# Electricity Power System Test Networks

This report documents the status at 30/10/2012 of our project to assemble data for a wide range of electricity power system test networks and experience using them in a variety of models.

## OR and Optimization Energy group software

The OR group in the School of Mathematics has developed 5 models that need electricity system data:

(1) Security Constrained OPF
(2) Risk based OPF
(3) An extension of PSAT to simulate cascading events.
(4) A program to limit blackouts by preventive islanding. This solves a optimal load shedding model.
(5) Stochastic unit commitment model, solved by scenario decomposition.

Our optimization software can read models in Matpower format. Dynamic data (that is not part of the Matpower specification) is specified in auxiliary matpower files.

## Components of a complete data set

Different problems needed different component from the following list

(1) Generator costs: generation and startup costs
(2) Generator properties: startup times, min on and off times, ramp rates, ramp profile on start up.
(3) Fuel type and efficiently
(4) Transmission line characteristics and ratings
(5) Transformer data. Tap ranges and typical setting.
(6) Generator emission information. Emmission pricing and limits.
(7) Generator and load dynamics
(8) Governor and voltage controller dynamics and setting
(9) Demand time series at nodes of the network
(10) Wind time series by region or wind farm site
(11) Statistics on wind forecast error
(12) Demand response characteristics
(13) Existence/placement of FACTS devices, especially those that provide control and not merely monitoring/measurement, e.g. power system stabilizers.

So far we have the gathered or have obtained agreement to access the following data sets:

## 1. UK transmission system data - Version 1

**Source:** Jansuz Bialek, Durham University
**Description:** DC model of full UK transmission network
**Size:** 815 buses, 1211 lines, 190 generators
**Components:**

(1) DC line and transformer data including tap ratio limits.
(2) Generator types and upper bound on real power generation
(3) Real power load

(4) Line ratings (MVA)

**Data Status:** Available in MATPOWER format.

**Missing Data:**

(1) Power factors and load voltage dependency
(2) Dynamic data for loads, synchronous generators, and control systems.
(3) Generator data for start-up and shut-downs. Min up and down times.
(4) Reactive power capability of generators
(5) Placement of FACT devices

**Testing:** Waqquas Bukhsh and Paul Trodden created a DC OPF model with fixed loads and taps fixed at midpoint of range. Assumed same generator costs for all generators. Model was DC feasible. An attempt was made to obtain AC version of this data by generating random load factors between [0.90,1.00] and having fixed reactive power capabilities of [-300,300] MVars for all generators. The AC version was feasible with soft constraints (small voltage and line limit errors).

## 2. UK transmission system data - Version 2

**Source:** Richard Lincoln, Strathclyde University

**Description:** AC model of full UK transmission network

**Size:** 878 buses, 1264 lines, 292 generators

**Components:**

(1) AC line and transformer data.
(2) Real and reactive power demands.
(3) Line ratings

**Data Status:** Available in Matpower format.

**Missing Data:**

(1) Type of generators
(2) Generator costs, start-up and shut-down costs
(3) Dynamics

**Testing:** This data is AC infeasible. Richard Lincoln obtained this data for PYLON project at Strathclyde and is not sure what is causing feasibility problems in this data set.

## 3. Reduced UK transmission system data Version 1 + Wind

**Source:** Dan Eager, AF-Mercator

**Description:** A lumped UK regions as defined by National Grid. Each region represented by a single node and lines between regions merged to single lines. energy balance is modelled but not voltages or voltage angles. Power flow limits between regions are modelled. All generators are modelled and plausible costs generator startup and shutdown properties assumed based on generator type. We have an agreement with AF-Mercator to exchange information of unit commitment work using this data set.

**Size:** x buses, y lines, z generators

**Components:**

(1) Allocation of generators to regions.
(2) Inter-region real power flow limits
(3) Min and max operation levels of generators.
(4) Min on times and off times.
(5) Startup times

(6) Estimate of load in each region over time.
(7) Estimate of wind generation within each region over time.

**Data Status:** Agreement from AF-Mercator that we can use their generator and network data, and from Sam Hawkins that we can use his locational wind data.

**Missing Data:** (1) generator and controller dynamics

**Testing:** Annina Palin (OR group and now working for AF-Mercator) has used the data in a deterministic unit commitment model.

## 4. Reduced UK transmission system data - Version 2

**Source:** Manolis Belivanis, Strathclyde University

**Description:** A representative model of the electricity transmission network in Great Britain (GB) was developed at the University of Strathclyde in 2010.

In this network, branches are intended to represent the main routes on which power flows across the GB transmission system and over which power is exchanged between the Seven Year Statement's study zones and have realistic parameters including thermal ratings. The model is based on and has been validated against a solved AC Load Flow reference case that was provided by national grid.

**Size:** 29 buses, 99 lines, 66 generators

**Components:**

(1) Real and reactive power capability of generators
(2) Generator types
(3) Line characteristics and ratings

**Data Status:** Available in xls and Matpower format.

**Missing Data:**

(1) Generator costs, up and down time
(2) Dynamics

**Testing:** We converted the xls data provided by Manolis into Matpower format and found that ACOPF problem is feasible. We have not tested our other models on this data set yet.

## 5. Icelandic Transmission System

**Source:** Paddy McNabb, Psymetrix Ltd.

**Description:** AC model of Icelandic transmission network with generator and controller dynamics

**Size:** 189 buses, 235 lines, 34? generators

**Components:**

(1) Bus voltage limits, shunt conductances and susceptances.
(2) Line characteristics and limits.
(3) Loads as constant $P$ and $Q$.
(4) Synchronous machine data: model types and parameters.
(5) Excitor (AVR) data.
(6) Power system stabilizers placement and data.
(7) Turbine governors data

**Data Status:** Available in MATPOWER/PSAT format.

**Missing Data:**

(1) Startup/shutdown behaviour and costs

(2) Generator operation costs

**Testing:** We have successfully solved OPF model with PSAT, but not with our own AC/DC OPF system. Time domain simulation from these initial states leads immediately to instability. Paddy McNabb has agreed to help with getting consistent controller data for the dynamics.

The dynamic simulation has instabilities. Paddy McNabb has agreed to help with getting consistent controller data for the dynamics

## 6. System Data for U.S. East Coast Transmission Network

**Source:** Staff report, prepared by the U.S. Federal Energy Regulatory Commission (FERC) at the Office of Energy Policy and Innovation, Washington D.C.

**Description:** The provided test system is representative of, but not an exact replica of the Pennsylvania-New Jersey-Maryland Interconnection (PJM) Regional Transmission Organization (RTO) based in Valley Forge, Pennsylvania. PJM operates the world's largest wholesale electricity market and serves the majority of the east coast states. The system data comes in two parts:

- Part A: generator characteristics, generator bid data, load demand, demand response, virtual demand and (deterministic) wind power supply data. (Publicly available)
- Part B: linearized DC network topology data. (Clearance required)

For the volatile part of the data (demand, wind etc.) there is one sample period of 24h in summer and winter respectively. The wind penetration is under 2%.

**Size:** 1011 generators including 17 wind injections, 3753 demand nodes, ? buses, ? lines

**Components:**

(1) Generator data: fuel type, operational limits, ramp rates, minimum up/down times, startup and running costs, power output bids.

(2) Demand data: forecast and actual demand values by bus number, discretized in hourly time steps, for 24h on August 1, 2009 and January 31, 2010.

(3) Wind data: actual power injection values by bus number, discretized in hourly time steps, for 24h on the same days as above.

(4) Reserve data: system wide spinning reserve requirements in hourly resolution.

(5) Network data [Clearance required]: bus information including name, base kV, bus type and zone. Branch information including end buses, resistance, reactance and susceptance (all p.u.), thermal limits and current outage status. Transformers are modelled as fixed branches. Ties with neighbouring systems are modelled as flow injections/withdrawals. Areas with monitored flow (interfaces) are highlighted.

**Data Status:** We have the public Part A data. It is provided in excel spreadsheets that can be read by the GAMS model provided with it or used otherwise. The model, however, can only be executed with a full dataset ,that is, it requires Part B data. We have built a network free AMPL model that uses Part A data except demand response offers/bids and virtual demand offers. The data was converted to AMPL format. We are waiting for security clearance to get the network data.

**Missing Data:**

(1) Generator and controllers dynamic data.
(2) Anything described as Part B/Network data.

**Testing:** We have converted the data and built an AMPL model of the full system without the network. We have extended and significantly scaled the wind model to investigate the performance of our stochastic unit commitment method.

## 7. Electricite de France unit commitment data

**Source:** Electricite de France (EDF) unit commitment data, supplied via the Gaspard Monge Program for Optimization (PGMO).

**Description:** A cleaned version of the EDF unit commitment and economic dispatch data for the French system. This includes detailed thermal generator, hydro plant and reservoir data. There is no network data.

**Size:** 1 bus, 0 lines, 58 nuclear units, 47 other thermal units, 50 hydro valleys (448 hydro plants, 150 reservoirs)

**Components:**

(1) Thermal generator data: cost curves, discretized real power capacity sets, operating costs, startup costs, minimum up/down times, ramp rates, startup and shutdown ramping profiles, nuclear plant variational limits.
(2) Hydro valley data: reservoir inflows, capacities, interconnections. Plant location, turbine numbers, throughput capacities and power rates. Discharge and pump storage model.
(3) Demand data: aggregated system demand profiles for 48h periods in half hourly resolution.
(4) Integer Programming models for individual generators and hydro valleys, and for the overall system. A decomposition based heuristic method to find a unit commitment solution.

**Data Status:** Awaiting release of data by PGMO committee.

**Missing Data:**

(1) All Network data.
(2) Generator and controller dynamics.

**Testing:** Plan to integrate with our stochastic unit commitment system.

## 8. Polish networks

**Source:** Roman Korab
**Description:** 4 Polish networks
**Size:** about 2736 buses, 3556 lines, 424 generators
**Components:**
(1) All have AC network data
(2) Generator real and reactive capacities
(3) Costs for OPF
**Data Status:** Available in MATPOWER format.
**Missing Data:**
(1) Dynamic data
(2) Startup costs
(3) Startup, min up-down times for most cases
**Testing:** Tested for blackouts using our DC MILP model.

## 9. IEEE cases

**Source:** Various
**Description:** Standard commonly used networks, mainly IEEE
**Size:** 9-300 buses, y lines, z generators
**Components:**
(1) All have AC network data
(2) Generator real and reactive capacities
**Data Status:** Available in MATPOWER/PSAT format.
**Missing Data:**
(1) Dynamic data except for 39 bus case.
(2) Realistic costs for same cases
(3) Startup, min up-down times for most cases
(4) Control systems data for all networks except for 39 bus.
(5) Load models (dynamic or static) beyond constant $P/Q$.
**Testing:** Tested for blackouts, OPF, Risk-base OPF (39 bus), stochastic UC (24 and 96 bus cases).

## 10. Local Optima Cases

**Source:** Constructed by Waqquas Bukhsh and OR Group
**Description:** A range of examples illustrating local optima. Some are small constructed examples and some are modified versions of standard examples.
**Testing:** All local minima verified by checking KKT conditions and convergence to the local minima.
**WEB:** Examples are documented here: www.maths.ed.ac.uk/OptEnergy/LocalOpt.

## Distributed Wind data for Stochastic Unit Commitment Test Cases

Realistic wind data is needed to test unit commitment solution methods and in particular our stochastic unit commitment methods.

Sam Hawkins, (Gareth Harrison's ex PhD Student, now at Vattenfall) has agreed to let us use his distributed UK wind data. This is the same data as is being used by AF-M in section 3 above.