NREL

Transforming ENERGY

Integrated Systems Planning: A Software Perspective

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Sienna

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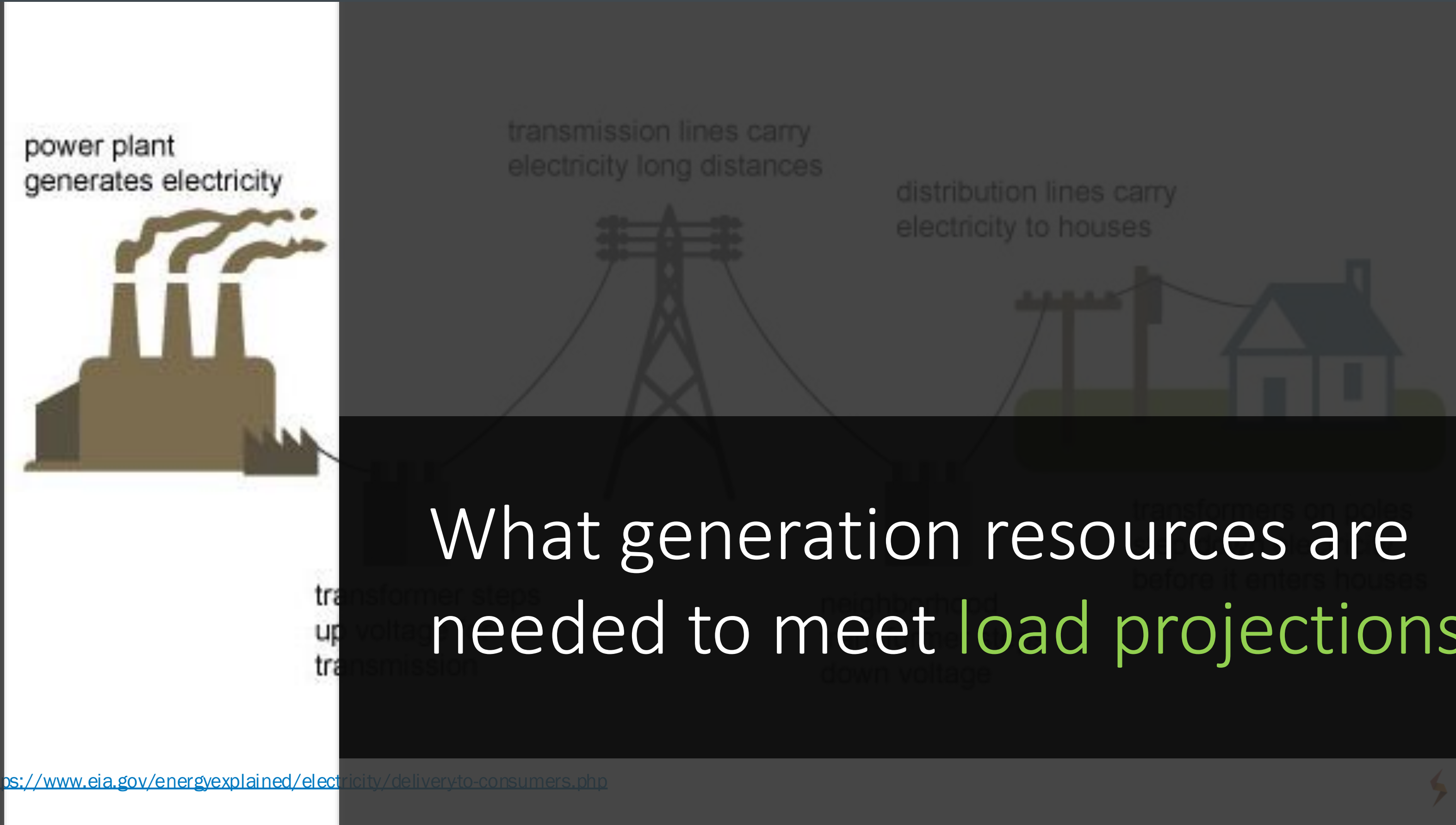
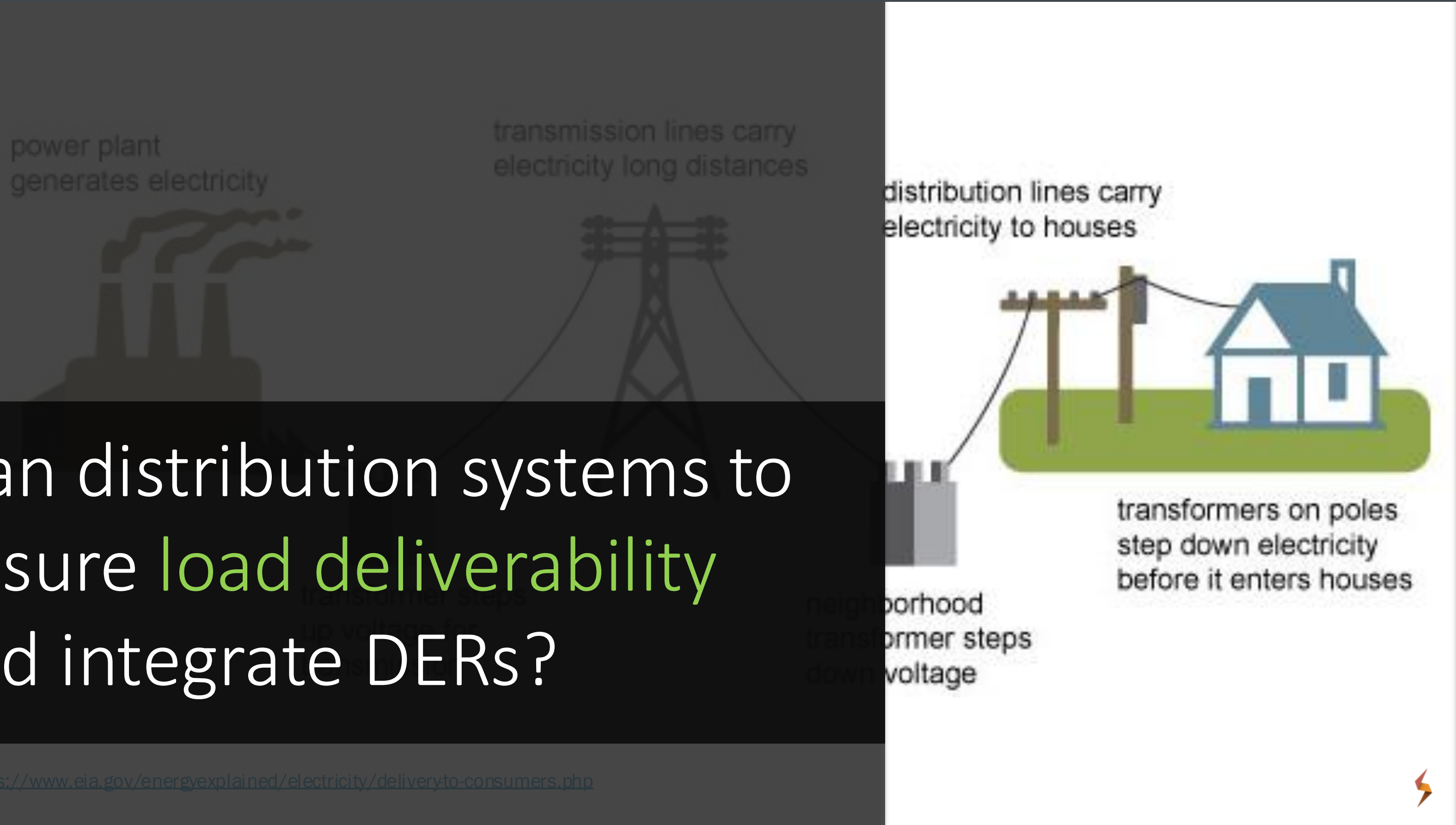
Where we've been: IRP



What generation resources are needed to meet load projections?

Source: https://www.eia.gov/energyexplained/electricity/deliveryto-consumers.php

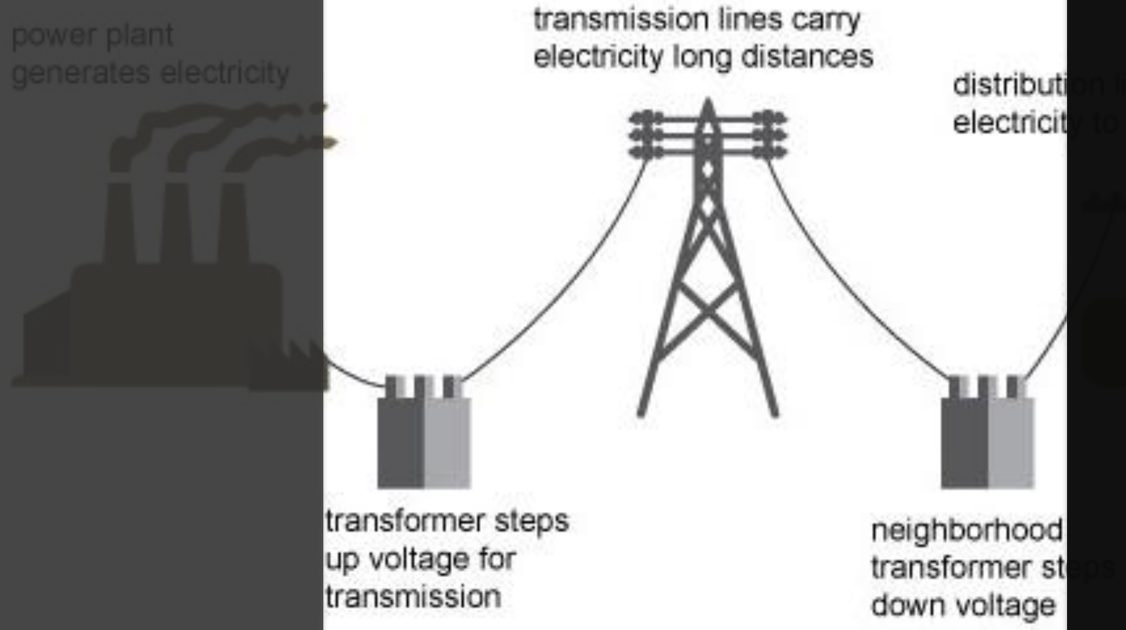
Where we've been: Distribution Planning



Plan distribution systems to ensure load deliverability and integrate DERs?

Source: https://www.eia.gov/energyexplained/electricity/deliveryto-consumers.php

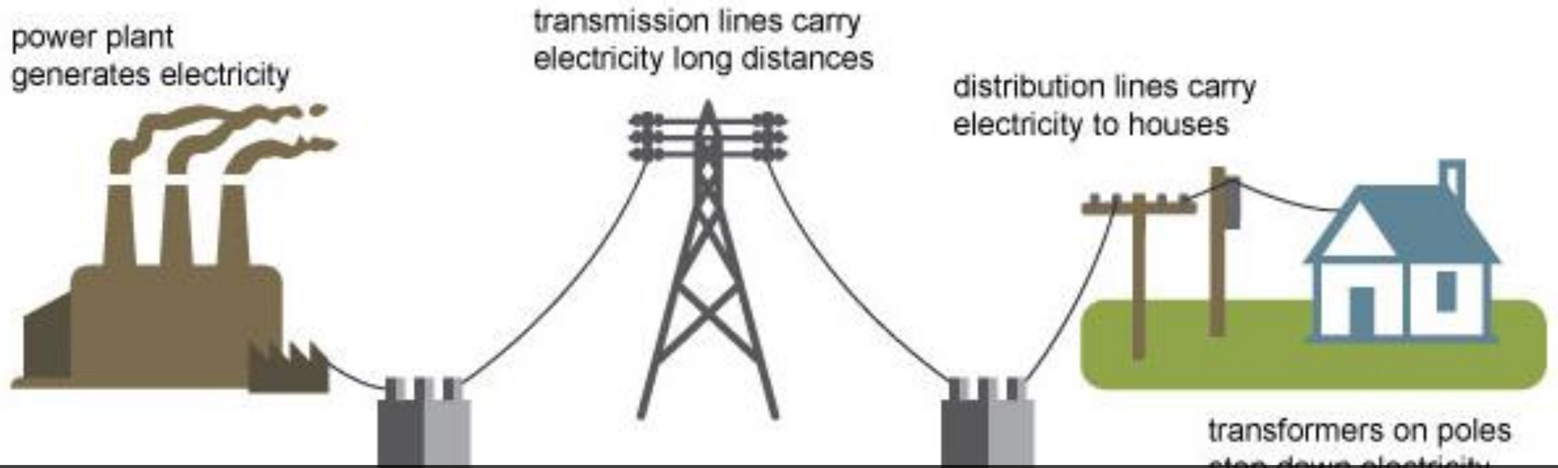
Where we've been: Transmission Planning



What transmission is needed needed to maintain reliability?

Source: https://www.eia.gov/energyexplained/electricity/deliveryto-consumers.php

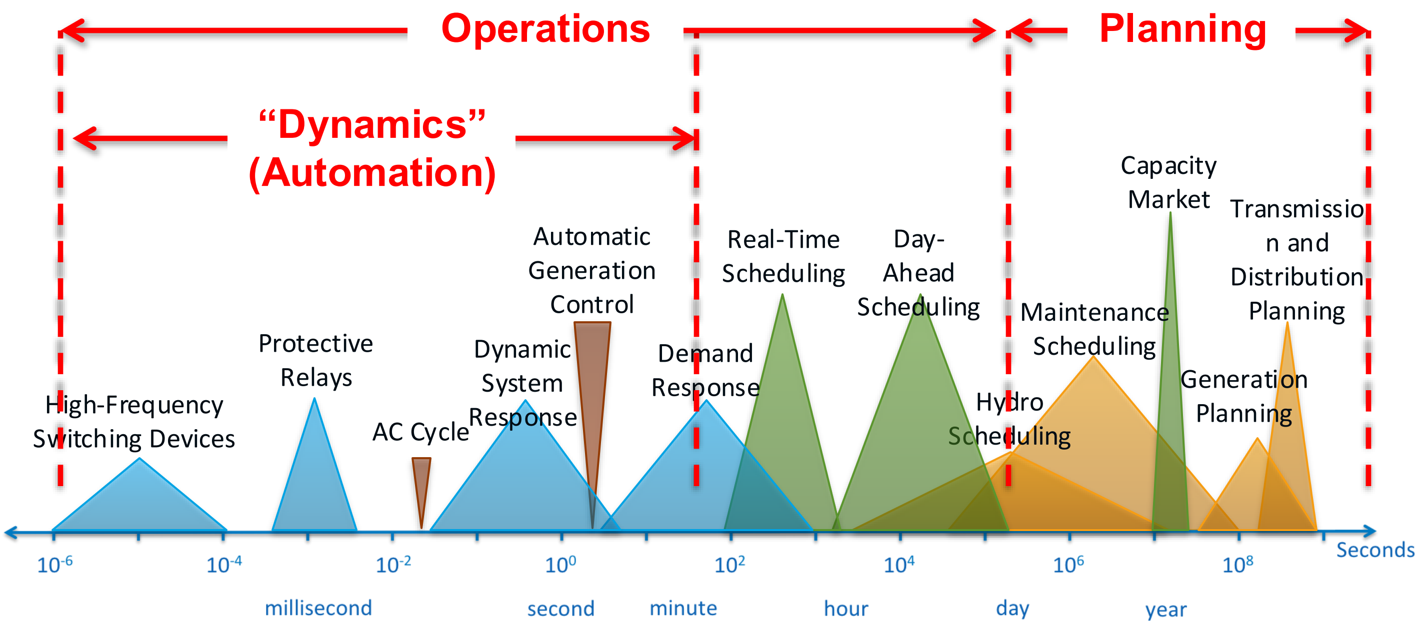
Where we're going: ISP



Which generation, transmission, and distribution projects achieve desired outcomes?

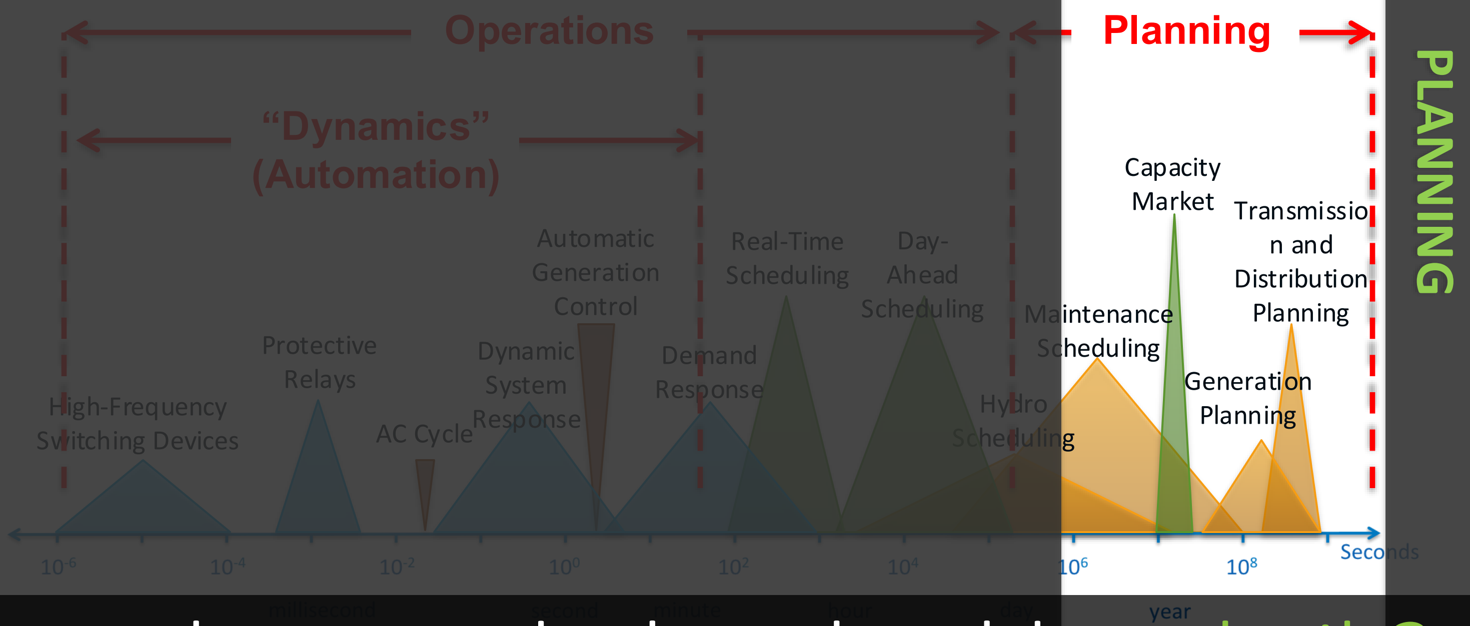
Source: https://www.eia.gov/energyexplained/electricity/deliveryto-consumers.php

Relevant grid decision timescales span 15 orders of magnitude



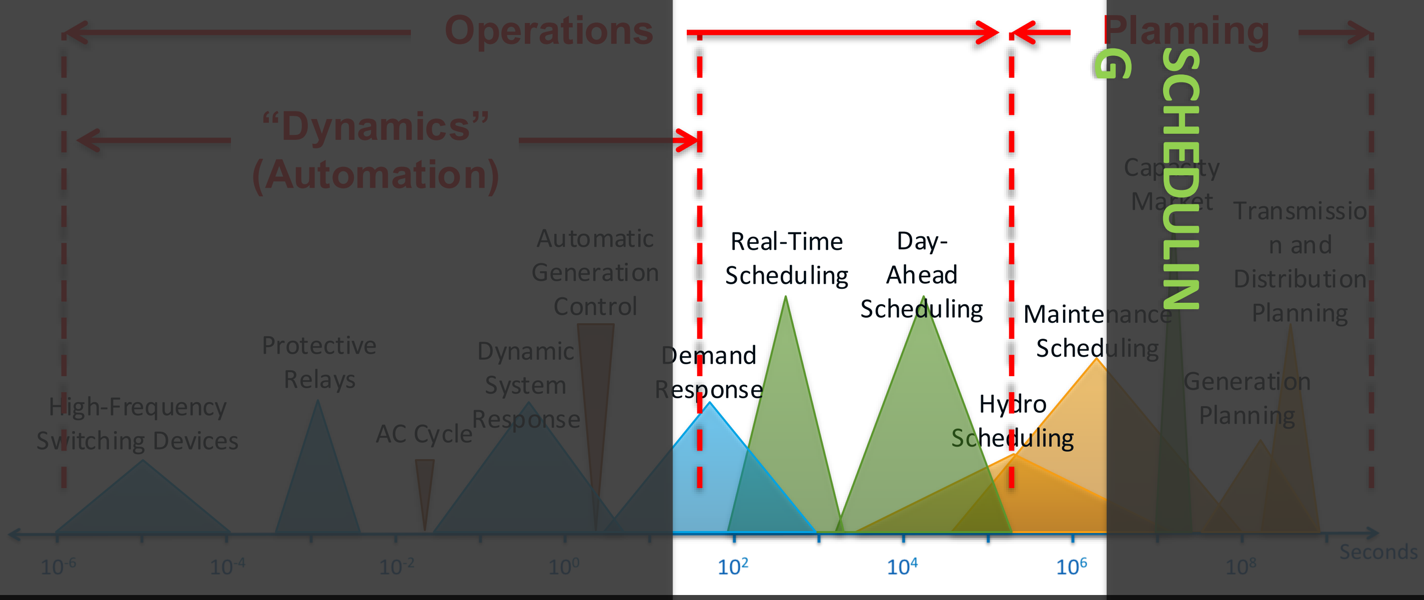
Adapted from A. Von Meier

Relevant grid decision timescales span 15 orders of magnitude



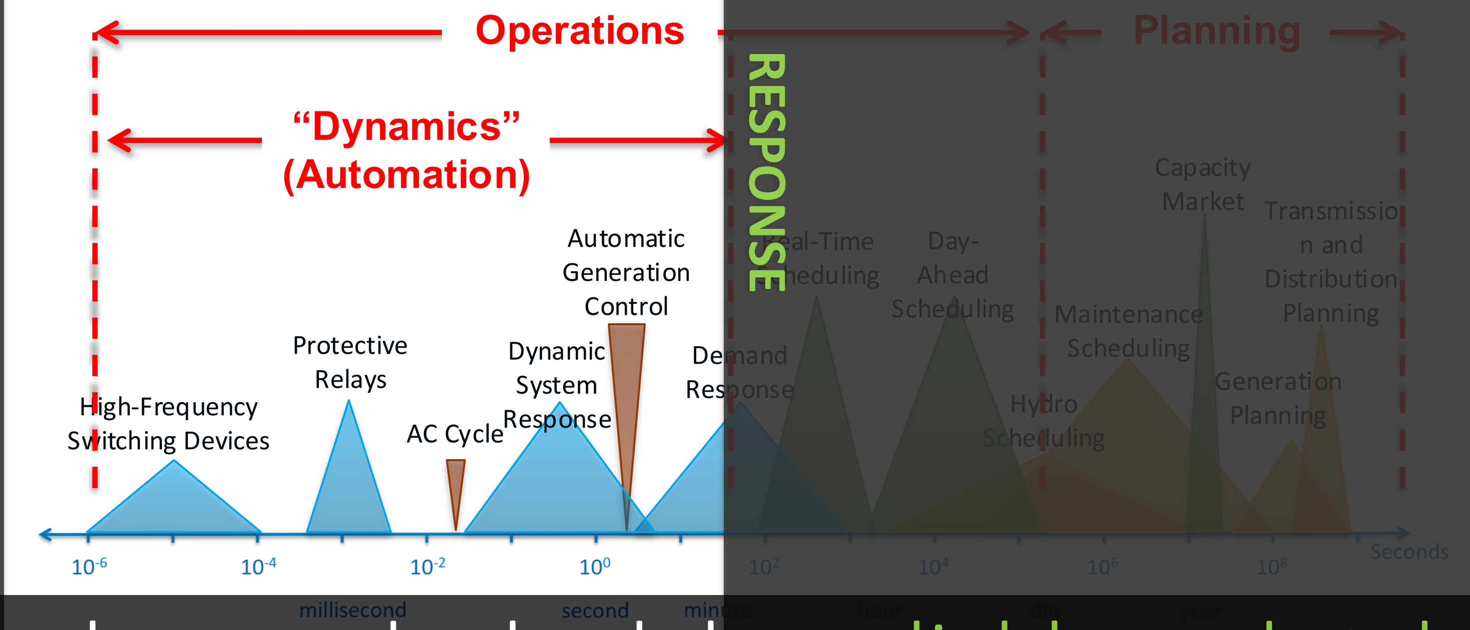
When, where, and what should get built?

Relevant grid decision timescales span 15 orders of magnitude



How to **schedule** planned system operations?

Relevant grid decision timescales span 15 orders of magnitude

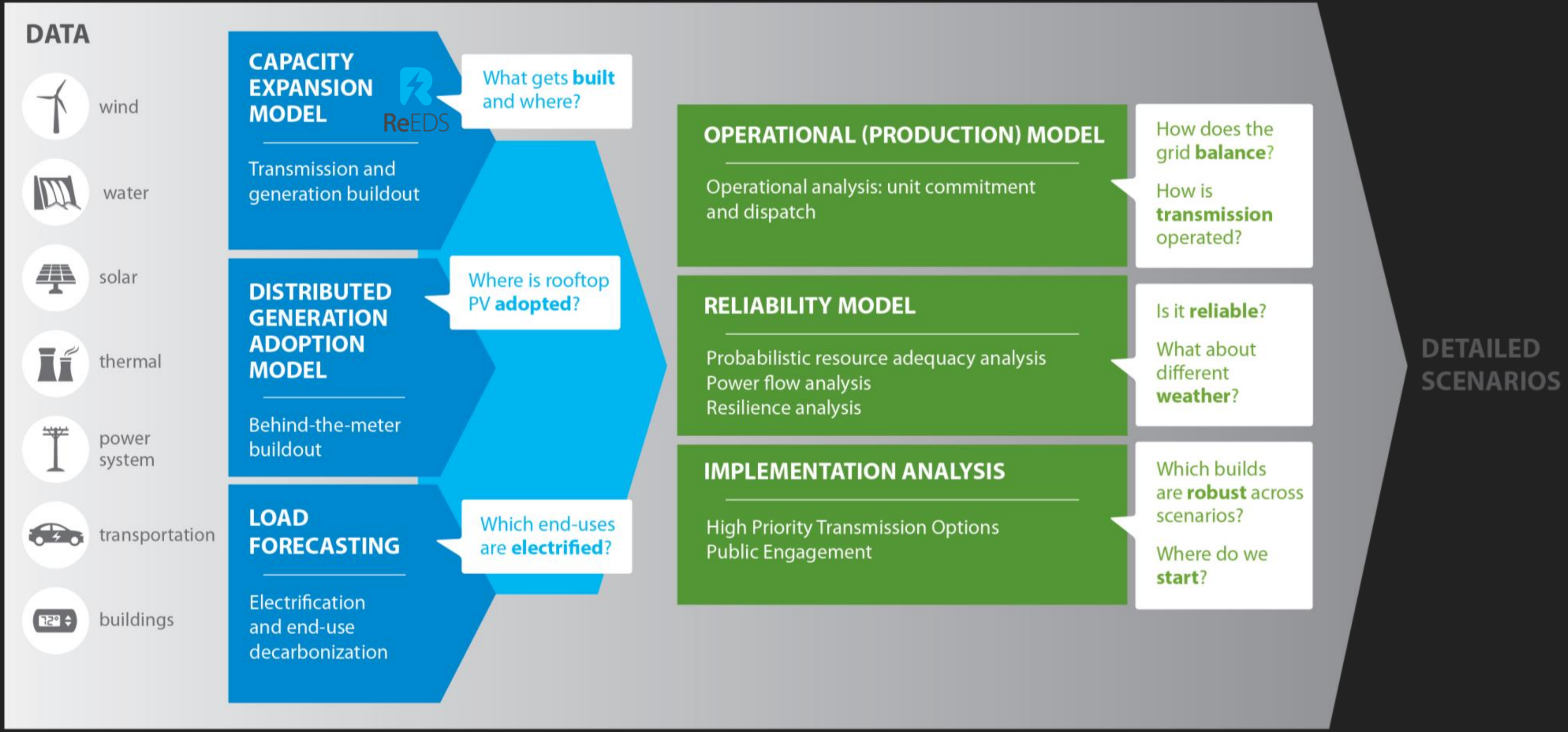


Are plans and schedules reliable and stable?

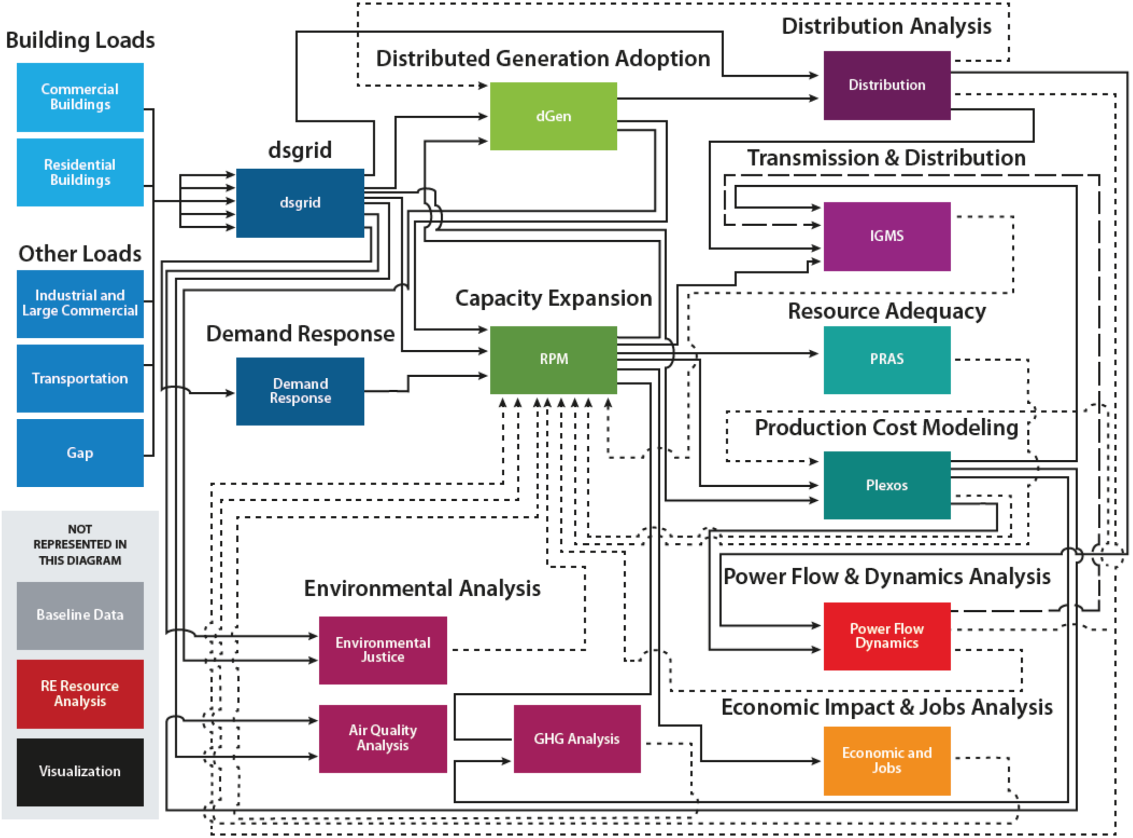
GPAC integration studies rely on multiple linked modeling exercises

Frame and Develop Scenarios

Scenario Refinement and Detailed Reliability Evaluations



Problem Description from the software perspective



Each one of these arrows is doing A LOT OF WORK.

In most cases the software requirements for these arrows is not understood correctly and leads to using **"Heuristic Ad-hoc Code"** (HAC) that isn't reproducible or re-usable

Open-Source Ecosystem for Power System Modeling, Simulation, and Optimization

Sienna\Inv

Simulation of system investment, including sequential problems for resource siting and sizing

Sienna\Data

Efficient intake and use of energy systems input data

Sienna\Ops

Simulation of system scheduling, including sequential problems for production cost modeling

Sienna\Dyn

Simulation of power system dynamic response to disturbances and contingencies

https://github.com/NREL-Sienna

What we think integrated planning is…

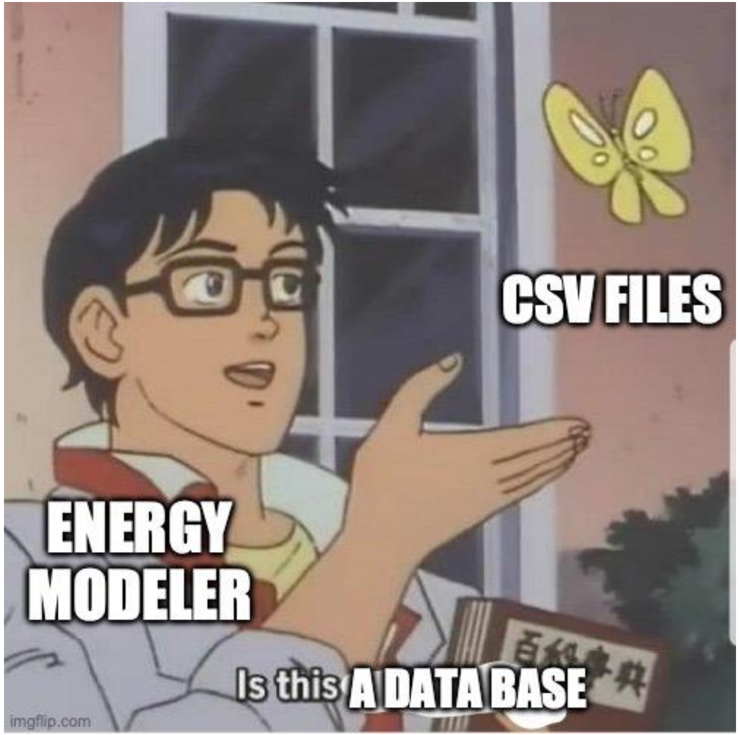
- Integrated planning is a sort of catch all term that comprises multiple aspects.
  - Many subsectors of study: Generation, Transmission, Distribution
  - Many tools that need to be used for the study: PowerFlow Solver, Production Cost, Resource Adequacy, Capacity Expansion
  - Many stakeholders involved: utilities, ISO's, consumer advocacy groups and government agencies
- By definition is a complex process and making it systematic has been an elusive objective in the field for decades.

Lessons Learned in Sienna

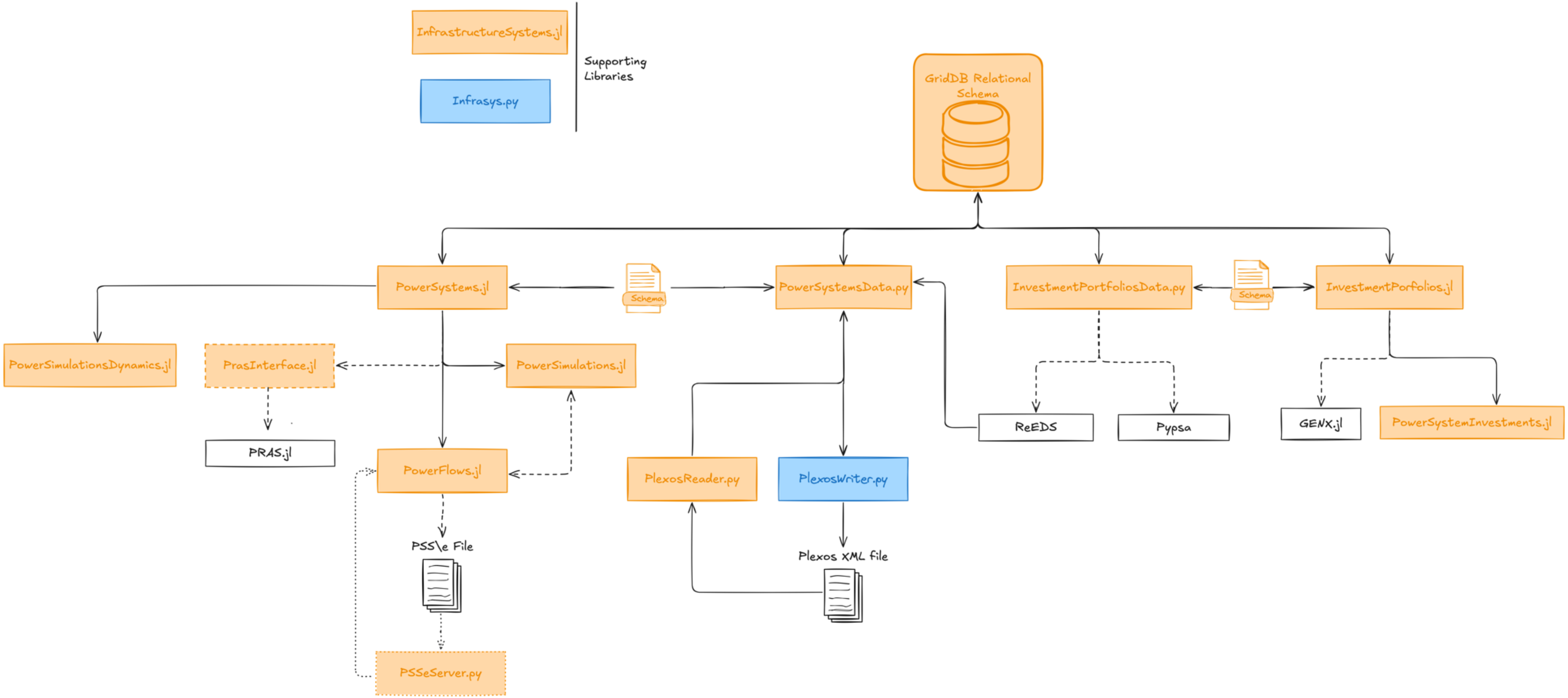
Part 1: The data needs to be handled cohesively.

Current Issues with data handling for modeling

- **Motivation**
  - Diverse representation, file formats and file transformation across different tools. Makes the process inconsistent.
  - Addressing the challenges posed by CSV files as input data, including potential data inconsistencies and limitations in data validation. The process is not always repeatable.
  - Every analyst manipulates a different version of the data.



Unified Data Model For Analysis Applications



Lessons Learned in Sienna

Part 2: The information needs to flow from detailed to simplified models.

R2X

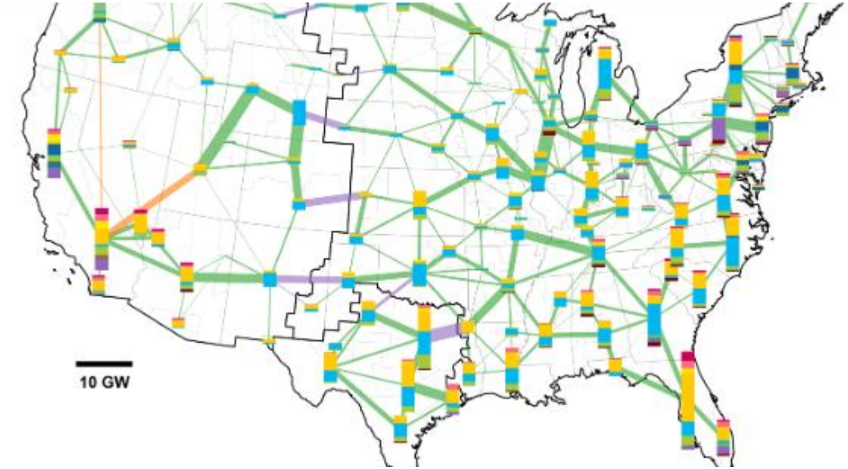
OpenSource Conversion Libraries

- WHAT IT IS?
  - Application for converting inputs/outputs of power system model to an “X” model(s).
  - Modular code-base to customize requirements for any model.
- WHY WE BUILT IT?
  - Originally to translate results from ReEDS to production cost models.
  - Reproducible CEM -> PCM workflows

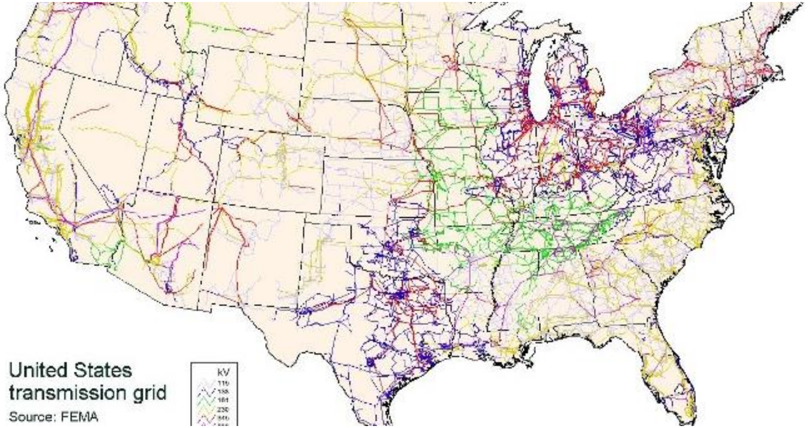
- plexosdb.py
- Infrasys.py
- chronify.py
- powersystemsdata.py

CEM to PCM

- Application interoperability requires computations
- Translations can require solving intermediate models



It is not possible to recover PCM data from CEM results without additional information



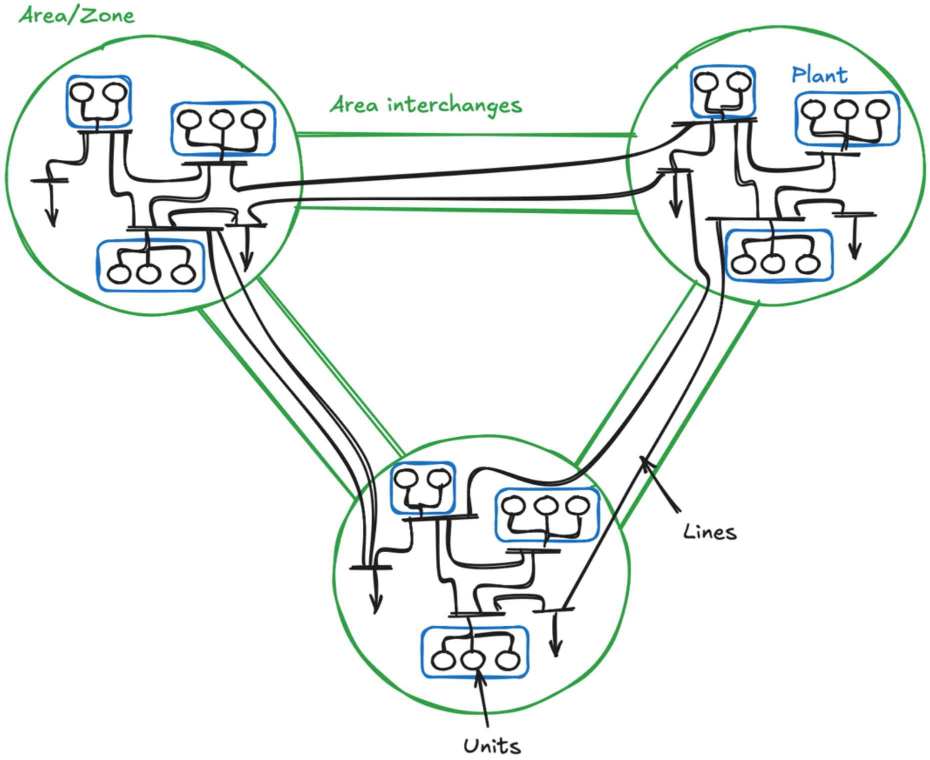
“Zonal to Nodal”

- Needed to perform any integrated generation and transmission study
- Implies solving two problems at once

Two of the basic processes are

1. Specification from capacity results to plant or unit level
2. Transmission planning design which might include contingency analysis to determine effective capacity between “zones” which could be limited by contingencies

Solving these two problem requires that more information get included into the process.

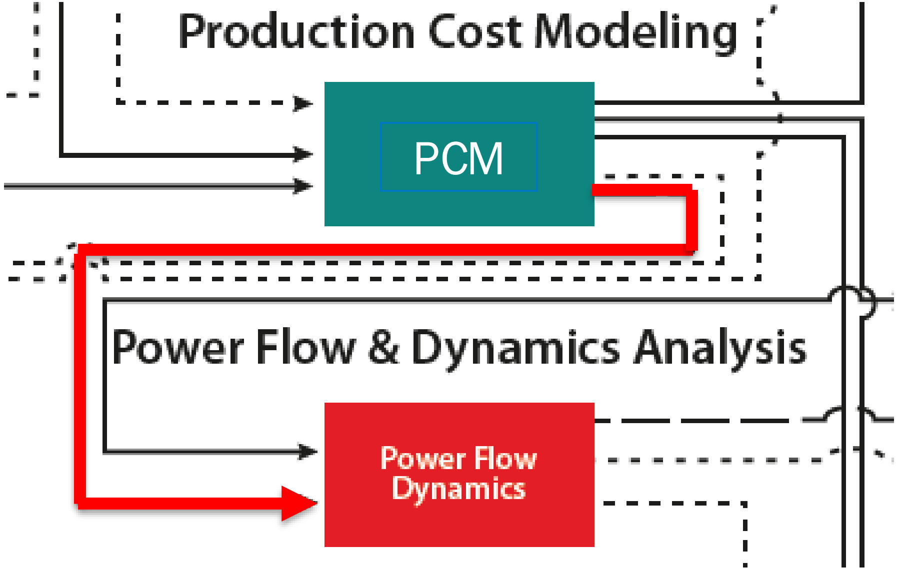


Lessons Learned in Sienna

Part 3: Application “connections” are more complicated than you think.

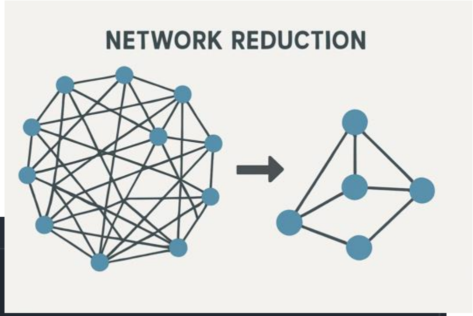
A deeper look into one single arrow in the diagram: PCM to PF

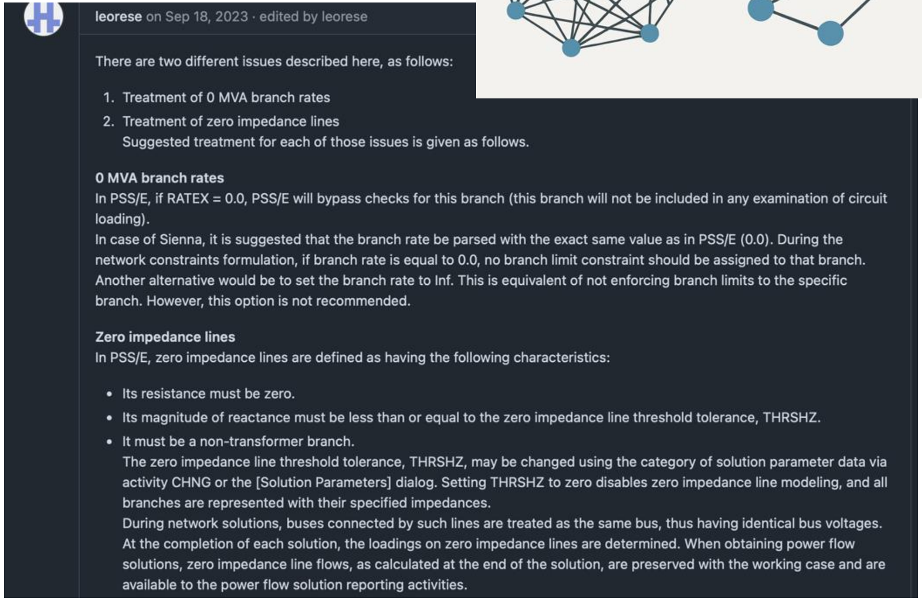
- The devil is in the detail when operationalizing this simple arrow.
- A simplistic view of this arrow is ”send the generator’s active power set points” will cause the process to fail
- Questions we try to answer
  - What information needs to shared through this arrow?
  - Does the arrow need to perform any calculations?
  - What’s a valid fallback if the power flow calculation fails?
  - How to square the simplified network representation in the PCM with the detailed network representation in the Power Flow?



Consistency of the data between the applications

- The data must start from the power flow files and <u>**the data is messy and poorly documented.**</u>
- Which units are on/off for the case file that need to be re-enabled for the PCM run? Switches/Breakers?
- Power flow cases have MANY pass-through nodes (degree 2 nodes) with no injections.
- Some entries represent double circuits explicitly, other as two lines or aggregated. How many lines go into your PCM?
- Do the load levels in the PCM and the Power Flow case match? What about the renewable generation representation?





leorese on Sep 18, 2023 · edited by leorese

There are two different issues described here, as follows:

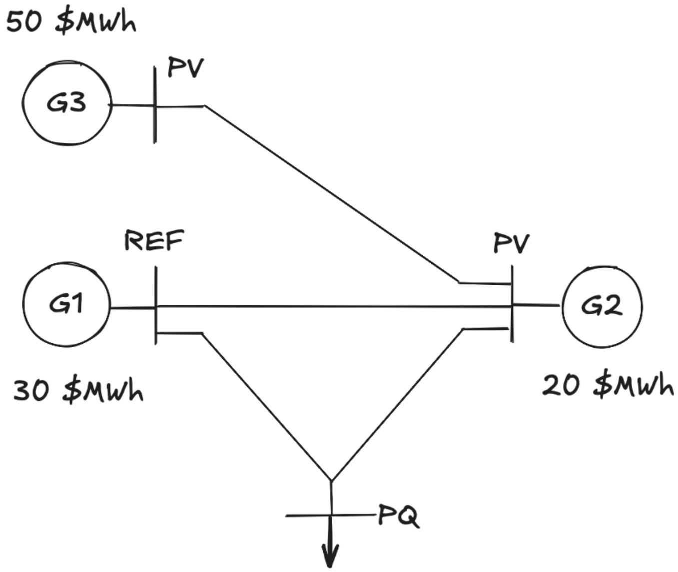
1. Treatment of 0 MVA branch rates
2. Treatment of zero impedance lines
   Suggested treatment for each of those issues is given as follows.

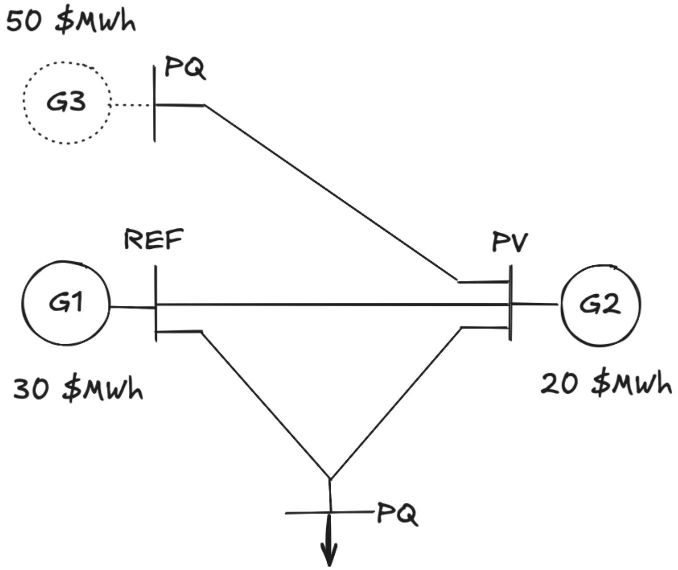
0 MVA branch rates
In PSS/E, if RATEX = 0.0, PSS/E will bypass checks for this branch (this branch will not be included in any examination of circuit loading).
In case of Sienna, it is suggested that the branch rate be parsed with the exact same value as in PSS/E (0.0). During the network constraints formulation, if branch rate is equal to 0.0, no branch limit constraint should be assigned to that branch.
Another alternative would be to set the branch rate to Inf. This is equivalent of not enforcing branch limits to the specific branch. However, this option is not recommended.

Zero impedance lines
In PSS/E, zero impedance lines are defined as having the following characteristics:

- Its resistance must be zero.
- Its magnitude of reactance must be less than or equal to the zero impedance line threshold tolerance, THRSHZ.
- It must be a non-transformer branch.
  The zero impedance line threshold tolerance, THRSHZ, may be changed using the category of solution parameter data via activity CHNG or the [Solution Parameters] dialog. Setting THRSHZ to zero disables zero impedance line modeling, and all branches are represented with their specified impedances.
  During network solutions, buses connected by such lines are treated as the same bus, thus having identical bus voltages. At the completion of each solution, the loadings on zero impedance lines are determined. When obtaining power flow solutions, zero impedance line flows, as calculated at the end of the solution, are preserved with the working case and are available to the power flow solution reporting activities.

Unit Commitment + Power Flows

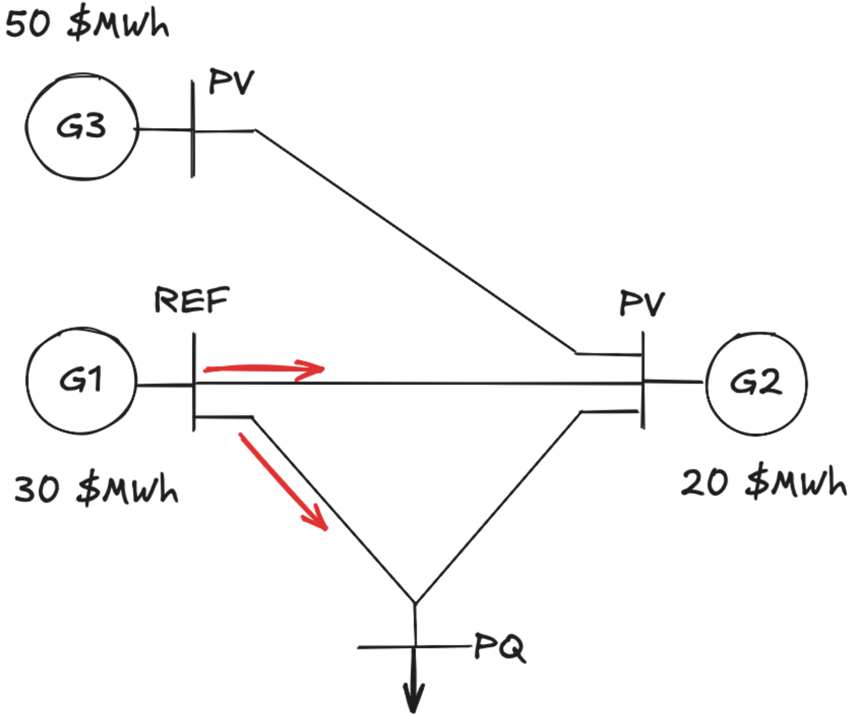




The PCM can decommit a unit and the bus type needs to change in the power flow model. The decommited unit could even be connected to the reference bus and these cases need to be handled by the arrow between the applications

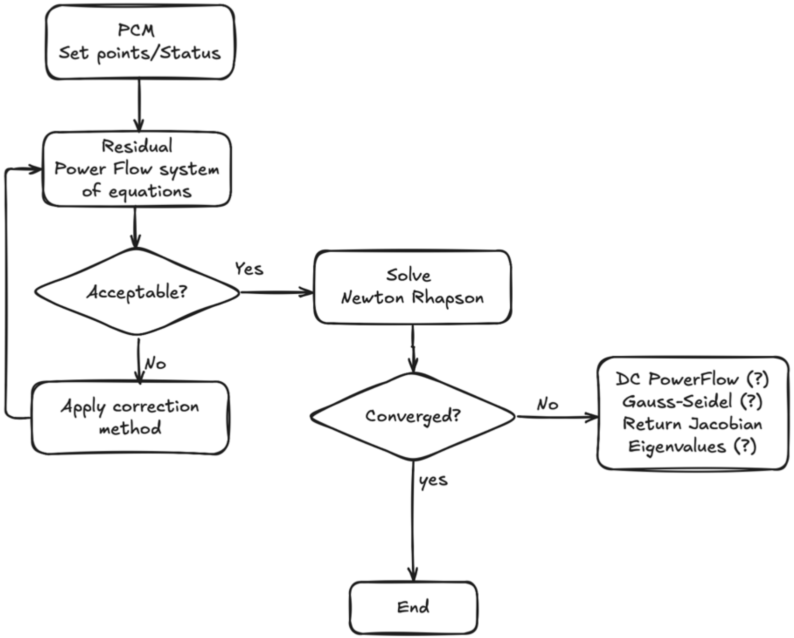
What about losses?

- PCM models are lossless models, which means that there will be a mismatch between the set points and the power flow.
- If done naively, the power flow solver will allocate all the losses to the reference bus (slack) and induce increased flows in the proximity of the bus and it can potentially cause power flow convergence failures.
- How to address this?
  - Include losses in the PCM, increase computational cost.
  - Implement a distributed slack, but now the factors are PCM results dependent.



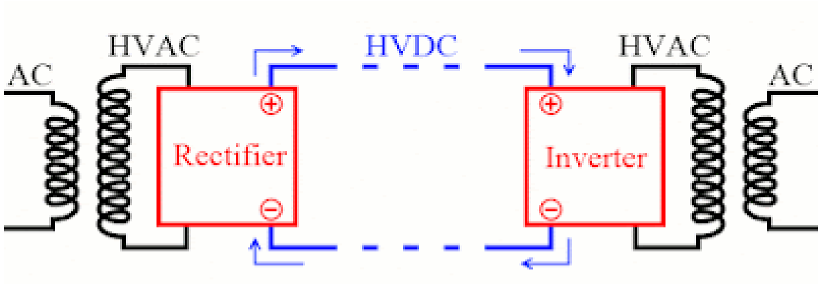
Convergence Failures

- Naively hitting solve on a power flow that has changed bus types, injections can cause failed solves.
- The "arrow" needs to determine if the residual is too large between the initial guess and the solver to correct the guess.
- If the power flow still fails to converge it isn't possible to determine if its numerical or a system collapse. What's a valid fallback in those cases?



How to handle HVDC?

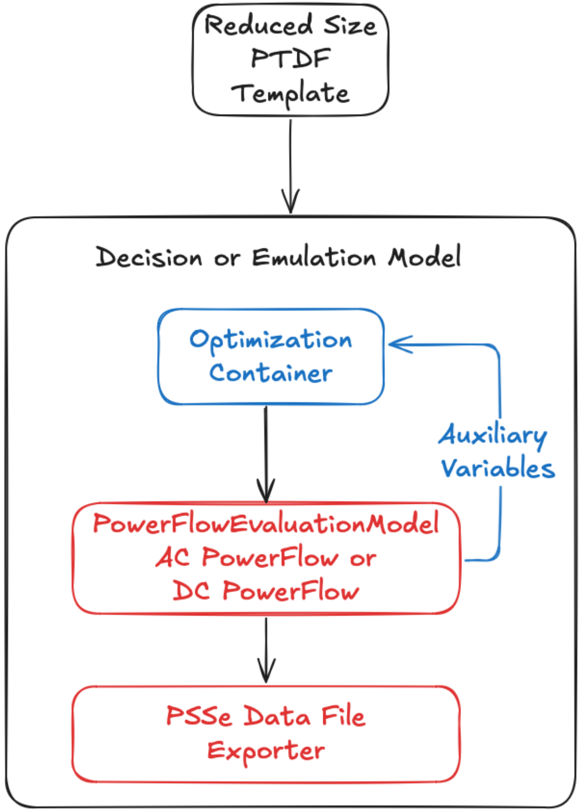
- What's the technology in the Power Flow case VSC, LCC?
- Does the PCM assume the HVDC is reversible?
- What are the reactive power requirements to operate the HVDC link as specified in the PCM?
- Which are the control modes enabled for the back-back link?



PCM -> PowerFlow in a nutshell

- Before conducting an analysis that requires the interoperability of PCM and PowerFlow there needs to be consistency in the data.
- A list of tasks the arrow needs to perform
  - Map network simplifications to full network.
  - Send active power setpoints, HVDC setpoints, bus type changes and participation factors.
  - Potentially make corrections to initial conditions before requesting a power flow solve call.
  - Identify the fallback strategy in case of convergence failure.

Interoperable Power Flow evaluation for reduced order operation problems



- PowerFlowEvaluationModel is multiperiod object by default that can take the details of the optimization model and populate the correct power flow model for that time-step and handle all the intermediate operations and handle fallbacks.
- Integrate Loss Factors as auxiliary variables from Power Flow as well as other loss allocation models.
- For each time in the horizon evaluates the power flow and if required export a PSSe file correctly specified for the formulation in the PCM. Yes, you can export 8760 power flow cases for a PCM simulation of any size grid.

Conclusions

- Workflow requires huge amount of effort for “connecting” applications simply to feedforward information.
- In many cases the feedback methodologies between tools is not well defined or understood. E.g., reactive power shortfalls into a CEM model.
- You can't really make up data, you need to start from a detailed model (today data) and augment it. It's a fool's errand to start from capacity data and make up operational pcm data.

Thank You

https://nrel-sienna.github.io/Sienna/

NREL/PR-6A40-94634

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