



ELEKTRO MARIBOR

# Širimo energetsko odličnost!

**Projekt NEDO**

Energija zame!



# NEDO

- Razvojno demonstracijski projekt NEDO je bil decembra 2019 uspešno zaključen.
- V obsegu projekta so bile uspešno demonstrirane in delno tudi razvite specifične funkcionalnosti z namenom spodbujanja novih pristopov za zagotavljanje sistemskih storitev v elektroenergetskem sistemu, uporabe izdelkov v sistemskih aplikacijah, ki še niso na tržišču ter ustrezno uporabo prostorskih, demografskih in tehnoloških značilnosti distribucijskega elektroenergetskega omrežja Elektra Maribor d.d..



# Cilji projekta NEDO

- Informacije iz omrežja in stanja topologije uporabiti v realnem času z namenom izboljšanja kvalitete napajanja,
- Optimizacija omrežja za vključevanje in obratovanje razpršenih obnovljivih virov
- Optimizacija konične moči

Za dosego omenjenih ciljev projekta je bil fundamentalni pogoj

- na višji nivo dvigniti spoznavnost in vodljivost omrežja ter
- ustrezno pripraviti, strukturirati in avtomatsko prenašati tehnične ter geografske-topološke podatke omrežja.

Poleg uspešno doseženih ciljev projekta predstavljajo nova znanja in spoznanja pri pripravi, povezovanju in prenosu podatkov v realnem času med različnimi podatkovnimi bazami in sistemi največjo dodano vrednost projekta NEDO.

# Cilji in izzivi



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| Challenge and Goals                                                              | DMS Solution                                                      |                                                                                                                                                                                                       |
|----------------------------------------------------------------------------------|-------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Utilize real-time information and connectivity to automate for quality of supply | <b>FLISR</b><br>Fault Location, Isolation and Service Restoration | <b>The focus of this material</b><br>Automatic power restoration upon a fault on a distribution line with remote controllable sectionalizing switches                                                 |
| Maximize RES with automated dispatch control                                     | <b>VC</b><br>Voltage Control                                      | Advanced control for high penetration of distributed generators                                                                                                                                       |
| Obtain the reserve power without depending on power generator or battery         | <b>CVR</b><br>Conservation Voltage Reduction                      | Energy saving by reducing the voltage of the whole network as much as possible within a lower limit of the appropriate voltage.                                                                       |
| Shave and optimize peak demand                                                   | <b>EMS+</b><br>Collaboration with AEMS                            | Collaboration with AEMS for below purposes <ul style="list-style-type: none"><li>• Area Energy Optimization</li><li>• Life Continuous Planning(LCP)</li><li>• DR Solution as a new business</li></ul> |
| Postpone needed investments                                                      | <b>DR</b><br>Demand-Response for Utility                          | Demand Response by using DLC(Direct Load Control) and HEMS                                                                                                                                            |

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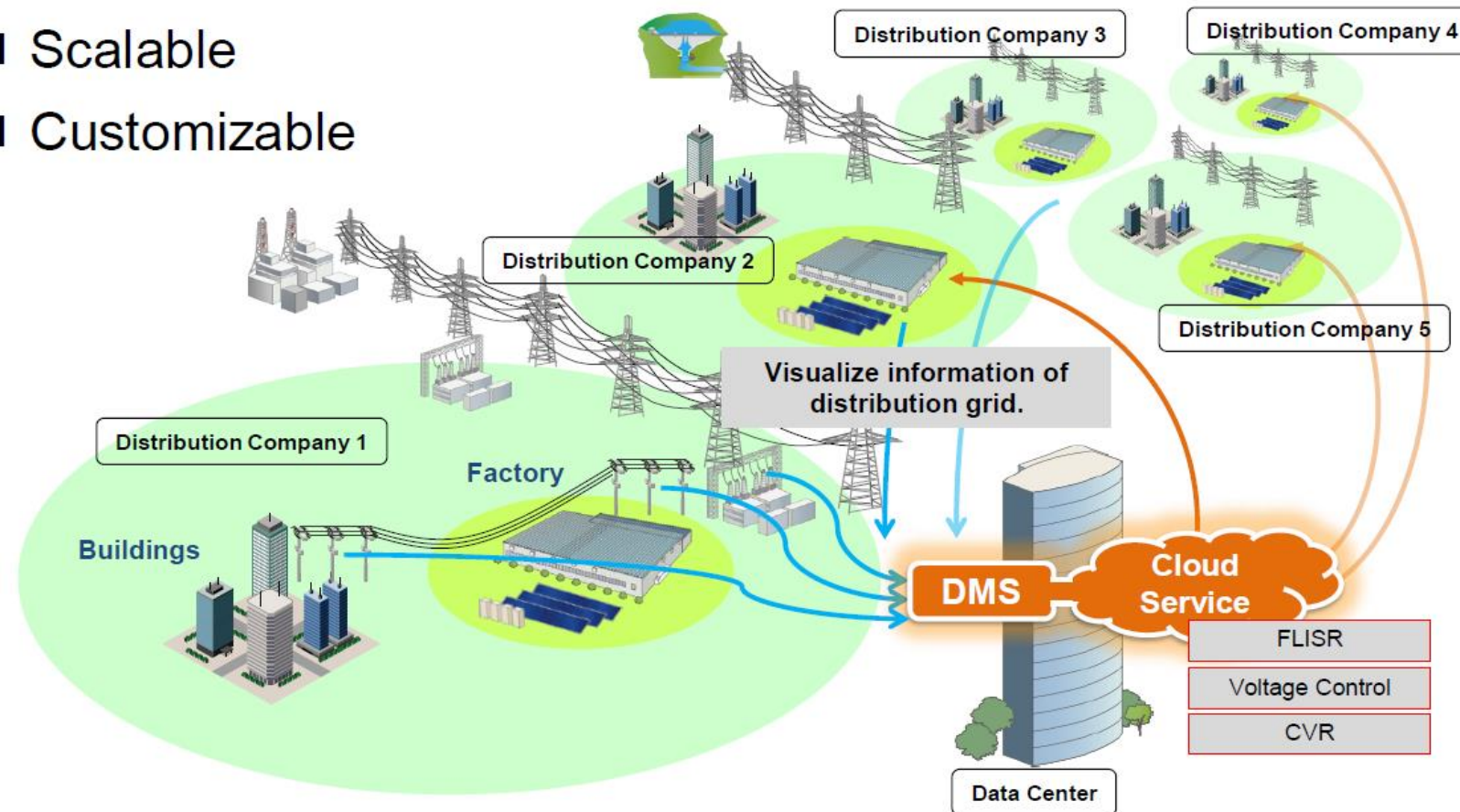


# Koncept Oblačne strukture DMS



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- Cloud based system
- Modular Solution
- Scalable
- Customizable



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Slovenj Gradec  
in Elektro Celje



RMU & Re-Closer

Kleče D.C. in Ljubljana



Cloud DMS

Ptuj in Elektro Maribor



Re-Closer

1x Cloud DMS

27x Re-Closer

9x RMU

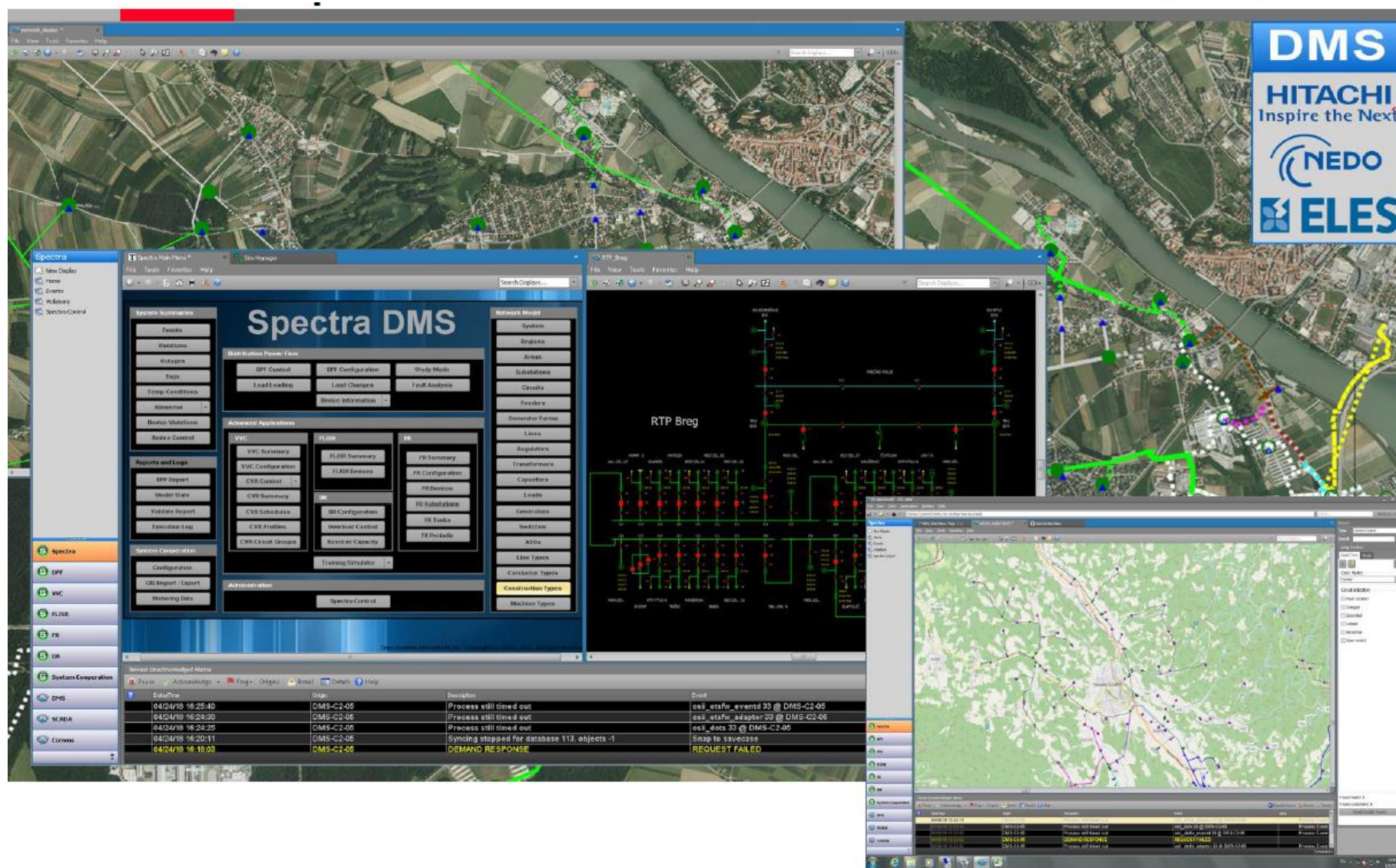
5x Local voltage  
controller

99x Network  
measurements





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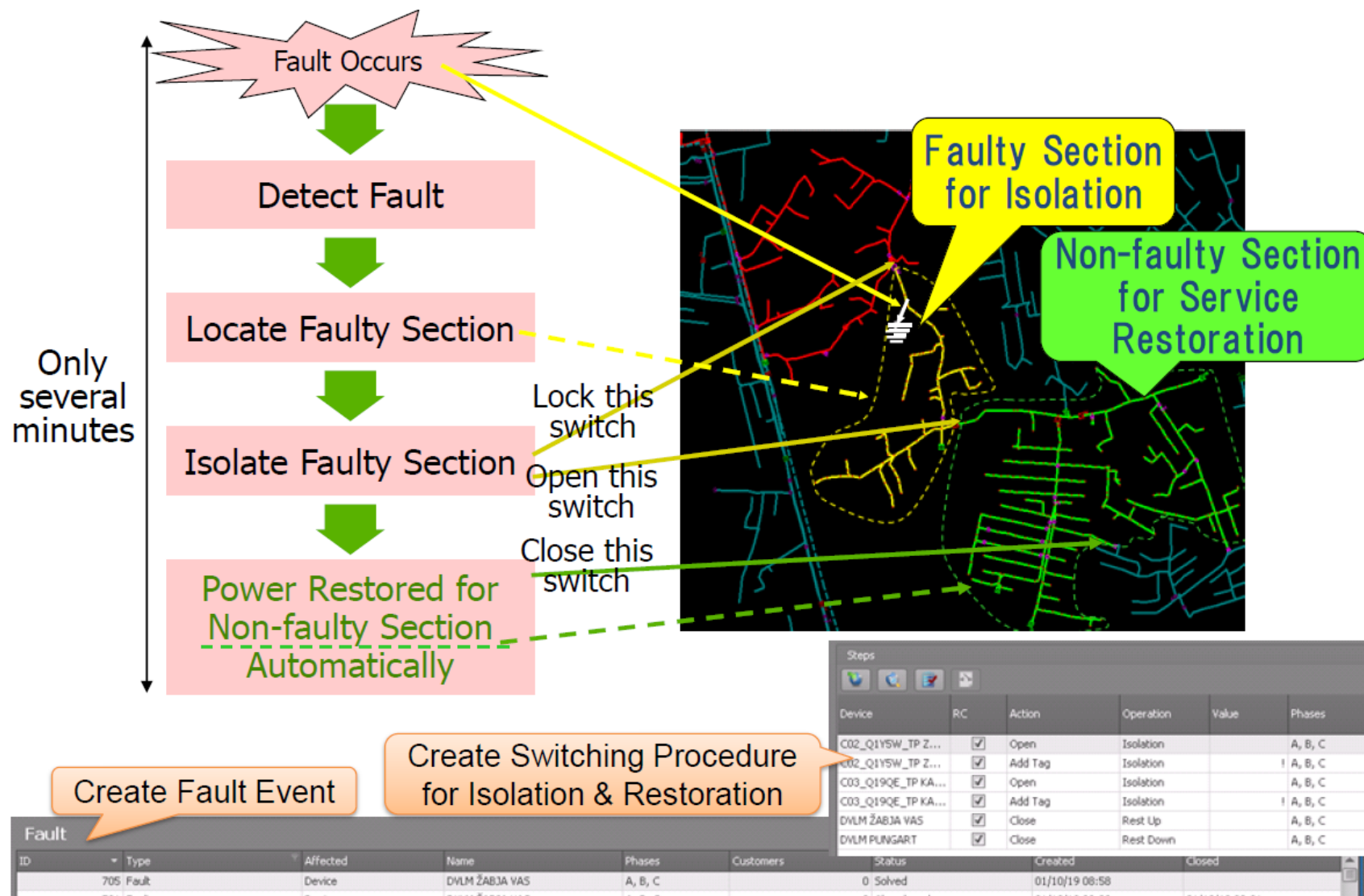


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# FLISR



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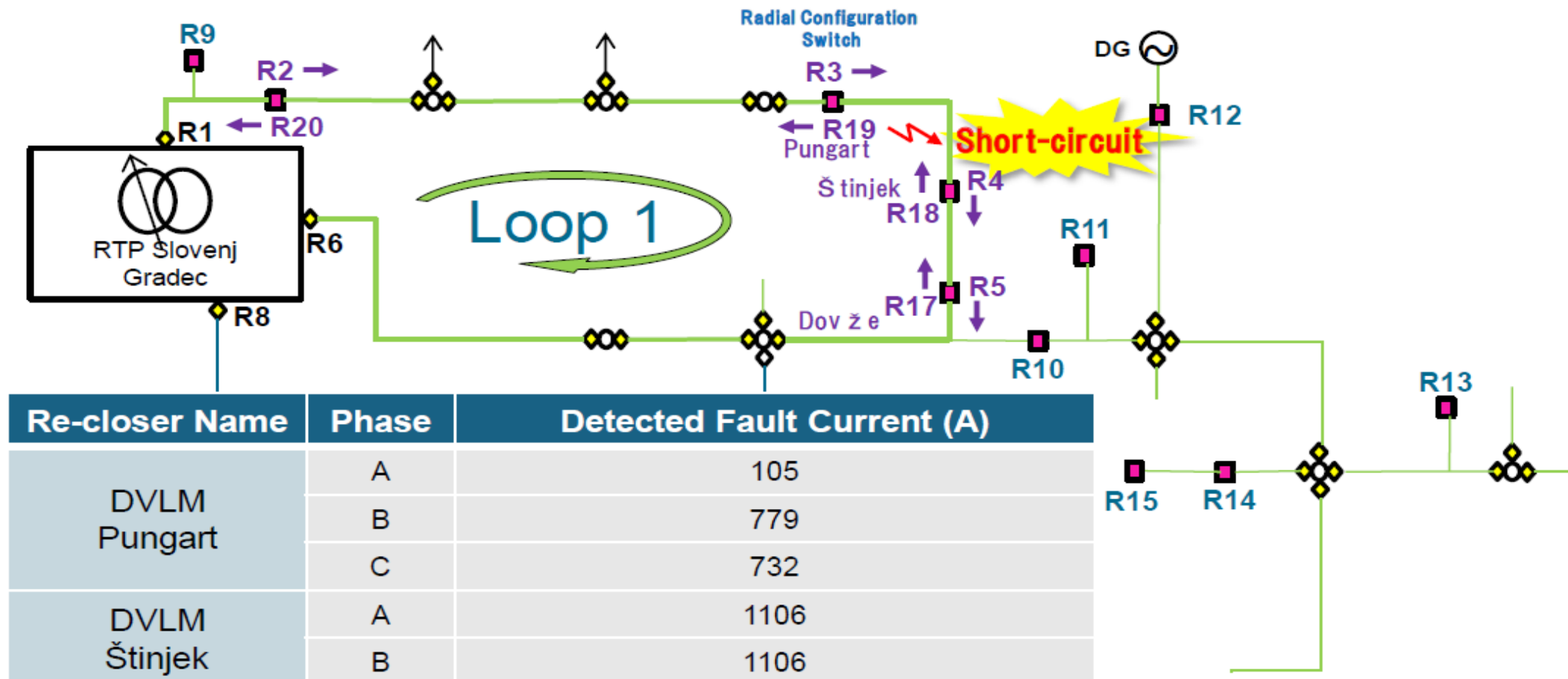
Okvara: Kratek stik

Lokacija: Štinjek (R4, R18) – Pungart ( R3,R19)

Čas: 26.04.2019, 16:53



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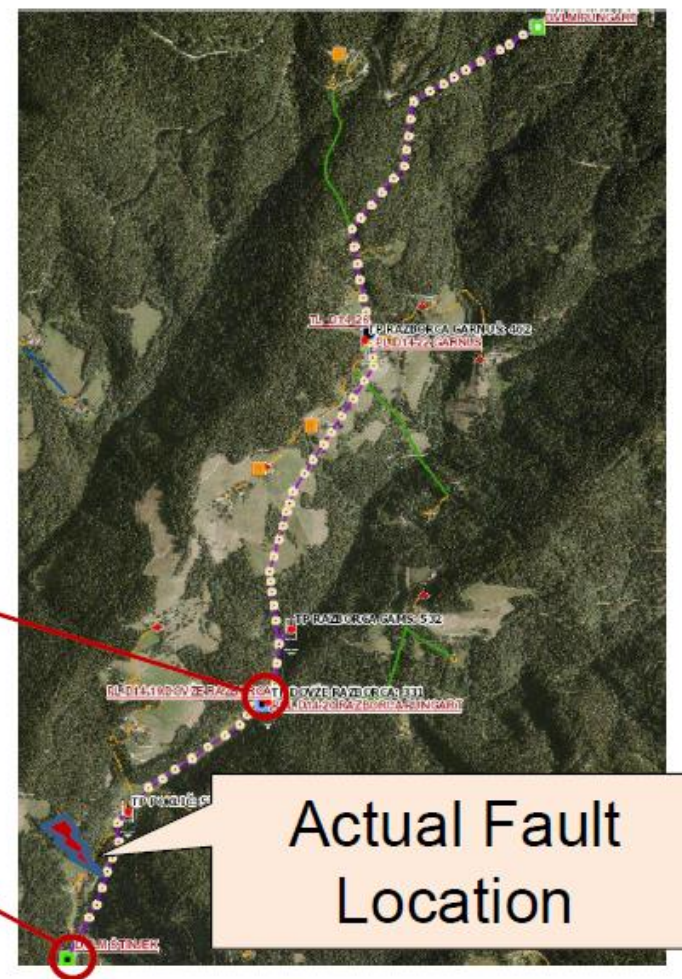
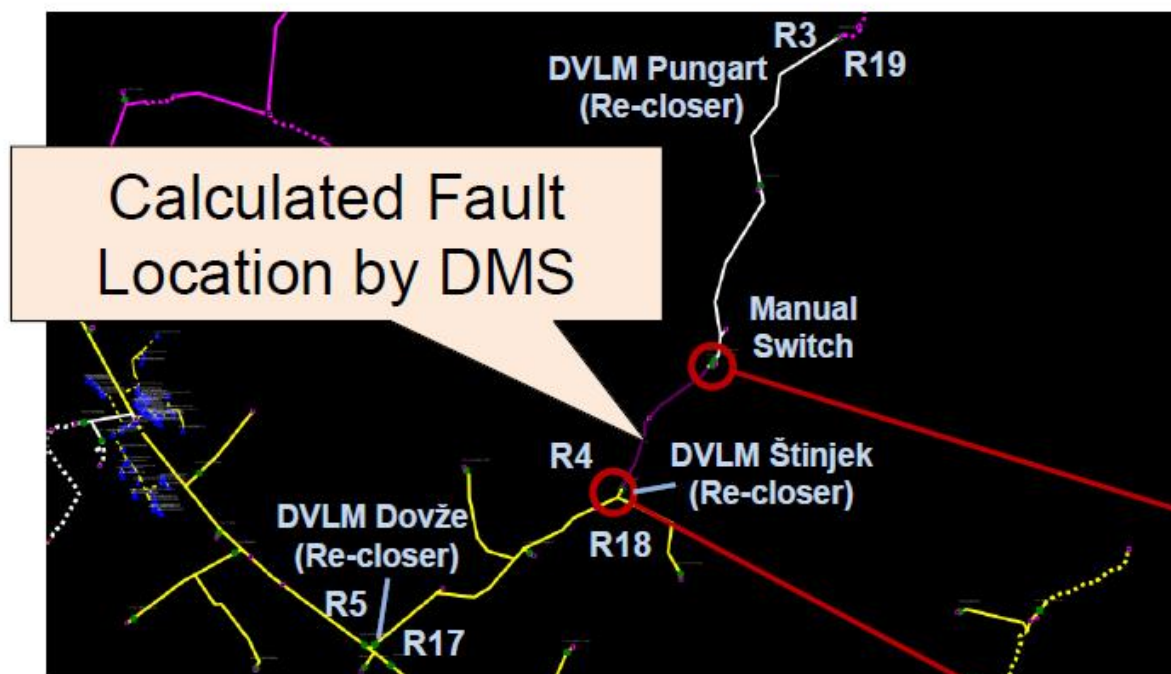
\*Referenced from the report "Closed-loop operation and reactive power provision presentation 16.05.2019" by Maribor University

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FLISR je izračunal potencialno mesto okvare. Izračunana lokacija je bila izjemno natančna (nekaj m od dejanske okvare)  
Razred točnosti izračuna okvare je odličen.



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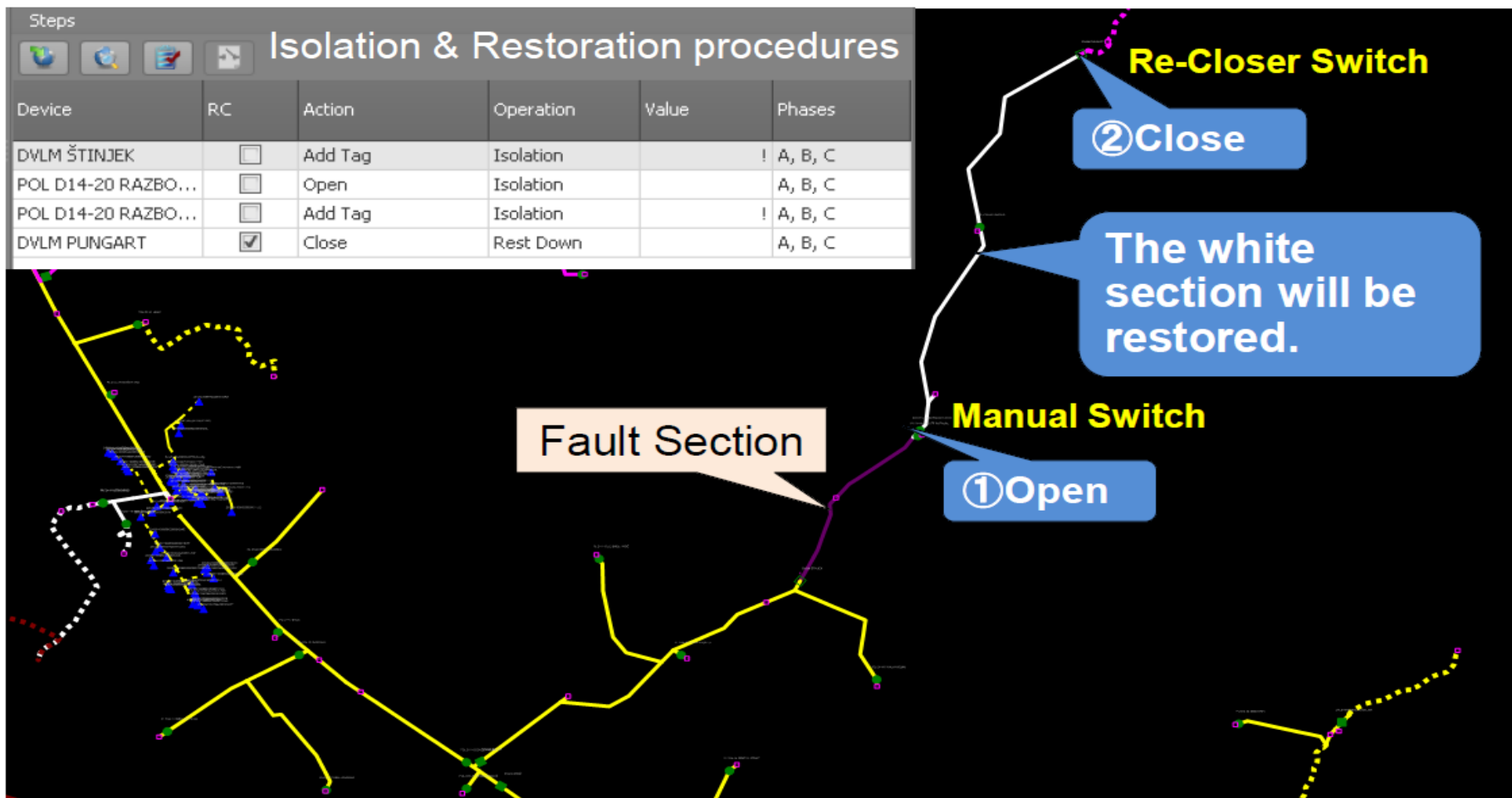


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- DMS je izračunal in predlagal pravilne procedure stikalnih manipulacij za Izoliranje mesta okvare in ponovno vzpostavitev napajanja neokvarjenih delov omrežja – izvoda SN



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# Kaj je SAIDI

## What's SAIDI?

### System Average Interruption Duration Index

$$SAIDI = \frac{\text{Sum of all customer interruption durations}}{\text{Total number of customers served}}$$

Za namen analize smo uporabili podatke okvar – defektov z naslednjimi atributi:

Izvod:

EM: TRŽEC

EC: DOLIČ

Obdobje:

-01.10.2018 do 30.06.2019 ( iDMS, Hitachi je bil zagnan oktobra 2018

Karakteristika:

- neplanirani dogodki – izpadi
- trajanje izpada > 3 min
- re-closer, odklopnik ( njegova zaščita) bila pobujena
- dejanska mesta okvare bila kasneje potrjena iz strani obratovalcev EM in EC

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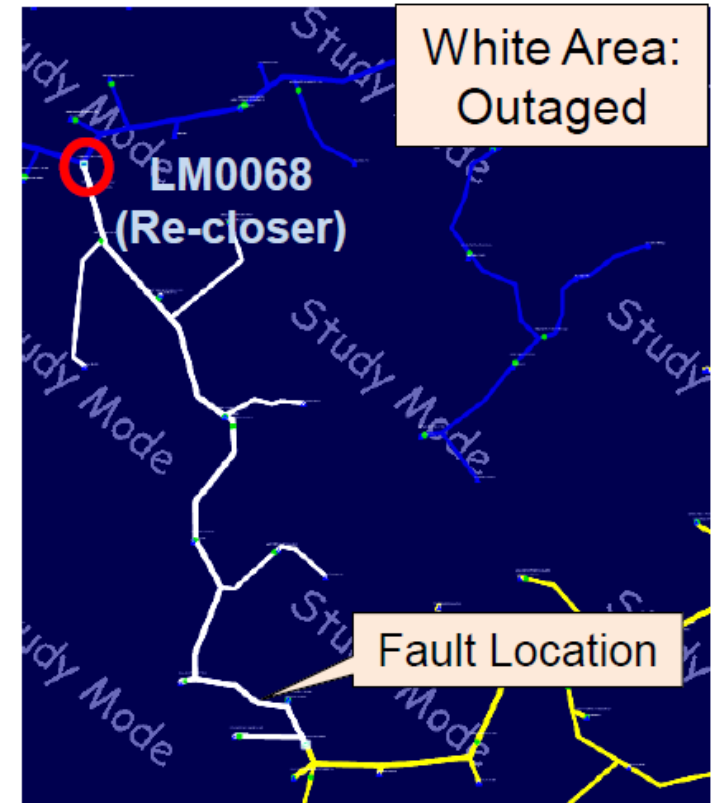
# Primer TRŽEC



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| Date     | Outaged Time (min) | Disconnection Element | Number of Customers Outaged |
|----------|--------------------|-----------------------|-----------------------------|
| 30/10/18 | 178.10             | LM0068                | 362                         |

- Odklopnik LM0068 (zaščita) se pobudi zaradi okvare v omrežju ( za njim)
- Napajalno področje ozir. daljnovod za LM0068 bi bil brez napajanja do odprave vzroka okvare



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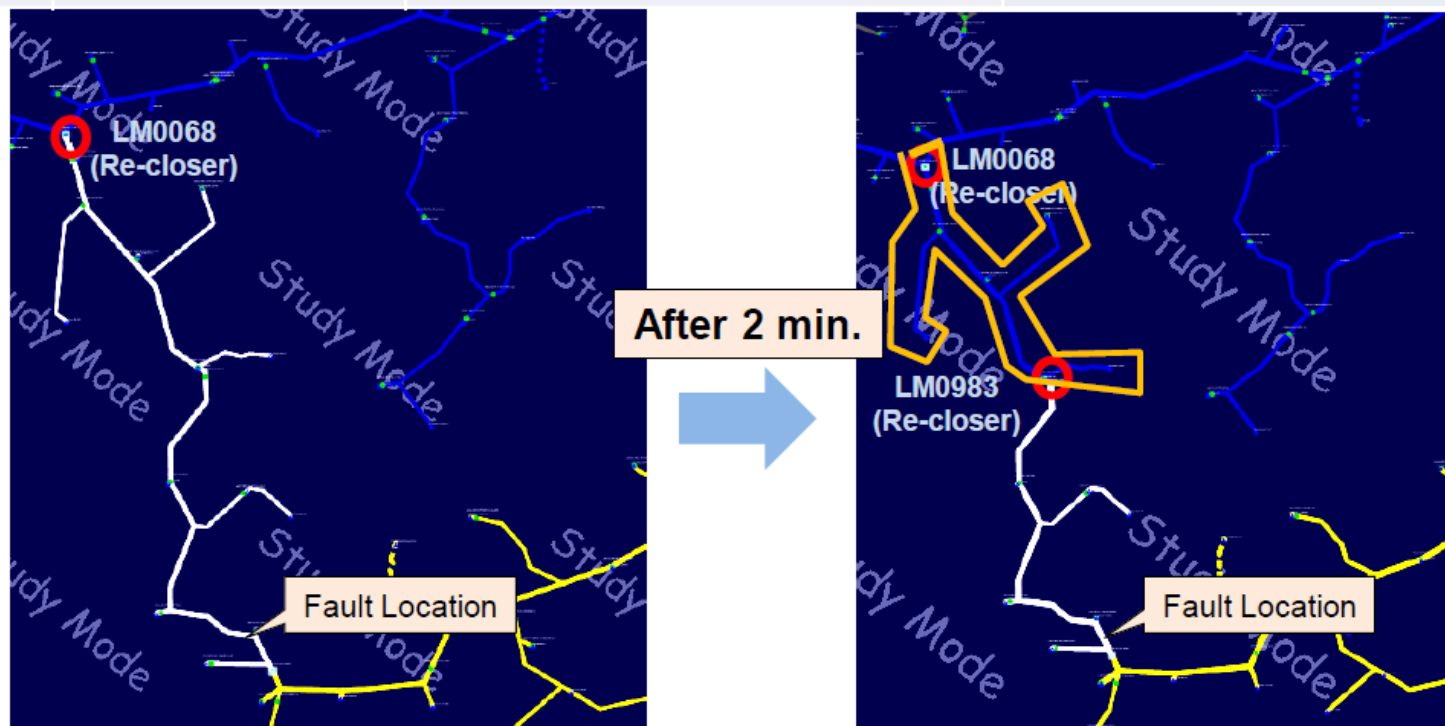
z uporabo FLISR, lahko vzpostavimo ponovno napajanje večjega dela izpadlega omrežja – prikazano z oranžno



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| Date     | Outaged Time (min) | Disconnection Element | Number of Customers Outaged |
|----------|--------------------|-----------------------|-----------------------------|
| 30/10/18 | 2.00               | LM0068                | 362                         |
|          | 176.10             | LM0983                | 136                         |

Izoliranje okvarjenega dela in vzpostavitev napajanja na neokvarjenem je bila izvedena znotraj 2 min kar bistveno vpliva na kvaliteto napajanja - SAIDI



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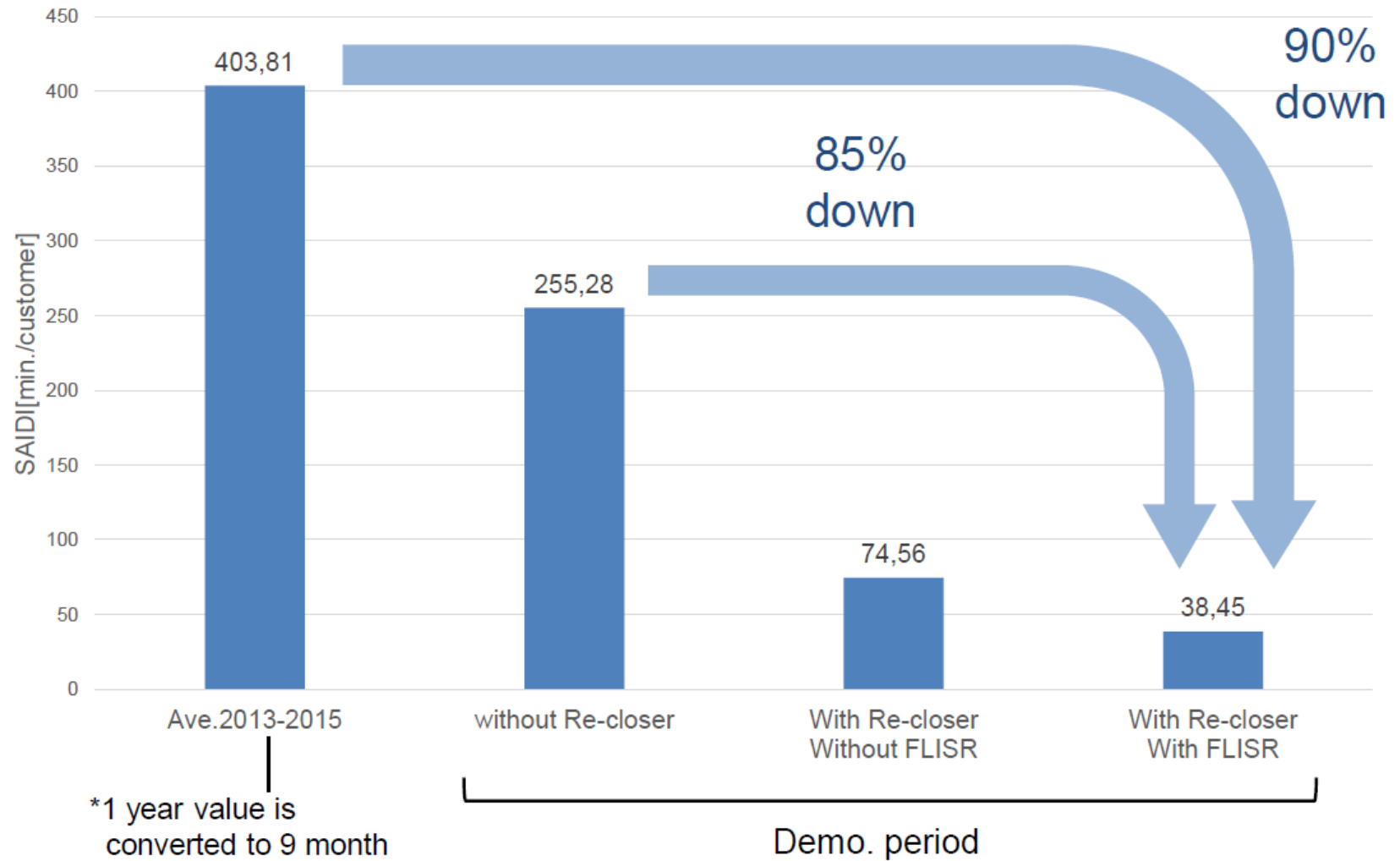
## znižanje SAIDI na TRŽEC z FLISR



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primerjava SAIDI  
TRŽEC

01.10.2018 – 30.06.2019  
čas demonstracije FLISR



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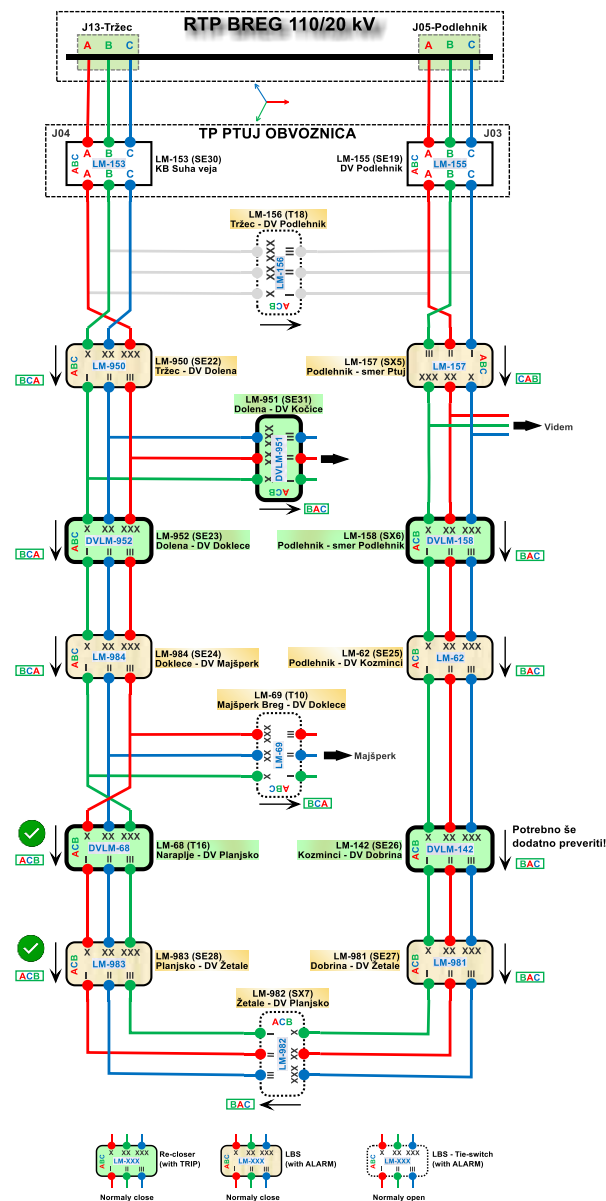
- Potrdili smo, da FLISR zmanjšuje čas trajanja okvare
- Dokazali smo da FLISR lahko zmanjša SAIDI za 86% v primerjavi do obratovanja brez FLISR
- V povprečju FLISR zniža SAIDI za 55% glede na povprečje SAIDI 2013-2015.
- Zaključimo lahko, da je FLISR učinkovito orodje za znižanje SAIDI

|         | Feeder | SAIDI Reduction<br>compared to Ave.2013-2015 |                        |                | SAIDI Reduction<br>compared to without FLISR |                        |                |
|---------|--------|----------------------------------------------|------------------------|----------------|----------------------------------------------|------------------------|----------------|
|         |        | SAIDI<br>Ave.<br>2013-2015                   | SAIDI<br>with<br>FLISR | Reduction      | SAIDI<br>without<br>FLISR                    | SAIDI<br>with<br>FLISR | Reduction      |
| EC      | DOLIČ  | 117                                          | 94                     | 23<br>(19.7%)  | 783                                          | 94                     | 689<br>(88.0%) |
| EM      | TRŽEC  | 404                                          | 38                     | 366<br>(90.6%) | 255                                          | 38                     | 217<br>(85.1%) |
| Average |        | -                                            | -                      | 55.2%          | -                                            | -                      | 86.6%          |

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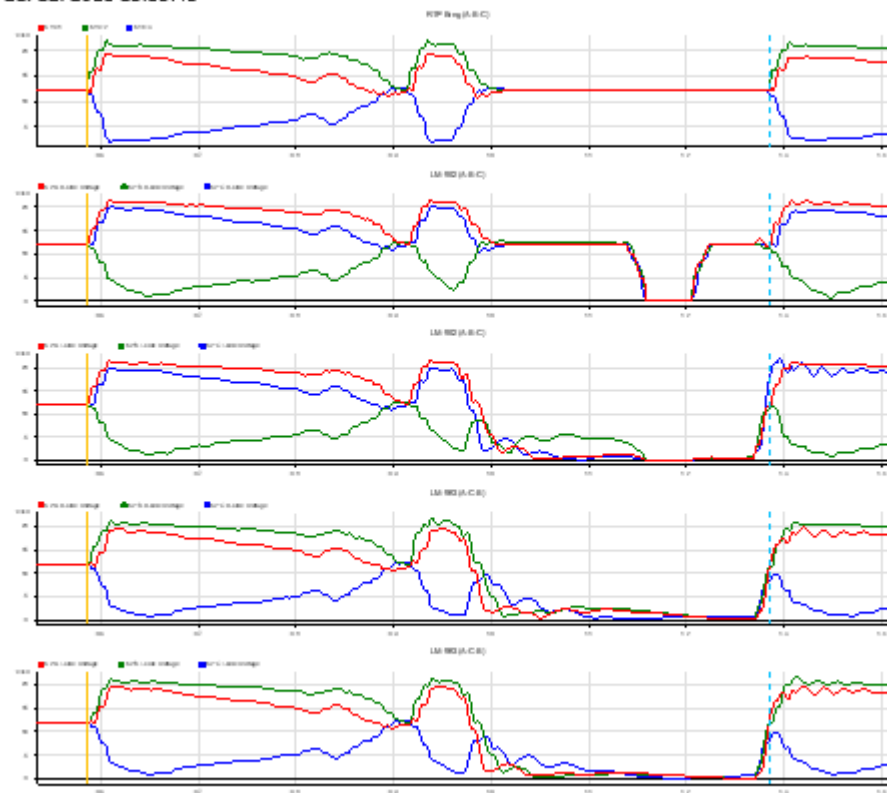


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Pravilno stanje, usklajeno z RTP z analizo defektov!

21. 12. 2018 13:35:43

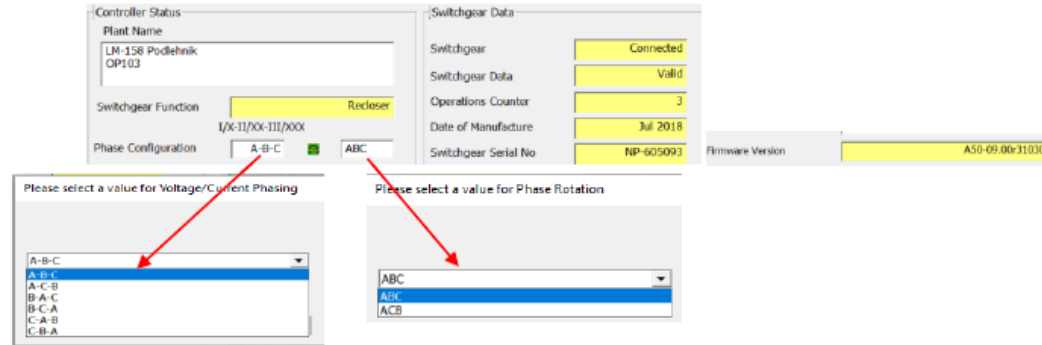


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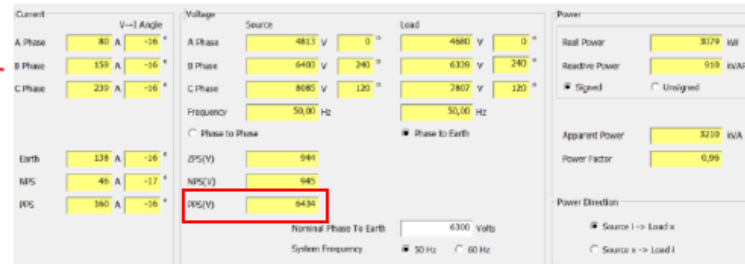
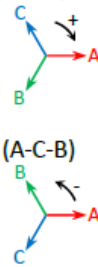
## Testiranje faznosti zaporedja (identifikacija faz) na Nulec AVDC3

Namen testiranja faznosti zaporedja je ugotoviti, kako vplivata parametra Voltage/Current Phasing in Phase Rotation na vrednosti meritev in oscilografije. Zakaj? Za potrebe analiz in naprednih algoritmov je pomembna pravilna usklajenosti faznosti na posameznih DVLM z RTP-jem, še posebej ob okvarah v omrežju.



Testiranja smo izvedli tako, da smo sekundarno priključili napetosti in tokove in sicer:

- Priključitev napetosti in tokov za pozitivno zaporedje (A-B-C)
  - $U_{LA} = 4 \angle 0^\circ \text{ kV}$ ;  $I_{LA} = 80 \angle 340^\circ \text{ A}$
  - $U_{LB} = 6 \angle 240^\circ \text{ kV}$ ;  $I_{LB} = 160 \angle 220^\circ \text{ A}$
  - $U_{LC} = 8 \angle 120^\circ \text{ kV}$ ;  $I_{LC} = 240 \angle 100^\circ \text{ A}$
- Priključitev napetosti in tokov za negativno zaporedje (A-C-B)
  - $U_{LA} = 4 \angle 0^\circ \text{ kV}$ ;  $I_{LA} = 80 \angle 340^\circ \text{ A}$
  - $U_{LB} = 6 \angle 120^\circ \text{ kV}$ ;  $I_{LB} = 160 \angle 100^\circ \text{ A}$
  - $U_{LC} = 8 \angle 240^\circ \text{ kV}$ ;  $I_{LC} = 240 \angle 220^\circ \text{ A}$



Pri tem smo vedno imeli nastavljeno **Power Direction na Source i -> Load x**.

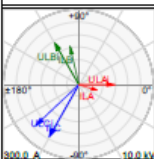
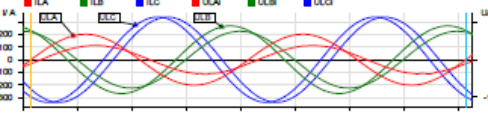
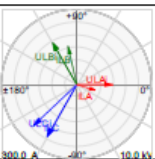
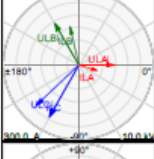
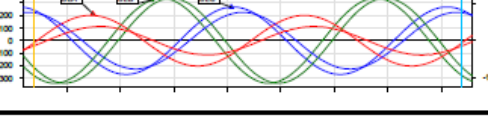
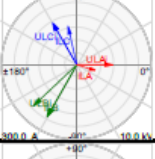
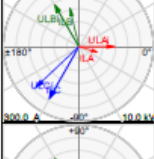
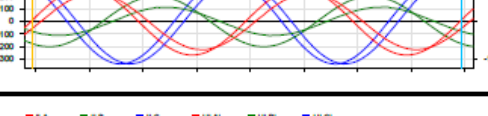
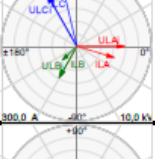
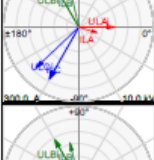
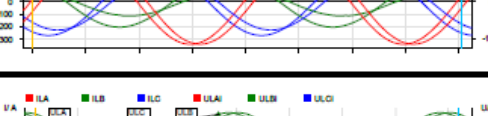
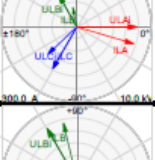
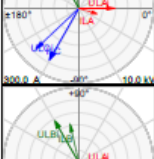
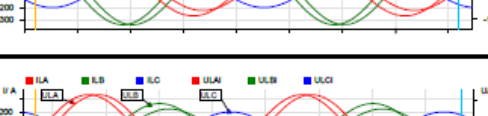
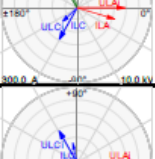
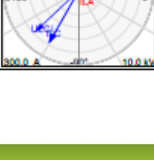
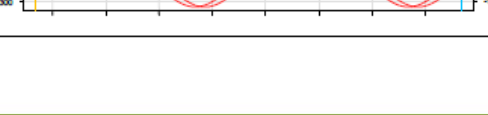
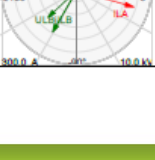
V log datotekah je prikaz napetosti  $U_{LA1}/U_{LB1}/U_{LC1}$  in  $U_{LA2}/U_{LB2}/U_{LC2}$  vezan na izbiro Power Direction (Source = 1, Load = 2).

Izvedli smo vse možne kombinacije, pri tem pa za vsako meritev posneli ročno oscilografijo in odčitali vrednosti tako na samem AVDC in WSOS ter na komunikacijskem protokolu IEC 104. Rezultati meritev so prikazani v nadaljevanju.





Meritve, ko je bil vir orientiran negativno (ACB)

| Source (negative)                                                                                                                                                  | U/I phasing | Phase rotation | Phase | Meas. on WSOS                                                            | Meas. on IEC 104                          | Manual Waveform Trigger                                                               | Phasor diagram                                                                        | Comment                           |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------|----------------|-------|--------------------------------------------------------------------------|-------------------------------------------|---------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|-----------------------------------|
| <br>UL-I = 4 $\angle$ 0°<br>UL-II = 6 $\angle$ 120°<br>UL-III = 8 $\angle$ 240°   | A-B-C       | ABC            | NPS   | UL-A = 4 $\angle$ 0°<br>UL-B = 6 $\angle$ 120°<br>UL-C = 8 $\angle$ 240° | UL-A = 4 kV<br>UL-B = 6 kV<br>UL-C = 8 kV |    |    | Correct.<br>U I II III<br>U A B C |
|                                                                                                                                                                    |             | ACB            | PPS   |                                                                          |                                           |                                                                                       |                                                                                       |                                   |
| <br>UL-I = 4 $\angle$ 0°<br>UL-II = 6 $\angle$ 120°<br>UL-III = 8 $\angle$ 240°   | A-C-B       | ABC            | PPS   | UL-A = 4 $\angle$ 0°<br>UL-B = 8 $\angle$ 240°<br>UL-C = 6 $\angle$ 120° | ULA = 4 kV<br>ULB = 8 kV<br>ULC = 6 kV    |    |    | Correct.<br>U I II III<br>U A C B |
|                                                                                                                                                                    |             | ACB            | NPS   |                                                                          |                                           |                                                                                       |                                                                                       |                                   |
| <br>UL-I = 4 $\angle$ 0°<br>UL-II = 6 $\angle$ 120°<br>UL-III = 8 $\angle$ 240°   | B-A-C       | ABC            | PPS   | ULA = 6 $\angle$ 0<br>ULB = 4 $\angle$ 240°<br>ULC = 8 $\angle$ 120°     | ULA = 6 kV<br>ULB = 4 kV<br>ULC = 8 kV    |    |    | Correct.<br>U I II III<br>U B A C |
|                                                                                                                                                                    |             | ACB            | NPS   |                                                                          |                                           |                                                                                       |                                                                                       |                                   |
| <br>UL-I = 4 $\angle$ 0°<br>UL-II = 6 $\angle$ 120°<br>UL-III = 8 $\angle$ 240°   | B-C-A       | ABC            | NPS   | UL-A = 8 $\angle$ 0°<br>UL-B = 4 $\angle$ 120°<br>UL-C = 6 $\angle$ 240° | ULA = 8 kV<br>ULB = 4 kV<br>ULC = 6 kV    |    |    | Correct.<br>U I II III<br>U B C A |
|                                                                                                                                                                    |             | ACB            | PPS   |                                                                          |                                           |                                                                                       |                                                                                       |                                   |
| <br>UL-I = 4 $\angle$ 0°<br>UL-II = 6 $\angle$ 120°<br>UL-III = 8 $\angle$ 240°  | C-A-B       | ABC            | NPS   | ULA = 6 $\angle$ 0<br>ULB = 8 $\angle$ 120°<br>ULC = 4 $\angle$ 240°     | ULA = 6 kV<br>ULB = 8 kV<br>ULC = 4 kV    |  |   | Correct.<br>U I II III<br>U C A B |
|                                                                                                                                                                    |             | ACB            | PPS   |                                                                          |                                           |                                                                                       |                                                                                       |                                   |
| <br>UL-I = 4 $\angle$ 0°<br>UL-II = 6 $\angle$ 120°<br>UL-III = 8 $\angle$ 240° | C-B-A       | ABC            | PPS   | UL-A = 8 $\angle$ 0<br>UL-B = 6 $\angle$ 240°<br>UL-C = 4 $\angle$ 120°  | ULA = 8 kV<br>ULB = 6 kV<br>ULC = 4 kV    |  |  | Correct.<br>U I II III<br>U C B A |
|                                                                                                                                                                    |             | ACB            | NPS   |                                                                          |                                           |                                                                                       |                                                                                       |                                   |



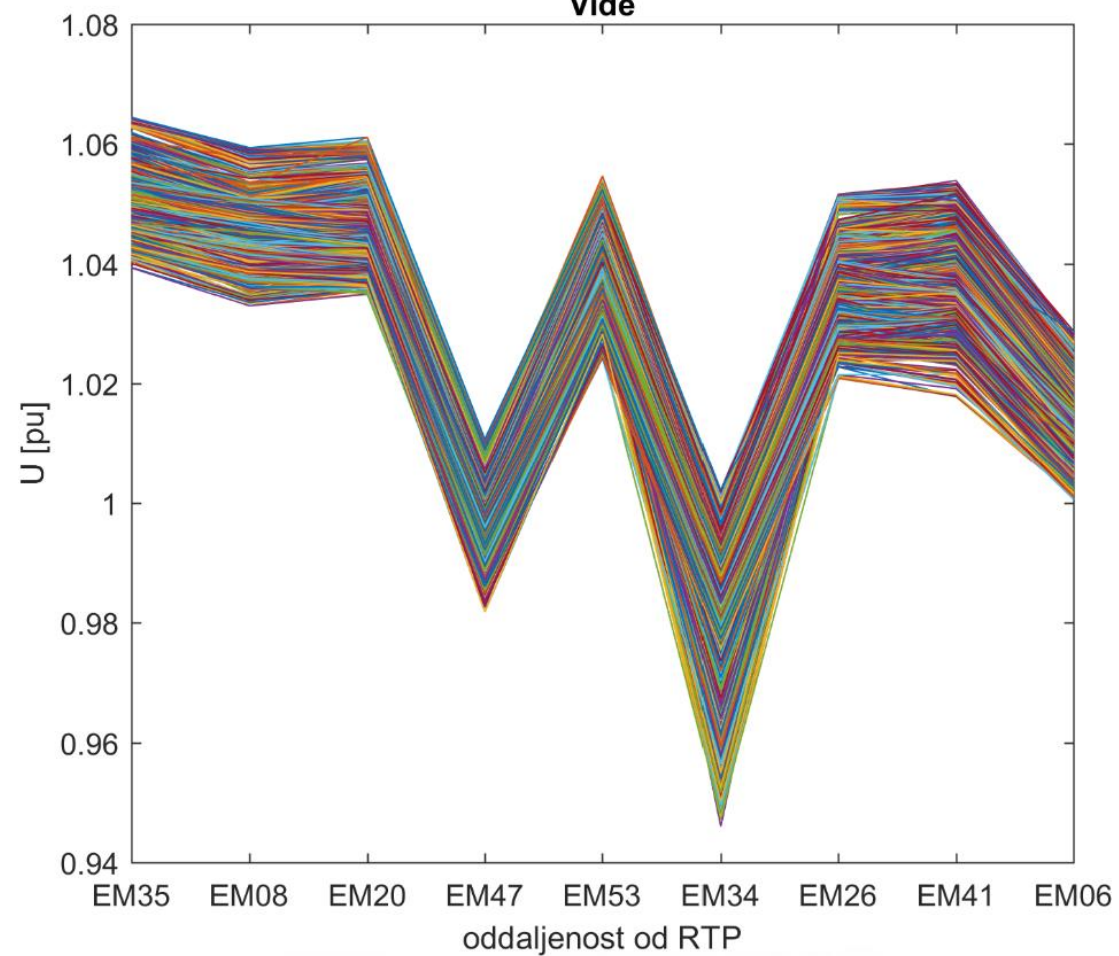
# stopnje TR

|   |    |      |                                         |       |           |      |       |     |    |   |   |       |     |      |         |         |                     |  |
|---|----|------|-----------------------------------------|-------|-----------|------|-------|-----|----|---|---|-------|-----|------|---------|---------|---------------------|--|
| 0 | 9  | EM09 | TP105 Pongrce                           | 75925 | 21/0,42   | 160  | 21000 | 420 | 50 | 3 | 5 | 0     | 230 | 50,0 | 11500,0 | 19918,6 |                     |  |
| 1 | 51 | EM10 | TP729 Zbirni center Starše v Zaltolicju | 74436 | 21/0,42   | 35   | 21000 | 420 | 50 |   | 5 | FALSE | 230 | 50,0 | 11500,0 | 19918,6 |                     |  |
| 2 | 10 | EM11 | TP146 SPOLENJAKOVA-PTUJ                 | 54608 | 20/0,4    | 400  | 20000 | 400 | 50 | 3 | 5 | 0     | 230 | 50,0 | 11500,0 | 19918,6 |                     |  |
| 3 | 11 | EM12 | TP149 Kidričevo Slikar                  | 77293 | 21/0,42   | 1000 | 21000 | 420 | 50 | 3 | 5 | 0     | 230 | 50,0 | 11500,0 | 19918,6 |                     |  |
| 4 | 12 | EM13 | TP171 Sestrže 2                         | 70061 | 20/0,4    | 250  | 20000 | 400 | 50 | 2 | 5 | 2,5   | 230 | 51,3 | 11787,5 | 20416,5 |                     |  |
| 5 | 13 | EM14 | TP173 Gerečja vas 2                     | 29364 | 20/0,4    | 160  | 20000 | 400 | 50 | 2 | 3 | 0     | 230 | 50,0 | 11500,0 | 19918,6 |                     |  |
| 6 | 14 | EM15 | TP192 SLOVENJA VAS 1                    | 54495 | 20/0,4    | 250  | 20000 | 400 | 50 | 2 | 5 | 2,5   | 230 | 51,3 | 11787,5 | 20416,5 |                     |  |
| 7 | 15 | EM16 | TP198 PLETERJE                          | 58262 | 20/0,4    | 250  | 20000 | 400 | 50 | 3 | 5 | 0     | 230 | 50,0 | 11500,0 | 19918,6 |                     |  |
| 8 | 16 | EM17 | TP230 SELA                              | 85326 | 20/0,4    | 160  | 20000 | 400 | 50 | 3 | 5 | 0     | 230 | 50,0 | 11500,0 | 19918,6 |                     |  |
| 9 | 18 | EM18 | TP269 MIZARSTVO-PTUJ                    | 21907 | 20-10/0,4 | 250  | 20000 | 400 | 50 | 3 | 3 | -5    | 230 | 47,5 | 10925,0 | 18922,7 |                     |  |
| 0 | 19 | EM19 | TP284 Mejna cesta Ptuj                  | 45619 | 20-10/0,4 | 400  | 20000 | 400 | 50 | 3 | 5 | 0     | 230 | 50,0 | 11500,0 | 19918,6 |                     |  |
| 1 | 20 | EM20 | TP309 Videm 2                           | 54476 | 20/0,4    | 250  | 20000 | 400 | 50 | 2 | 5 | 2,5   | 230 | 51,3 | 11787,5 | 20416,5 |                     |  |
| 2 | 21 | EM21 | TP320 Draženci 4                        | 54856 | 20/0,4    | 100  | 20000 | 400 | 50 | 3 | 5 | 0     | 230 | 50,0 | 11500,0 | 19918,6 |                     |  |
| 3 | 22 | EM22 | TP328 Majšperk Vrhe                     | 57588 | 20/0,4    | 100  | 20000 | 400 | 50 | 3 | 5 | 0     | 230 | 50,0 | 11500,0 | 19918,6 |                     |  |
| 4 | 23 | EM23 | TP348 SP.GRUŠKOVJE                      | 70139 | 20/0,4    | 100  | 20000 | 400 | 50 | 3 | 5 | 0     | 230 | 50,0 | 11500,0 | 19918,6 |                     |  |
| 5 | 24 | EM24 | TP379 Stopno                            | 47902 | 20-10/0,4 | 250  | 20000 | 400 | 50 | 3 | 5 | 0     | 230 | 50,0 | 11500,0 | 19918,6 |                     |  |
| 6 | 25 | EM25 | TP389 KUNGOTA 2                         | 59598 | 20/0,4    | 100  | 20000 | 400 | 50 | 2 | 5 | 2,5   | 230 | 51,3 | 11787,5 | 20416,5 |                     |  |
| 7 | 26 | EM26 | TP400 Cirkulane 2 - Kožarija            | 59623 | 20/0,4    | 100  | 20000 | 400 | 50 | 4 | 5 | -2,5  | 230 | 48,8 | 11212,5 | 19420,6 |                     |  |
| 8 | 27 | EM27 | TP402 Koritno                           | 58150 | 20/0,4    | 50   | 20000 | 400 | 50 | 4 | 5 | -2,5  | 230 | 48,8 | 11212,5 | 19420,6 |                     |  |
| 9 | 28 | EM28 | TP430 DRAŽENCI 5-TOMAŽIČ                | 62954 | 20/0,4    | 100  | 20000 | 400 | 50 | 3 | 5 | 0     | 230 | 50,0 | 11500,0 | 19918,6 |                     |  |
| 0 | 29 | EM29 | TP437 LOVRENC 4-ŠOLA                    | 67513 | 20/0,4    | 100  | 20000 | 400 | 50 | 3 | 5 | 0     | 230 | 50,0 | 11500,0 | 19918,6 |                     |  |
| 1 | 30 | EM30 | TP452 NJIVERCE 3                        | 79791 | 21/0,42   | 250  | 21000 | 420 | 50 | 2 | 5 | 2,5   | 230 | 51,3 | 11787,5 | 20416,5 |                     |  |
| 2 | 31 | EM31 | TP460 Planika                           | 22540 | 20/0,4    | 400  | 20000 | 400 | 50 | 3 | 5 | 0     | 230 | 50,0 | 11500,0 | 19918,6 |                     |  |
| 3 | 32 | EM32 | TP471 Doklece 2 - Angel                 | 70128 | 20/0,4    | 50   | 20000 | 400 | 50 | 3 | 5 | 0     | 230 | 50,0 | 11500,0 | 19918,6 |                     |  |
| 4 | 33 | EM33 | TP475 Zg. Pletenje                      | 63940 | 20-10/0,4 | 160  | 20000 | 400 | 50 | 2 | 5 | 2,5   | 230 | 51,3 | 11787,5 | 20416,5 |                     |  |
| 5 | 34 | EM34 | TP493 Gradišča 3 - Farma                | 19031 | 20-10/0,4 | 100  | 20000 | 400 | 50 | 3 | 3 | -5    | 230 | 47,5 | 10925,0 | 18922,7 |                     |  |
| 6 | 36 | EM35 | TP504 POBREŽJE 2                        | 75949 | 20/0,4    | 160  | 20000 | 400 | 50 | 3 | 5 | 0     | 230 | 50,0 | 11500,0 | 19918,6 |                     |  |
| 7 | 37 | EM36 | TP513 NARAPLJE-POLUCE                   | 67515 | 20/0,4    | 100  | 20000 | 400 | 50 | 3 | 5 | 0     | 230 | 50,0 | 11500,0 | 19918,6 |                     |  |
| 8 | 38 | EM37 | TP541 Bolečka vas 2 - dom krajanov      | 26131 | 20/0,4    | 100  | 20000 | 400 | 50 | 3 | 5 | -5    | 230 | 47,5 | 10925,0 | 18922,7 | sprememba ne vpliva |  |
| 9 | 39 | EM38 | TP544 SKRBLJE 2-POD KRIŽEM              | 62517 | 20/0,4    | 100  | 20000 | 400 | 50 | 2 | 5 | 2,5   | 230 | 51,3 | 11787,5 | 20416,5 |                     |  |
| 0 | 40 | EM39 | TP546 NA OBREŽJU 2                      | 56337 | 20-10/0,4 | 250  | 20000 | 400 | 50 | 3 | 5 | 0     | 230 | 50,0 | 11500,0 | 19918,6 |                     |  |

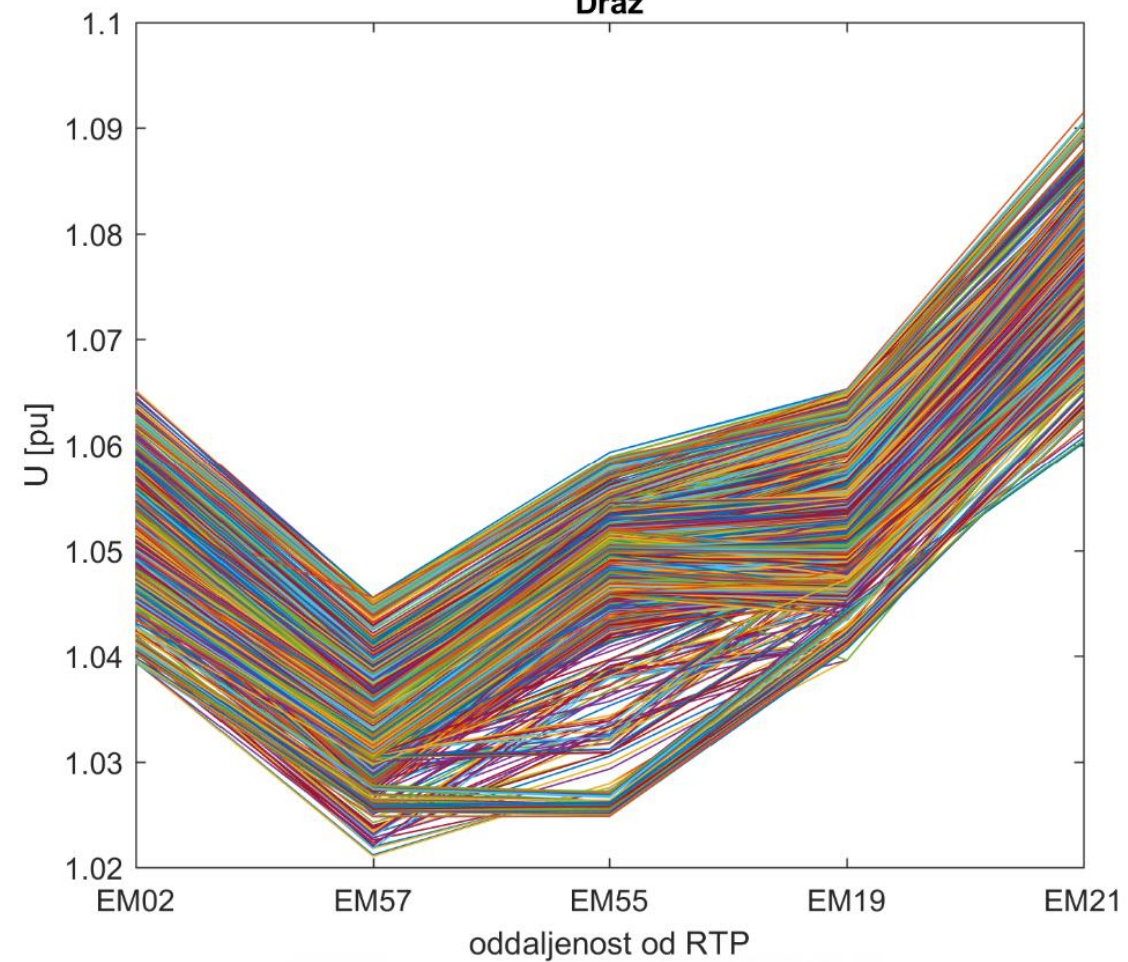
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Vide



Draz



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1. Komunalna energetika 2017, FERI UM

<https://dk.um.si/IzpisGradiva.php?id=67037>

2. Kotnikovi dnevi 2018, Radenci