Open source tools for cross-voltage-level electricity grid optimization developed in the open_eGo project
- Learn-a-thon

Open Energy Modelling Workshop
Zürich, June 8th, 2018

by:
Birgit Schachler, Reiner Lemoine Institut Berlin
Wolf-Dieter Bunke, Europa-Universität Flensburg
Agenda

- The open_eGo project
- The OpenEnergyPlatform and eGo dataprocessing
- ding0 - Synthetic distribution grid generator
- osmTGmod+ - Synthetic transmission grid
- eDisGo and eTraGo tutorial session
Agenda

- The open_eGo project
- The OpenEnergyPlatform and eGo dataprocessing
- ding0 - Synthetic distribution grid generator
- osmTGmod+ - Synthetic transmission grid
- eDisGo and eTraGo tutorial session
open_eGo - Project overview

The Project
- Project duration: 3 years from August 2015 to July 2018

Project Ideas
- Market simulation
- AC power flow across several voltage levels
- Optimizing flexibility options
- "Open Source and Open Data"

Partners
- ZNES
- DLR
- Reiner Lemoine Institut
- Otto von Guericke Universität Magdeburg
open_eGo – Aim

Aim → Develop a transparent, **inter-grid-level grid planning tool** to investigate economic viable grid expansion scenarios considering alternative **flexibility options such as storages or redispatch**.

- **Grid**
  - EHV ≥ 220 kV
  - HV 110 kV
  - MV 1–35 kV
  - LV ≤ 1 kV
- **Substation**
  - Transmission station
  - High voltage grid district
  - Medium voltage grid district
  - Distribution station
  - Low voltage grid district
- **Catchment area**

**eGo**

- Optimization of redispatch measures,
- Grid and storage expansion on extra high / high voltage - level
- Optimization of flexibility options and grid expansion for distribution grids (MV and LV) under the restrictions of the Transmission grid parameters (top-down approach)

**Interface HV/MV**

**eTraGo**

**eDisGo**

Aim → Create **OpenEnergy Platform (OEP)** to increase transparency, reproducibility and quality in energy system research.
**open_eGo - Models**

**eGo**

**eTraGo**

**eDisGo**

**osmTGmod+**

**ding0**

**DataProcessing**

---

**Tool to extract the German transmission grid** (EHV and HV) from the free geo-database OSM (OpenStreetMap)

**Tool to generate synthetic medium and low voltage power distribution grids based on open data**

---

Processing of raw data of various open-data sources, assumptions and research for grid-planning tools, e.g. high spatial resolution generation and load data.
open_eGo - Models

Integrated optimization of flexibility options and grid extension measures for power grids

- eGo
  - eTraGo
    - osmTGmod+
  - eDisGo
    - ding0

DataProcessing

Optimization of flexibility options for transmission grids (EHV and HV) based on PyPSA

Optimization of flexibility options and grid expansion for distribution grids (MV and LV) based on PyPSA
Agenda

The open_eGo project

The OpenEnergyPlatform and eGo dataprocessing

ding0 - Synthetic distribution grid generator

osmTGmod+ - Synthetic transmission grid

eDisGo and eTraGo tutorial session
open_eGo – OpenEnergy Platform

→ available at: openenergy-platform.org
open_eGo – OpenEnergy Platform: Database
OEP – Database (oedb)

**API**

- Easy access and data selection via HTTP-requests
  
  ```python
  import requests
  schema = 'supply'
  table = 'ego_conventional_powerplant'
  oep_url= 'http://oep.iks.cs.ovgu.de/
  requests.get(oep_url+'/api/v0/schema/' + schema + '/tables/' + table + '/rows/"
  ```

- SQL-Alchemy dialect for Python
  
  - Python package **oedialect**
  - Direct connection and communication with the OEP

  ```python
  table = Table('ego_conventional_powerplant', MetaData(bind=engine),
                Column('name', VARCHAR(50)),  
                Column('fuel', VARCHAR(50)), ...
  schema= 'supply')
  session.query(table)
  ```
open_eGo – github.com

- Github is a code hosting platform
- It provides a version control and enables collaborative working
- Currently 48 people are involved in this project
- Single projects are organized in repositories
- The code is open source and the project free for external contribution
- Transparent and reproducible by using git

→ available at: github.com/openego/
Dataprocessing

Data tools and snippets organisation
*Bring data models and data code snippets of several use case together.*

- Wrapped up in one Python script that executes several SQL-snippets
- From raw data to data which can be used for calculation with eTraGo, eDisGo, PyPSA, ...
- Reproducibility of data
- Visualization with BPMN (Business Process Model and Notation)

- Code: github.com/openego/data_processing
- Documentation: (coming soon) data-processing.readthedocs.io
The open_eGo project

The OpenEnergyPlatform and eGo dataprocessing

ding0 - Synthetic distribution grid generator

osmTGmod+ - Synthetic transmission grid

eDisGo and eTraGo tutorial session
Distribution Network Generator

A tool to generate synthetic medium and low voltage power distribution grids based on open (or at least accessible) data.

- MV grid topologies based on location and electricity demand in defined demand areas and capacitated vehicle routing problem\(^1\)
- LV grid topologies based on typified grid models

- Code: github.com/openego/ding0
- Documentation: dingo.readthedocs.io/en/dev/

Challenges and solutions

- Challenges in MV and LV grid:
  - Heterogeneity
  - Lack of publicly available data
  - Grid extension case-by-case decision

- Synthetic distribution grids:
  - At status quo
  - Topologies & equipment
  - Loads & Feeders
  - Open-data & -source
  - Local characteristics
High-resolution spatial representation of demand by Hülk et al. (open_eGo)

Find data at: [Hülk et al.]
Ding0 – Data basis

High-resolution spatial representation of generation

- from OPSD project (based on Energymap, BNetzA)
- + method for spatial distribution

*Find data at:* [OpenEnergy Platform]
We focus on MV grids with:

- low load density areas
  (< 1 MW/km²)
- 20 kV, overhead lines
- ring topology

Typification of load areas by peak load:

- Aggregated load area
- Regular load area
- Satellite load area
Methodology:

- Open ring topology
- Analogy from operations research: **Capacitated Vehicle Routing Problem (CVRP)**
- Objective: minimise cumulative route length

Progress of ring construction
Ding0 – Synthetic MV grids

- MV grid district (MVGD)
- HV-MV substation (Transition point)
- Satellite load area
- Regular load area
- Aggregated load area
- MV branch (line/cable)
- Circuit breaker
- MV generator
- MV-LV station
- Cable distributor
Ding0 – Synthetic LV grids

- Based on reference/template grids by Kerber and Scheffler
- 196 different low voltage topologies based on inhabitants
- Data is no geo-located
Agenda

The open_eGo project

The OpenEnergyPlatform and eGo dataprocessing

ding0 - Synthetic distribution grid generator

osmTGmod+ - Synthetic transmission grid

eDisGo and eTraGo tutorial session
osmTGmod+

OpenStreetMap Transmission Grid Modelling

*Tool to extract the German transmission-grid (EHV and HV) from the free geo-database OpenStreetMap (OSM) including electrical properties to enable power flow calculations.*

- Grid topology based on OSM data
- Technical parameters based on literature
- Resulting grid suitable for static AC power flow calculations

- Code: github.com/openego/osmTGmod
- Documentation:
  - github.com/openego/osmTGmod/blob/master/osmTGmod_documentation_0.1.0.pdf
Grid model – background and motivation

- Modeling of the 380, 220 and 110 kV electricity grid in Germany
- Must be suitable for static AC power flow calculations
- n-0 conditions
- Only based on open-data, especially:
  - openstreetmap.org (osm)
  - Literature
  - Publications by TSOs
- Interface to medium voltage levels necessary
- Two-phased grid model:
  - Setup a grid model with highest degree of detail according to needs
  - Consider options to reduce complexity for computational reasons
Grid model - Definition of grid nodes

• What is a MV-grid district?

- 380, 220, 110 kV positions of nodes and links from openstreetmap
- Grid districts are the interface to the synthetic MV-modeling
- n-0 case, switches between grid districts are not considered
- Load and generation are aggregated per type and assigned to the closest grid node
- Area of grid districts fully covers Germany
Grid model - OpenStreetMap (Power-)Data structure

```json
{
    "type": "way",
    "id": 207248812,
    "tags": {
        "frequency": "50",
        "location": "outdoor",
        "name": "Umspannwerk Neurott",
        "operator": "EnBW",
        "power": "substation",
        "substation": "transmission",
        "voltage": "380000;220000"
    }
}
```
Grid model - Abstraction of osm-based substations

- power = substation v sub_station v station ; voltage = 110000 v 60000
- Additionally consideration of substation without voltage value, if HV-line ends or starts within its area.

General reduction
- substation = transition v traction
- Items of railway grid (via „frequency“- and „operator“-values)
- Items outside of administrative border of Germany
- → Reduction by 353 substations

Reduction of HV/MV substations
- Merge of close substations
  - Buffer each substation-area with 75m
  - If buffer overlap, the smaller area is disregarded
- → Reduction by 110 substations

→ $\sum$ HV/MV-substations: 3606
Grid model - EHV/HV: results

<table>
<thead>
<tr>
<th>Category</th>
<th>count</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC-Links</td>
<td>10868</td>
</tr>
<tr>
<td>Transformators</td>
<td>577</td>
</tr>
<tr>
<td>Nodes</td>
<td>8061</td>
</tr>
<tr>
<td>- sockets</td>
<td>3473</td>
</tr>
<tr>
<td>- substations</td>
<td>4588</td>
</tr>
<tr>
<td>→ 110kV substations</td>
<td>3849</td>
</tr>
<tr>
<td>→ 220kV substations</td>
<td>378</td>
</tr>
<tr>
<td>→ 380kV substations</td>
<td>361</td>
</tr>
</tbody>
</table>

All 3606 HV/MV substations are part of the grid model.
Generation & Demand – Result HV/MV level

[Image of maps showing annual electricity consumption and installed capacity levels across Germany]
RE power plants are assigned to the nearest CoastDat weatherpoint and individual time series are calculated for every substation.

**Allocation to weather point and substation**

- Georeferenced RE powerplants
- Allocation to corresponding substation
- Assignment of weather data by nearest-neighbour
- Calculation of times series per substation
- p_set, p_max_pu
Agenda

The open_eGo project

The OpenEnergyPlatform and eGo dataprocessing

ding0 - Synthetic distribution grid generator

osmTGmod+ - Synthetic transmission grid

eDisGo and eTraGo tutorial session
Electrical Distribution Grid Optimization

*Optimization of flexibility options and grid expansion for distribution grids based on PyPSA.*

- Reinforcement of lines and transformers based on distribution grid study of dena\(^{[1]}\) and Baden-Wuerttemberg\(^{[2]}\)
- Considered flexibility options curtailment and storages

- Code: github.com/openego/eDisGo
- Documentation: edisgo.readthedocs.io/en/dev/

---

\(^{[1]}\) A.C. Agricola et al.: dena-Verteilnetzstudie: Ausbau- und Innovationsbedarf der Stromverteilnetze in Deutschland bis 2030. 2012.

eDisGo – Grid expansion

• Issues

Transformer over-loading
Line over-loading
Over-voltage

• Measures

Parallel transformer or replacement
Parallel line or replacement
Parallel line over 2/3 of the feeder
eDisGo – Curtailment

- Curtailment function is used to spatially distribute the curtailment required by the transmission grid (eTraGo) to the generators.
- There are currently two curtailment methods:
  - Curtail all generators equally.
  - Curtail depending on node voltage.
    - Linear characteristic between curtailed power and voltage.
eTraGo

Electrical Transmission Grid Optimization
Optimization of flexibility options and grid expansion for transmission grids based on PyPSA

- Modeling of the 380, 220 and 110 kV electricity grid in Germany
  - Optimization of grid and storages expansion
  - Interface to medium voltage levels

- Code: github.com/openego/eTraGo
- Documentation: etrago.readthedocs.io/en/latest/

Darstellung des open_eGo EHV/HV Netzmöbilds. Abbildung erstellt durch Ilka Cußmann / CC BY-SA 4.0
eGo

Integrated electrical cross-voltage-level grid optimization

*Optimization of flexibility options and grid expansion for cross-voltage-level electricity grids based on PyPSA, eTraGo and eDisGo*

- eGo = eTraGo + eDisGo
- Interface and interacting of the models in order to:
  - investigate economic viable grid expansion scenarios considering alternative flexibility options such as storages or redispatch

- Code: github.com/openego/eGo
- Documentation: openego.readthedocs.io/en/dev/
eGo – Results of ehv and mv voltage levels

- Calculation of Germany’s expansion costs by using cluster methods for different use cases e.g. spatial 'network_clustering_kmeans', voltage level 'network_clustering_ehv' or temporal 'snapshot_clustering' clustering.

- Transparent and reproducible by using setting-files for model methods and parameter.
Get ready for the tutorial

Check list:

- Notebooks are downloaded?
  - https://github.com/openego/eGo/tree/features/tutorial/eGo/examples/tutorials

- Anaconda, Environment and notebooks installed?
  - See README.md
Notebook installation

with Anaconda

Download and install your Python 3.x version of Anaconda here. The full Documentation can be found on this page.

We use Anaconda with an own environment in order to reduce problems with Packages and different versions on our system. Learn more about Anaconda environments. Remove your environment with 'conda env remove -n openMod_Zuerich2018'.

Quick start - steps to do:

0. Sign-in on openenergy-platform.org
1. Install Anaconda
2. Get eGo Repository from github
3. Create environment
4. Activate your environment
5. Install your notebook requirements
6. Make few settings for your notebook
7. Start your notebook and check if the notebook is running

Get eGo Repository and install it with an environment

```
$ git clone -b features/tutorial https://git@github.com/openego/eGo.git
$ cd eGo/ego/examples/tutorials/
$ conda env create --file requirements.yml
```

Activate your environment and run your notebooks

```
$ source activate openMod_Zuerich2018
$ jupyter notebook
$ source deactivate
```
Thanks for your attention!

M.Eng. Wolf-Dieter Bunke
Europa-Universität Flensburg
Energie- & Umweltmanagement
Energiesystemanalyse
Telefon: +49 (0) 416 805-3018
E-Mail: wolf-dieter.bunke@uni-flensburg.de

Birgit Schachler, M.Sc.
Reiner Lemoine Institut gGmbH
Transformations of Energy Systems
Telefon: +49 (0) 30 1208-434-71
E-Mail: birgit.schachler@rl-institut.de