

Using TIMES for integrated generation and transmission expansion planning in South Africa

Bruno Merven, Glen Heinrich
Energy Research Centre
University of Cape Town

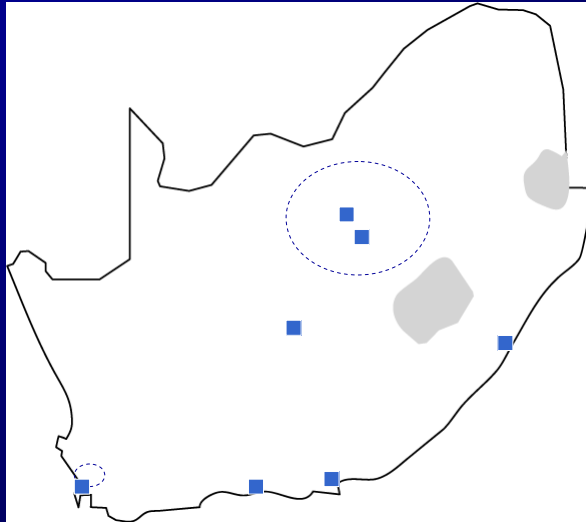


Overview

- Background
- Areas of focus:
 - Interface with ESKOM databases
 - Grid representation
 - Reliability

Background: South African Electricity Sector

- 220 GWh
- 40 GW pk demand
- 95% ESKOM
- 91% From Coal
- 5% Nuclear
- 4% hyd/PS/diesel



Aim/Ambition

- Setup a 27 node/region TIMES model
- Integrate generation and transmission planning
- Model would be handed over to ESKOM planners

The plan

- Interface with ESKOM data
- Representation of grid
- Representation of outages/reliability

- Start with smaller model
- Compare with EGEAS on 1 node
- Expand/explode model into 6 nodes
- Expand for SA model 27 nodes?

ESKOM data

- Technology/process data
 - Existing + new Generation capacity
 - Existing + new Transmission capacity
- Demand data
 - Base year demand (for every hour in the year)
 - Demand projection over study period

Output

Raw Data – ANT file

AR_ACTLDMDELCS01wh1	VAR_ACTL	REG	DMDLCL	s01wh1	4.8891	4.8803	4.9779	5.1384	5.7078
AR_ACTLDMDELCS01wh2	VAR_ACTL	REG	DMDLCL	s01wh2	3.8038	3.9344	4.0379	4.1665	4.63
AR_ACTLDMDELCS01wh3	VAR_ACTL	REG	DMDLCL	s01wh3	5.925	6.1288	6.29	6.4902	7.2123
AR_ACTLDMDELCS01wh4	VAR_ACTL	REG	DMDLCL	s01wh4	7.1375	7.383	7.5772	7.8384	8.8882
AR_ACTLDMDELCS01wh5	VAR_ACTL	REG	DMDLCL	s01wh5	4.293	4.3834	4.4781	4.6207	5.1949
AR_ACTLDMDELCS01wh6	VAR_ACTL	REG	DMDLCL	s01wh6	3.0231	3.1271	3.2093	3.3116	3.6799
AR_ACTLDMDELCS01wh7	VAR_ACTL	REG	DMDLCL	s01wh7	3.5805	3.7038	3.801	3.922	4.3684
AR_ACTLDMDELCS01wh2h1	VF			s01wh2h1	1.7067	1.7654	1.8118	1.8695	2.0775
AR_ACTLDMDELCS01wh2h2	VF			s01wh2h2	1.1718	1.212	1.2429	1.2826	1.4263
AR_ACTLDMDELCS01wh2h3	VF			s01wh2h3	2.0674	2.1095	2.1947	2.2846	2.5065
AR_ACTLDMDELCS01wh2h4	VAR_ACTL	REG	DMDLCL	s01wh2h4	2.2926	2.3714	2.4338	2.5103	2.7907
AR_ACTLDMDELCS01wh2h5	VAR_ACTL	REG	DMDLCL	s01wh2h5	1.4306	1.4738	1.5187	1.567	1.7414
AR_ACTLDMDELCS01wh2h6	VAR_ACTL	REG	DMDLCL	s01wh2h6	1.0597	1.0961	1.1249	1.1608	1.2899
AR_ACTLDMDELCS01wh2h7	VAR_ACTL	REG	DMDLCL	s01wh2h7	1.2512	1.2943	1.3283	1.3706	1.5231
AR_ACTLDMDELCS02wh1	VAR_ACTL	REG	DMDLCL	s02wh1	1.829	1.8919	1.9416	2.0034	2.2263
AR_ACTLDMDELCS02wh2	VAR_ACTL	REG	DMDLCL	s02wh2	2.3983	2.4706	2.5295	2.6162	2.9172
AR_ACTLDMDELCS02wh3	VAR_ACTL	REG	DMDLCL	s02wh3	4.2367	4.3823	4.4976	4.6408	5.1571
AR_ACTLDMDELCS02wh4	VAR_ACTL	REG	DMDLCL	s02wh4	4.8042	4.9694	5.1001	5.2625	5.848
AR_ACTLDMDELCS02wh5	VAR_ACTL	REG	DMDLCL	s02wh5	2.6441	2.735	2.807	2.8963	3.2188
AR_ACTLDMDELCS02wh6	VAR_ACTL	REG	DMDLCL	s02wh6	2.2569	2.3368	2.3981	2.4744	2.7497
AR_ACTLDMDELCS02wh7	VAR_ACTL	REG	DMDLCL	s02wh7	2.1196	2.2049	2.2629	2.3349	2.5947

Activity Aggregated

Capacity Plan

Year	Coal Fired	Gas	Pumped Storage	Reserve on Moderate Forecast
2005				33%
2006				28%
2007				30%
2008	462	151		34%
2009	154	151	452	29%
2010		151	151	33%
2011			452	32%
2012			384	27%
2013	705			40%
2014	1409		334	49%
2015				46%
2016			688	51%
2017				50%
2018				48%
2019				44%
2020				42%
2021				41%
2022				39%
2023				34%
TOTAL	2114	616	452	603

Representation of Outages

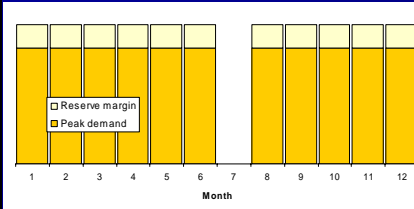
- 2 kinds of outages:
 - Planned (POR),
 - Unplanned/forced (FOR)
- TIMES deals with this specification using:
 - Planned Outages: NCAP_AFA parameter
 - Reserve margin (COM_PKRSV - set exogenously)
 - Cost of unserved energy cannot easily be traded-off against reliability

Principle:

Capacity de-ration:

If plant is out for maintenance for 1 out of 12 time periods, set AVAILABILITY parameter to 11/12

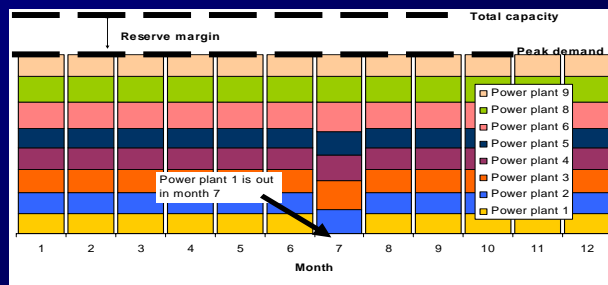
One single power unit:



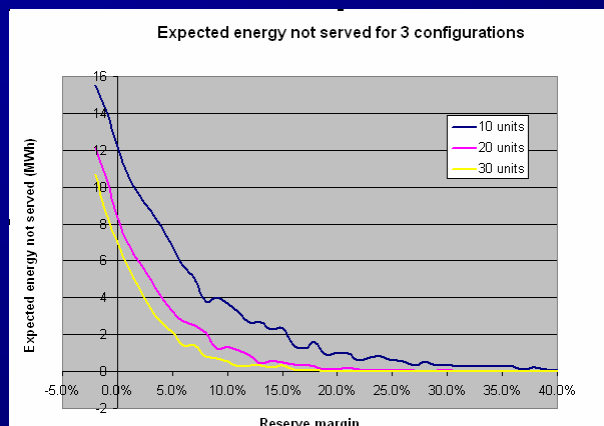
In the case of one power plant: however high the reserve margin, demand will not be met when plant is out.

8 units:

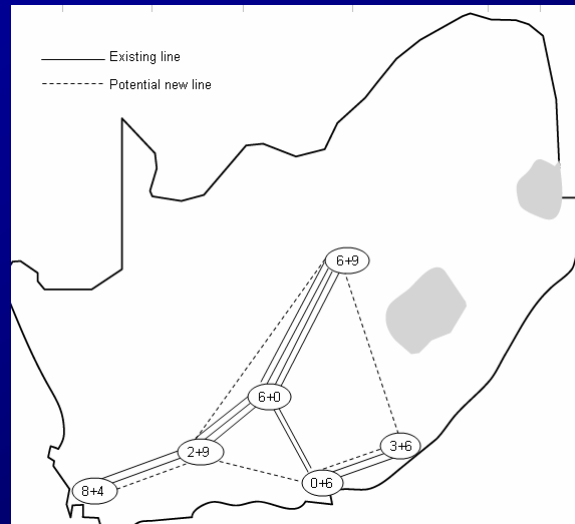
With more power plants to supply the demand, the outage of one power plant less of a problem



Expected unserved electricity for different configurations



The 6 node model



Simulated outage – forced outage

- Proposed methodology
 - Separate problem into Master (investment) and slave (operation) problems.
 - Solve master problem for specified reserve margin
 - Solve operational problem for given investment plan and set of random outages using external scheduling of forced outage with [Monte Carlo sampling](#)
 - Adjust reserve margin in Master problem based on results of slave problem.

Monte Carlo sampling

	A	B	C	D	E	F	G	H	I
1	TABLE ANCAP_AF								
2		2005	2006	2007	2008	2009	2010	2011	2012
3	REG:'EHYDGAR1':s01w1h1'.UP'	1	1	1	1	1	1	1	0
4	REG:'EHYDGAR1':s01w1h2'.UP'	1	1	1	1	1	1	1	1
5	REG:'EHYDGAR1':s01w1h3'.UP'	1	1	1	1	1	1	1	1
6	REG:'EHYDGAR1':s01w1h4'.UP'	1	1	1	1	1	1	1	1
7	REG:'EHYDGAR1':s01w1h5'.UP'	0	1	1	1	1	0	1	1
8	REG:'EHYDGAR1':s01w1h6'.UP'	1	1	1	1	1	1	1	1
9	REG:'EHYDGAR1':s01w1h7'.UP'	1	1	1	1	1	1	1	1
10	REG:'EHYDGAR1':s01w2h1'.UP'	1	1	1	1	1	1	1	1
11	REG:'EHYDGAR1':s01w2h2'.UP'	1	1	1	1	1	1	1	1
12	REG:'EHYDGAR1':s01w2h3'.UP'	1	1	1	1	1	1	1	0
13	REG:'EHYDGAR1':s01w2h4'.UP'	0	1	1	1	1	0	0	1
14	REG:'EHYDGAR1':s01w2h5'.UP'	1	1	1	1	1	1	1	1
15	REG:'EHYDGAR1':s01w2h6'.UP'	1	1	1	1	1	1	0	0
16	REG:'EHYDGAR1':s01w2h7'.UP'	1	1	1	1	1	1	1	1
17	REG:'EHYDGAR1':s02w1h1'.UP'	1	1	1	1	1	1	1	1
18	REG:'EHYDGAR1':s02w1h2'.UP'	1	1	1	1	1	1	1	1
19	REG:'EHYDGAR1':s02w1h3'.UP'	1	1	1	0	1	1	1	1
20	REG:'EHYDGAR1':s02w1h4'.UP'	1	1	1	1	1	1	0	1
21	REG:'EHYDGAR1':s02w1h5'.UP'	1	0	1	1	1	1	0	1
22	REG:'EHYDGAR1':s02w1h6'.UP'	1	1	1	1	1	1	1	1
23	REG:'EHYDGAR1':s02w1h7'.UP'	1	1	1	1	1	1	1	1
24	REG:'EHYDGAR1':s02w2h1'.UP'	1	0	1	1	1	1	0	1

Future Alleys to Explore

- Outage representation:
 - Further experimentation with current method
 - Bender's Decomposition
 - Balerieux and Booth
- Grid representation:
 - 27 nodes?
- Consolidating interface:
 - Smoother addition of new stations
- Incorporate Stochastics?