README

Get started with TZ-APG v1

TransitionZero's TZ-APG is an open access power systems model of the ASEAN Power Grid built using PyPSA, representing 10 Southeast Asian countries, focusing on regional transmission. Version 1 of the model, released in December 2024, covers 24 nodes over a 2023 to 2035 modelling horizon with 2-hour temporal representation. It optimises capacity expansion and operation of power plants, storage, and transmission to meet electricity demands and national policy targets at the least cost.

This document provides an overview of the models, input data, and results data; helps you set up and run models using TZ-APG v1; and outlines the attribution to TransitionZero required under the terms of TZ-APG's open access software license.

1. Dataset description

The TZ-APG package includes seven files.

- 4 model files in NetCDF (*.nc*) format*:* TZ-APG v1 models used for PyPSA[1].
    - *tz-apg-v1_scenario-bau.nc:* network file for the Business-As-Usual (BAU) scenario, featuring 31 of the existing interconnectors with no expansion allowed.
    - *tz-apg-v1_scenario-ebau.nc:* network file for the Enhanced Business-As-Usual (EBAU) scenario, featuring 31 existing interconnectors and allowing their expansion.
    - *tz-apg-v1_scenario-regi.nc:* network file for the Regional Interconnection (REGI) scenario, featuring 54 existing and proposed interconnectors.

[1] Note that the number of interconnectors listed for each network count each direction of flow separately. This allows for the capacity and flows for the two directions of an interconnector to be optimised independently.

    - *tz-apg-v1_scenario-isg.nc*: network file for the Indonesia Super Grid (ISG) scenario, featuring 62 existing and proposed interconnectors.

- *tz-agp-v1_data-inputs.xlsx:* excel tables containing all the model inputs by scenario used in TZ-APG v1.
- *tz-agp-v1_results.xlsx:* excel tables containing all the model results used in TZ-APG V1 and analysed in the "*From Vision to Voltage*" report.
- *tz-apg_technical-annex.pdf*: A pre-print article that explains the methodology and data sources in detail.

1.1 Scenario interconnections available

The table below shows the nodes and their abbreviations as represented in the model:

Abbreviation	Node
BRNXX	Brunei Darussalam
IDNJW	Indonesia Jawa
IDNKA	Indonesia Kalimantan
IDNML	Indonesia Maluku
IDNNU	Indonesia Nusa Tenggara
IDNPP	Indonesia Papua
IDNSL	Indonesia Sulawesi
IDNSM	Indonesia Sumatera
KHMXX	Cambodia
LAOXX	Lao PDR
MMRXX	Myanmar
MYSPE	Malaysia Peninsular
MYSSH	Malaysia Sabah
MYSSK	Malaysia Sarawak
PHLLU	Philippines Luzon
PHLMI	Philippines Mindanao
PHLVI	Philippines Visayas
SGPXX	Singapore
THACE	Thailand Central
THANO	Thailand North
THASO	Thailand South
VNMCE	Vietnam Central

VNMNO	Vietnam North
VNMSO	Vietnam South

The following table lists the node1-node2 interconnectors available per scenario:

Scenario	To-From
BAU & EBAU	IDNJW-IDNNU, IDNKA-MYSSK, IDNNU-IDNJW, KHMXX-LAOXX, KHMXX-THACE, KHMXX-VNMSO, LAOXX-KHMXX, LAOXX-THANO, LAOXX-VNMCE, MYSPE-SGPXX, MYSPE-THASO, MYSSH-MYSSK, MYSSK-IDNKA, MYSSK-MYSSH, PHLLU-PHLVI, PHLMI-PHLVI, PHLVI-PHLLU, PHLVI-PHLMI, THACE-KHMXX, THACE-THANO, THACE-THASO, THANO-LAOXX, THANO-THACE, THASO-MYSPE, THASO-THACE, VNMCE-LAOXX, VNMCE-VNMNO, VNMCE-VNMSO, VNMNO-VNMCE, VNMSO-KHMXX, VNMSO-VNMCE
REGI	*In addition to the interconnectors in the BAU/EBAU scenarios:* BRNXX-MYSSK, IDNJW-IDNKA, IDNJW-IDNSM, IDNKA-IDNJW, IDNKA-MYSSH, IDNSM-IDNJW, IDNSM-MYSPE, IDNSM-SGPXX, KHMXX-SGPXX, LAOXX-MMRXX, MMRXX-LAOXX, MMRXX-THANO, MYSPE-IDNSM, MYSPE-MYSSK, MYSSH-IDNKA, MYSSH-PHLLU, MYSSK-BRNXX, MYSSK-MYSPE, PHLLU-MYSSH, SGPXX-KHMXX, SGPXX-VNMSO, THANO-MMRXX, VNMSO-SGPXX
ISG	*In addition to the interconnectors in the BAU/EBAU and REGI scenarios:* IDNKA-IDNSL, IDNML-IDNPP, IDNML-IDNSL, IDNNU-IDNSL, IDNPP-IDNML, IDNSL-IDNKA, IDNSL-IDNML, IDNSL-IDNNU

1.2 Caveats and limitations

Linear demand growth

Each node's future annual demand is computed based on a compound annual growth rate.

RE potentials and profiles

Capacity factors for solar and wind technologies are currently averaged over each node, rather than the most suitable sites within that node. The impact is that we're likely underestimating the actual CF of a node. Scaling it up will require an associated reduction in RE potential based on the total land area of the suitable sites. While this was not possible in this iteration of the model, future iterations will seek to address this limitation.

Region-wide technology, fuel costs

Fuel costs, capital expenditure and operational costs across all technologies use an average of the Danish Energy Agency's Vietnam and Indonesia data, making it similar

across most nodes (the exception being Vietnam and Indonesia). TZ-APG does not represent upstream fuel supply in detail. We use a single price for each fossil fuel (coal, gas, oil) across all countries. There is also a 2-year time lag with current market conditions.

Total system cost

Estimated total system cost by node/country does not yet include the following: cost of imported electricity, and new or upgraded transmission capex.

Transmission with China

The model does not consider grid connections and trade with China, which several member states currently have.

Construction date estimates

Efficiency rates per technology are constant regardless of the current age of plants. This will be addressed in future iterations of the project.

Technology palettes available

TZ-APG v1 does not yet consider nuclear power, ammonia and hydrogen co-firing technologies, or carbon capture and storage. Pumped storage is also categorized as hydro, and not as a battery storage technology, which may affect how the model dispatches it.

2. Getting started with the .nc files on PyPSA

This guide provides instructions on how to download a .nc (NetCDF) file, process its data, and integrate it into a PyPSA model for you to run new scenarios and analysis.

2.1 Prerequisites

Install the required tools and packages:

- Python (3.8+)
- PyPSA: `pip install pypsa`
- NetCDF Libraries: `pip install netCDF4 xarray`
- A solver (we recommend, HiGHS[2], a powerful, free, and open source solver): `pip install highspy`

2.2 Step-by-step installation guide

1. Import a dataset into a PyPSA network

Load the entire dataset from .nc file into PyPSA network:

```python
import pypsa

# Load or create a PyPSA network
network = pypsa.Network()

# Import the .nc file into PyPSA (e.g. tz-apg-v1_scenario-bau.nc)
network.import_from_netcdf(path = 'path/to/file.nc')
```

[2] https://highs.dev/

2. View or change input data

Identify the variables you want to investigate (e.g., renewable energy potential, installed capacity):

```python
# View or change data for a variable (e.g., maximum bioenergy capacity
# that can be installed in Sumatra according to its potential)

bio_potential_IDNSM =
      network.generators['p_nom_max'].loc['IDNSM-bioenergy-unspecified-e
xt-2023']

print(bio_potential_IDNSM)
```

3. Run the PyPSA model

Solve the model with the data incorporated:

```python
# Solve the network optimization
network.optimize(
      solver_name='highs',
      solver_options={"solver": "pdlp"},
      multi_investment_periods=True
)
```

4. Validate and visualise results

After running the model, analyse the results to ensure everything works as expected:

```python
# Inspect summary of outputs
network.statistics()

# Plot results if necessary
network.generators_t.p.plot()
```

3. Attribution and license

The TZ-APG v1 model, data, and associated metadata have been made available through TransitionZero under the Affero General Public License (AGPL). Anyone is free to use, modify, and distribute the TZ-APG data in any format, including for commercial purposes, provided that derivative works are also distributed under the same AGPL license.

You must clearly indicate if you have made any changes to the TZ-APG model and datasets, as well as describe what these changes are. Please refer to the suggested citation formats when using or referencing the dataset:

- "TransitionZero ASEAN Power Grid, version 1. December 2024 release."
- "TZ-APG v1, TransitionZero, December 2024."
- "TransitionZero (2024) ASEAN Power Grid Model v1."