Grid Planning Assumptions workshop

Interregional transmission capacity analysis

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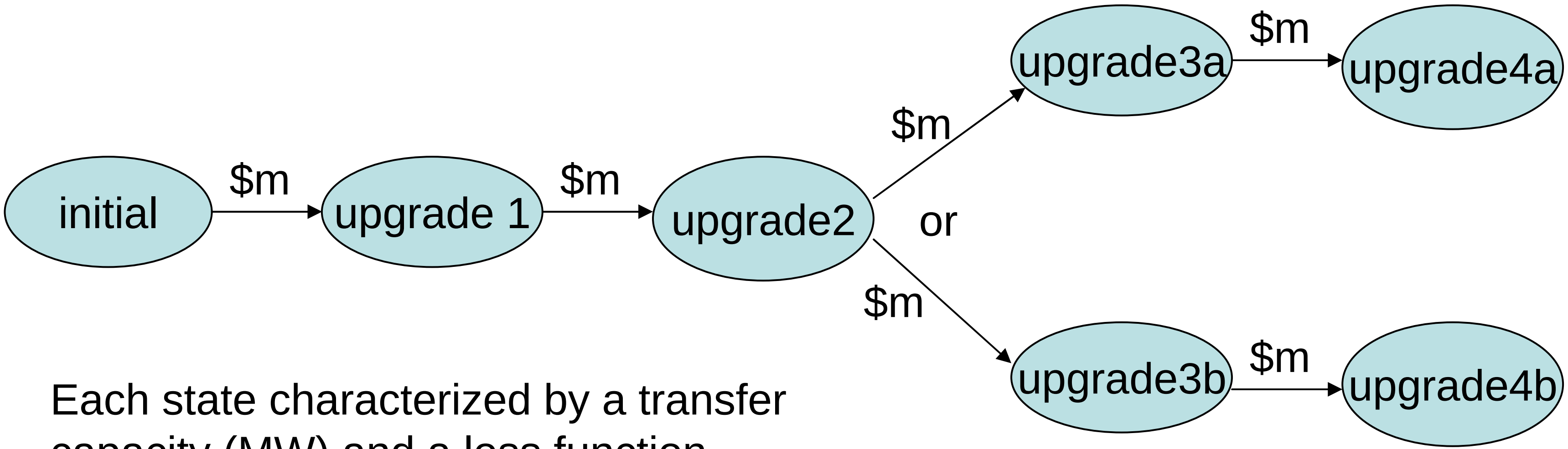
Current status

- There isn't any GEM-based interregional transmission capacity analysis in the draft 2008 GPAs… yet.
- There might be before the process is complete.
- Endogenous transmission investment added to GEM (TTER).
- GEM developments
  - Recent
  - Forthcoming

States and transitions – path specific



Each state characterized by a transfer capacity (MW) and a loss function

Transitions incur a cost, can only happen once, may have multiple options, and restrictions on sequencing

Electricity Commission

Path states and upgrade projects

Set PS; Array name 'PathStates'

PS	Description
initial	initial state
upgr1	1st upgraded state
upgr1a	1st upgraded state (a)
upgr1b	1st upgraded state (b)
upgr2	2nd upgraded state
upgr2a	2nd upgraded state (a)
upgr2b	2nd upgraded state (b)
upgr3	3rd upgraded state
upgr3a	3rd upgraded state (a)
upgr3b	3rd upgraded state (b)
upgr4	4th upgraded state
upgr4a	4th upgraded state (a)
upgr4b	4th upgraded state (b)
upgr5	5th upgraded state

Set TUPG; Array name 'Upgrades'

TUPG	Description
Exist	Existing transmission path
HPI_BRBdplx	Duplex HPI-BRB circuit
PEN_ALB220a	New PEN-ALB 220kV cable
PEN_ALB220b	Additional PEN-ALB 220kV cable
WKM_OTA40022	Approved WKM-OTA 220/400kV double circuit triplex sulphur run at 220kV
WKM_OTA400	Energise the approved WKM-OTA 220/400kV at 400kV
ATI_TRKdplx	Duplex ATI-TRK 1 and 2 and thermally uprate OHK-KAW
React110	Additional reactive support (600MVAr) on the 110kV system to BOPy
WRK_RDFthrm	Thermally uprate WRK-RDF circuits and SVC and caps on 110kV
HBay220	New 220kV circuit from Waikato to Hawke's Bay
BPE_TKUthrm	Thermal upgrade of BPE-TKU 1 and 2 circuits
DuplexLots	Duplex BPE-TKU-WKM 1 and 2 and BPE-TNG-RPO-WRK-PPI-WKM circuits
BPE_WKM220	New 220kV double circuit line BPE-WKM
BPE_WKM40022	New BPE-WKM 220/400kV double circuit triplex sulphur run at 220kV
BPE_WKM400	Energise the BPE-WKM 220/400kV at 400kV
BRK_SFDthrm	Thermal upgrade of BRK-SFD circuits to 120 degrees
.	.
.	.
NMA_ROX220b	A second NMA-ROX 220kV double circuit line
NMA_ROX40022	New NMA-ROX 220/400kV double circuit triplex sulphur run at 220kV
NMA_ROX400	Energise the NMA-ROX 220/400kV at 400kV
MAN_NMAthrma	Thermally upgrade short Pheasant sections of MAN-NMA line
MAN_NMAthrmb	Thermally upgrade entire MAN-NMA line and replace Pheasant with Chukar
MAN_NMA220	New MAN-NMA 220kV double circuit line
HVDC1200	Pole 1 replacement with no new cables
HVDC1400	Pole 1 replacement with additional cable
HVDC2800	Additional 1400 MW HVDC link
HVDCslnd	New 1400 MW 350 kV HVDC link from Southland to Whakamaru

GEM transmission data - sample

Array name suffix: 18 **Transmission path and state transition data (specific to 18-region configuration - see elements of set 'dr' for the 18 regions)**

i_TxData18(*,r,rr,ps,Tx_hdr)

tupg	r	rr	ps	CapFwd	CapRev	ResistFwd	ResistRev	CapPOfwd	CapPOrev	$m	ErlyYr	FixYr
exist	nthd	nshr	initial	377	380	0.000098	0.000098					
exist	nshr	akld	initial	1004	1067	0.000014	0.000014					
exist	akld	waik	initial	2588	2588	0.000025	0.000025					
exist	waik	bopy	initial	529	427	0.000022	0.000022					
exist	waik	hbay	initial	508	585	0.000045	0.000045					
exist	waik	btpe	initial	468	468	0.00014	0.00014					
exist	waik	tari	initial	eps	eps	0.999	0.999					
exist	tari	btpe	initial	587	587	0.000085	0.000085					
exist	btpe	wgtn	initial	900	1456	0.000049	0.000049					
exist	wcst	kiki	initial	61	99	0.00027	0.00027					
exist	kiki	nmlb	initial	345	332	0.000039	0.000039					
exist	chch	kiki	initial	330	642	0.000095	0.000095					
exist	chch	wtki	initial	1100	1100	0.00005	0.00005					
exist	wtki	otag	initial	576	576	0.000036	0.000036					
exist	otag	slnd	initial	814	877	0.00008	0.00008					
exist	slnd	flnd	initial	1176	1176	0.000029	0.000029					
exist	slnd	tiwa	initial	1176	1176	0.000029	0.000029					
exist	wgtn	wtki	initial	626	970	0.000069	0.00006	eps	270			
exist	waik	slnd	initial	eps	eps	0.999	0.999					
HPI_BRBdplx	nthd	nshr	upgr1	703	703	0.000058	0.000058			22	2012	
PEN_ALB220a	nshr	akld	upgr1	1556	1556	0.0000079	0.0000079			148	2012	
PEN_ALB220b	nshr	akld	upgr2	2177	2177	0.0000067	0.0000067			148	2013	
WKM_OTA40022	akld	waik	upgr1	2999	2999	0.000015	0.000015			710	2012	
WKM_OTA400	akld	waik	upgr2	4053	4053	0.000012	0.000012			181	2013	
ATI_TRKdplx	waik	bopy	upgr1	830	830	0.000015	0.000015			38	2012	
React110	waik	bopy	upgr2	1031	1031	0.000015	0.000015			22	2013	
.	.	.	.	.	.	.	.			.	.	
.	.	.	.	.	.	.	.			.	.	
MAN_NMAthrma	slnd	flnd	upgr1	1405	1405	0.000029	0.000029			3	2012	
MAN_NMAthrmb	slnd	flnd	upgr2	1760	1760	0.000029	0.000029			56	2013	
MAN_NMA220	slnd	flnd	upgr3	2930	2930	0.000019	0.000019			176	2014	
HVDC1200	wgtn	wtki	upgr1a	1000	1200	0.00005	0.000045	eps	500	607	2012	
HVDC1400	wgtn	wtki	upgr1b	1000	1400	0.000049	0.000045	eps	700	686	2012	
HVDC2800	wgtn	wtki	upgr2	2000	2800	0.000025	0.000023	eps	2100	1446	2013	
HVDCslnd	waik	slnd	upgr1	1400	1400	0.000089	0.000089			2100	2012	2099

GEM transitions data - sample

i_Transitions18(tupg,r,rr,ps,pss)

tupg	r	rr	ps	pss
HPI_BRBdplx	nthd	nshr	initial	upgr1
PEN_ALB220a	nshr	akld	initial	upgr1
PEN_ALB220b	nshr	akld	upgr1	upgr2
WKM_OTA40022	akld	waik	initial	upgr1
WKM_OTA400	akld	waik	upgr1	upgr2
ATI_TRKdplx	waik	bopy	initial	upgr1
React110	waik	bopy	upgr1	upgr2
.	.	.	.	.
.	.	.	.	.
MAN_NMAthrma	slnd	flnd	initial	upgr1
MAN_NMAthrmb	slnd	flnd	upgr1	upgr2
MAN_NMA220	slnd	flnd	upgr2	upgr3
HVDC1200	wgtn	wtki	initial	upgr1a
HVDC1400	wgtn	wtki	initial	upgr1b
HVDC2800	wgtn	wtki	upgr1b	upgr2
HVDCslnd	waik	slnd	initial	upgr1

Code for transmission investment

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Variables
  TXCAPCOSTYR(y,t)                'Annual capital cost to upgrade transmission paths in each modelled year, $m'
  TXPROJVAR(tupg,y)               'Continuous 0-1 variable indicating whether an upgrade project is applied'
  TXUPGRADE(r,rr,ps,pss,y)        'Continuous 0-1 variable indicating whether a transmission upgrade is applied'
  BTX(r,rr,ps,y)                  'Binary variable indicating the current state of a transmission path'
* Assume that transmission capital costs are incurred in first period of each year.
calc_txcapcost(y,t)$( ord(t) = 1 )..
  TXCAPCOSTYR(y,t) =e= sum((paths,ps)$upgtxps(paths,ps), txcapcharge(paths,ps,y) * BTX(paths,ps,y) ) ;
* Piecewise linear transmission losses.
boundTxloss(paths(r,rr),ps,y,t,lb,nsegment(n),h)$alltxps(paths,ps)..
  LOSS(paths,y,t,lb,h) =g=
  intercept(paths,ps,n) + slope(paths,ps,n) * TX(paths,y,t,lb,h) - bigloss(paths,ps) * ( 1 - BTX(paths,ps,y) ) ;
* Calculate the relevant transmission capacity.
tx_capacity(paths,y,t,lb,h)..
  TX(paths,y,t,lb,h) =l= sum(alltxps(paths,ps), txcap(paths,ps) * BTX(paths,ps,y)) ;
* Associate projects to individual upgrades (also ensures both directions of a path get upgraded together).
tx_projectdef(transitions(tupg,paths,ps,pss),y)..
  TXPROJVAR(tupg,y) =e= TXUPGRADE(paths,ps,pss,y) ;
* A link must be in exactly one state in any given year.
tx_onestate(paths,y)..
  sum(ps, BTX(paths,ps,y)) =e= 1 ;
* Make sure the upgrade of a link corresponds to a legitimate state-to-state transition.
tx_upgrade(paths,ps,y)$upgtxps(paths,ps)..
  sum(trntxps(paths,pss,ps), TXUPGRADE(paths,pss,ps,y)) - sum(trntxps(paths,ps,pss), TXUPGRADE(paths,ps,pss,y) ) =e=
  BTX(paths,ps,y) - BTX(paths,ps,y-1) ;
* Only one upgrade per path in a single year.
tx_oneupgrade(paths,y)..
  sum(upgtxps(paths,ps), sum(trntxps(paths,pss,ps), TXUPGRADE(paths,pss,ps,y) )) =l= 1 ;
```

Some recent GEM developments

- GEM first released on Commission website in May 2007. Seven updates since May
- Transmission co-optimisation (18 regions)
- Re-optimize with peakers
- Optimize build schedule over multiple hydro sequences - simultaneously
- Monthly, quarterly or seasonal
- Existing hydro catchment-based rather than aggregated by island
- Extensive output reporting and plots (Matlab executables)
- Incremental peak load constraints replaced with system security constraints – select either n, n-1, or n-2
- Three load growth trajectories – low/medium/high
- Five load blocks per month/quarter/season (previously used 4)
  - Greater LDC resolution in future

Some recent GEM developments – cont'd

- Formulation of HVDC charges to SI generators modified to better reflect the nonlinear nature of the pricing rule (Transpower)
  - Function of installed capacity of each SI generator
- Rolling horizon procedure to cope with large number of integer variables

Forthcoming GEM developments

- Refine modelling of hydro generation
  - Output of existing hydro to depend on the mix of other generation on the system
  - Output of new hydro related to inflows
- Greater resolution in LDC (~10 blocks)
  - No energy block?
  - Variability of intermittent generation to be handled via the LDC, e.g. ‘low wind’ and ‘high wind’ blocks
- Revenue adequacy – produce PDC consistent with build schedule
- Reserves
- Regional peak load – for use with 18-region transmission co-optimization
- Model EV storage more accurately – similar to pumped hydro
- User manual and update documentation