



# HELM-Flow Advanced Walkthrough

How to Work with Difficult Cases



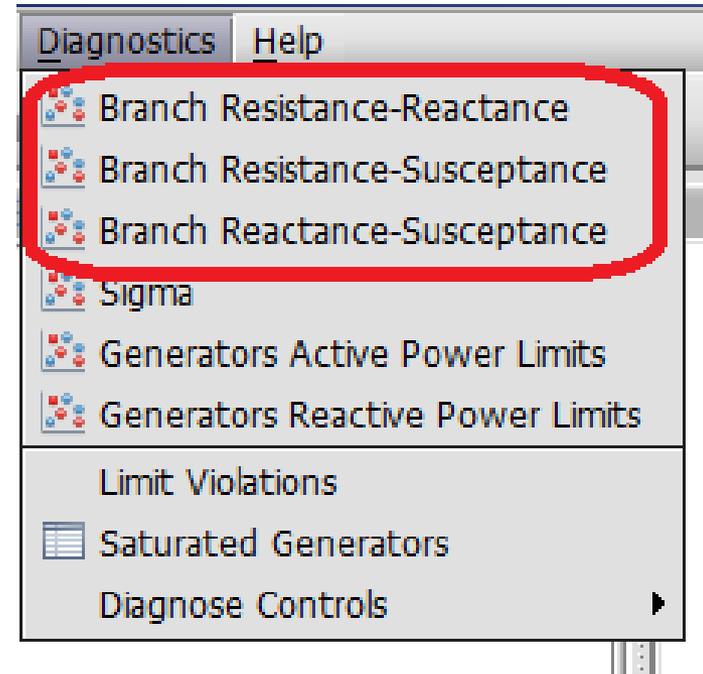
1. Diagnose model parameters.
2. Run Full-HELM with default configuration settings (first feeling).
3. Review configuration parameters and fine tune some of them for hard cases.
4. Remove some or all enforcement of controls & limits.
5. Run Q-HELM (pure reactive power-flow).
6. Run PQ-HELM (lossless grid power-flow).
7. Run Full-HELM.
8. Re-enable controls and their limits.



# 1. Diagnose Model Parameters

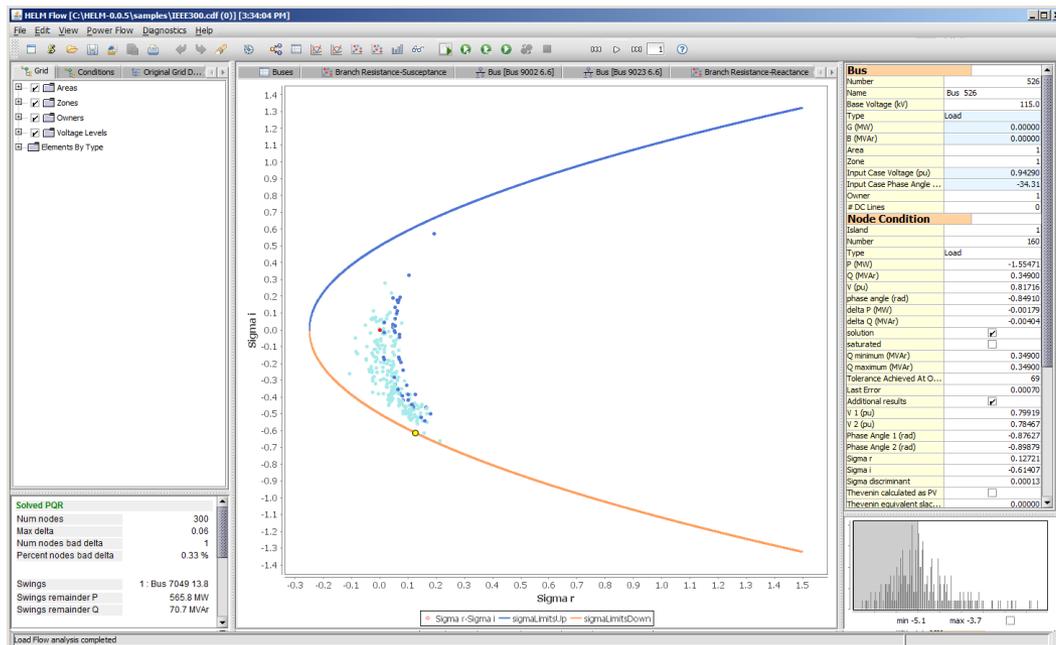
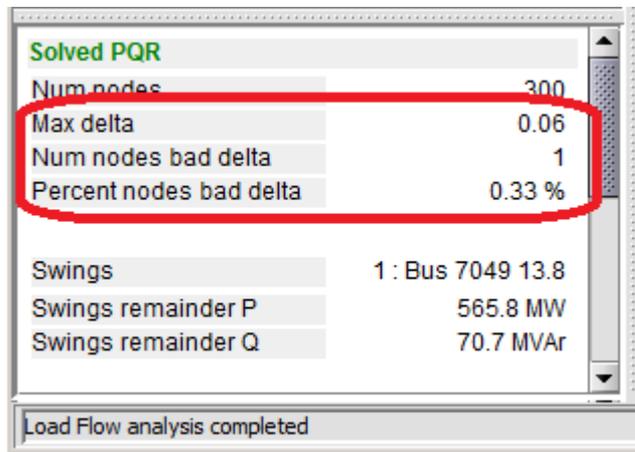
- **Diagnose Model Data**

- Check for obvious outliers on any of the diagnostic charts that plot model (equipment) parameters.
- Example: View->Chart->Branch Resistance vs. Reactance
  - Search for clear outliers.
  - Click on them to inspect values.
  - Correct obvious mistakes.
- After fixing outliers, you may want to right click the graph and re-plot to auto range values.
- Look out for anomalies such as negative values for resistance.





## 2. Run Full-HELM with Default



- Check the Sigma plot and voltage conditions.
- Note about **tolerance and precision**: if you allow for a small % of nodes to have a delta over the required mismatch tolerance, then it is normal to observe maybe a few nodes outside the parabola on the Sigma Plot. Also if you configure things to require a precision in voltage that is too low, you may see again points outside the parabola (and note that requiring too many orders in the power series will be counterproductive because of numerical round-off errors, ending up in lower precision as well).



# 3. Review configuration parameters and fine tune some of them for hard cases

- **Max Order for Power Series**
  - This controls the numeric precision achieved in the calculation of voltages (Analytic Continuation)
  - Normally, the higher the order, the higher the precision (up to the limit of machine accuracy, reached at around 70 terms).
  - *But for larger cases that are close to collapse, we should reduce this.* Moreover, round-off effects warrant the search for an optimal number of terms (one may use the script “ScanOrder.js”).
- **Number of orders to compute at each stage**
  - Default is 5, meaning 5 orders are computed at once each time.
  - Reduce to 1, meaning the power series will be completed one by one, and convergence will be checked one by one.
  - We do this because if you always did 5 orders at each stage, and the optimum precision happened to be at, say, the next 2 orders, you would miss it.
- **Jumper Threshold**
  - The jumper threshold defines which branches will be collapsed when computing the load-flow. Raise the value (for instance from  $2.9e-4$  to  $7e-4$ ) when looking for a better precision in the solution.
  - Jumper thresholds are used in all planning tools (PSS/E, PSLF), and if a case is stitched from several others, different companies may have used different values for the JT. We probably want ours to be the highest (more tolerant) among those.



# 3. Review configuration parameters and fine tune some of them for hard cases

The screenshot shows a software configuration window with two tabs: 'General' and 'Controls'. The 'Controls' tab is active. The window is divided into several sections:

- Options affecting the acceptance of the solution:**
  - Min # of buses in island: 7
  - Max mismatch in node (in MW): 0.05
  - Max % of nodes not solving: 1.5%
- Options affecting the precision of the solution:** (This section is highlighted with a red box)
  - Max order for power series: 70
  - Num orders to compute initially: 15
  - Num orders to compute at each stage: 5
  - Tolerance for A.C. approximants: 1.0E-4
  - Calculation stop policy: Analytic continuation is converged
- Options affecting the merging of nodes:**
  - Jumper threshold (reactance in p.u.): 2.9E-4
- Global scaling of key parameters:**
  - Resistance (%): Slider set at 100
  - Active power injections (gen and load) (%): Slider set at 100
  - Slack and phase shifter angles (%): Slider set at 100



## 4. Remove some or all enforcement of controls & limits

- In general, controls and the enforcing of limits impose additional constraints on the load flow solution (therefore they normally make it harder to satisfy the equations). Therefore:
  - **Uncheck Enforce VAR Limits ( $Q_{\max}$ ,  $Q_{\min}$  at generators).**
    - Freeing the VAR limits may help to uncover information about V set-points that cannot be realistically fulfilled; but be aware that on the other hand it may produce situations with no solutions.
  - **Try checking "Move remote PV controls to local".**
    - This will move the set-point of all generators to their local bus. It may help uncover cases where the remote set-point is unrealistically far.
  - **A\* strategy and A\* maximum expansions.**
    - The A\* algorithm is used to search for the best configuration of enforced and (possibly) saturated controls. If we deactivate it, we will obtain a solution where the limits on controls may be violated. It may help to inspect this solution, in cases where we do not get any otherwise.
    - A bigger number of A\* steps does not necessarily improve things, since the system will stop searching if it detects that there is no way to improve the solution. However, setting it to a very low value could force the system to stop before the best solution has been found (it will make the computation faster in that case).



# 4. Remove some or all enforcement of controls & limits

General Controls

Activation

Enforce VAR limits on generators

Enable on-load tap changer transformers

Enable automatically switched shunts

Enable area interchange constraints

Matrix factorization (conflicting controls) SVD

Remote Controls

Move remote PV controls to local

Setpoint for remote PV controls moved to local  Generator setpoint  
 Bus value

Limited controls search

Strategy  None  
 A\*

A\*

Maximum expansion 10

A\* Spots

Max number of consecutive spot Loadflows 3

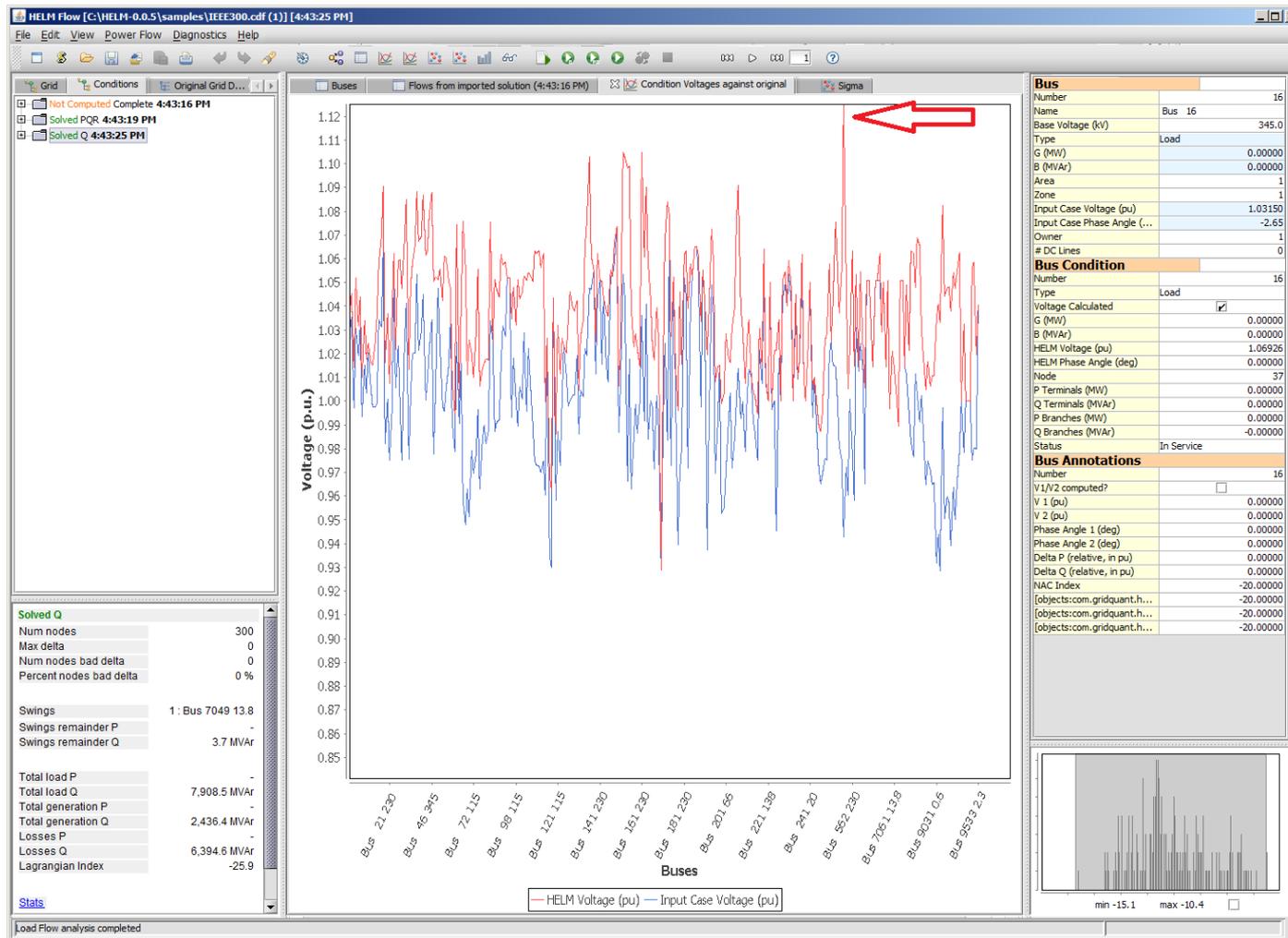


# 5. Run Q-HELM (pure reactive power-flow)

- We start with Q-HELM because this shows the “barebones” of the transmission grid, that is, the health of the underlying support structure.
- Points to remember:
  - In Q-HELM power flow, PV buses become Q-swings and PQ buses become Q buses.
  - Since P is absent, there are no angles and all you have to look at are voltage magnitudes and Q flows.
  - Beware that in this mode the voltages will always be higher than on Full HELM.
- Solve Q-HELM and look at the voltage profile and the Sigma Plot. This will reveal whether any branch has too high reactance (i.e. it is consuming too much reactive power) or a load is requesting a reactive power demand that is too high.
- To do so:
  - **check for spikes in the voltage conditions graph.**
  - **check for outliers in the Sigma plot (which is on a single line now).**
- Once we find a suspicious bus/branch, we examine it closely in a bus diagram or “3 nearest neighbor plot” (shows all buses within 3 hops) to determine where the problem is in the neighborhood. It could be a load that is too high, or an X that is too high, or a path that is too long (and therefore an effective X that’s too large), etc.



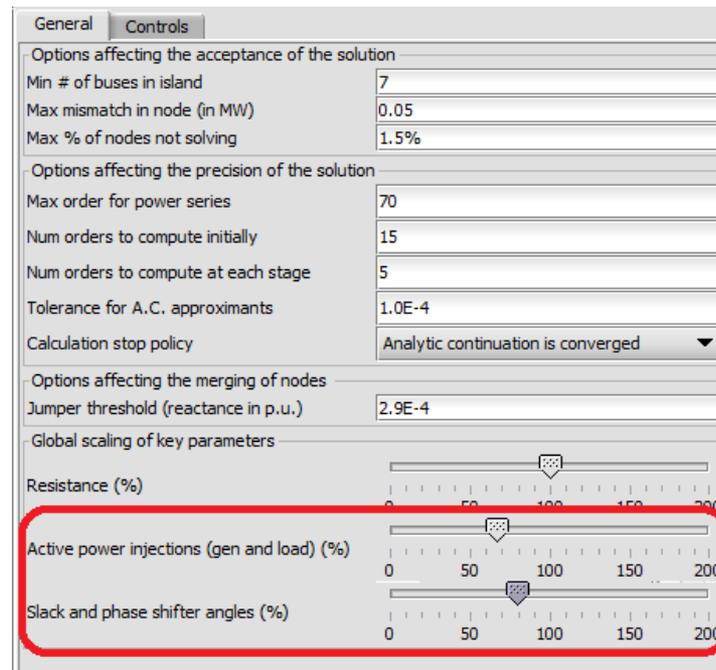
# 5. Run Q-HELM (pure reactive power-flow)





## 6. Run PQ-HELM (lossless grid power-flow)

- **Once all errors are identified in Q-HELM, we move to PQ-HELM.** Now we are back to a grid with both Q and P, but the resistances in lines and transformers are set to zero.
- If it doesn't solve, but did using Q-HELM (and the same controls), we can then assume that the active power (P) demand is too high for the system. We can then play around with the *global scaling slider for P and the one for swing/phase-shifter angles*.
- Remember that we can always analyze the Sigma Plot even if the case doesn't solve. This is a clear benefit because in other systems, once the case doesn't converge, you cannot dig any deeper.

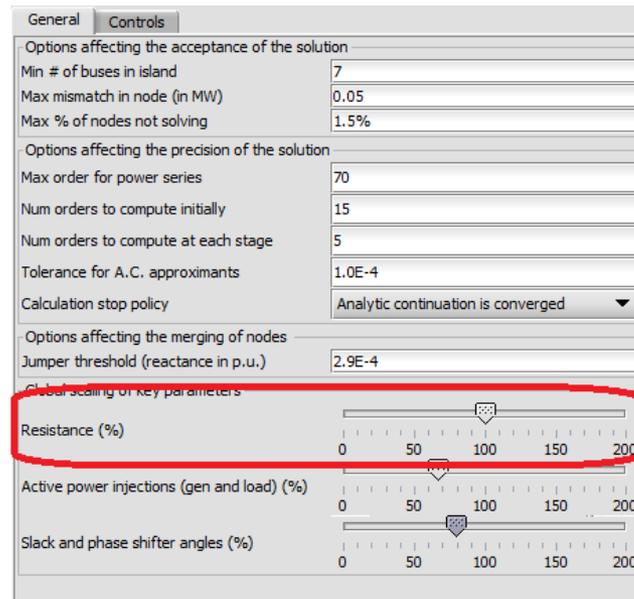




# 7. Run Full-HELM

The difference between running PQ-HELM and Full-HELM (also known as PQR) is only that resistances on branches are now active.

- Having a case that solves under PQ-HELM but does not under PQR-HELM indicates that the resistive losses tip the system over to collapse. This may help uncover anomalous resistances somewhere.
- You may also experiment with the *slider for global scaling of resistances*.





## 8. Re-enable controls and their limits

- **Adding controls back: once the case is solving under Full-HELM, it is time to re-enable any controls that we may have disabled before.**
- **Re-enable “enforce VAR limits on generators”.**
  - If the case solved before and does not when VAR limits are enforced, we know that a generator set-point may be relying on too much reactive power. Either this set-point needs to be corrected, or we need more “reactive support” from other nearby devices.
  - After you apply this control, go to *Diagnostics* -> *Saturated Generators* to check.
  - Under this control, we also again check voltage conditions to look for anomalous spikes (specifically, depressed nodes).
- **Activate transformer taps (OLTCs) and switched shunts.**
  - With this control on, you should look for large deltas (node mismatches where flow in does not equal flow out) or anomalous voltages in the bus voltage condition graph.
  - In both cases, once you find a bad node or anomalous voltage, you should look around in the topological neighborhood, in order to find root causes.
- **Activate area interchanges the last:** especially when working with large, stitched-together models, these controls are typically the most problematic.
- **You can analyze and diagnose the results related to controls and their limits under the menu: *Diagnostics* -> *Diagnose controls*.**



# 8. Re-enable controls and their limits

The screenshot shows the 'Diagnostics' menu with the following options:

- Branch Resistance-Reactance
- Branch Resistance-Susceptance
- Branch Reactance-Susceptance
- Sigma
- Generators Active Power Limits
- Generators Reactive Power Limits
- Limit Violations
- Saturated Generators
- Diagnose Controls

The 'Diagnose Controls' sub-menu is open, showing the following options:

- Diagnose Generators Controls
- Diagnose Transformers Controls
- Diagnose Switched Shunt Controls
- Diagnose Areas Controls
- Diagnose All Controls

The background table displays generator data with the following columns: Generator, Q (MVar), Q max (MVar), Q min (MVar), Q Limit, Q Out of limits?, and Q out of limit (MVar). The table lists several generators, with Bus 91 115 Generator 1 highlighted in blue.

Generator	Q (MVar)	Q max (MVar)	Q min (MVar)	Q Limit	Q Out of limits?	Q out of limit (MVar)
Bus 8 115 Generator 1	10.00000	10.00000	-10.00000	Qmax	<input type="checkbox"/>	0.00000
Bus 10 230 Generator 1	20.00000	20.00000	-20.00000	Qmax	<input type="checkbox"/>	0.00000
Bus 20 115 Generator 1	20.00000	20.00000	-20.00000	Qmax	<input type="checkbox"/>	0.00000
Bus 84 115 Generator 1	154.44046	240.00000	-240.00000	-	<input type="checkbox"/>	0.00000
Bus 91 115 Generator 1	46.10969	96.00000	-11.00000	-	<input type="checkbox"/>	0.00000
Bus 94 115 Generator 1	32.98137	153.00000	-153.00000	-	<input type="checkbox"/>	0.00000
Bus 95 115 Generator 1	5.00000	-30.00000	-	-	<input type="checkbox"/>	0.00000
Bus 97 115 Generator 1	7.00000	-24.00000	-	-	<input type="checkbox"/>	0.00000
Bus 100 115 Generator 1	0.00000	-500.00000	-	-	<input type="checkbox"/>	0.00000
Bus 103 115 Generator 1	0.00000	-60.00000	Qmax	<input type="checkbox"/>	0.00000	
Bus 106 115 Generator 1	0.00000	-125.00000	-	-	<input type="checkbox"/>	0.00000
Bus 109 115 Generator 1	5.00000	-50.00000	-	-	<input type="checkbox"/>	0.00000
Bus 112 115 Generator 1	0.00000	-100.00000	-	-	<input type="checkbox"/>	0.00000
Bus 146 230 Generator 1	35.00000	35.00000	-15.00000	Qmax	<input type="checkbox"/>	0.00000
Bus 147 230 Generator 1	-48.04094	100.00000	-50.00000	-	<input type="checkbox"/>	0.00000
Bus 149 230 Generator 1	50.00000	50.00000	-25.00000	Qmax	<input type="checkbox"/>	0.00000
Bus 152 230 Generator 1	-34.57832	175.00000	-50.00000	-	<input type="checkbox"/>	0.00000



Thank you !



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