Foundational Resource Planning Concepts; Considerations for Variable Resources, Capacity Expansion, Balancing Reserves, and Adequacy

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Why Planning for Renewables?

• Wind and solar generation
  ▪ Key for decarbonization
  ▪ High interest to increase renewable
  ▪ U.S. fastest growing resources (together with natural gas) \(^{(1)}\)
  ▪ More than 50% share of global new generation built in the last 8 years \(^{(2)}\)

(1) U.S. EIA, “Short Term Energy Outlook,” October 2020
(2) IRENA, “Renewable capacity highlights,” March 2021
Main Challenges For Integrating Variable Renewable Energy (VRE)

• Variable and uncertain output
  ▪ Forecasts for next day, or hours, have advanced
  ▪ Forecasts for next month, or week, are more inaccurate

• Flexibility needs to deal with load and renewables variability
  ▪ Other flexible generation (hydro, natural gas, retrofitting plants)
  ▪ Energy storage
  ▪ Controlled curtailment of solar and wind

• Developing technologies
  ▪ Costs rapidly decreasing
  ▪ Standards for large-scale integration are being developed

Planning methods have evolved over the last 15 years as more VRE resources are integrated worldwide
Planning Studies for Integration of Variable Renewable Energy

VRE resources data
- What are the VRE characteristics?
  - Resource maps, time series, forecasting, capacity factors

Capacity expansion
- Which generation and transmission should be built, nationally and regionally?

Adequacy
- Are there enough resources?
- Is there enough transmission?

Balancing reserves
- How much reserves is required?

Production cost model
- Are there operational challenges?

Power flow and stability
- Are expansions feasible?
- Is the system reliable?

Studies resolution
- Years to months
- Hours to minutes
- Seconds to sub-seconds
Planning Studies in Offshore Wind Integration Study

Figure 1: Abbreviated study approach to design 3 scenarios

Figure 2: Offshore wind generation (10.1 GW) connected to 6 points

Planning Studies Applied in Puerto Rico 100% Renewable Energy Study

1. **Responsive Stakeholder Engagement and Energy Justice**
   - Stakeholder engagement inclusive of procedural justice
   - Energy justice and climate risk assessment

2. **Data Gathering and Generation**
   - Resource potential and demand projections (solar, wind, hydro)
   - Demand projections and adoption of DER (considering load, EVs, energy efficiency, distributed PV and storage)

3. **Scenario Generation and Capacity Evaluation**
   - Detailed scenario generation
   - Distributed PV and storage grid capacity expansion
   - Production cost and resource adequacy

4. **Impacts Modeling and Analysis**
   - Bulk system analysis for enhanced resilience
   - Distribution system analysis
   - Economic impacts

5. **Reports, Visualizations, and Outreach**
   - Scenarios for grid resilience and 100% renewable electricity for Puerto Rico
   - Reports and outreach
   - Implementation roadmap

More information on PR100 Study funded by FEMA and managed by DOE GDO: NREL, Sandia, PNNL, LBNL, Argonne, ORNL, [https://www.energy.gov/gdo/puerto-rico-grid-resilience-and-transitions-100-renewable-energy-study-pr100](https://www.energy.gov/gdo/puerto-rico-grid-resilience-and-transitions-100-renewable-energy-study-pr100)
National Transmission Planning Study

NTPS Scenario Analysis Relies on Multiple Linked Modeling Exercises

Frame and Develop Scenarios
- Capacity Expansion Planning
  - Inter-Zone Transmission Capacity and Generation Buildout
  - Probabilistic Resource Adequacy Analysis
- Load forecasts
- Electrification
- Distributed solar

Detailed Transmission Expansion Planning Analysis of Selected Scenarios
- Nodal Transmission Planning
  - Production cost modeling
  - DC power flow & contingency
- Resilience Analysis & Power Flow
  - Integrating varied weather
  - AC power flow

High Value Transmission Expansion Options
- What is the network architecture?
- Which builds are robust across scenarios?
- Can the system operate reliably?
- What about different weather?
- Is the system secure?

~200 Candidate Scenarios  3-5 Nodal Transmission Plans

NREL and PNNL, National Transmission Planning Study, August 2023,
https://www.energy.gov/gdo/events/august-1-national-transmission-planning-study-updates-webinar
What is capacity expansion planning?

- Decide what, when, and where to make generation and transmission investments
- Drivers of new investments: load growth, retirements
- Time horizons: 10-50 years
- Generation and Transmission solved serially
  - Generation more expensive
  - Different assets owned by different organizations

Bottom Figure adapted from James McCalley's EE 552 course materials (http://home.engineering.iastate.edu/~jdm/ee552/Cooptimization.pdf)

Slide credit: Patrick Malloney, PNNL
Example of Capacity Expansion Planning Tools

- Modeling Tools (specifically for CEP/TEP/GEP)
  - Commercial Tools
    ✓ Energy Exemplar Aurora (CEP)
    ✓ PSR Netplan (TEP), OptGen (GEP)
  - Free
    ✓ NREL ReEDS (GAMS)
    ✓ GridPath (Python)
    ✓ E3 Resolve (Python)
Resource Adequacy

• Are there enough generation resources and transmission to supply electricity?
• Resource adequacy should consider
  ▪ Consider both generation and transmission availability
  ▪ Failure probability
  ▪ Chronological hourly operation
  ▪ Weather datasets for several years, influencing both generation and load
  ▪ Seasonal, yearly, and long-term study horizons
• Extreme weather events (e.g.; heatwaves, droughts, wildfires)

Michael Mulligan, “Resource Adequacy: How did we get here (and where are we going)?” NARUC/NASEU Training, May 2021
Three Dimensions of Balancing Reserve Requirements

• Reserve requirements have three dimensions:
  ▪ capacity requirements -- \( \pi \)
  ▪ ramp rate -- \( \rho \)
  ▪ ramp duration -- \( \delta \)

• For analysis of:
  ▪ Load Following
  ▪ Regulation

Balancing Reserves: Generation Flexibility Requirements and Assessments

**Scenarios** of wind and solar generation — existing + planned (meteorological models)

**Forecast and operation model**
- Minute by minute load, wind, and solar data
- Forecasting practices for wind, solar, and loads
- Available flexible generation
  - Balancing timeseries signal
  - Swinging-door algorithm

**Operational practices** – dispatch, scheduling, and reserves

**Calculation of flexibility requirements**
- Capacity
- Ramp rate
- Ramp duration

**Characteristics of flexible resources**

**Estimation of Flexibility Exceedances**
- Can flexible resources cover needs?

PNNL’s Grid Reserve And Flexibility Planning Tool (GRAF-Plan)

- GRAF-Plan methodology has been applied to several utilities in North America, including WECC 2028 and 2030 studies (covering all balancing authorities), as well as internationally in 6 Central American countries and Vietnam
- GRAF-Plan reserve requirement method integrated with Hitachi GridView

Chronological AC Power Flow Analysis

Why round trip (PCM to PF): Planning issues that cannot be dealt with only PCM or PF
- PCM: cannot deal with voltage stability
- PF: cannot deal with resource adequacy, flexibility requirement

Challenges to perform round trip
- DC to AC power flow conversion
- Time consuming: Typically, it takes several days to months to create a base AC power flow case from PCM data

- Chronological AC Power Flow Automated Generation Tool (C-PAGE),
- Used in several projects, such as the Atlantic and Pacific offshore wind studies, PR100, DOE HydroWIRES initiative

Select 100s of hours of interest
99% cases automatically solved within minutes
1% unsolved
Finally, 100% of cases can be solved within a day or two

Automatic or manual settings to help convergence

Summary

• Key aspects of planning:
  ▪ Generation and transmission expansion, resource adequacy, production cost modeling (simulation of operation), and balancing reserves planning
  ▪ Power flow, stability, and contingency analysis
  ▪ Model multi-year weather data
  ▪ Model effects of extreme weather events

• Power system planning has evolved and needs to continue evolving to study grid transformation
Thank you