REVITALIZATION OF OLD TRANSMISSION LINES USING THE CONDUCTORS OF NEW TECHNOLOGIES

D. MIHALIC; V. ILIJANIĆ; I. PAVIĆ
1) INTRODUCTION

Great number of OHLs in Croatia, esp. 110 kV (cca 2 000 km of OHLs in next 10 years!), have to be revitalized (lifetime of the electromechanical equipment at the very end; towers still good);

Very often: current capacity encrease needed in the same time! (120 MVA → 150; 200 MVA or even more!). Two (2) possible solutions:

1) To build new OHL on the same corridor.
   - construction permits; considerably time-consuming procedure,...
   - financial costs = the greatest possible.

2) Revitalization of old OHL (reconductoring; shielding wire, insulation,...)
   - on existing towers (eventually with strengthening of few)
     - the same or lowering tensions on towers
   - requirement for: - encreasing the current capacity
     - decreasing the sags (encreasing safety distances)
     - lowering the losses
   - Financial costs = must be techno-economically justified
Consequences:

- old (classic) Al/Fe (ACSR) conductors can not satisfy
- the need for introduction of new technology conductors is required.

Conductors of new technology - HTLS (High Temperature Low Sag) conductors:

- today proven technology on the world market
- more and more applied in the world (≥ 36,000 km of HTLS conductors with composite core in operation)
- satisfy above mentioned technical criteria,
- still significantly more expensive than conventional ACSR

- “High Temperature Conductor” is defined as a conductor that is designed for applications where continuous operation is above 100°C or the conductor is designed to operate in emergency conditions above 150°C.
- In fact some can be run at over 200°C continuously and over 220°C for short times.
- This gives us spare capacity or ‘redundancy’ in the network for future expansion
- To take advantage of the high temperatures (and so ampacities) low sag is also required → “Knee point”

3
(hard: solution heat-treated, cold worked, and artificially aged) round wire for electrical purposes.
Comparison of Al/Fe, ACCR i ACCC conductors for 110 kV network

Max Power (MVA)

350
300
250
200
150
100
50
0

150/25
240/40
360/57

Type of Al/Fe conductors

- Al/Fe
- ACCR 1
- ACCR 2
- ACCC 1
- ACCC 2
The applicable methodology in techno-economic analysis involves:

1) Comparison of the total cost of OHL revitalization and the investment in the new OHL, taking into account:
   - technical analysis to find the best HTLS candidates for reconductoring
   - the costs of equipment and works
   - the difference of energy losses through the period of 30 years.
   - other applicable parameters

2) Assessment of electric energy losses and the annual costs in the future (to obtain the real limits of the estimated values) must:
   - have several future scenarios, according to development plans - TYNDPs) of the transmission network,
   - be vaulted to the first year of the investment → Present Value (PV) method for future costs.
Future costs are vaulted down to the starting year of the investment (or making a decision about it)

Present Value (PV) of the total cost (of losses, and other costs) over 30 years is calculated using a discount rate "p" to the well-known formula:

\[ PV = \sum \frac{C_i}{(1+p)^{i}} \]

where: \( C_i \) = the amount of money in the year „i“

„i“ = the number of years from the first (1, ..., n)

\( p \) = discount rate (here: 7% and 8%, resp. 0.07 and 0.08)

The resulting value of cost of losses (and other applicable costs) is added to the investment value of considered variant (e.g. revitalization) and is compared with the total value of other investments (e.g. construction of new OHL).

**Lower total present value** is certainly a **better choice** from an economic point of view.
This paper shows the methodology applied and the main results of the techno-economic analysis for 2 examples of the old OHLs, candidates for revitalization:

- 110 kV OHL Sinj - Meterize
- 110 kV OHL Žerjavec-Rešnik.

The results of the technical analysis are shown only in the extent necessary for the proper monitoring and understanding of matter.

The methodology and results of the economic analysis are shown more in detail.
2. MAIN RESULTS OF TECHNO-ECONOMIC ANALYSIS OF THE CONSIDERED LINES

2.1. Introductional notes

The usage of dozen types of conductors for technical analysis was analysed:

1) classic Al/Fe 150/25 mm² and 240/40 mm²,

2) "black conductors" (BTAL / Stalum 154/19) - candidate in some older considerations (and built on some lines, such as 110 kV OHL Ston-Komolac),

3) modern HTLS conductors with composite core: ACCR (Aluminum Conductor Composite Reinforced) and ACCC (Aluminum Conductor Composite Core).

For the purposes of calculations and analyzes, available catalog data of manufacturers were used.
Clarification of few details:

- The use of composite core **HTLS conductor names** - more or less related to the name of the manufacturer. New EU standards for this conductors have not yet been officially adopted. → world literature common names of these conductors are used.

- The names for these conductors → in accordance with the principles for labeling conductors in our practice (Al sheath area / core area) and in accordance with the principles of international conductor labeling (e.g. special names) in many countries.

- The same principle is applied consistently in labeling other catalog types of ACCC and ACCR conductors.
ACCC conductors (more manufacturers exist on the world market, although most are associated with the composite core manufacturer), → the absence of conductors with Al cross-section between 150 mm² and about 200 mm² was noted.

In communication with manufacturers → that further conductors can be produced with the same composite core and various cross-section aluminum layers, using standard aluminum wires, without special restrictions and/or peculiarities - so it is not about making the so-called „tailor-made” conductor!

The result = adoption of two new standard-sectioned aluminum sheaths of ACCC conductors:

- ACCC 192/28 Rovinj - composite core of 28 mm² with nominal cross-section of Al sheath 192 mm²
- ACCC 180/40 Zadar - composite core of 40 mm² with nominal cross-section of Al sheath of 180 mm²
2.2. OHL 110 kV Sinj – Meterize (22 km)

- Conductor: Al/Fe 150/25 mm², ampacity 90 MVA (5xx A) – aged, on the end of lifetime
- Revitalization needed - changing the conductors, insulation, suspension and jointing equipment, tower corrosion protection and replacement of existing poles grounding.
- Replacing the existing conductors should meet following requirements:
  - Keeping the existing towers (without any works on them) – still in good condition, will withstand another life cycle, at least 40 and more years.
  - Increase the transmission capacity - at least 115 MVA (605 A) – under the most difficult ambient conditions (ambient temperature 40 °C; ice -5 °C)
  - Same or lower sags at higher currents, under the ambient temperature of 40 °C,) with the same or less tensions to the towers. → diameter and weight of the conductor may not increase!
The most important results of the technical analysis of the conductor sags, the possible current loads and losses on the observed line, were the following:

1) Conductor type AAAC-185 and BTAL / Stalum 154/19 ("black conductor"), as well as existing conductor Al/Fe 150/25, does not meet the requirements with regard to sags.

2) With respect to requirements on sags, the conductor type ACCC meet them all, even at the extreme environmental conditions and power loads. Due to the reserves in sags, it is possible to reduce the tensions on towers approximately 5%!

3) Conductors type ACCC fully satisfy the maximum demands on the current capacity in all environmental conditions and sags. So conductor ACCC 192/28 Rovinj allows permanent transfer of initially required 605 A (115 MVA), and without any restrictions even 850 A (160 MVA).
Load losses in the period of next 30 years were considered in 3 scenarios, from small loads like today, to larger loads, in accordance with the existing long-term transmission network development plans.

Table I. Total cost of load losses at OHL 110 kV-Sinj - Meterize in the 30 year period (at 45 EUR/MWh)

<table>
<thead>
<tr>
<th>Applied conductor</th>
<th>Scenario 1</th>
<th>Scenario 2</th>
<th>Scenario 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total Costs</td>
<td>Difference to Al/Fe 240/40</td>
<td>Total Costs</td>
</tr>
<tr>
<td>154 BTAL/19-A20SA *</td>
<td>6,7</td>
<td>2,4</td>
<td>4,6</td>
</tr>
<tr>
<td>ACCC – 192/28 Rovinj</td>
<td>5,3</td>
<td>1,0</td>
<td>3,6</td>
</tr>
<tr>
<td>Al/Fe 240/40</td>
<td>4,3</td>
<td>0</td>
<td>2,9</td>
</tr>
</tbody>
</table>
• Revitalization with conductors ACCC 192/28 Rovinj is actually the only solution that is technically justified.

• For a final decision it is necessary to conduct an analysis of economic indicators in comparison with the construction of new line with Al/Fe 240/40, which has the lowest cost of losses, to determine whether such a revitalization is economically viable.

• The price of building a new OHL (22 km) on the same route → 3,3 MEUR (higher price due to the significantly larger number - 27% of tension towers).

• The cost of the new conductor (ACCC 192/28 Rovinj) was assumed to be around 10 EUR/m

• The cost of the new conductor BTAL/Stalum 154/19 ("black conductor") was assumed to be 3,4 EUR/m
Table II. The cost of the complete revitalization of the OHL 110 kV Sinj – Meterize

<table>
<thead>
<tr>
<th>Conductor case</th>
<th>154-BTAL/19-A20SA (EUR)</th>
<th>ACCC 192/28 Rovinj (EUR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conductor</td>
<td>244,800</td>
<td>720,000</td>
</tr>
<tr>
<td>Tower works</td>
<td>500,000</td>
<td>0</td>
</tr>
<tr>
<td>Dismantling of the existing equipment and installation of new</td>
<td>575,000</td>
<td>575,000</td>
</tr>
<tr>
<td>Suspension and jointing equipment and insulation</td>
<td>175,000</td>
<td>200,000</td>
</tr>
<tr>
<td>Tower grounding and corrosion protection</td>
<td>250,000</td>
<td>250,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1,744,800</strong></td>
<td><strong>1,745,000</strong></td>
</tr>
</tbody>
</table>

1) The price of building a new OHL is higher around **1,555 MEUR**
2) Total cost of losses in the 30 year period are lower for new OHL from **0,5 MEUR to 1,0 MEUR**, due to largest cross-section of Al sheath.
Therefore, the Present value (PV) method is applied (for 30 years period):

- Financial source for both investments is:
  - loan; interest rate of 8%; repayment period of 10 years; equal annual annuities
  - without loan
- Discount rate of 8%;

### Table III. The present value of the costs of load losses and financing for 30 years for one development scenario

<table>
<thead>
<tr>
<th>OHL 110 kV-Sinj - Meterize</th>
<th>PV (losses + financing)</th>
<th>PV (only losses)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>EUR</td>
<td>EUR</td>
</tr>
<tr>
<td>Difference (revitalization – new OHL)</td>
<td>- 275.300</td>
<td>309.300</td>
</tr>
</tbody>
</table>
Cash flows for costs of losses and costs of investment financing

a) revitalization of OHL

b) new OHL with Al/Fe 240/40
• PV of building a new OHL is bigger about 275 000 EUR than of a revitalization, if we take into account the costs of losses and also financing costs (loan interests).

• PV of building a new OHL is lower around 310 000 EUR than of a revitalization, if we take into account only the costs of losses without financing costs (without loan).

• As the investment in the revitalization is cheaper for 1,55 million EUR, the conclusion is unmistakable - the revitalization of the line with the application of new conductor HTLS 192/28 Rovinj is economically the best option.
2.3. OHL 110 kV Žerjavinec-Resnik

- Conductor: Al/Fe 240/40; ampacity 115 MVA (605 A) – aged, on the end of lifetime
- Revitalization needed - changing the conductors, insulation, suspension and jointing equipment.
- Replacing the existing conductors should meet following requirements:
  - Keeping the existing towers (without any works on them) – still in good condition, will withstand another life cycle, at least 40 and more years.
  - The new conductors must have the lower sags (minimum 1 m) at higher currents, under most difficult ambient conditions (ambient temperature of 40 °C; ice -5 °C) with the same or less tensions to the towers!
  - Increase the transmission capacity - at least 150 MVA (800 A) – under the most difficult ambient conditions (ambient temperature 40 °C), in the same time!
The most important results of the technical analysis of the conductor sags, the possible current loads and losses on the observed line:

1) New conductor Al/Fe 240/40, does not meet the requirements with regard to sags and current capacity,

2) With respect to requirements on sags, only HTLS conductors ACCC 274/40 Casablanca and ACCR 238/39 Hawk meet the requirements.

3) The best choice is ACCC 274/40 Casablanca, which allows a substantial reserve in the sag, with even possibility of reducing the tensions while sag parameters remain within the set limits, with the transmission capacity of line higher than 150 MVA - illustration of part of sag calculations is shown in following figure.
Load losses in the period of next 30 years were considered in three scenarios, from small loads like today, to larger loads, in accordance with the existing long-term transmission network development plans.
### Load losses costs on OHL in 30-years period (M EUR)

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Al/Fe 240/40</th>
<th>ACCC 274/40 Casablanca</th>
<th>Difference (Al/Fe – ACCC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1,1</td>
<td>0,95</td>
<td>0,15</td>
</tr>
<tr>
<td>B</td>
<td>1,3</td>
<td>1,1</td>
<td>0,2</td>
</tr>
<tr>
<td>C</td>
<td>2,6</td>
<td>2,2</td>
<td>0,4</td>
</tr>
</tbody>
</table>

### Costs / case

<table>
<thead>
<tr>
<th>Costs / case</th>
<th>Conductor</th>
<th>Dismantling of the existing equipment and installation of new</th>
<th>Grounding wire, suspension and jointing equipment and insulation</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACCC 274/40</td>
<td>Al/Fe 240/40</td>
<td>250 000</td>
<td>1 000 000</td>
<td>1 250 000</td>
</tr>
</tbody>
</table>

### Scenario A

- **Scenario A**
  - Al/Fe 240/40: 250 000 EUR
  - ACCC 274/40 Casablanca: 250 000 EUR
  - Total: 500 000 EUR

### Scenario B

- **Scenario B**
  - Al/Fe 240/40: 1 000 000 EUR
  - ACCC 274/40 Casablanca: 1 000 000 EUR
  - Total: 2 000 000 EUR

### Scenario C

- **Scenario C**
  - Al/Fe 240/40: 1 250 000 EUR
  - ACCC 274/40 Casablanca: 2 750 000 EUR
  - Total: 4 000 000 EUR
Present values (PV) of cost differences of losses per year, with a discount rate of 7% in the 30-year period, for OHL 110 kV Žerjavinec-Resnik, are shown in next figure:
• **Investment in the revitalization:**
  - is cheaper 516 000 EUR from the construction of new line with Al/Fe 240/40
  - the present (PV) value of cost savings due to losses → additional increases of 63 000 to 108 000 EUR, depending on the assumed load scenario on observed line in the next 30 years.

• **The final conclusion** - the revitalization of OHL 110 kV Žerjavinec-Resnik with application of new (though considerably more expensive) conductors ACCC 274/40 Casablanca, which fully meet the technical criteria set out in terms of sag and current capacities, is significantly more cost effective than building new line with a classic Al/Fe 240/40.
3. CONCLUSIONS

• The revitalization of the line and the use of relevant HTLS conductor is technically and economically the best option, even though the price of these conductors compared to classic Al/Fe conductors is substantially higher.

• Obtained experiences show that the choice of replacing HTLS conductor should be carefully analysed to obtain the optimal selection.

• Depending on the OHL loading and estimated load losses in 30-year period (multiple scenario analysis, according to TYNDP requirements), the revitalisation with conductors of new technology (HTLS, composite core) can be techno-economically better choice, even the classic conductor (e.g. Al/Fe 240/40) satisfy technical requirements.

• Finally, each OHL has its own characteristics and requirements for the revitalization, →presented methodology should be applied to each OHL - candidate for revitalization
1) What are the tests utilized or procedures for defining max temperature of conductor according with life design of OHL?

→ it is question about expected lifetime of HTLS conductors:

1. Some facts:
   - Numerous accelerated heating tests on conductors (many reports)
   - So far: manufacturers declare satisfying lifetimes of HTLS conductors
   - New standards (in EU) – under procedure

2. In real life, HTLS conductors are running under 100 °C majority of time!
• Max loads (≥ 90 %) → 3,5 % time (300 h/year)

Temp. of HTLS conductors ~ 90 % of time ≤ 100 °C!
2) What is technical and economical impact on fittings and accessories for ACCC and ACCR conductors type?

- Enough manufactured HTLS fittings on the market
- Technical requirements (also ACSS!) →OK; higher (~1/3) costs
- Some examples:

Note the significant difference in size between ACCC and ACSR dead-ends. Increased mass = cooler temperatures, less thermal expansion in the crimp zone and less stress on the oxidation inhibitor = longer service life!!!
Compression Dead-End Assembly

- Fabricated by FCI/Burndy

Compression Splice Assembly
THANK YOU FOR YOUR ATTENTION!

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