OPF Strategies and Tips

2006 PowerWorld Client Conference

June 14-15

Chattanooga, Tennessee

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Potential OPF Challenges

- Unenforceable Transmission Constraints
- Unenforceable Area Constraints due to insufficient generation reserves
- Too much power transfer in LP causes power flow solution to diverge

Analysis of Unenforceable Constraints

- *Example: PJM Case*
- Initial solution has 16 unenforceable constraints
- Of these many seem to be caused by radial
  - *Change Limit Monitoring Settings to "Ignore Radial Lines and Buses*"
    - Radial Bus is connected to the system by only one transmission line
    - Radial Line is a line connected to a radial bus.
  - Choosing this eliminates the unenforceable constraints

Unenforceable Constraints

- Check unenforceable lines for VERY large MVar flows
  - *Add Columns for Max MW and Max MVar on LP OPF, Lines and Transformers*
- LTC tap ratios
- Phase-shifters in series with an overloaded branch

Reset the Tap Settings

- Set all transformers on tap control to have a ratio of 1.00
- Set all phase-shifters to be controlled by the OPF solution
  - Phase Shifters have three control options
    - None – leave at a fixed angle
    - Power Flow – Allow the power flow solution to dispatch according to the setpoints of the controller
    - OPF – Allow the OPF's linear program to "dispatch" the transformer for a more global optimization
  - Use caution with Phase Shifter MW limits when using OPF control – large ranges may cause OPF to dispatch to an unstable point

Unenforceable Constraints Left

- This results in a reduced list of 17 unenforceable constraints

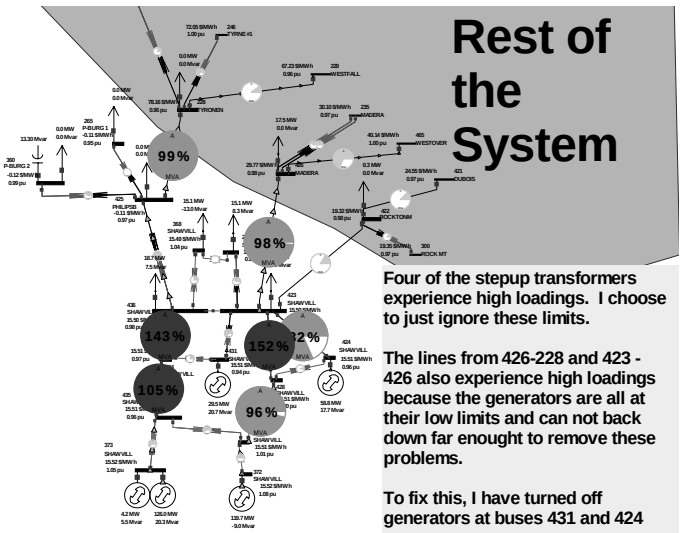
Lines/Transformers | Interfaces

	From Number	From Name	From Area Name	To Number	To Name	To Area Name	Circuit	Monitor	Max MVA	% of MVA Limit (Max)	Lim MVA	MVA Marg. Cc ▼
1	4257	PLYMOUTH	PECO	4262	PLYMOUTH	PECO	1	YES	71.9	126.1	57.0	9999.0
2	430	TRADECIT	PENELEC	432	PUNXSUTA	PENELEC	1	YES	45.8	158.1	29.0	9999.0
3	3390	KEY CM 1	PP&L	3399	NAZARETH	PP&L	1	YES	47.4	103.0	46.0	9999.0
4	440	EPIKE	PENELEC	445	EPIKE	PENELEC	1	YES	61.6	236.9	26.0	9999.0
5	419	SHAWVILL	PENELEC	428	SHAWVILL	PENELEC	1	YES	128.5	100.4	128.0	9999.0
6	384	NMESHOPP	PENELEC	406	MEHOOPAN	PENELEC	1	YES	82.0	115.5	71.0	9999.0
7	434	SHAWVILL	PENELEC	435	SHAWVILL	PENELEC	1	YES	129.1	100.9	128.0	9999.0
8	3080	SAKRON	PP&L	3230	SAKRON	PP&L	3	YES	197.2	108.3	182.0	9999.0
9	4257	PLYMOUTH	PECO	4261	PLYMOUTH	PECO	1	YES	71.6	121.4	59.0	9999.0
10	8863	MILLROAD	DP&L	8872	SUNSETLA	DP&L	1	YES	140.7	102.7	137.0	9999.0
11	3080	SAKRON	PP&L	3230	SAKRON	PP&L	5	YES	99.4	109.2	91.0	9999.0
12	3390	KEY CM 1	PP&L	3408	SIEGFRIE	PP&L	1	YES	45.5	105.8	43.0	9999.0
13	434	SHAWVILL	PENELEC	436	SHAWVILL	PENELEC	1	YES	118.7	154.1	77.0	9999.0
14	3391	KEY CM 2	PP&L	3399	NAZARETH	PP&L	1	YES	47.4	103.1	46.0	9999.0
15	3080	SAKRON	PP&L	3230	SAKRON	PP&L	4	YES	194.1	107.3	181.0	9999.0
16	423	SHAWVILL	PENELEC	428	SHAWVILL	PENELEC	1	YES	119.0	154.6	77.0	9999.0
17	4214	NWALES	PECO	4217	N WALES4	PECO	1	YES	92.7	113.0	82.0	9999.0
18	1562	BIRDBORO	METED	1593	PINE LNE	METED	1	YES	34.0	100.0	34.0	9327.0
19	228	TYRONEN	PENELEC	425	PHILIPSB	PENELEC	1	YES	125.0	100.0	125.0	413.3
20	1152	HUNTERST	METED	1221	HUNTERST	METED	2	YES	251.0	100.0	251.0	299.4
21	4111	EDDYSTON	PECO	4172	LLANERCH	PECO	1	YES	215.0	100.0	215.0	158.5
22	9017	KENT	DP&L	9650	DOVERA28	DP&L	1	YES	106.0	100.0	106.0	101.5

A Closer Look

- Look more closely at the majority of the remaining unenforceable constraints
  - Continues to show a large number of under radial elements which should probably just be ignored
- A handful of elements require greater study
  - Breakdown and just start drawing a oneline diagram to represent this part of the system
  - You will start to see what the problem is

Example: Internal Shawvill

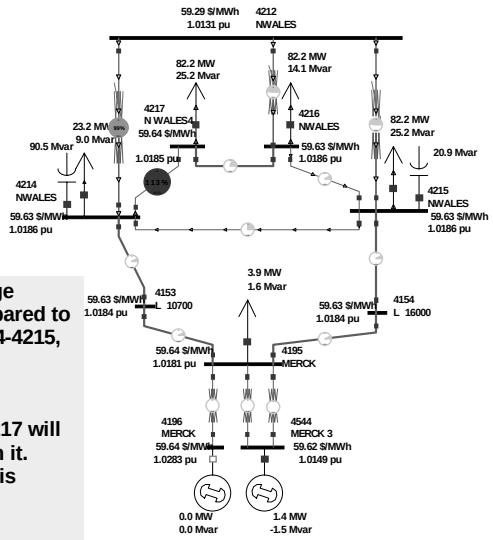


Four of the stepup transformers experience high loadings. I choose to just ignore these limits.

The lines from 426-228 and 423 - 426 also experience high loadings because the generators are all at their low limits and can not back down far enought to remove these problems.

To fix this, I have turned off generators at buses 431 and 424

Example: Internal MERCK



4217-4216 line has a large impedance of 0.15 compared to the lines 4214-4217, 4214-4215, 4216-4215 which have impedances of 0.0002

This means that 4216-4217 will NEVER have any flow on it. Thus the line 4214-4217 is essentially radial.

After these changes we remove all unenforceable Constraints

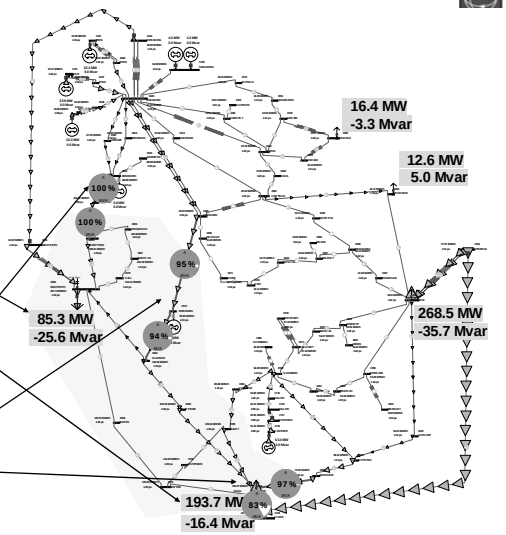
- Still some very high cost constraints remain
- BIRDBORO – Pine LNE = 772.8 $/MVAhr

Lines/Transformers | Interfaces

	From Number	From Name	From Area Name	To Number	To Name	To Area Name	Circuit	Monitor	Max MVA	% of MVA Limit (Max)	Lim MVA	MVA Marg. C	M
1	1562	BIRDBORO	METED	1593	PINE LNE	METED	1	YES	34.0	100.0	34.0	772.8	
2	3390	KEY CM 1	PP&L	3408	SIEGFRIE	PP&L	1	YES	43.0	100.0	43.0	229.9	
3	1152	HUNTERST	METED	1221	HUNTERST	METED	2	YES	251.0	100.0	251.0	109.1	
4	228	TYRONEN	PENELEC	425	PHILIPSB	PENELEC	1	YES	125.0	100.0	125.0	95.4	
5	4111	EDDYSTON	PECO	4172	LLANERCH	PECO	1	YES	215.0	100.0	215.0	78.8	
6	5002	LUMBERTO	PSE&G	5179	LUMBERTO	PSE&G	1	YES	95.0	100.0	95.0	56.7	
7	4957	BAYONNE	PSE&G	5004	MARION	PSE&G	1	YES	221.0	100.0	221.0	9.2	
8	2550	WHIPPANY	JCP&L	5017	ROSELAND	PSE&G	1	YES	1183.0	100.0	1183.0	9.2	
9	6361	GOULDST	BGE	6372	WP PH.S1	BGE	1	YES	41.0	100.0	41.0	4.5	
10	6361	GOULDST	BGE	6373	WP PH.S2	BGE	1	YES	41.0	100.0	41.0	4.4	
11	8601	SILVERLA	AE	8608	SILVERLA	AE	2	YES	228.0	100.0	228.0	1.3	
12	4088	CROYDON	PECO	4971	BURLINGT	PSE&G	1	YES	466.0	100.0	466.0	1.1	
13	4954	ATHENIA	PSE&G	5020	SADDLEBR	PSE&G	1	YES	366.0	100.0	366.0	0.3	
14	4957	BAYONNE	PSE&G	5005	PVSC	PSE&G	1	YES	187.0	100.0	187.0	0.3	
15	4	CONASTON	PJM500	5963	CONASTON	BGE	1	YES	638.8	65.2	980.0		
16	4	CONASTON	PJM500	26	HUNTERST	PJM500	1	YES	1457.8	47.5	3066.0		
17	2	BRANCHBU	PJM500	7	ELROY	PJM500	1	YES	822.2	26.8	3066.0		

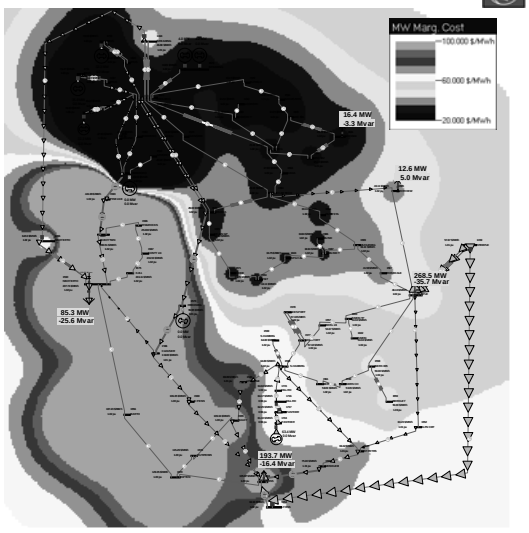
Birdboro – Pine LNE

- Yellow Region forms a "load pocket" for two large loads
  - 85.3 MW
  - 193.7 MW
- The 69 kV lines feeding this region have high loadings



Contour of Prices around Birdboro – Pine Lne

- Load Pocket
- These prices could be reasonable.

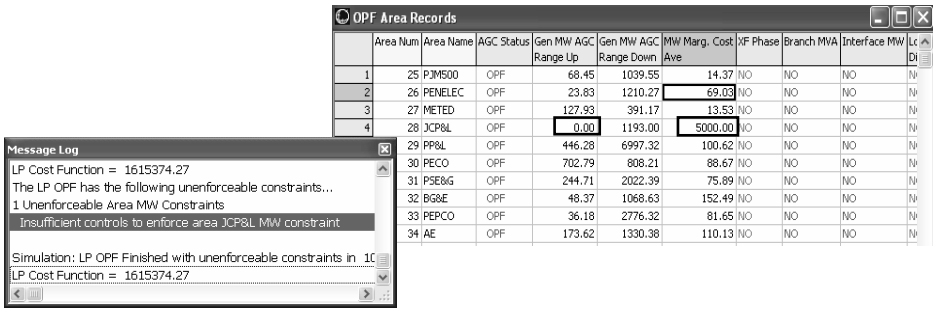


Unenforceable Constraints Summary

- Look for radial systems and “load pockets”
- Look for generators or phase-shifters which can relieve problems
  - Give the OPF more controls to FIX the problems
- Look for constraints which don’t make sense
  - Radial lines serving load
  - Radial transformers/lines leaving generators
- Use your judgment to setup a reasonable case
- Realize that some unenforceable constraints are inevitable at first

Insufficient Reserves

- In this example, Area 28 (JCP&L) does not have enough AGCable generation
- Message Log: “Insufficient controls to enforce area … constraint”



Insufficient Reserves: Tips

- Examine Generator records or Area field "Gen MW AGC Range Up"
- To resolve
  - Commit more generation
  - Make more generation AGCable
  - Increase imports, or make Area part of a Super Area
  - Decrease load, or make load dispatchable

Too Much Power Transfer

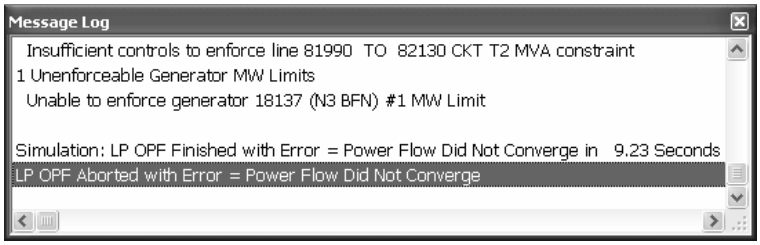
- The linear program (LP) iterates with the non-linear power flow to achieve convergence of the entire solution
- If an AC OPF is performed over a very large area, the LP may dispatch generators in a manner that exceeds voltage stability margins
- May occur more frequently in WECC cases

Too Much Power Transfer

- Example: A Northern and a Southern section of the eastern interconnection in one Super Area
  - North: includes eastern PJM, AEP, First Energy
  - South: includes TVA, Southern Company, Entergy
- Assume generation much less expensive in the south, so OPF will try to increase the transfer from south to north
- OPF may exceed stability margin of power flow

Too Much Power Transfer

- Message Log



Too Much Power Transfer: Tips

- Tighten MW Limits on generators with unrealistic limits (e.g. Max MW = 9999)
- Place less of the system on OPF control
- Use interface limits
- Break a large area (or super area) into two or more smaller areas; use OPF dispatchable transactions between the smaller areas
- Manually move generation in the direction of the LP transfer, resolve power flow, restart OPF
- Use DC Power Flow

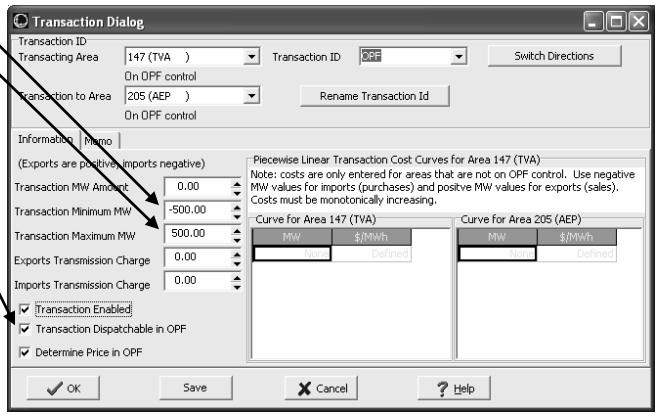
OPF Dispatchable Transactions

- Example: Break MMWG super area into Northern and Southern super areas
- Add a new transaction between a Northern area (e.g. AEP) and a Southern area (e.g. TVA)
- Set MW limits on the new transaction
- If OPF and power flow solve, try increasing the limits of the transaction – stop when the power flow will not converge

OPF Dispatchable Transactions

South-North transaction limited to 500 MW beyond base case transfer

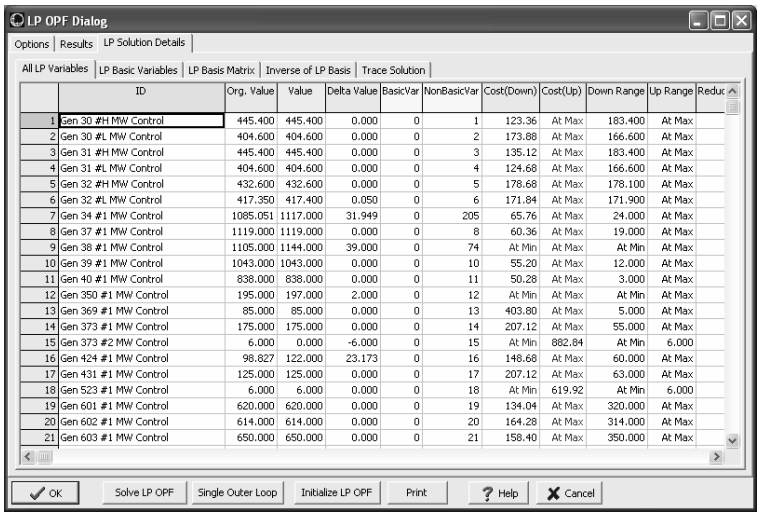
OPF determines optimal transaction. If transaction is non-binding at the solution, then areas are acting as a single super area.



Manually Move Generation

- Solve a “Single Outer Loop” of the OPF
- Look at OPF controls following the failure
- Move generation in direction of transfer (e.g. 10% of the transfer)
- Attempt to resolve the OPF
  - Often additional transmission constraints will become binding before the full transfer is made
  - OPF will know to move in a different direction

Manually Move Generation:
OPF Controls



	ID	Org. Value	Value	Delta Value	BasicVar	NonBasicVar	Cost(Down)	Cost(Up)	Down Range	Up Range
1	Gen 30 #H MW Control	445.400	445.400	0.000	0	1	123.36	At Max	183.400	At Max
2	Gen 30 #L MW Control	404.600	404.600	0.000	0	2	173.88	At Max	166.600	At Max
3	Gen 31 #H MW Control	445.400	445.400	0.000	0	3	135.12	At Max	183.400	At Max
4	Gen 31 #L MW Control	404.600	404.600	0.000	0	4	124.68	At Max	166.600	At Max
5	Gen 32 #H MW Control	432.600	432.600	0.000	0	5	178.68	At Max	178.100	At Max
6	Gen 32 #L MW Control	417.350	417.400	0.050	0	6	171.84	At Max	171.900	At Max
7	Gen 34 #1 MW Control	1085.051	1117.000	31.949	0	205	65.76	At Max	24.000	At Max
8	Gen 37 #1 MW Control	1119.000	1119.000	0.000	0	8	60.36	At Max	19.000	At Max
9	Gen 38 #1 MW Control	1105.000	1144.000	39.000	0	74	At Min	At Max	At Min	At Max
10	Gen 39 #1 MW Control	1043.000	1043.000	0.000	0	10	55.20	At Max	12.000	At Max
11	Gen 40 #1 MW Control	838.000	838.000	0.000	0	11	50.28	At Max	3.000	At Max
12	Gen 350 #1 MW Control	195.000	197.000	2.000	0	12	At Min	At Max	At Min	At Max
13	Gen 369 #1 MW Control	85.000	85.000	0.000	0	13	403.80	At Max	5.000	At Max
14	Gen 373 #1 MW Control	175.000	175.000	0.000	0	14	207.12	At Max	55.000	At Max
15	Gen 373 #2 MW Control	6.000	0.000	-6.000	0	15	At Min	882.84	At Min	6.000
16	Gen 424 #1 MW Control	98.827	122.000	23.173	0	16	148.68	At Max	60.000	At Max
17	Gen 431 #1 MW Control	125.000	125.000	0.000	0	17	207.12	At Max	63.000	At Max
18	Gen 523 #1 MW Control	6.000	6.000	0.000	0	18	At Min	619.92	At Min	6.000
19	Gen 601 #1 MW Control	620.000	620.000	0.000	0	19	134.04	At Max	320.000	At Max
20	Gen 602 #1 MW Control	614.000	614.000	0.000	0	20	164.28	At Max	314.000	At Max
21	Gen 603 #1 MW Control	650.000	650.000	0.000	0	21	158.40	At Max	350.000	At Max

Manually Move Generation:
Spreadsheet

- Use a spreadsheet to step the transfer
- Set GenMW = Orig. Value + (Value – Orig. Value)* PercentMove

1. Send OPF controls to the spreadsheet

2. Paste Gen Records back into Simulator, solve power flow, and restart LP OPF