# RELIABILITY IMPACT FACTORS ANALYSIS FOR DISTRIBUTION IN SLOVENIA

Tomaž MOHAR
Elektroinštitut Milan Vidmar-Slovenia
tomaz.mohar@eimv.si

Leon VALENČIČ
Elektroinštitut Milan Vidmar-Slovenia
leon.valencic@eimv.si

David BATIČ
Energy Agency of the Republic of Slovenia
david.batic@agen-rs.si

## *ABSTRACT*

*Paper describes methodology and results of study of different impact factors on reliability of MV distribution network in Slovenia in the period 2003-2010. For the purpose of upright regulation of quality of supply the analysis of wide range possible impact factors were made.*

## INTRODUCTION

Data reports obtained from Energy Agency platform for observation of reliability indicators: system average interruption frequency (SAIFI) and system average duration time (SAIDI) in the period 2003-2010 show considerable differences by each of the five Slovenian distribution companies (Figure 1). There could be several reasons overtaking between distribution companies: geographic and demographics dissimilarities, organisation and network asset strategies, different investment and maintenance guidance which effect different network types and structures (Figure 2).

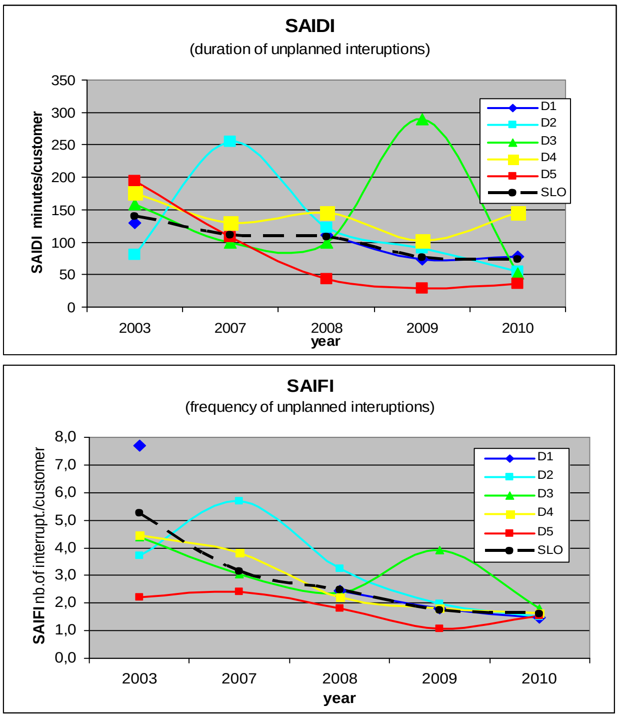



**Figure 1**

The influence of regulatory policy to the distribution core activities: investment, operation and maintenance should also be investigated in the impact factor hypothesis.

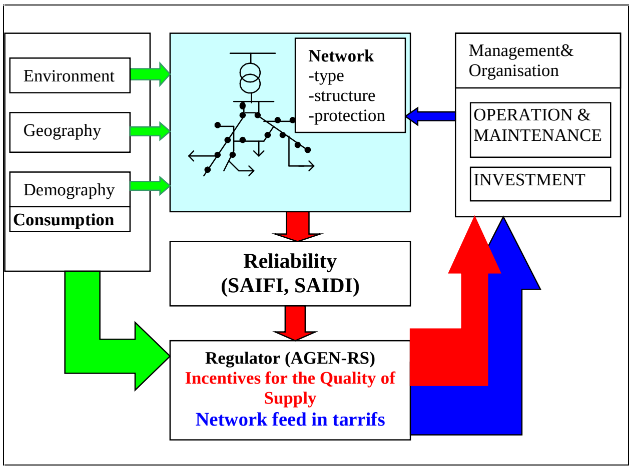



**Figure 2**

## RELIABILITY IMPACT FACTORS

For the purpose of proper regulation of quality of supply the initial study [1] contemplated a wide range of possible impact factors:

- demography (consumers dispersion, power supply density - Figure 3 );
- weather (lightening - Figure 4, stormy days: with extreme wind, wet snow and floods - Figure 5);
- geography (terrain configuration-Figure 6, woods-Figure 7 );
- network type and structure (share of cables - Figure 8, share of semi insulated OVH lines- Figure 9, share of share of looped network - Figure 10 , feeder length, - Figure 11, etc.).

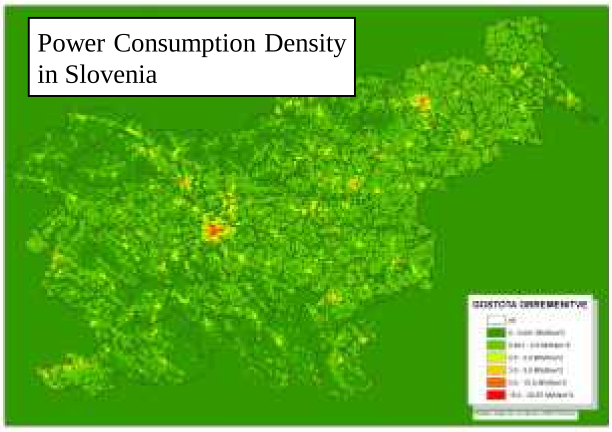
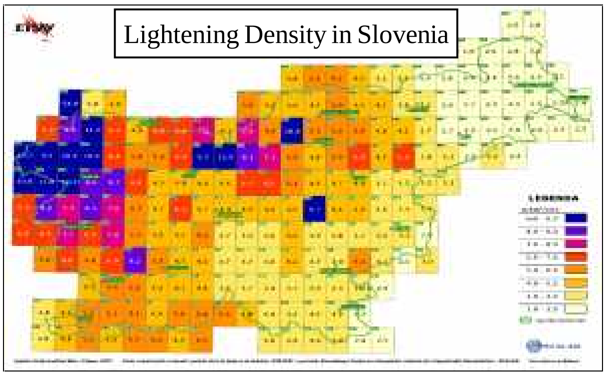



**Figure 3**

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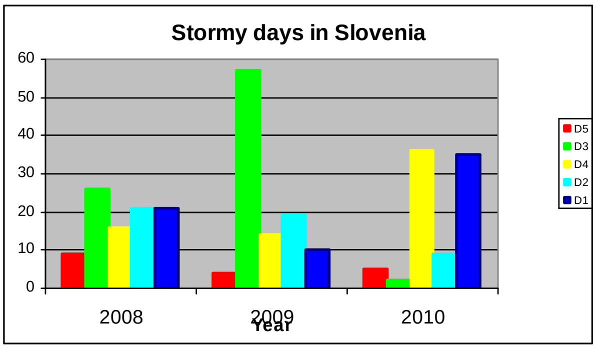


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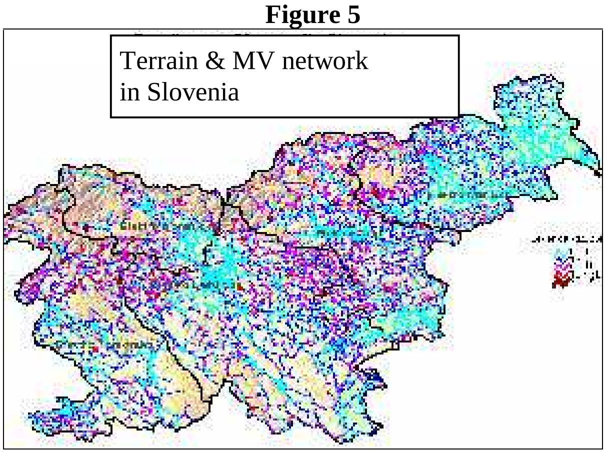


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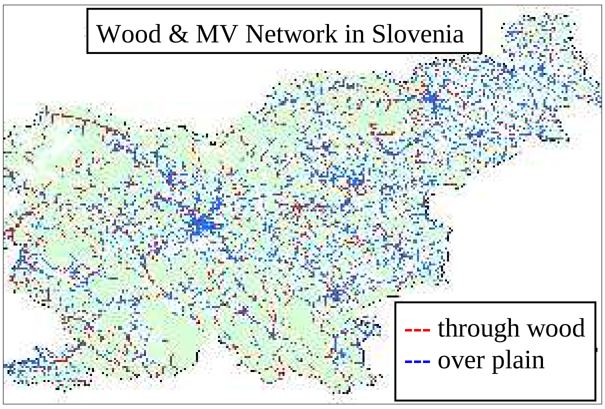


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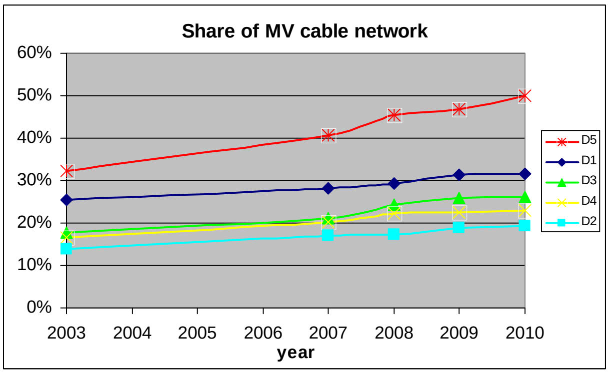


**Figure 8**

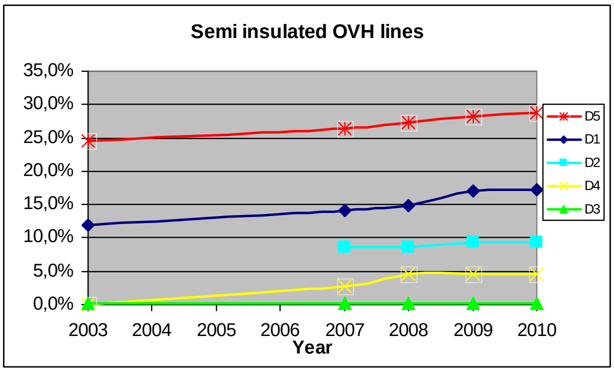


**Figure 9**

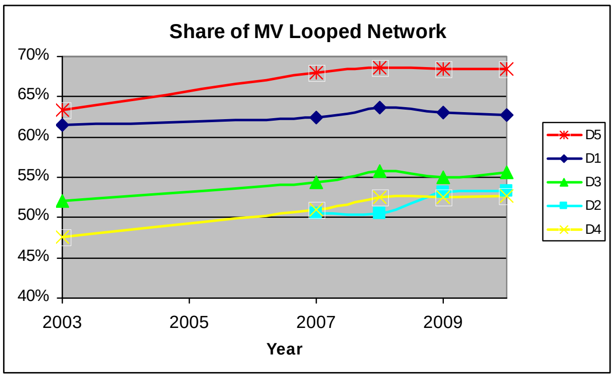


**Figure 10**

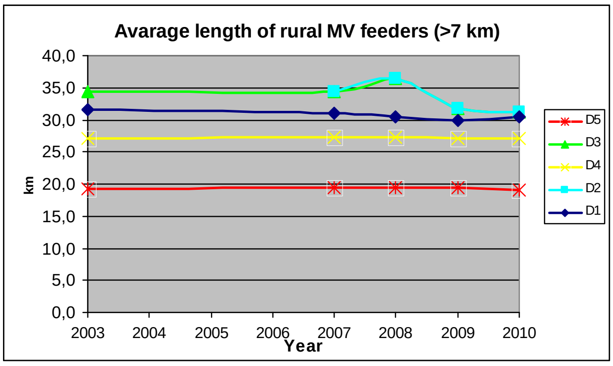


**Figure 11**

## Estimated correlation to reliability

For the reason of comparison and proper consideration of reliability impact factors the indexation on average value between distribution companies was made (Table 1). Impact factors were also attributed to environment and to network structure group.

Initially most impact factors were considered at the weight factor 1 and only few of them (Cable share, looped network and length of rural feeders) were considered with factors previously estimated by experts.

**Table 1**

| | Impact factor (index) | D1 | D2 | D3 | D4 | D5 | AVG | Note | Weight |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Cable_share | 1,05 | 0,63 | 0,87 | 0,77 | 1,63 | 0,99 | | 4 |
| 2 | Shunt&resonance prot. | 0,15 | 0,05 | 0,45 | 0,09 | 0,00 | 0,15 | part | 1 |
| 3 | Looped network | 1,08 | 0,89 | 0,95 | 0,90 | 1,17 | 1,00 | | 3 |
| 4 | Feeder_length | 1,13 | 0,82 | 0,87 | 0,89 | 1,48 | 1,04 | inverse | 1 |
| 5 | Feeder_>7km | 0,94 | 0,86 | 0,83 | 1,05 | 1,47 | 1,03 | inverse | 2 |
| 6 | Semi-insulated wire | 1,43 | 0,93 | 0,02 | 0,45 | 1,85 | 0,93 | | 1 |
| 7 | Substation_SF6_equip | 0,27 | 0,91 | 0,86 | 0,59 | 3,92 | 1,31 | | 1 |
| 8 | TS_SF6_equip | 0,89 | 0,53 | 0,49 | 1,07 | 1,32 | 0,86 | | 1 |
| 9 | RemoteControl_switch | 0,88 | 0,88 | 0,75 | 0,89 | 2,57 | 1,19 | | 2 |
| 10 | Failure locator | 0,32 | 0,71 | 2,61 | 0,57 | 0,78 | 1,00 | | 1 |
| 11 | DMS | 0,88 | 1,05 | 0,96 | 1,23 | 0,88 | 1,00 | | 1 |
| 12 | Automatisation | 0,00 | 0,00 | 0,00 | 0,00 | 0,07 | 0,01 | part | 1 |
| 13 | Helicopter monitoring | 0,13 | 0,56 | 0,13 | 0,00 | 0,10 | 0,18 | part | 1 |
| 14 | Surge arrester | 0,70 | 1,03 | 0,35 | 2,10 | 1,52 | 1,14 | | 1 |
| | **SUM:** | **16,99** | **15,28** | **16,24** | **16,63** | **30,02** | 19,03 | part | 21 |
| | **inverse** | **21,3** | **23,7** | **22,3** | **21,8** | **12,1** | | | |
| | **Network structure** | **1,12** | **1,25** | **1,17** | **1,14** | **0,63** | **1,00** | inverse | |
| 15 | Storms | 1,36 | 1,01 | 0,86 | 1,36 | 0,37 | 0,99 | | 4 |
| 16 | Ligtning | 1,07 | 1,16 | 1,21 | 0,96 | 0,68 | 1,01 | | 1 |
| 17 | Consumer dispersion | 0,99 | 1,07 | 1,27 | 0,82 | 0,75 | 0,98 | inverse | 1 |
| 18 | Power density | 0,81 | 1,22 | 1,13 | 1,12 | 0,79 | 1,01 | inverse | 1 |
| 19 | Woods | 1,11 | 0,74 | 0,62 | 1,64 | 1,08 | 1,04 | | 2 |
| 20 | Terrain height variation | 0,97 | 1,17 | 0,73 | 1,26 | 0,94 | 1,01 | | 2 |
| | **SUM:** | **12,44** | **11,31** | **9,77** | **14,11** | **7,74** | 11,07 | | 11 |
| | **Invironmental impact** | **1,12** | **1,02** | **0,88** | **1,27** | **0,70** | **1,00** | | |
| | **Impacts value** | **33,76** | **35,01** | **32,08** | **35,89** | **19,80** | 31,31 | | |
| | **All impacts** | **1,08** | **1,12** | **1,02** | **1,15** | **0,63** | | | |
| | **(SAIFI+SAIDI)_index** | **1,02** | **1,12** | **1,00** | **1,28** | **0,60** | | | |

The correlation based on some expert-estimated weight factors produced quite reasonable results. Distribution companies with very unfavourable impact factors index had much higher reliability (SAIFI+SAIDI) index. The network structure was indicated as a guide impact group if extreme-event years were not taken into account (Figure 12).

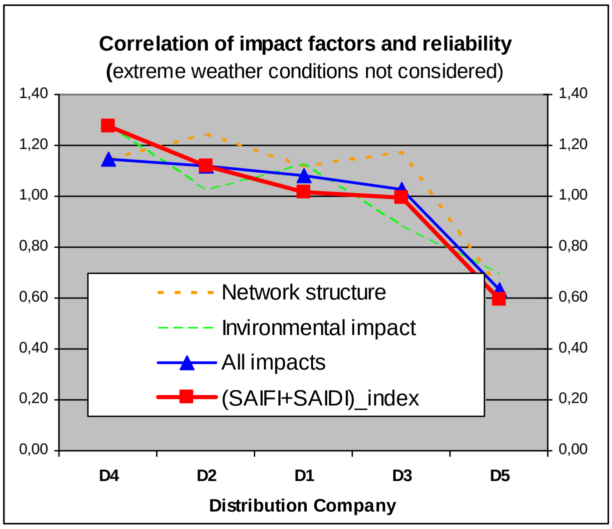


**Figure 12**

## Statistical analysis

For the exact determination of impact factors a linear multiple regression statistical analysis was performed where the impact factors were presented as control variables (X) and SAIFI and SAIDI were presented as output variables (Y):

$$Y = \beta_0 + \beta_1.X_1 + \beta_2.X_2 + \dots + \beta_k.X_k \quad (1)$$

The impact factors were represented as calculated set of $\beta$.

Figure 13 shows the simplest linear regression with one variable. It also shows a key problem of poor statistical significance revealed by the factor $R^2$ on the set off all data.

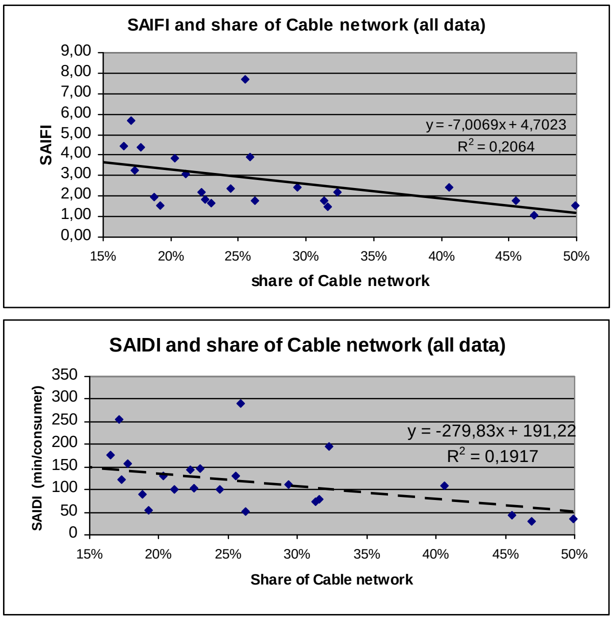


**Figure 13**

To obtain better results of impact factors the next study [2] with wide range of calculations was made on different sets of data and variables. Expert tests were made excluding and including untypical years, companies, using small and large set of input variables. The resulting calculated impact factors $\beta$ for SAIDI are shown in Table 2. Linearity of the control variables is represented by factor H.

The main impact factor for SAIDI is the network structure parameter the share of cable network. If the very untypical years with extreme weather events, which render to the small significance, are excluded then correlation between share of cable network to both SAIDI and SAIDI is clear and can be proved with high statistical significance.

Further investigations were made on the company average data configuration on a set of data from 2008-2010 obtained on the new Energy Agency unified platform for reliability data collection.

**Table 2**

| | N | | Cable share | Shunt& Reson | Loop share | Loop OVH share | Feeder Length | Feeder L >7km | Lighte-ning | Storms | SAIDI | $R^2$ | $R^{2\_adjust}$ | Note |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | N | | X1 | X2 | X3 | X4 | X5 | X6 | X7 | X8 | Y | | | |
| All Data | 24 | β | -90,6 | 44,8 | -708,2 | 482,1 | -4,9 | 2,5 | 19,0 | | 207,0 | | | |
| | | H | 11% | 29% | 32% | 27% | 20% | 23% | 91% | | 33% | 35% | 7% | poor |
| excl D2 2007, D3 | 22 | β | -850,2 | -27,2 | 1069,6 | -829,0 | -5,7 | -5,5 | 4,6 | | 358,7 | | | |
| 2009 | | H | 98% | 32% | 75% | 72% | 44% | 76% | 55% | | 0,841 | 68% | 51% | good |
| excl D2 & D3 | 18 | β | **-899,6** | **-85,6** | -1304,2 | 2068,1 | -1,2 | -3,9 | -9,8 | | 219,4 | | | **very** |
| | | H | **99%** | **86%** | 69% | 90% | 18% | 60% | 97% | | 87% | **93%** | **88%** | **good** |
| excl D2 & D3 | 18 | β | **-1232,4** | | 70,8 | 847,0 | 0,5 | -9,4 | -8,3 | | 263,2 | | | |
| | | H | **100%** | | 6% | 61% | 7% | 99% | 92% | | 90% | 91% | 87% | **illogical** |
| Data (2008-2010) | 15 | β | **576,7** | 93,7 | **-2594,5** | 1692,1 | -15,9 | 5,1 | 22,0 | **3,0** | 455,1 | | | |
| with D3 2009 | | H | 79% | 60% | **87%** | 75% | 44% | 53% | 99% | **100%** | 44% | **95%** | **87%** | **illogical** |
| Data (2008-2010) | 15 | β | | **12,4** | **-229,6** | | | | | **3,4** | 166,7 | | | **very** |
| with D3 2009 | | H | | 17% | **84%** | | | | | **100%** | 90% | 80% | 74% | **good** |
| Data (2008-2010) | 15 | β | **-107,6** | 16,3 | | | | | | **3,4** | 62,1 | | | **very** |
| with D3 2009 | | H | 69% | 21% | | | | | | **100%** | 87% | 77% | 71% | **good** |

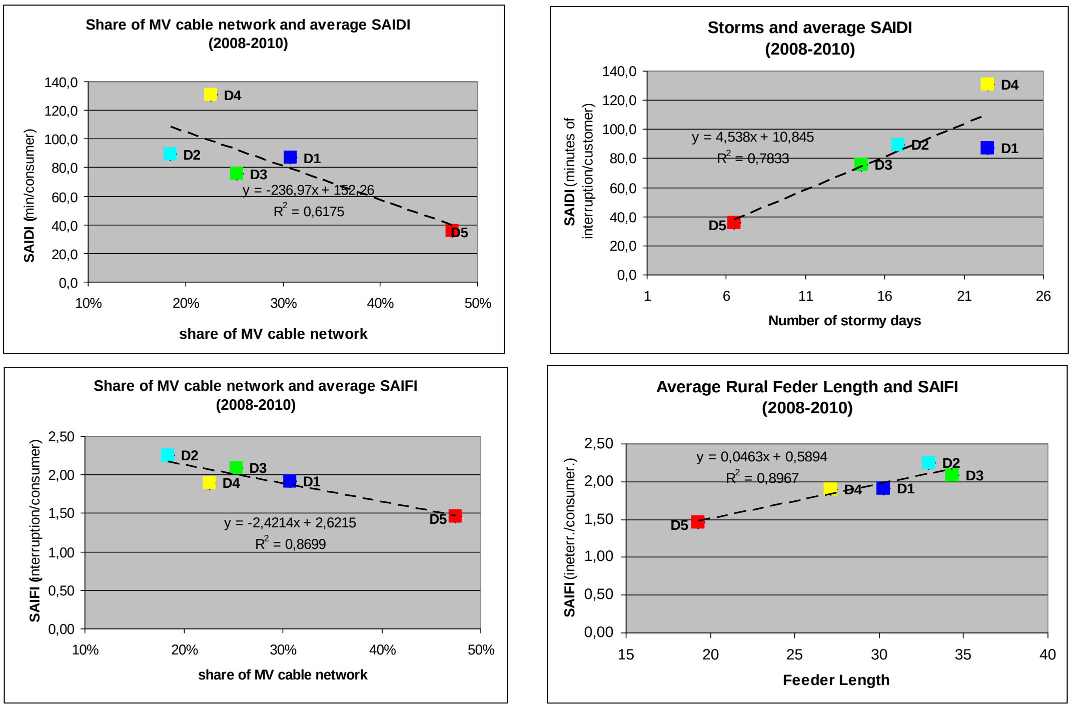


**Figure 14**

## CONCLUSION

The results of analysis confirm practical experience and theory (Figure 14):

- company's reliability is connected to both environmental and network structure factors;
- share of cable network is the most important network impact factor which is strongly correlated with both SAIFI and SAIDI;
- average length of long feeders (> 7 km) is significantly correlated to SAIFI;
- stormy weather events as the most important environmental impact factor is strongly correlated with the duration of unsupply SAIDI, thus extremely weather events should be excluded from company benchmarking;
- lightening is not statistical very significant parameter;
- share of looped network is well correlated with SAIDI and share of MV lines in woods to SAIFI

Next reflection should be made on investigation of reasons for such different share of cable network between distribution companies as the most significant reliability impact factor. First indication is that the higher rate of cable lines is influenced by the power density and average revenue per kWh. This ascertainment leads to further improvements of regulatory framework to set the proper incentives for improving network reliability.

## REFERENCES

[1] T. Mohar, L. Valenčič, 2011, The Methodology of Network Continuity of Supply Impact factors analysis for Slovenia, Elektroinštitut Milan Vidmar, Ljubljana, Slovenia.

[2] T. Mohar, L. Valenčič, 2011, The analysis of network continuity of supply impact factors for Slovenia, Elektroinštitut Milan Vidmar, Ljubljana, Slovenia.