Integrated Distribution Network Planning Tool Supported by Geographical Information System

Content

IMAGINE Project (1)

- Innovative Modelling and Laboratory Tested Solutions for Next Generation of Distribution Networks
- Keywords:
  - Energy transition
  - Flexibility
  - Mathematic modeling
  - Low carbon distribution networks
  - Power system resistance
  - Security of supply

IMAGINE Project (2)

- End user is becoming more important in new strategies and visions in energy transition
- Energy packet "Clean Energy for All Europeans" emphasizes their role, equal participation on electricity markets and the value of flexibility during the transition towards low carbon power systems
- Currently, end users are mainly passive
- Renewable energy sources, electrical vehicles and electrical heating are creating new challenges for Distribution System Operator (DSO)
- Quality of electric energy and security of supply

IMAGINE Project (3)

- DSO needs, not only, an increase in low voltage (LV) networks observability, but also a creation of services that would encourage flexibility
- The necessity of advanced tools which enable data analysis and help with optimal decisions
- IMAGINE Project goals:
  - Development of models which will enable the defining of flexibility services values for DSO
  - Development of models which will define the ability and value of services for DSO during the transition of the network part into island operation mode
  - Upgrade of SmartGrid laboratory and testing developed models
  - Knowledge exchange with DSO and creating a basis for development of educational center in smart grids operation and control

Introduction (1)

- Complexity and importance of power system
- Minimization of costs and time in which electrical energy is not supplied
- Distribution network planning
- Increased need of finding optimal ways for utilization of data from different sources in power systems
- Availability of the data
- Developing tools for smart management of distribution level power systems

Introduction (2)

- Prior to development of computer science, all geospatial data were physically drawn on maps
- Usage of CAD tools
- CAD tools are being replaced with geographical information system (GIS) tools
- GIS tools enable digitalization of additional technical and economical attributes
- Minimizing the impact of human factor

Introduction (3)

- Croatian DSO’s system contains majority of the MV distribution grid
- Increase in the LV distribution grid in Croatian DSO’s GIS tool
- Complemented with open source GIS tools
- Usage of Open Street Map layers
- Planning of distribution network based on combining multiple data sources, applications and programming languages

Methodology (1)

- Importance of substations and powerlines with their belonging attributes in the planning phase
- Usage of CADDiN, planning tool that is based on genetic algorithms
- Initially, CAD tools were used for data preparations
- One layer presented powerlines and routes and other layer presented substations
- Initial method of extracting and preparing data made the entire process complex and time consuming

Methodology (2)

- The new tool maintains the logic and modelling behind the CADDiN tool
- Upgraded procedures and scripts, digitalization, automatization

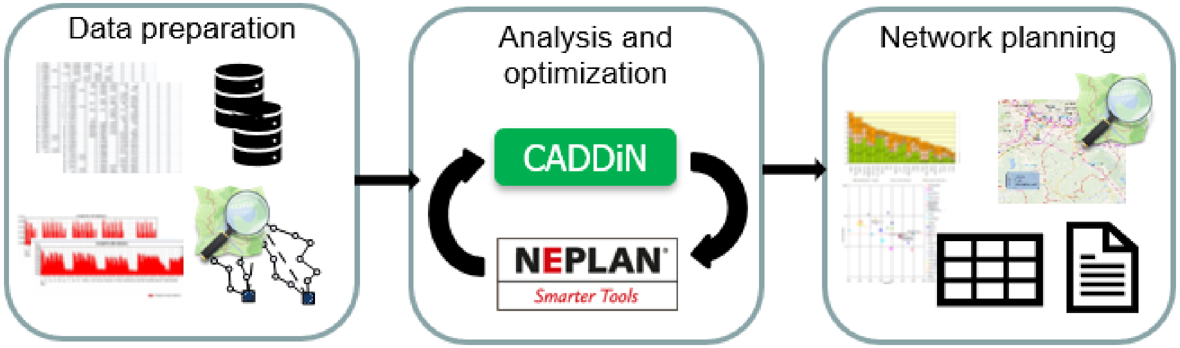

Figure 1 Workflow of data preparation for network planning

Methodology (3)

- Export from DSO GIS to a central database – GeoJSON format
- Data extracted from OSM with the help of QGIS and PostGIS
- Extracted roads and highways are used as new possible routes
- Merging the data from multiple sources and GIS tools
- Creating of shortest path matrix – matrix with shortest distance between each pair of substations
- Tested network is part of Zagreb's distribution network

Data preparation (1)

- Substation attributes:
  - Geometry: center of the substation’s area
  - Name: name of the substation
  - ID: unique key of the substation
  - Power: summed power of all installed transformers
  - Voltage: nominal voltage of the substation
- Powerlines attributes:
  - Geometry: coordinates of the line object
  - Name: label of the powerline
  - ID: unique key of the powerline
  - ID TS1: ID of the substation at the beginning of the powerline
  - ID TS2: ID of the substation at the end of the powerline

Data preparation (2)

- All elements, except substations and powerlines are disregarded
- Creating CADDiN input files with Python script:
  - .ts – information about substation, name, nominal power and coordinates
  - .t file – information about costs of connecting substations, depending on the existence of powerlines and routes
  - .m file – information about the material of which powerlines are made
  - .p file – information about the section of powerlines
  - .d_s file – length (meters) and section (mm^2) ratio

Data preparation (3)

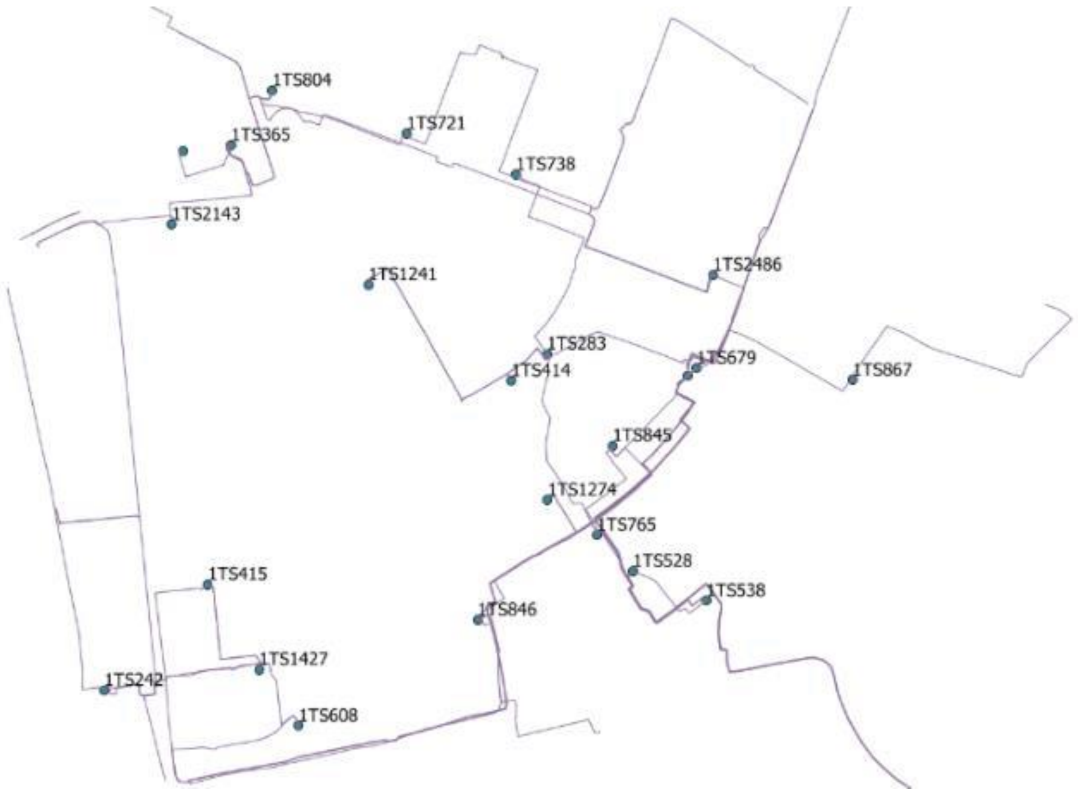

Figure 2 Initial network before optimization

Network Planning Using Genetic Algorithms (1)

- The complexity of distribution network planning increased over the past couple of decades
- Change from passive networks with unidirectional flow to active distribution networks with bidirectional power flow
- Genetic algorithms are part of evolutionary algorithms
- Computational models based on behavior that can be found studying species in the nature

Network Planning Using Genetic Algorithms (2)

- Only stronger, better adapted individuals, will manage to survive and pass on their genes to succeeding generations
- Similar situation is with algorithms
- Bad solutions are disregarded
- Good solutions are taken in consideration for next iteration or optimal solution
- Selection of initial population is randomized
- It is possible that substations selected for creating a path are geographically far from one another
- Found solutions can be incorrect and therefore time needed for finding an optimal solution can be slow
- Heuristic procedure is added to GA in network planning tool

Parameters of Genetic Algorithms (1)

- **Number of generations** – determines a number of generations in case of divergence
- **Number of closest x/0.4 kV substations** – creates sets of substations that are considered during crossing
- **Number of substations closest to the feeding substation 110(30)/x kV** – combined with previous parameter, secures quality of heuristic process
- **Intensity selection** – determines probability of best chromosome selection

Parameters of Genetic Algorithms (2)

- **Intensity selection – selection of 110(30)/x kV substations** – used during pairing of radial connections
- **Size of the population** – directly affects the speed of finding an optimal solution and indirectly on quality and convergence of algorithm
- **Mutation parameter** – determines number of generations after which mutation is done

Energy parameters

- **Maximal allowed load of ring**
- **x/0.4 kV substation utilization factor** – percent value of the substation's installed power at the end of the planning process
- **Maximal number of x/0.4 kV substations per ring**
- **Allowed voltage drop in normal state** – usually 2% - 8% of nominal voltage
- **Allowed voltage drop in emergency state** – usually 10% - 12% of nominal voltage

Cost parameters

- **Energy loss price** – price of energy at the beginning of distribution network, it is used to convert energy loss into money value
- **Power loss price** – price of monthly power at the beginning of distribution network, it is used to convert power loss into money value
- **Annual load increment** – calculated with exponential law
- **Yearly time of maximal load** – time in hours when maximal power is used, it is used to calculate the value and the loss of energy in the network

Optimization results (1)

- Functionality is tested on part of the distribution network in Zagreb, Croatia
- The observed network is supplied from the 30/10 kV substation
- Network contains 23 10/0.4 kV substations
- Powerlines and routes defined with their length
- Thermal constraints and maximal currents are defined through section and material

Optimization results (2)

Parameter	Value
Operative voltage	10 kV
Planning period (n)	5 years
Powerlines section	150 mm^2
Cost per length (CPL) of powerline	300 points/m
Annual cost factor (ACF)	5%
Discount rate	1

Table 1 Parameters for calculating cost matrix

Parameter	Value
Energy loss price	0.07 points/kWh
Annual load increment	4%
Yearly time of maximal load	5000 h

Table 2 Cost parameters and their values

Optimization results (3)

- The output of CADDiN is a proposed scheme of network and report with information about economic and technical results of optimization
- Idea is to determine the range of values of GA parameters in which solutions could be found
- Avoiding divergence, too slow execution of algorithm and finding a solution that is only a local optimum
- Heuristic method

Optimization results (4)

Parameter	Value		
	Scenario 1	Scenario 2	Scenario 3
Number of generations	1000	20000	70000
Number of closest x/0.4 kV substations	3	5	10
Number of substations closest to 110(30)/x kV	5	10	15
Intensity selection	1.02	1.1	1.15
Size of the population	50	150	250
Mutation parameter	500	200	100
Constraint control	1000	500	200

Table 3 Values of GA depending on scenario

Optimization results (5)

- Case 1 – initial case before optimization
- Cases 2 and 5 – scenario 1
- Cases 3 and 6 – scenario 2
- Cases 4 and 7 – scenario 3
- Difference in the calculation of the cost matrix for multiple cases of the same scenario

Optimization results (6)

- Network is divided in two rings
- Sum of powers of all 10/0,4 substations is 9286 kVA
- Voltage drop in the first ring is larger than in the second because of the total length of the ring

Case	Total cost (m.u.)	Voltage drop (%)
1	6364800	0.088100
2	1705414	0.339821
3	1634040	0.358833
4	1591678	0.351193
5	1744592	0.991797
6	1701016	0.842034
7	1756416	0.972846

Table 4 Total cost of connecting and voltage drop for each scenario

Optimization results (7)

- Due to large number of powerlines, cost of connecting substations is the highest in the initial scenario
- Shorter length of line objects result in the lower cost of connecting substations
- Results of costs of the substations connecting are dependent on parameters of GA
- Voltage drop results are more dependent on the distance between feeding substation and the furthest one

Conclusions (1)

- With the GIS tools development, geographical attributes are being combined with technical and economical parameters
- The developed tool enables easy export of necessary information into common database
- Combination of multiple tools, algorithms and programming languages
- The results analyze the impact of changing values of GA parameters in distribution network planning

Conclusions (2)

- Further development of existing tool, new studies and tests, other network configurations
- The main idea behind creating a central database is to build multiple smart distribution network tools using a unified set of data
- Future research will also strive to extend the developed CADDiN tool to capture operational aspects and decisions

Acknowledgments

- Project funded by Croatian Science Foundation (HRZZ) and Croatian Distribution System Operator (HEP ODS) supported by project IMAGINE – Innovative Modelling and Laboratory Tested Solutions for Next Generation of Distribution Networks and supported by the China-Croatian Science and Technology Exchange Program Basic Research on Urban Flexible Multi-Energy System under project FUTURE – Flexible Urban Systems in Multi-Energy Environment

Thank you for your attention!

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