THE ANALYZE OF SOLUTIONS FOR SUPPLYING THE ELECTRICAL ENERGY TO RURAL ISOLATED AREAS CONSUMERS

Nicolae COROIU  
ELECTRICA S.A. – Romania  
nicolae.coroiu@electrica.ro

Ioan FELEA  
University of Oradea – Romania  
lfelea@uoradea.ro

Ionel BOJA  
SDFEE Oradea - Romania  
ionboja@eldior.ro

INTRODUCTION

In Romania there are still almost 2500 relatively isolated small rural communities with no, or only partial, electricity. The first part of the paper is a presentation of the isolated settlements in Romania that need electrification: number of inhabitants, distances, electricity demand and load forecast. The Romanian regulatory framework on this matter is also presented. The latter part of the paper shows some feasible technical solutions and the criteria and indicators for a comparative analysis of such solutions in terms of the investment costs, operation and maintenance costs and specific consumption. The third part of the paper shows the assessment results, based on indicators, of the technical solutions for the electrification supply of the isolated settlements in the district of Bihor (MV network, LV network, distributed generation) while establishing the optimum variant for each case. This study conclusions are presented in the last part of the paper.

1. SOCIAL DIMENSION

There are currently in Romania over 80,000 isolated households, mountain cottages, monasteries, elementary schools, forest dwellings, farms etc. that are not connected to electricity networks. These are located in almost 2500 non or only partially electrified settlements with a population of over 300,000 inhabitants. Romania has firmly committed to the recognition of the values shared by the West-European civilization, which includes meeting the social dimension for sustainable development. In this context, financial resources and adequate technical solutions are sought in order to complete the electrification process within a few years. The power connection of over 36,800 households during the 1999-2004 period of time, with the contribution of Electrica SA, stands proof for our commitment to this social requirement. The further financing of the electrification works in isolated rural settlements requires political decision focused on social cohesion, as:

- The users can only support a small part of the investment expenses;
- The investment payback is practically impossible given the average annual consumption/customer of 400–500 kWh which is characteristic for the rural areas in Romania;
- the maintenance of such connection works may cost more than the value of the electricity bills collected;

By GoR Decision No. 702/2003 ELECTRICA S.A. was given permission to engage a credit of $ 200 million for electrification works financing until 2007.

2. REGULATORY FRAMEWORK

The basic regulation in the field is the Energy Law No. 318/2003 which as far as electrification is concerned stipulates:

- Art.12 (1) The electrification of the localities will be financed from the local or State’s budgets or other funds legally constituted.
- (2) The local public administrations and ministries involved are responsible of the implementation of the projects and plans of electrification or network extension.

- Art. 40 (1) The localities that aren’t connected to the National Power System’s network can be supplied with electricity from separate systems. Consumers supplied with electricity from separate systems will pay the same price as the captive customers supplied from the NPS.

- (3) The relevant authority will settle the local price and minimal terms of the electricity supply quality and continuity.
- (4) If the local price doesn’t cover the cost related to the supply from a public interest network, the margin will be covered by the State’s budget.

The General Urbanism Rules (GoR Decision No. 525) regulates the authorization of civil buildings, their location in areas fitted with public utilities and the obligation - in case of a deviation request - for users to bear the costs related to network extension/ capacity increase. Romania has an important potential of solar, wind and small hydro energy. To promote attraction of such renewable energy sources (RES) in isolated areas, the following regulations were issued:

- Law No. 318/2003 stipulates the conditions and facilities for rural electrification based on RES;
- GoR Decision No. 443/2003 foresees an increase of RES share in Romania – the target is 30% electricity generated by RES (including hydro) and 11% of the primary consumption in 2010;
- GoR Decision No. 1535/2003 establishes the national strategy for RES.

According to Government and departmental regulations,[2,8] the assessment of more technical variants, in terms of economic feasibility indicators, is compulsory.

3. TECHNICAL SOLUTIONS

As the National Power System (NPS) is very well structured and is characterized by high electricity availability, the NPS supply variant - for each case - is obviously accepted. Depending on the distance from the NPS line, the installed power, the local RES potential, the affordability to construct
and maintain the connection lines, other variants are also analyzed and compared. Table 1 synoptically presents the technical solutions for the electricity supply of isolated settlements (potential electricity customers) accepted as variants for a compared analysis.

**TABLE 1 – Assessed variants regarding the electricity supply of isolated settlements (potential customers)**

<table>
<thead>
<tr>
<th>Item No.</th>
<th>Source</th>
<th>Variant</th>
<th>Electric diagram</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>1.1. – OL 20 kV three-phase</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.2. – OL 1 kV three-phase</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.3. – OL 0,4 kV three-phase</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.4. – OL 20 kV two-phase</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.5. – OL 20 kV single-phase with return through soil</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**II Liquid fuel**

<table>
<thead>
<tr>
<th>Source</th>
<th>2.1</th>
</tr>
</thead>
<tbody>
<tr>
<td>GE</td>
<td></td>
</tr>
</tbody>
</table>

**III Solar energy + Wind energy (RES)**

<table>
<thead>
<tr>
<th>Source</th>
<th>3.1</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPV</td>
<td></td>
</tr>
<tr>
<td>GPV generator</td>
<td>+</td>
</tr>
<tr>
<td>Photovoltaic</td>
<td>+</td>
</tr>
<tr>
<td>Storage and conversion sub-system (SSAC)</td>
<td>=</td>
</tr>
<tr>
<td>Storage and conversion sub-system (SSAC)</td>
<td>=</td>
</tr>
<tr>
<td>Monitoring and control sub-system (SSUC)</td>
<td>+</td>
</tr>
<tr>
<td>Switch and protection filtering elements EFC</td>
<td>+</td>
</tr>
</tbody>
</table>

**IV Liquid fuel + RES**

<table>
<thead>
<tr>
<th>Source</th>
<th>4.1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Storage and conversion sub-system (SSAC)</td>
<td>=</td>
</tr>
<tr>
<td>Storage and conversion sub-system (SSAC)</td>
<td>=</td>
</tr>
<tr>
<td>RES when the requested power is ensured</td>
<td>+</td>
</tr>
<tr>
<td>Electric power set with liquid fuel when the power available from RES is not enough</td>
<td></td>
</tr>
</tbody>
</table>
Depending on:
- The transformer power;
- The type and characteristics of the conductors used for OLs;
- The type and characteristics of switching equipment used;
- The type of support used for OL, with reference to each of the variants [1.1 + 1.5]; a number of [4 + 12] sub-variants [2, 3, 4] are possible.

The power of GE (variant 2.1) and the connection and protection equipment is selected depending on the power requested by the customer.

With reference to variant 3.1 it must said that in Romania there are pilot applications [7] in three power ranges:
- Powers in the range of [200 + 500] VA photovoltaic, intended for small households and social centers, only for lighting and radio-TV purposes;
- Powers in the range of [1 + 2] kVA (PV + W), for more households, cottages monasteries and social centers;
- Sets of [5 + 10] kVA (PV + W) for isolated hamlets.

4. CRITERIA FOR ESTABLISHING THE OPTIMUM VARIANT

Under the given conditions, the investment cannot be possibly paid back within the usual time interval (10 years) and not even during the equipment lifetime. Consequently, to establish the optimum variant we shall apply the criterion “total minimum updated expenses” (CTA min) [2, 9].

To prioritize the applicants in terms of time scheduling of the investment works, we shall use the criterion “maximum social effect” (ESmax).

The relation used for CTA is:

\[ CTA = I + \sum_{i=1}^{20} C_i (1 + a)^t \]

where,
- \( I \) – investment value [UM];
- \( C_i \) - operation expenses in year „t” [UM];
- UM – currency units [EUR; USD].

In this case it is not justified to introduce damages, remnant and residual values in the structure of CTA, because:
- Damages are much smaller than other components (I, C) and are very close for the different variants;
- Remnant and residual values are negligible compared with I, considering the very long (irreal) investment payback period.

The evaluation of component „I” is not difficult; for variant „j” it is:

\[ I_j = \sum_{i,j} I_{ji} + I_{pj} + I_{pj} \]

where,
- \( I_{ji} \) - cost of owning the equipment/component (i) necessary for the execution of variant „j” [UM];
- \( I_{pj} \) - designing expenses, variant (j) [UM];
- \( I_{pj} \) - execution costs, variant „j” [UM].

Evaluation of component „C” needs an ampler discussion. For variants [1.1 + 1.5], with all their sub-variants „C,” is expressed [2, 9]:

\[ C_t = C_\alpha + C_{Et} \]  

For material and personnel expenses necessary for operation (C\( C_\alpha \)), according with the experience gained in Romania it is recommended that \([3 + 7]\% \) from „I” is effected each year. Considering the location of these facilities, \( C_\alpha = 0, 05I \) will be adopted.

Component \( C_{Et} \) represents the cost of annual losses in the electricity network elements:

\[ C_{Et} = \Delta W_t K_w = (\Delta W_{t,1} + \Delta W_{t,2}) K_w \]  

where,
- \( \Delta W_{t,1}, \Delta W_{t,2} \) - energy losses in transformers (one or two, as applicable) and in OLs [kWh] respectively;
- \( K_w \) - specific cost of electricity [UM/kWh].

In case of variant 2.1, to evaluate component \( C_t \) the following relation is used:

\[ C_{tt} = 0, 05I + (K_{WII} - K_{W}) W_i \]  

where,
- \( K_{WII} \) - specific cost of electricity generated by burning liquid fuel in GE [UM/kWh];
- \( W_i \) - estimated electricity consumption in year \( t \) [kWh].

In case of variant 3.1, component „C,” is estimated based on the investment value \( C_{III} = 0, 05I \) and in case of variant 4.1 the following relation is applied:

\[ C_{IV} = 0, 05I + (K_{WW} - K_{W}) W_{II} \]  

where,
- \( W_{II} \) - share of the consumption of electricity generated by GE.

After evaluating CTA for the analyzed variants, the variant CTA min. is selected.

These evaluations are conducted at the level of the electricity distribution branches (SDFEES) of the Electricity Distribution and Supply Company ELECTRICA S.A. For an efficient distribution of the electrification effort (in terms of the social effect) for „n” cases in SDFEES the criterion „maximum social effect” is applied:

\[ ES_{i} = \frac{NL_i}{CTA_{min}} \]  

where,
- \( NL_i \) - number of inhabitants of settlement „i” (village, hamlet, cottage, monastery, etc.)

Values „ES” are ordered in a variational string:

\[ ES_1 < ES_2 < \ldots < ES_n \]  

Investments are made annually, within the limits of the existing financial resources, for the eligible number of settlements as results from reading the variational string starting from the maximum value term (ES\( n \)) towards the minimum value term (ES\( 1 \)).

CIRED2005
Session No 5
5. RESULTS OF A CASE STUDY

The Electricity Distribution and Supply Branch (SDFEE) Oradea is one of the 42 branches of ELECTRICA S.A. in Romania. The mission of Oradea branch is to supply electricity to the customers in Bihor, a district that currently has 15 non-electrified hamlets (Table 2).

To analyze the electricity supply solution for the respective hamlets, the criterion CTA was applied along with the following calculation data:

- \[ a = 0.1; \quad K_w = 6.56 \text{centE/kWh}; \]
- the cost prices of the electrical equipment in the OL structure [10, 11];
- the cost prices and the specific consumption of the GE that uses diesel oil [12];
- estimated annual average consumption: 500 kWh/household.

Since no certain and credible data related to the specific cost (E/kW) are available for the photovoltaic generators (GPV) and the wind generators (GW), our analysis does not reveal the values of CTA with reference to these solutions (III, IV).

The results obtained for variants I and II are shown in Table 2.

<table>
<thead>
<tr>
<th>Item no.</th>
<th>Location name</th>
<th>Characteristics [No. of households/distance from OL]</th>
<th>CTA\textsubscript{I} [thousand EURO]</th>
<th>CTA\textsubscript{II} [thousand EURO]</th>
<th>( ES_i )</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Termeeu</td>
<td>43/3.1 km</td>
<td>274</td>
<td>124</td>
<td>0.347</td>
</tr>
<tr>
<td>2</td>
<td>Peştea and Fertisag</td>
<td>20/4.1 km</td>
<td>160</td>
<td>52</td>
<td>0.385</td>
</tr>
<tr>
<td>3</td>
<td>Codrişor</td>
<td>14/1.2 km</td>
<td>151</td>
<td>43</td>
<td>0.326</td>
</tr>
<tr>
<td>4</td>
<td>Puşcaşeşti</td>
<td>27/2.4 km</td>
<td>250</td>
<td>112</td>
<td>0.241</td>
</tr>
<tr>
<td>5</td>
<td>Berec Toii</td>
<td>7/0.5 km</td>
<td>60</td>
<td>33</td>
<td>0.212</td>
</tr>
<tr>
<td>6</td>
<td>Surdaceul</td>
<td>23/2.7 km</td>
<td>300</td>
<td>54</td>
<td>0.426</td>
</tr>
<tr>
<td>7</td>
<td>Rugeş şi Huta</td>
<td>27/2.5 km</td>
<td>210</td>
<td>112</td>
<td>0.241</td>
</tr>
<tr>
<td>8</td>
<td>Strămturi</td>
<td>9/1.2 km</td>
<td>90</td>
<td>36</td>
<td>0.25</td>
</tr>
<tr>
<td>9</td>
<td>Romi – Tinca</td>
<td>40/0.5 km</td>
<td>75</td>
<td>124</td>
<td>0.533</td>
</tr>
<tr>
<td>10</td>
<td>Osoiu</td>
<td>5/0.8 km</td>
<td>40</td>
<td>33</td>
<td>0.151</td>
</tr>
<tr>
<td>11</td>
<td>Grui</td>
<td>20/0.5 km</td>
<td>70</td>
<td>52</td>
<td>0.385</td>
</tr>
<tr>
<td>12</td>
<td>Romi – Dealu Mare</td>
<td>60/1.2 km</td>
<td>160</td>
<td>180</td>
<td>0.375</td>
</tr>
<tr>
<td>13</td>
<td>Dealu Bondi</td>
<td>38/0.8 km</td>
<td>140</td>
<td>124</td>
<td>0.306</td>
</tr>
<tr>
<td>14</td>
<td>Brusturi</td>
<td>31/13 km</td>
<td>1145</td>
<td>124</td>
<td>0.25</td>
</tr>
<tr>
<td>15</td>
<td>Groapa Goghi</td>
<td>4/1.5 km</td>
<td>45</td>
<td>33</td>
<td>0.121</td>
</tr>
</tbody>
</table>

To get a more complete picture of the matter, we must make the following clarifications:

- The specific cost of electricity generated by GE, which was considered in the calculation of CTA\textsubscript{II} [12] falls within the interval 13.6 \( \div \) 17.5 centE/kWh;
- The energy potential of Romania as regards wind, solar-photovoltaic energy is significant [6, 7];
- The guaranteed purchase tariffs for electricity generated renewable energy sources in European countries [8]: 8.33 centE/kWh biogas, biomass
- 10 centE/kWh Wind
- 20 centE/kWh Photo-voltaic

6. CONCLUSIONS

The Government of Romania decided to finance the electrification works in isolated rural areas, which implies a significant financial effort (over $ 200 M) coordinated by the Electricity Distribution and Supply Company ELECTRICA SA.

The existing regulatory framework in Romania fosters the electrification of isolated settlements while discouraging the construction of civil buildings in such areas.

The compulsory technical-economic assessment necessary when establishing a source and the best electrification variant for the isolated rural settlements must accept as possible sources the following: then national power system (NPS), the autonomous power sets running on liquid fuel, the wind and solar energy (RES) and combinations among the last two solutions according with the potential of RES.

As regards the supply from NPS, in Romania there are analyzed 5 variants, with a number of 4 to 12 possible sub-variants depending on the technical characteristics of the equipment considered.

The optimum electricity supply solution for isolated rural settlements is established by applying the criterion “minimum updated total expenses” while for the time scheduling of the respective investments the “maximum social effect” criterion should be applied.

The use of the optimization and prioritization criteria is currently prevented by the fact that no certain, credible data is available regarding the specific cost [euro/kW] of the investment equipment for RES (photo-voltaic generators and wind farms).

With reference to the case study conducted for the isolated settlements in Bihor district the following findings have been made:

- For most settlements (13 out of 15) solution II is more economic, while for two settlements (9, 12) solution I is recommended;

- Investment prioritization in time according with the “CS max” criterion is as follows: 9-6-(2, 11)-12-1-3-13-(4, 7)-(8, 14)-5-10-15.

Since the cost of the electricity generated by GE is higher than the actual electricity selling price to residential customers, if solution II is adopted the state’s effort will be distributed over the entire period under study (20 years), compared with solution I when the initial effort of the investor is higher.

Considering that the price of the electricity generated by GE is comparable with the guaranteed tariff for the electricity generated by RES, and the fact that Romania’s energy
potential for RES (wind and solar energy) is much higher than the electricity demand in the isolated rural areas, we consider opportune that solution III (RES) should be mainly applied, which also meets our national energy policy of increasing the RES share in the total energy consumption.

References


