



Planning Assistant: Human-Supervised Agentic AI for Power System Planning and IBR Model Verification

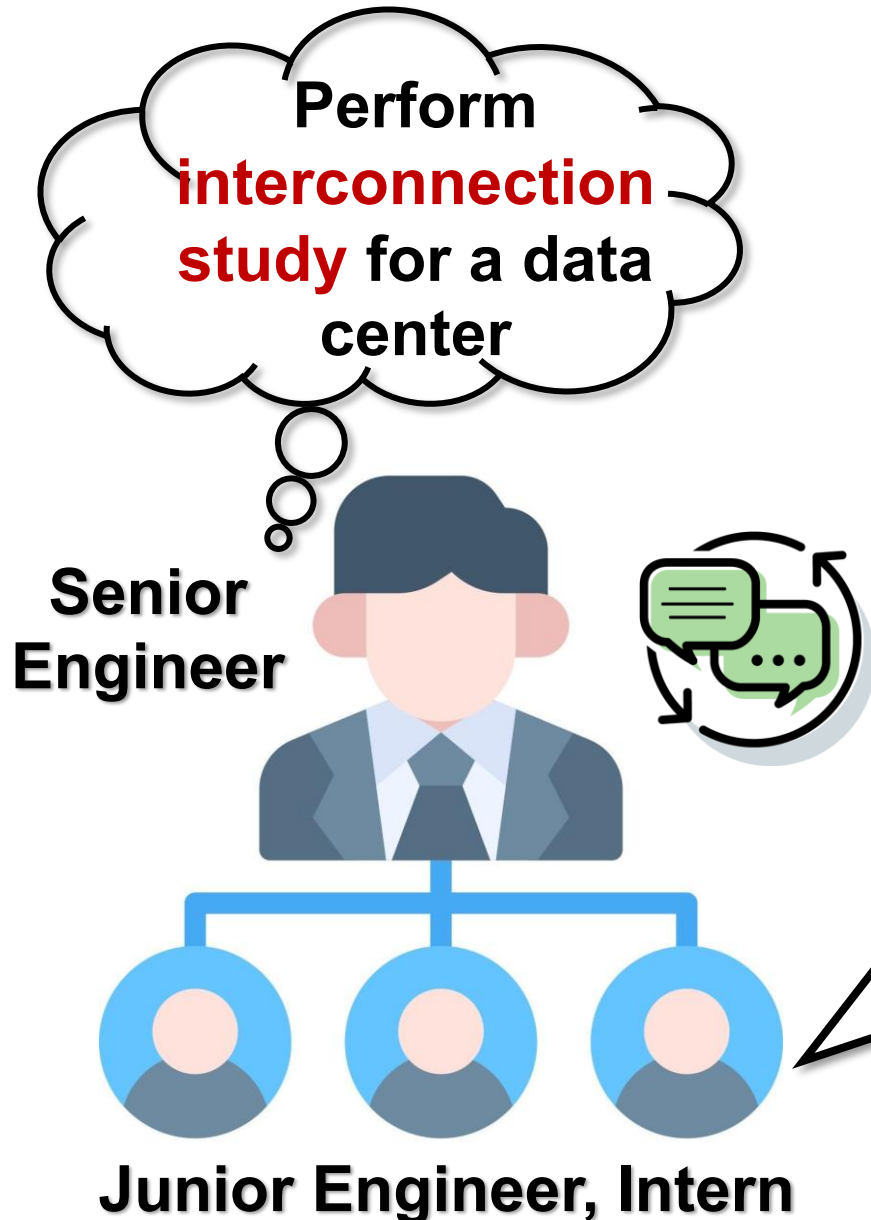
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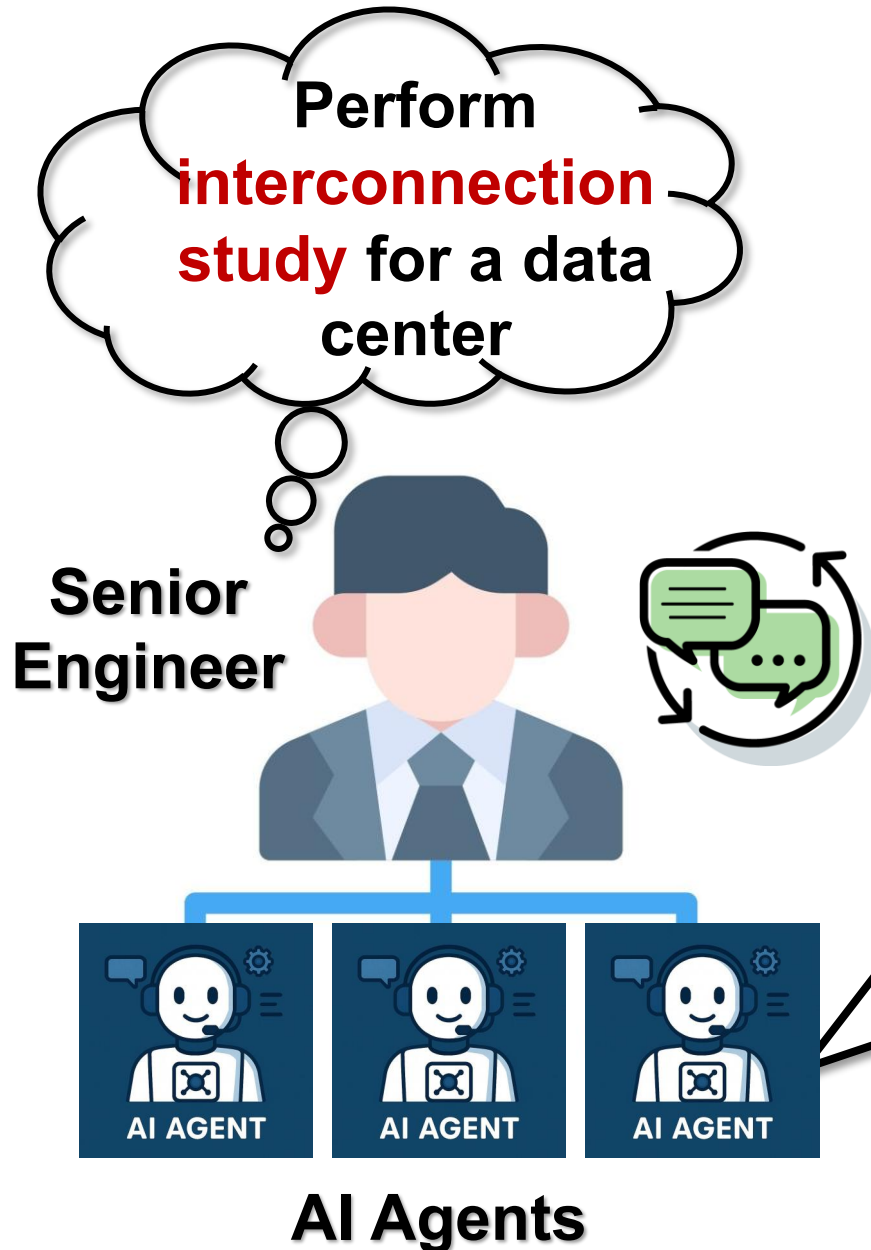
Oct 7, 2026

Human vs AI System Planner



- ✓ Build scenarios (**peak, off-peak**, etc.)
- ✓ Base case **power flow**, contingency
- ✓ **Voltage** control, reactive power support
- ✓ **Transient** stability, **oscillation**, EMT
- ✓ Short circuit analysis, **weak grid** risk
- ✓ **Mitigation measures**: network upgrades, an output-limitation or curtailment agreement, reactive devices, or phased interconnection
- ✓ **Investment cost** analysis

Human vs AI System Planner

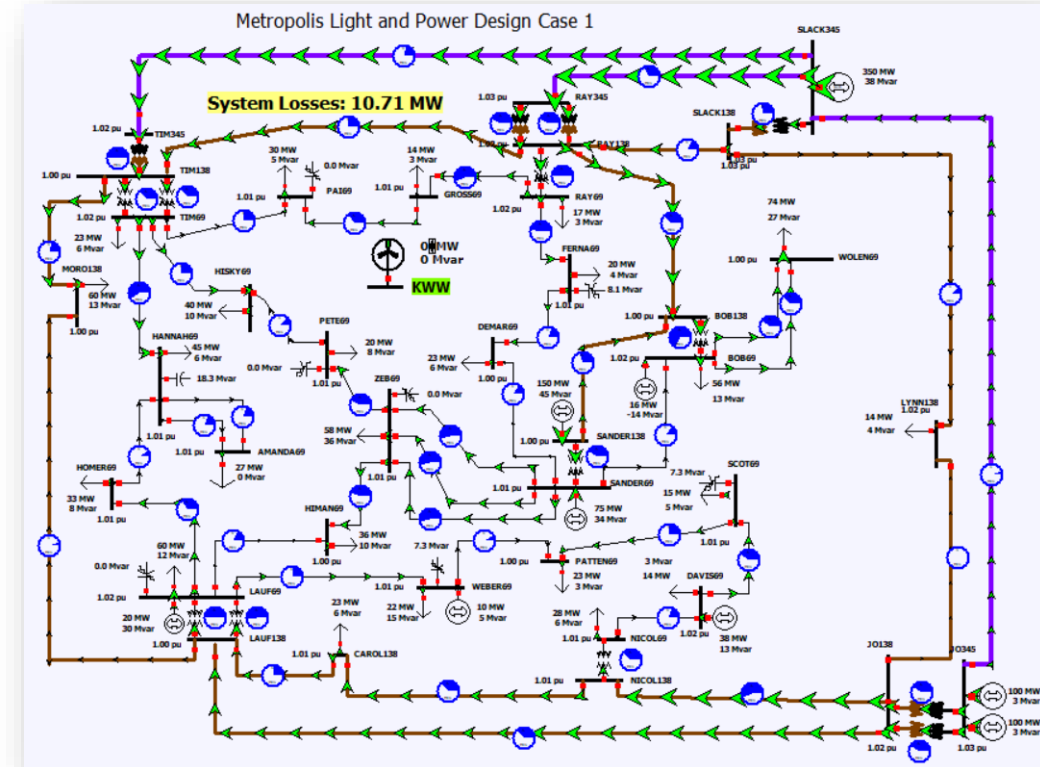


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AI System Planner: Power Flow, Contingency, Investment Cost

►► Textbook Project: Wind Farm Interconnection

- Least-cost transmission expansion to connect a **200 MW wind farm** into a 37-bus system.
- Interconnected by at least **2 separate feeds**, through **8 candidate rights-of-ways**, using **4 candidate conductor types**.
- No voltage or line flow violation in base case **power flow** and N-1 **contingency** analysis.
- **Investment costs** on new transmission lines, transformers, substation upgrades, as well as the price for system power losses over 5 years.



- T.J. Overbye, M.S. Sarma, and J.D. Glover. "Power system analysis & design", 2019.

AI System Planner: Power Flow, Contingency, Investment Cost



User Queries



1. **Solve the project with PSSE** using these inputs: (1) the project description (.pdf); (2) power flow case (.raw) converted from PowerWorld; (3) conductor characteristics table (.pdf).
2. List all the calculations and analysis needed for the project.
3. Find ambiguities in the project and **design checkpoints to request human approval**.
4. **Design a detailed workflow** and solve the project with PSSE.

AI System Planner: Power Flow, Contingency, Investment Cost



❖ **AI-designed workflow:**

1. Convert the power flow case (.raw) into a usable PSSE case.
2. Build contingency list.
3. Solve base case + contingency analysis without the wind farm.
4. Calculate line parameters using conductor characteristics table.
5. Build candidate expansions with at least 2 separate feeds.
6. Solve base case + contingency analysis for candidate expansions.
7. Compute the loss-adjusted construction costs.
8. Select final design and generate final report.

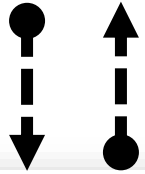
AI System Planner: Power Flow, Contingency, Investment Cost



❖ **AI-designed human approval checkpoint:**

1. Approve the designed **workflow**.
2. Approve **candidate design scope**: multi-feed 69kV, mixed 69/138 kV, and 138 kV lines.
3.

AI System Planner: Power Flow, Contingency, Investment Cost



❖ **AI system planner:**

1. Within **2 hours**, performed base case power flow for **5,348 candidate designs**, found 2,722 base-case feasible designs. 200 lowest-cost designs were run through all 57 contingencies.
2. **Recommended design:** 3 separate 69kV feeds from the wind farm to 69kV buses (PAI, PETE, TIM) with Crow, Crow, and Rook conductors.
3. **Construction cost:** \$ 9.3397 Million; **Worst N-1 loading:** 99.49%; **Worst N-1 voltage:** 0.956 pu.

AI System Planner: Power Flow, Contingency, Investment Cost

Executive Summary

The recommended design remains:

- KWW-PAI69 using Crow conductor
- KWW-PETE69 using Crow conductor
- KWW-TIM69 using Rook conductor

This design passes the PSS/E base case and all original 57 existing line/transformer contingencies with KWW fixed at 200 MW.

Metric	Value
Candidate designs evaluated	5348
Base-case feasible designs	2722
Full N-1 screened designs	200
Fully N-1 feasible designs	6
Recommended construction cost	\$9.3044M
Recommended losses	10.70147 MW
Original base losses	10.68533 MW
Recommended net cost vs base	\$9.3397M
Worst N-1 loading	99.49%
Worst N-1 minimum voltage	0.95648 pu

Study Basis

- Student ID suffix: 1234, so conductor spacing is 17.1234 ft.
- Thermal basis: Rate A with MAXMVA/RateA <= 100%.
- Voltage basis: 0.95 pu to 1.10 pu.
- Power-flow controls disabled: transformer taps, phase shifting, area interchange, DC taps, and switched shunts.
- New line model: short line, series R and X only.
- N-1 list: original 57 existing elements only; new KWW facilities are not outaged.
- PSS/E base case:
C:\Users\zzhou157\Documents\PSSE_MCP\PSSE\DesignCase1_fix_after_15_54_and_18_37_xcorr.sav .

Recommended Design Parameters

New line	Length km	R pu	X pu	Rate A MVA	Cost
KWW-PAI69 Crow	9.66	0.018684	0.094766	99.19	\$2.2502M
KWW-PETE69 Crow	11.91	0.023036	0.116839	99.19	\$2.7452M
KWW-TIM69 Rook	20.92	0.046088	0.207140	92.02	\$4.3090M

AI System Planner: Power Flow, Contingency, Investment Cost

Human-In-The-Loop Checkpoint Log

This section records the actual conversation-level human checkpoints available in this chat. For several planned checkpoints, no separate approval message was requested during execution because the user explicitly authorized the full end-to-end PSS/E study after reviewing the checkpointed workflow.

Checkpoint	Question or prompt to human	Human response received	Action taken
1. Input scope and student ID	Which project files and student-specific value should be used, and should PSS/E remain closed?	User provided the three files, gave student ID suffix 1234, and instructed: do not start PSS/E yet; analyze only the three files.	Read only the PDFs and RAW file; used D = 17.1234 ft; did not start PSS/E.
2. Study list confirmation	What power-system studies and mathematical analyses are required before running PSS/E?	User requested an analysis-only list of all required studies and calculations.	Produced the study list: base case, N-1, candidate upgrades, line parameter calculations, ratings, costs, and loss economics.
3. Ambiguity review	Are there unclear or conflicting project-description items that affect the workflow?	User asked whether any uncertainties would affect the workflow.	Documented the main ambiguities and converted them into workflow guardrails.
4. Human-in-the-loop workflow approval	Should the workflow include explicit human-in-the-loop checkpoints and PSSE MCP functions?	User requested a new workflow including human-in-the-loop modifications and PSSE MCP functions.	Generated the checkpointed workflow with approval points before assumptions, formulas, candidate cases, PSS/E start, baseline, contingency list, loss baseline, and final recommendation.

AI System Planner: Power Flow, Contingency, Investment Cost

Human-In-The-Loop Checkpoint Log

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Checkpoint	Question or prompt to human	Human response received	Action taken
5. PSS/E start authorization	May PSS/E now be started to run the project studies?	User explicitly authorized: now you can start PSS/E and complete the final project based on the latest workflow and the three provided files.	Started PSS/E, solved cases, ran candidate screening, ran N-1 studies, and generated the final recommendation.
6. Study assumptions during execution	Approve Rate A, voltage limits, fixed KWW MW, no tap/shunt changes, and original-contingency-only screening?	No separate response was requested during execution; the user had already globally authorized completion based on the latest workflow.	Applied the documented assumptions consistently and recorded them in the report.
7. Line calculation basis during execution	Approve 17.1234 ft equal spacing, Table A.4 60 Hz/50 C resistance, GMR-based reactance, and short-line model?	No separate response was requested during execution; this followed the previously reviewed workflow and the assignment text.	Used those formulas and assumptions for all candidate line parameters.

AI System Planner: Power Flow, Contingency, Investment Cost

Human-In-The-Loop Checkpoint Log

This section records the actual conversation-level human checkpoints available in this chat. For several planned checkpoints, no separate approval message was requested during execution because the user explicitly authorized the full end-to-end PSS/E study after reviewing the checkpointed workflow.

Checkpoint	Question or prompt to human	Human response received	Action taken
8. Candidate design scope during execution	Approve screening 69 kV, mixed 69/138 kV, and 138 kV alternatives, including multi-feed 69 kV options?	No separate response was requested during execution; this followed the user's instruction to complete all required studies end-to-end.	Screened 5,348 candidate designs and ran full N-1 on the 200 lowest loss-adjusted base-feasible designs.
9. PSS/E base-case repair judgment	Should the repaired imported PSS/E base be used after the direct imported RAW case solved unrealistically?	No separate response was requested during execution.	Used the repaired imported PSS/E base that satisfied the assignment's no-initial-violation expectation, and documented this caveat in the report.
10. Loss baseline	Approve using the original no-KWW base-case losses as the loss-economic reference?	No separate response was requested during execution; this was selected as a consistent documented baseline.	Ranked designs by construction cost plus five-year loss change versus original base-case losses.

AI System Planner: Power Flow, Contingency, Investment Cost

Human-In-The-Loop Checkpoint Log

This section records the actual conversation-level human checkpoints available in this chat. For several planned checkpoints, no separate approval message was requested during execution because the user explicitly authorized the full end-to-end PSS/E study after reviewing the checkpointed workflow.

Checkpoint	Question or prompt to human	Human response received	Action taken
11. Expanded appendix request	Should the report include the complete N-1 list, all 5,348 candidates, all 2,722 base-case-feasible designs, and the N-1 screened subset?	User requested those tables and asked for a PDF report with all details.	Generated the expanded report, 195-page PDF, expanded JSON, and CSV table exports.
12. Human-in-the-loop audit request	Should the expanded report include the human-in-the-loop checkpoint prompts and received responses?	User requested this additional information in the report.	Generated this updated expanded report with a human-in-the-loop checkpoint log.
13. Base-case repair documentation request	Should the final report describe the original base-case power-flow problem, the repair, why the repair was made, and before/after results?	User requested this additional information in the report.	Computed before/after PSS/E results and added the base-case repair explanation, changed-data table, and power-flow comparison tables.

AI System Planner: Voltage, Reactive Power Support

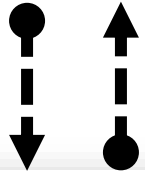


User Query



1. Perform base case power flow (WECC-179).
2. Increase system-wide load until **voltage collapse** happens.
3. Suggest **mitigation measures** for the voltage collapse. Explain your reasons, estimate the costs, and **run PSSE** to verify your suggestions.
4. For your successful mitigation measures, select some faults to perform transient stability analysis and calculate critical clearing times (CCTs).

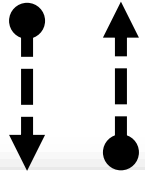
AI System Planner: Voltage, Reactive Power Support



❖ AI system planner:

- ❑ The base-case load is 60785.4 MW, 15351.3 Mvar, with losses of 626.0 MW, 18604.1 Mvar. The **base case already has high-voltage buses** above 1.10 pu. Voltage-control cleanup should be part of any operating plan.
- ❑ Uniformly **scaling all constant-power loads** produced a **voltage collapse** with a 2.5% load growth. The last converged point was 62336.0 MW.

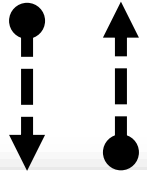
AI System Planner: Voltage, Reactive Power Support



❖ AI system planner:

- ❑ The weak-area pattern points to **reactive margin depletion in the southern/central 500 kV pocket around TEVATR, TABLE, ROUND MT, and OLINDA**, led by bus 134 TEVATR3 at 0.9307 pu. The rising Mvar losses from 18604.1 Mvar at base to 20442.2 Mvar near the nose are a strong indicator that the incremental load is being carried through a reactive-stressed extra-high-voltage corridor.

AI System Planner: Voltage, Reactive Power Support

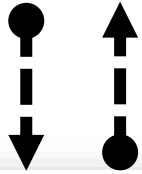


❖ AI system planner:

❑ Recommended Mitigation Measures:

- 1) Operational voltage schedule at nearby generating plants. Raise the **voltage schedules of nearby generators to 1.04 pu**. This a low-cost operating action, not a planning-grade fix. This recommendation was **selected from 12 candidate cases**. The candidates were determined by **engineering judgements**, not rigorous algorithms.

AI System Planner: Voltage, Reactive Power Support

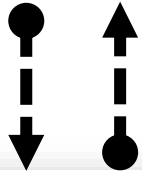


❖ AI system planner:

❑ Recommended Mitigation Measures:

- 2) Install mechanically switched or breaker-switched **capacitor banks (5 x 500 Mvar) at buses 134, 132, 128, 119, and 115.** I modeled these as fixed shunts in PSS/E; in an actual plan they should be switched or blocked at light load because the base case already has high voltages. **Estimated cost** is $2,500 \text{ Mvar} \times \$25,000/\text{Mvar} = \$62.5 \text{ million}$ plus \$25 million for five extra-high-voltage substations, for a planning estimate of \$87.5 million. This was **selected from 54 candidate capacitor placement designs.**

AI System Planner: Voltage, Reactive Power Support



❖ AI system planner:

- ❑ **Transient stability** of corrected case: No sequence data was supplied; I used balanced 3-phase faults rather than unbalanced faults. **Fault choices:** (1) Fault 1 at bus 134 TEVATR3 (selected because this is the **weakest voltage bus**). (2) Fault 2 at bus 119 TEVATR with trip of 119-134 (selected because **bus 119 is the local 500 kV hub and the 119-134 circuit feeds the weakest bus**). (3) Fault 3 at bus 77 JOHN DAY (selected because it is the **swing/generation reference, a severe rotor-angle stress location**). Critical clearing times are: 0.932s, 0.208s, 0.966s.

AI System Planner: Voltage, Reactive Power Support

WECC 179 Base Case Voltage Stability and Transient Stability Study

Study folder: `C:\Users\zzhou157\Documents\PSSE_MCP\PSSE\base case test`

Input RAW: `C:\Users\zzhou157\Documents\TestCasesLibrary_Model\Basecase\wecc179.raw`

Input DYR: `C:\Users\zzhou157\Documents\TestCasesLibrary_Model\Basecase\wecc179.dyr`

PSS/E used for executed studies: PSS(R)E 35.4.0 from `C:\Program Files\PTI\PSSE35\35.4`.



Executive Summary

The imported 179-bus WECC case solves in PSS/E. Base-case load is 60785.4 MW and 15351.3 Mvar, with losses of 626.0 MW and 18604.1 Mvar. The base case already has high-voltage buses above 1.10 pu, so voltage-control cleanup should be part of any operating plan even before load growth is applied.

Uniformly scaling all constant-power loads while holding the dispatch pattern otherwise fixed produced a voltage-collapse nose at about $\lambda = 1.02551$. The last converged point was 62336.0 MW, and the next failed point was $\lambda = 1.02553$. The weak area was the TEVATR/TABLE/OLINDA 500 kV pocket, led by bus 134 TEVATR3 at 0.9307 pu.

The recommended corrective plan is a heavy-load switched capacitor program represented in the power-flow verification as five 500 Mvar shunt banks at buses 134, 132, 128, 119, 115. This solved a 5 percent load-growth case at $\lambda = 1.050$, raising the delivered load to about 63824.7 MW. The corrected case remains transiently stable for the selected 3-phase faults up to the critical clearing times summarized below.

AI System Planner: Voltage, Reactive Power Support

Engineering Recommendations

1. Operational voltage schedule at nearby generating plants.

Raise the voltage schedules of nearby PV buses to approximately 1.04 pu where reactive capability is available. This is low-cost and solved the first failed loading point, but it failed at 5 percent load growth. It is useful as an operating action, not a planning-grade fix.

2. Small capacitor program, 5 x 150 Mvar.

This option failed the 5 percent load-growth case. The cause is straightforward: 750 Mvar is too small compared with the incremental reactive loss and weak-area voltage depression near the PV nose. Estimated cost is about \$18.75 million for capacitor equipment at \$25/kvar-equivalent thousand per Mvar, plus roughly \$25 million for five substation integrations, or about \$44 million total.

3. Recommended heavy-load switched capacitor program, 5 x 500 Mvar.

Install mechanically switched or breaker-switched capacitor banks at buses 134, 132, 128, 119, and 115. I modeled these as fixed shunts in the heavy-load PSS/E verification; in an actual plan they should be switched or blocked at light load because the base case already has high voltages. Estimated cost is 2,500 Mvar x \$25,000/Mvar = \$62.5 million plus about \$25 million for five EHV substation projects, for a planning estimate of \$87.5 million. This option solved the $\lambda = 1.05$ case. Its traced loadability limit improved to about $\lambda = 1.05948$, with first failure near 1.05949.

4. Emergency load shedding or demand response.

If the system is already close to the nose, undervoltage load shedding is the emergency backstop. It avoids collapse by reducing the effective λ below the PV nose, but it does not serve the full increased demand and is therefore not a substitute for reactive support.

AI System Planner: Transient Stability, Oscillation

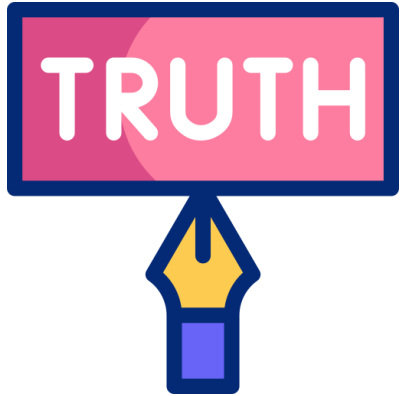


User Query



1. Perform power flow and transient stability studies with PSSE.
2. What problems do you see? If you see oscillations, identify the oscillation source (WECC-179).
3. If you see any problem, what are the possible causes and mitigation measures?
4. Generate a detailed report.

AI System Planner: Transient Stability, Oscillation



System model:

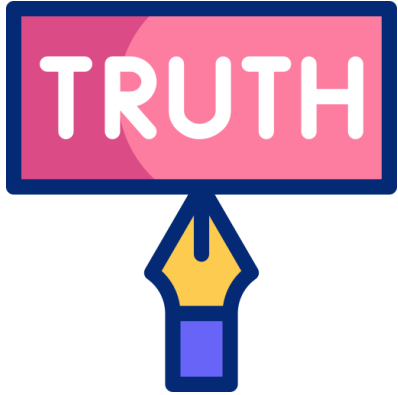
- All generators are in GENCLS model.
- Parameter D for generators 35 and 65 equals 0.5 and -1.5, respectively.
- Parameter D for all other generators equals 4.
- All loads are in constant MVA model.

Suspicious or unusual settings:

- Low GENCLS damping at bus 35 'CMAIN GM ': $D=0.5$
- Negative GENCLS damping at bus 65 'MONTA G1 ': $D=-1.5$



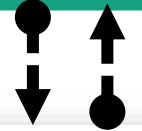
AI System Planner: Transient Stability, Oscillation



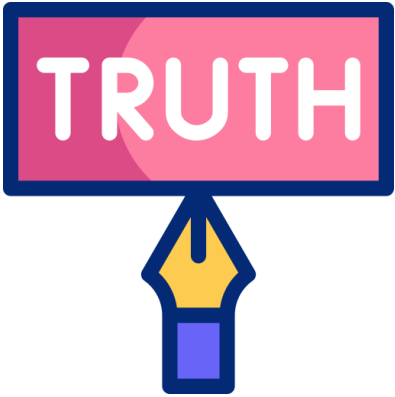
Natural oscillation case ND_2 ([Back to the homepage](#))

This case contains a single source - single inter-area mode natural oscillation case, where the oscillation source is generator 65.

Most likely source: bus 65 MONTA G1. In this study, the largest late machine speed and bus-frequency responses are at/near bus 65, while the largest machine-angle response is bus 35 and the largest bus-voltage response is bus 32. The largest observed oscillation location therefore depends on the measured signal; it is shaped by modal observability, electrical distance, inertia, and the mode shape, and is not automatically the source.



AI System Planner: Transient Stability, Oscillation

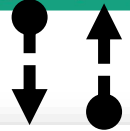


Small signal analysis:

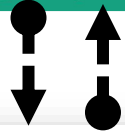
- The local mode at 0.37Hz has a low damping of 0.02%.

Oscillation Finding

The case contains a negatively damped electromechanical oscillation. In the bus-60 disturbance run, the dominant machine-speed component is approximately 0.335 Hz. Secondary spectral peaks from the same signal are 0.405 Hz, 0.265 Hz, 0.460 Hz.



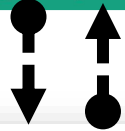
AI System Planner: Transient Stability, Oscillation



Source Evidence

1. Model-data evidence: the DYR has one negative damping coefficient: bus 65 MONTA G1 has GENCLS D=-1.5. Nearly all other machines have D=+4.0, with bus 35 CMAIN GM lower but still positive at D=+0.5.
2. Simulation energy evidence: using the speed channels and the GENCLS D values, the late-window damping-energy proxy $D \cdot \int (\text{speed}^2 dt)$ is negative only at bus 65. That means bus 65 is the only modeled machine injecting rather than dissipating oscillation energy through the GENCLS damping term.

AI System Planner: Transient Stability, Oscillation



4. Parameter-substitution evidence: changing D65 from -1.5 to +4.0 suppresses the growing oscillation. Increasing D35 from +0.5 to +4.0 also suppresses this bus-60 ringdown, which shows that bus 35 is a high-participation damping lever for the same mode. Because D35 is positive in the original case and its damping-energy proxy is dissipative, it is a mitigation/participation location rather than the negative-damping source.

5. Mode-shape evidence: the bus-60 run has bus 65 MONTA G1 and bus 35 CMAIN GM as the two largest speed components at the dominant frequency. Their phases are nearly opposite, indicating an electromechanical oscillation involving those machines/groups rather than a local voltage-only effect.

AI System Planner: Transient Stability, Oscillation



Natural Oscillation Case 2 Clean Study

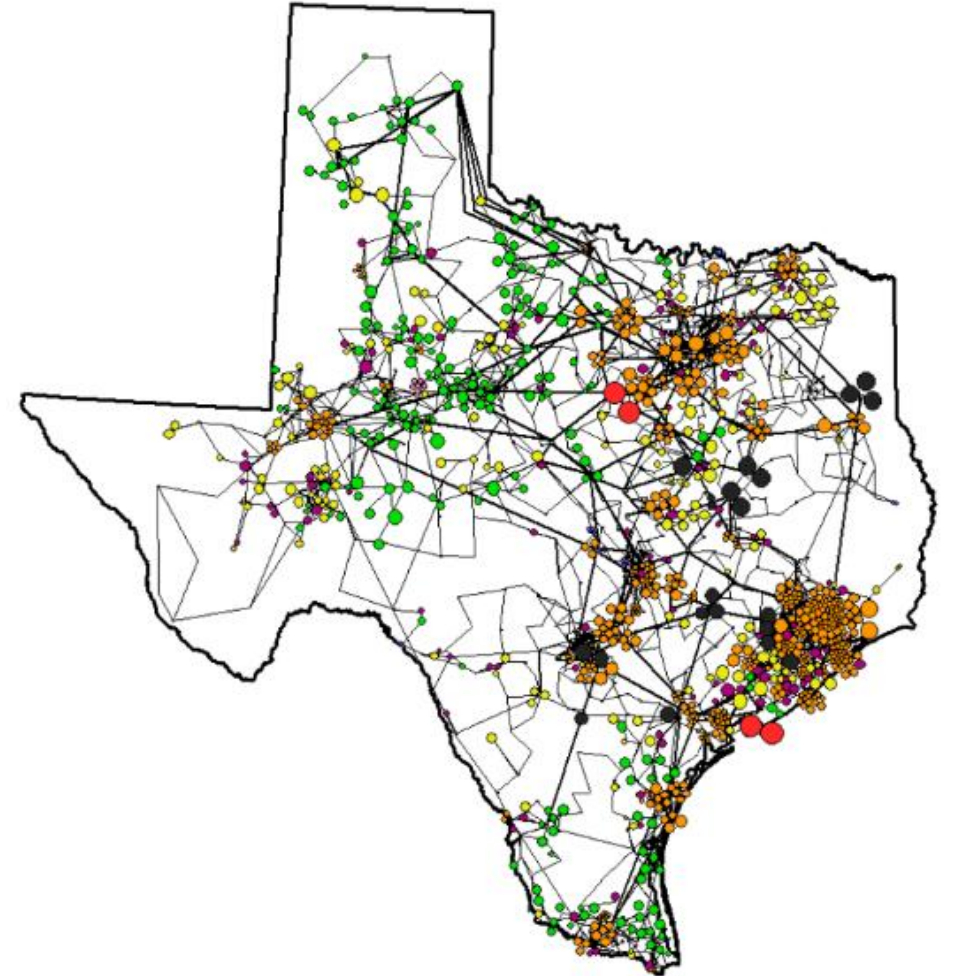
PSSE Studies Run

- Sanitized RAW import copy generated in this folder by removing only two non-network administrative records that PSSE35 conversion misread. The original RAW was not modified.
- Full PSSE35 power flow import and FNSL solve.
- Dynamic conversion with generator conversion, load conversion, network ordering/factorization, DYR loading, and channel setup.
- No-disturbance dynamic check.
- Three independent 3-phase bus-fault ringdown studies at buses 60, 74, and 142. The suspected source bus was not used as the disturbance location.
- Damping-parameter cross-checks using generated DYR variants: D65 changed from -1.5 to +4.0, and D35 changed from +0.5 to +4.0. The D35 case tests whether adding damping at a high-participation machine can also stabilize the mode.

AI System Planner: Synthetic Texas Grid – Transmission Expansion

➡ Synthetic Texas 2000-bus System

- Annual load and renewable profiles
- Load islands
- A list of transmission expansion candidates
- Power flow + Contingency (N-1) + 8760-hours production cost simulation
- Voltage limits: 0.95~1.10pu



AI System Planner: Synthetic Texas Grid – Transmission Expansion

►► **Q: Can this problem be solved mathematically?**

- **Security-constrained transmission expansion planning problem:**
 - ✓ **Binary planning decisions:** build candidate line, generator uprate, shunt, transformer upgrade, etc.
 - ✓ **Continuous operating decisions:** generator dispatch, shunt MVar output, bus voltages, branch flows, maybe load shed slack.
 - ✓ **Scenarios:** summer, winter, and N-1 contingencies.
 - ✓ **Objective:** minimize investment cost, possibly plus operating cost and very large penalties for infeasibility.
 - ✓ **Constraints:** AC power balance, voltage limits, thermal limits, island/load-shed rules, candidate asset limits.

AI System Planner: Synthetic Texas Grid – Transmission Expansion

►► Q: Can this problem be solved mathematically?

- The difficulty is that the true version is a large **mixed-integer nonlinear nonconvex optimization problem** because AC power flow has nonlinear voltage/angle equations and the planning choices are discrete.
- For a 2k-bus system with thousands of candidates and many N-1 cases, a full exact AC-MINLP solve is **usually not practical**.
- The best practical approach is usually **hybrid mathematical optimization + engineering validation**.

AI System Planner: Synthetic Texas Grid – Transmission Expansion

►► Q: Can this problem be solved mathematically?

- The best practical approach is usually **hybrid mathematical optimization + engineering validation**:
 - ✓ Use a simplified optimization model, usually DC MILP or linearized AC, to propose candidate portfolios.
 - ✓ Validate those portfolios with full AC pandapower N-1 simulation.
 - ✓ Add cuts/constraints for the violations found.
 - ✓ Repeat until feasible.
 - ✓ Use engineering heuristics to guide candidate pools, contingency screening, and reactive/voltage fixes.

AI System Planner: Synthetic Texas Grid – Transmission Expansion

►► Q: Can this problem be solved mathematically?

- The strongest approach for your case would probably be:
 - ✓ **Master MILP:** choose transmission/generator/shunt investments using DC or linearized constraints.
 - ✓ **AC validation subproblem:** Power flow checks summer/winter and active N-1 contingencies.
 - ✓ **Violation cuts:** if a line overload or voltage issue remains, add constraints or candidate requirements back into the MILP.
 - ✓ **Feasibility-restoration objective:** minimize weighted overload/voltage violations first, then minimize cost once feasibility is reached.

AI System Planner: Synthetic Texas Grid – Transmission Expansion

►► Q: Can this problem be solved mathematically?

- Best acceptable plan:
 - ✓ **Cost:** about \$41.065B
 - ✓ **Base summer/winter:** feasible
 - ✓ **Rating-B:** feasible
 - ✓ No load shedding
 - ✓ **Active N-1 residual:** 5 failures
 - ✓ **Voltage failures:** 0
 - ✓ **Remaining failures:** thermal only

AI System Planner: Synthetic Texas Grid – Transmission Expansion

►► Q: Can this problem be solved mathematically?

- I did not find a **completely feasible solution** under the current rules.
- **The main reason looks structural:** The remaining violations are all transformer thermal overloads, mostly small margins.
- I checked the official candidate catalog: it has **no direct upgrade candidates for the remaining overloaded transformer IDs**. So a fully feasible plan may still be found through indirect line additions or multi-candidate combinations, but the **more engineering-natural fix would be to add/directly allow transformer capacity upgrade candidates** for those remaining transformer bottlenecks, then rerun the hybrid search.

AI System Planner: Synthetic Texas Grid – Transmission Expansion

➡ **Q:** Allow additional synthetic candidates and find cheaper solutions:

5. Final planning portfolio

Source class	Action type	Projects	Investment cost
Official TAMU	New line	1,311	\$25,603,276,771.84
Official TAMU	Parallel line	121	\$950,150,000.00
Supplemental synthetic	Line capacity upgrade	14	\$39,690,000.00
Supplemental synthetic	New HVDC	18	\$12,150,000,000.00
Supplemental synthetic	Parallel transformer	2	\$188,230,000.00
Supplemental synthetic	Series compensation	5	\$107,825,000.00
Supplemental synthetic	Transformer capacity upgrade	1	\$36,025,000.00
Total		1,472	\$39,075,196,771.84

AI System Planner: Synthetic Texas Grid – Transmission Expansion

►► Q: Allow additional synthetic candidates and find cheaper solutions:

6. Engineering validation results

Requirement	Final result
Summer-Winter AC base	PASS
Base-case voltage and thermal violations	0
Worst base loading	99.985754%
Summer-Winter AC N-1	7,382 / 7,382 PASS
Minimum and maximum N-1 voltage	0.951176 pu / 1.098125 pu

Maximum N-1 loading	99.999839%
N-1 load shedding	0 MW
Economic-dispatch hours	8,760 / 8,760 optimal
Annual load shedding	0.000000 MWh
Annual production cost	\$298,315,443.85
Renewable curtailment	57,425,386.136 MWh

AI System Planner: Synthetic Texas Grid – Transmission Expansion

►► **Q: Allow additional synthetic candidates and find cheaper solutions:**

- The annual study reported 232 **congested physical lines**.
- Worst individual annual **congestion rent of \$20,163,864.58**
- Worst **congestion duration** of 8,551 hours.
- These are operational outputs, not additional investment-feasibility constraints unless specified by the benchmark reporting rules.

AI System Planner: IBR Model Verification

□ IBR design documents:

- PDF, Word, Excel

1. Model verification

□ IBR models:

- PSCAD or PSSE/PSLF
- Text files

PSCAD

```
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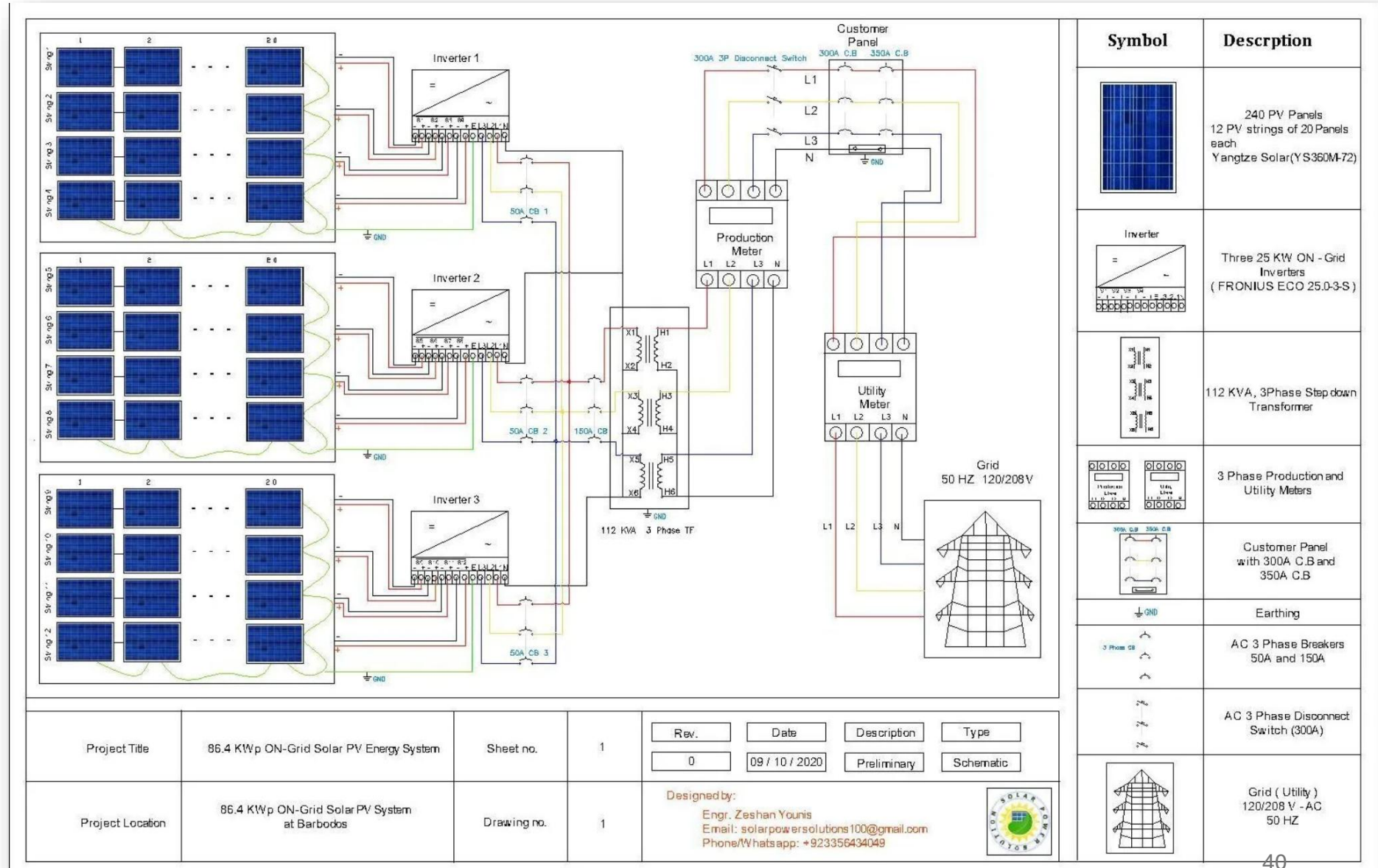
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```

**PSSE model
file (.dyr)**

**PSCAD
model file
(.pscx)**

AI System Planner: IBR Model Verification

➡ **AutoCAD
solar farm
design (PDF)**



AI System Planner: IBR Model Verification



- ❑ **Project information:** (1) on-grid solar PV system; (2) total DC capacity: 86.4 kWp; (3) grid: 120/208 V AC, 3-phase, 50 Hz, 3-phase + neutral (**Note: 120/208V systems are typically 60 Hz in many regions. 50 Hz labeling should be verified**).
- ❑ **PV array configuration:** (1) rating: 240 W; (2) model: Yangtze Solar (YS360M-72) (**Note: Model suggests 360W, drawing states 240W — inconsistency. The 240W label conflicts with the 86.4 kWp project size. Most likely actual modules are 360W**); (3) 12 PV strings per inverter section, 20 modules per string.
- ❑ **Inverter system:** (1) quantity: 3 inverters; (2) rating per inverter: 25 kW; (3) total AC capacity: 75 kW AC; (4) grounded.

AI System Planner: IBR Model Verification

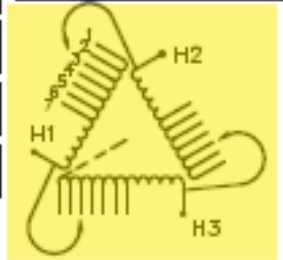
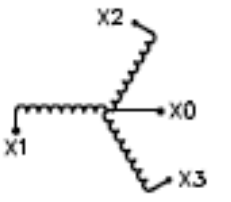


- ❑ **AC protection per inverter:** three AC Breakers: 50A, 3-Phase.
- ❑ **Main AC protection:** (1) 150A 3-phase breaker before transformer; (2) 300A 3-phase disconnect switch; (3) customer panel breakers: 300A CB and 350A CB.
- ❑ **Transformer:** (1) rating: 112 kVA; (2) type: 3-phase step-down transformer; (3) grounded; (4) connects inverter to utility/grid.
- ❑ **Metering:** (1) production meter: 3-phase (L1, L2, L3, N); (2) utility meter: 3-phase; (3) between customer panel and grid.

AI System Planner: IBR Model Verification

►► Transformer nameplate (picture)

hammond POWER SOLUTIONS		HPS Sentinel™ G Energy Efficient Distribution Transformer Transformateur de Distribution à Bon Rendement Énergétique		 LR 3902  DRY TYPE TRANSFORMER 77US E112313 LISTED		 8 05423 12196 9 ALSO VERIFIED IN ACCORDANCE TO ENERGY STANDARD C802.2-18 BY UNDERWRITERS LABORATORIES INC. © 3/18																																
Guelph, ONT Hyderabad, IN		Baraboo, WI Monterrey, MX		Part No. SG3A0075KB																																		
Cust. Ref. Ref. du Client		Serial No. No. de Serie		<table border="1"> <thead> <tr> <th>VOLTS</th> <th>CURRENT COURANT</th> <th>% RATED VOLTAGE % TENSION NOMINALE</th> <th>CONNECTION EACH PHASE CONNEXION PAR PHASE</th> </tr> </thead> <tbody> <tr><td>504</td><td>85.9</td><td>105</td><td>1</td></tr> <tr><td>492</td><td>88.0</td><td>102.5</td><td>2</td></tr> <tr><td>480</td><td>90.2</td><td>100</td><td>3</td></tr> <tr><td>468</td><td>92.5</td><td>97.5</td><td>4</td></tr> <tr><td>456</td><td>95.0</td><td>95</td><td>5</td></tr> <tr><td>444</td><td>97.5</td><td>92.5</td><td>6</td></tr> <tr><td>432</td><td>100.2</td><td>90</td><td>7</td></tr> </tbody> </table>		VOLTS	CURRENT COURANT	% RATED VOLTAGE % TENSION NOMINALE	CONNECTION EACH PHASE CONNEXION PAR PHASE	504	85.9	105	1	492	88.0	102.5	2	480	90.2	100	3	468	92.5	97.5	4	456	95.0	95	5	444	97.5	92.5	6	432	100.2	90	7	SPACINGS BETWEEN ANY VENTILATED ENCLOSURE PANEL AND ANY ADJACENT WALL SHALL BE A MINIMUM OF 3 INCHES
VOLTS	CURRENT COURANT	% RATED VOLTAGE % TENSION NOMINALE	CONNECTION EACH PHASE CONNEXION PAR PHASE																																			
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432	100.2	90	7																																			
Phase	3	HV/HT	480V 90.2A																																			
Type	K	BIL	10 kV																																			
Cooling Refroidissement	ANN	Term Bornes	H1 H2 H3																																			
kVA	75	LV/BT	208Y/120V 208A																																			
Temp. Rise Echauffement	150 °C	BIL	10 kV																																			
Temp Class Classe Temp	220 °C	Term Bornes	X0 X1 X2 X3																																			
Winding Enroulement	AL	Energy Regulations	DOE 10 CFR PART 431:2016																																			
Frequency Frequence Hz	60	Reglements de Energetique	CEE ACT SOR/2018-201																																			
Impedance % @ 170 °C	5.5																																					
Encl Type Type De Coffrage	3R																																					
Weight Poids lbs/kg	575/261																																					

SEISMIC QUALIFICATIONS:
AS FLOOR MOUNT ONLY
IBC 2018/ASCE 7-16
SDS<=2.0g Z/h=1 Ip=1.5

AI System Planner: IBR Model Verification



- ❑ **General information:** (1) 3-phase, 60 Hz. (6) rated power: 75kVA; (7) impedance: 5.5%; (8) connection: Delta-Y grounded.
- ❑ **Primary voltage ratings (HV/H1-H2-H3):** (1) rated voltage: 480V; (2) rated current: 90.2A; (3) BIL: 10kV.
- ❑ **Secondary voltage ratings (LV/X0-X1-X2-X3):** (1) rated voltage: 208Y/120V; (2) rated current: 208A; (3) BIL: 10kV.
- ❑ **Tap changer data:** (1) 7 taps; (2) primary voltage: 504V~432V; (3) 2.5% of rated voltage increase per tap change.

AI System Planner: IBR Model Verification

➡ **Solar controller panel (picture)**



- ❑ **General information:** (1) model/series: DEIF ASC; (3) solar controller (grid-tied plant controller for utility-scale PV plant).
- ❑ **Real-time electrical data:** fixed power active control mode, power factor = 0.97, active power = 1709kW, reactive power = 424kVar, apparent power = 1761kVA.

AI System Planner: IBR Model Verification

➡ PSCAD vs PSSE model files

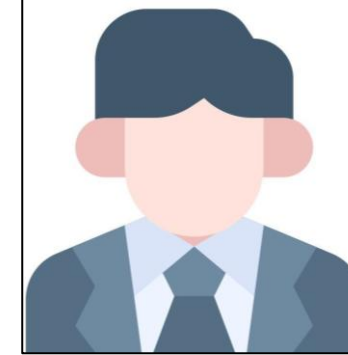
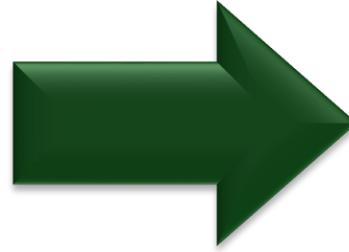
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39 'IEEEST' 1 1 0 0 0 0 0 0 0 5 0.6 3 0.5 10 10 1 0.2 -0.2 0 0 /
```



- ❑ These do not appear to be models of the same system.
- ❑ The **PSCAD** project is a detailed **PV/BESS model** with **converter and battery controls**. The **PSSE** files are a large **WECC system**.
- ❑ The .dyr file contains mostly classical machine models (GENCLS), no PV/BESS dynamic models (REGC_A, REEC_B, REPC_A, CBEST, BESS, vendor-specific renewable models).

Future Work: AI with Human Engineering Experience



- **AI-designed** workflow, mitigation measures, human approval checkpoints
- Based on **general reasoning, public information**
- **Single AI** agent

- **Human-instructed, AI-adapted** workflow, mitigation measures, human approval checkpoints
- Based on **company-specific** planning procedure, **engineering experience**
- **Multi-AI** collaboration

Future Work: Skills



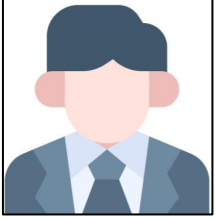
- **Skills** provided by human engineers
- **Teach AI** human engineering experience

- ▼  contingency-mitigation
 -  SKILL.md
- ▼  convergence-failure-mitigation
 -  SKILL.md
- ▼  der-hosting-capacity-mitigation
 -  SKILL.md
- ▼  dynamic-stability-mitigation
 -  SKILL.md

- ▼  frequency-response-mitigation
 -  SKILL.md
- ▼  interconnection-impact-mitigation
 -  SKILL.md
- ▼  operations-planning-mitigation
 -  SKILL.md
- ▼  short-circuit-mitigation
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Future Work: Skills



- **Skills** provided by human engineers
- **Teach AI** human engineering experience
- <https://github.com/Power-Agent/PowerSkills>

name	convergence-failure-mitigation
description	Senior power-engineer playbook for power-flow convergence failures. Use whenever a base case or post-change case diverges, oscillates, or fails to solve in PSS/E, PSLF, PowerWorld, pandapower, PyPSA, surge, or OpenDSS. Triggers on "power flow diverged", "case won't solve", "did not converge", "blown-up voltages", or "max iterations reached". Every tool skill stops on a non-convergent base case — this playbook is what to do next, separating data errors from numerical fragility from genuine physical infeasibility.

Convergence failure mitigation

Start from the failed solve and its mismatch report. The goal is to learn *why* it failed, not just to force a solution.

Preferred action order

1. Rule out data problems first: isolated or de-energized buses, zero or absurd branch impedances, missing or misplaced swing bus, transformer tap and phase-angle data, load/generation totals that cannot balance.
2. Check islanding and slack coverage: every energized island needs a slack with feasible MW. Use the tool's island or topology report before touching solver settings.
3. Simplify the solve, then restore: try flat start vs warm start, lock taps, switched shunts, and phase shifters, relax generator Q-limits — then re-enable controls stepwise once a solution exists.
4. Seed from an easier point: a DC solve, a previously solved neighbor case, or a reduced-stress version of the case, then scale load or transfer toward the target in steps.
5. If failure persists only near the target stress level, treat it as a feasibility boundary, not a numerical bug: reduce transfer or load, add reactive support, and flag possible voltage-collapse proximity.

Future Work: Skills



- **Skills** provided by human engineers
- **Teach AI** human engineering experience

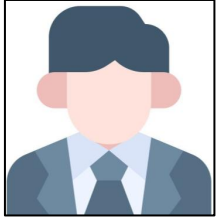
Working rules

- The largest mismatch bus tells you where to look — start there, not with global solver settings.
- Change one solver setting at a time and record what finally solved.
- A case solved with controls locked or Q-limits relaxed is not finished; restore realism before reporting results from it.
- Distinguish "the math failed" from "the operating point does not exist" — the corrective actions are completely different.

Deliver

- The failure category: data error, control interaction, numerical fragility, or physical infeasibility.
- The specific change that made the case solve.
- Any realism caveats that remain (locked controls, relaxed limits) and what to re-check.

Future Work: Skills



- **Skills** provided by human engineers
- **Teach AI** human engineering experience

name	interconnection-impact-mitigation
description	Senior power-engineer playbook for screening and mitigating the grid impact of a new generator, storage, or large-load interconnection. Use whenever the question is whether X MW can connect at a point of interconnection and what upgrades it needs. Triggers on "interconnection study", "system impact study", "POI", "can we connect this plant at bus Y", "short-circuit ratio", or "weak grid". Walks from steady-state screens through weak-grid and reactive checks to the binding constraint and its mitigation set.

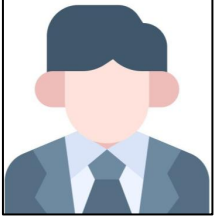
Interconnection impact mitigation

Start with a defined injection: MW and MVar capability, the point of interconnection (POI), and the dispatch scenarios to study.

Preferred action order

1. Pin down the study scenario set: peak and off-peak cases, high-renewable dispatch, and the prior-queued projects that must be modeled as in-service.
2. Run steady-state screens with the addition: base case and N-1 power flow, thermal loading and voltage screens around the POI. Route violations to `thermal-overload-mitigation` and `voltage-violation-mitigation` for the corrective toolkit.
3. Check weak-grid risk for inverter-based resources: short-circuit ratio at the POI. Low SCR (roughly below 3, critical below 2) flags control-interaction and stability risk — consider grid-forming controls, synchronous condensers, or POI relocation.
4. Verify reactive capability and voltage control: power-factor range and voltage ride-through at the POI against the applicable interconnection requirements.
5. Identify the binding constraint and assemble the mitigation set: network upgrades, an output-limitation or curtailment agreement, reactive devices, or phased interconnection — sized to the smallest set that clears the binding screen.

Future Work: Skills



- **Skills** provided by human engineers
- **Teach AI** human engineering experience

Working rules

- Screen with linear tools (PTDF on the injection) before full N-1 reruns; confirm the short list in AC.
- The fault contribution of the new plant changes breaker duty nearby; screen it and route over-duty to `short-circuit-mitigation`.
- Restudy after any material change in plant size, POI, or queue assumptions — interconnection results do not transfer between scenarios.
- Separate "needed to connect safely" from "needed to deliver full output" — reliability upgrades and deliverability upgrades have different urgency and cost allocation.

Deliver

- The injection studied (MW, POI, scenarios) and the screens it passed.
- The binding constraint with numbers (element, loading or voltage, contingency).
- The recommended mitigation set and what must be restudied if assumptions move.

Planning Assistant: Human-Supervised Agentic AI for Power System Planning and IBR Model Verification

Thank You!



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Arizona State University