Steel Reinforced) considering an average of 53-55% on copper (the reference international annealed copper standard has a conductivity equal to 100 IACS). The big overhead wires were composed of pure aluminium, but due to the poor tensile strength of the pure aluminium, it was necessary to use an internal core wire steel made for the mechanical properties, and of course, the active strand was aluminium made.

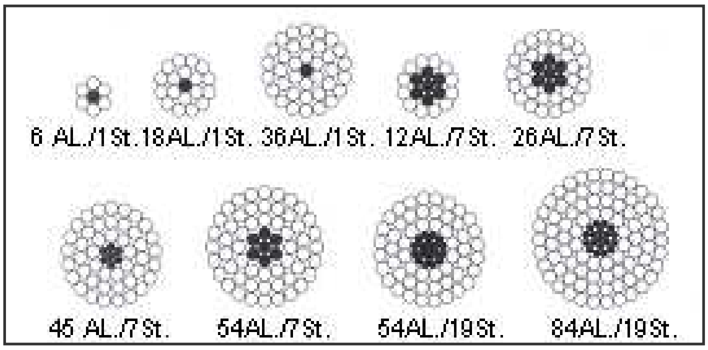

Fig. 3 – Typical ACSR Conductors

This system presented two big disadvantages: a) High weight per A/h transmitted; b) Serious problem of corrosion.
After the first Oil Shock (Kippur War – 1973) the cost of energy has grown dramatically and therefore the cable industry has become more conscious about the cost of energy loss, looking for new materials and new strategies. At the same time the growing demand of power has imposed the optimization of the power transmission on the existing infrastructure.
For such considerations the main parameters are the temperature of the conductors and the mechanical stresses of the wire. They determine the existing reserves in transmission capacity limited by the maximum allowed temperature of the metals and the critical sag and ground

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clearance. The new strategies of the wire and cable industries are reflected in the maximization of the transportable power on existing infrastructures or the minimization of the necessary number of pylons in case of the lines. The above inputs have found three main different follow-up:

a) development of new alloys reflecting the best compromise between tensile strength and conductivity. This is to realize AAAC (All Aluminium Alloys Conductors) in a way to eliminate the heavy steel core from the conductors. The wires have an almost double tensile strength as compared to pure aluminium and a satisfactory conductivity, having the resistivity higher by about 10% than pure aluminium. Some of the most used alloys are:

Fig. 2 – Typical Tower

AA6101 Rod with conductivity up to 53% IACS, and UTS (Ultimate Tensile Strength) up to 220 N/mm^2.

AA6201 Rod with conductivity up to 52.0% IACS, and UTS up to 300 N/mm^2.

AA5005 Rod with a minimum conductivity of 53.8% IACS, and UTS up to 200 N/mm^2.

AA8017 Rod with a minimum conductivity of 58.5% up to 60.8% IACS, and UTS up to 140 N/mm^2.

b) development of new alloys resulting in SAG resistant conductors. Alloys of Mg and Zr. TAL, ZTAL, XTAL.

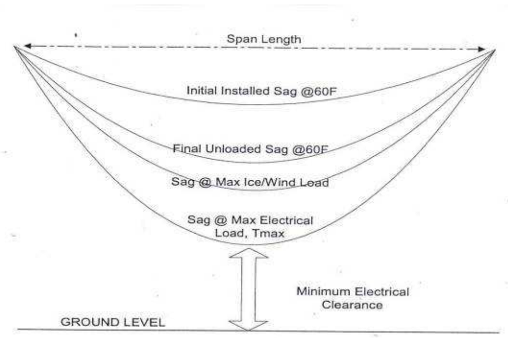

Fig. 5 – SAG development

These alloys are applied in steel reinforced overhead line conductors, allowing the line capacity to be increased by 50 to 100%.

Depending on the alloy, the maximum allowable temperatures are between 150°C and 230°C. Peak temperatures may vary between 180°C and 310°C. These conductors have a limited sag effect compared with others.

c) use of AA1370 in H11 temper (soft wire) for the manufacturing of conductors type ACCC (Aluminium Conductor Composite Core). The conductor consists of a carbon fiber wire with a typical tensile strength of 1500 N/mm^2, around which aluminium wires are wound. In order to optimize the filling of the apparent cross section area of the conductor, the wires are profiled instead of having a circular cross section area. ACCC conductor can significantly increase the capacity of an existing power corridor without requiring the necessary modifications to existing structures, as would be necessary if a larger conventional cable was used to increase the required capacity.

Fig. 6 - Typical ACCC

4- Recent Improvements on Properzi Rod Production Lines

In the previous paragraphs we have seen that the wire and cable sector is more and more demanding, and that the improvements in the casting and rolling lines have allowed the wire and cable industry to explore the boundary of new applications. While it was quite easy to produce (commercial) pure aluminium rod, the production of aluminium alloy rod requires the best advanced machinery, starting from the furnaces down to the coiler, and high technical know-how.

The most remarkable improvements realized to achieve a high and repeatable quality of the rod are identified in the following areas:

4.1- Metal Treatment and TiBAl Feeder

The in line filtering and degassing system, blowing Nitrogen or Argon as a mechanical mean to reduce the Hydrogen content, allows to reduce inclusions content and hydrogen content in such a quantity that it does not affect the drawing operations down to the smallest diameter.

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For producing quality rod it is also important the system to inoculate the fine refining means, commonly known as TiBAl, especially when the final product is AA 6xxx (Al-Mg-Si) or AA5xxx (Al-Mg).
Figure 9 shows a cast bar produced with the same casting machine processing molten metal not treated with TiBAl (left-hand side) and processed with TiBAl (right-hand side). It is quite evident, considering that the produced rod will subjected to heavy mechanical stress in the subsequent drawing operations, that as finer is the grain size as better is the mechanical behavior of the rod in the drawing operations.

5- Improvements in the Equipment

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