THE EVOLUTION OF POWER SYSTEM PLANNING WITH HIGH LEVELS OF VARIABLE RENEWABLE GENERATION

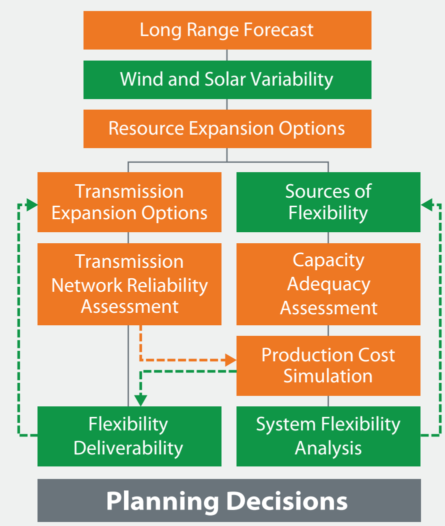
GREENING THE GRID

FUNDAMENTAL POWER SYSTEM PLANNING QUESTIONS

Reliable and economic operation of the power system requires significant planning. Traditionally, the planning activity is focused on a few fundamental questions across several possible future timeframes:

1. How much demand will there be?
2. How much and what type of generation is needed to serve this demand?
3. What enhancements to the transmission network are needed to ensure the reliable and economic delivery of energy when it is needed?

For systems targeting high levels of wind and solar generation, these core questions do not change, but planning methods and processes can evolve to address the unique characteristics of variable renewable energy (VRE). This brief presents an overview of the analyses involved in traditional power system planning, and describes the changes required to plan for higher levels of VRE integration.[1]



Key steps required for traditional power system planning are indicated by the orange boxes above [1]. Integrating variable renewable generation requires an evolution to the planning process to include the new analyses and approaches, indicated by green boxes. This new planning framework can facilitate higher levels of variable renewable energy (VRE) integration while maintaining system reliability and cost-effectiveness.

THE TRADITIONAL PLANNING PROCESS

PROJECTING ELECTRICITY DEMAND

Long-range demand forecasts lay the basis for power system planning. These forecasts, from various economic and statistical models, analyze potential growth in demand and typically produce hourly demand estimates for each year in the planning horizon (e.g., 10-20 years). The profile, or shape, of future hourly demand is typically based on historical data, scaled up or down according to projections of future peak demand and total annual energy consumption, and may include the potential impacts of different types of loads and their characteristics. Uncertainties include rate of demand growth; share of future demand across the industrial, commercial, residential, and transport sectors; and demand shape, which is a function of weather and other factors.

PLANNING THE GENERATION MIX

Following the demand forecasts, planners determine the least-cost mix of generating resources to serve this demand. This exercise takes into consideration planned retirements of existing power plants and potential additions to the generation fleet. Planning for new generation resources involves using a generation (or capacity) expansion planning model to characterize ***resource expansion options***. Long-range forecasted fuel prices are a key input into this characterization.

In addition to responding to demand at all times during the forecast period, the planned generation mix must also meet the reliability objectives of the power system. For example, the generation mix should include sufficient installed capacity (i.e., capacity adequacy) to withstand unforeseen outages of generation or major transmission lines. To this end, planning activities often include ***capacity adequacy assessments*** to estimate the contribution of each generator toward achieving a reliable supply of energy.[2]

DESIGNING THE TRANSMISSION SYSTEM

Once the generation mix is planned, ***transmission expansion options*** are evaluated using various types of models that assess ***transmission network reliability*** and characterize the potential economic impacts of new transmission. The objective of this assessment is to identify the least-cost transmission options that will ensure the reliable and economic delivery of energy when it is needed. Depending on the modeling results, there may be some iteration between transmission and generation options because of the interdependency between generation and transmission; different network configurations will affect energy flows, generator dispatch, and costs.

The operational costs and benefits of various generation and transmission scenarios are typically evaluated using an electricity ***production cost simulation*** model, which simulates dispatch to quantify the costs, fuel consumption, and emissions associated with different generation fleets, operational strategies, and transmission network configurations.

Together, these inputs, methods, and processes are used to make planning decisions. In some cases, additional considerations, such as environmental impacts, or other economic or social impacts, can also influence the power system plan.

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1. In countries/regions that have electricity markets, the planning functions described here will be carried out by market participants. This process will normally be less coordinated than that described here.
2. For more information on capacity adequacy, please see a related fact sheet, "Using Wind and Solar To Reliably Meet Demand."

PLANNING FOR NEW VRE

As power system planners begin to consider high penetrations of wind and solar, the traditional planning process continues to be relevant. However, new analyses (and possibly model enhancements) are also required so that power system planners can take into account key impacts related to VRE integration, namely, increased variability and uncertainty of electricity supply. These new analyses are critical to ensure that generation and transmission are planned and developed so that future systems can operate reliably and economically.

In systems moving toward significant levels of VRE, the first addition to the traditional planning process is the need to characterize ***wind and solar variability*** in the broader context of demand variability. The objective of this type of assessment is to enable the estimation of net load (i.e., the demand that must be met by other generation sources if all wind and solar power is consumed) to inform decisions about the quantities and qualities of the rest of the generation fleet. Accurately assessing the variability of VRE requires high-quality data sets (preferably including hourly or sub-hourly data for at least one year) for historic and forecasted wind and solar generation.[3]

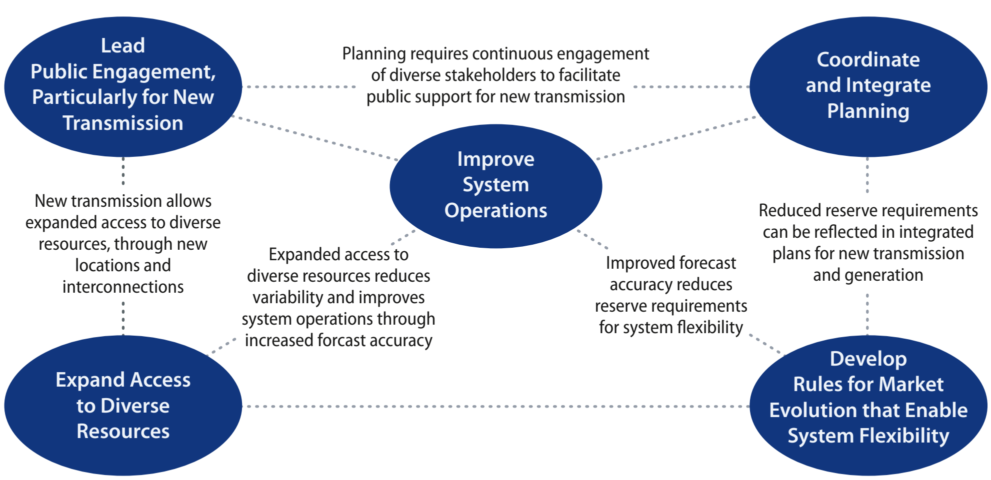
Planning the future generation mix to include a high share of VRE relies largely on traditional tools such as capacity expansion models to determine the best locations and capacity levels for both VRE and conventional generation. Additionally, planners can undertake detailed operational analysis using production cost simulation to identify key economic or reliability issues related to VRE variability, including changes in the way that conventional generation is scheduled and dispatched, and the impacts of VRE uncertainty on power system operation. To mitigate potential operational challenges posed by higher levels of VRE, planners need to identify ***sources of flexibility***, including, for example:[4]

- Improving system operations through practices such as wind and solar forecasting;
- Expanding access to diverse resources through new transmission;
- Coordinating and integrating planning with neighboring systems to reduce overall variability; and
- Enhancing market designs to encourage flexibility from all resources, including demand response.

The same production cost models that are used to identify impacts of VRE can also conduct ***system flexibility analysis*** to determine the most cost-effective approaches for meeting VRE integration goals. Analyzing a variety of VRE siting options and flexibility mechanisms can help planners identify trade-offs among different scenarios for future VRE development and prioritize actions and investments for implementation.

Another new planning step is to analyze the transmission system to ensure that ***flexibility options can be delivered***. For example, planners need to properly size and site planned transmission lines to enable energy flows with neighboring power systems, or to access wind and solar resources that align well with demand patterns or reduce overall variability.

Each of these analyses complements the traditional power system planning process. While these novel planning considerations do not represent fundamental shifts in how the power system is planned and designed, they do represent significant updates to the traditional planning framework, and are key components of planning for higher levels of VRE integration.



A system-wide approach to power system planning is most effective in improving overall efficiency and reliability in high VRE contexts [2].

3. For more information, please see a related fact sheet, "Grid Integration Studies: Data Requirements."
4. For more information, please see a related fact sheet, "Sources of Operational Flexibility."

REFERENCES

[1] J. Cochran et al. 2014. *Flexibility in 21st Century Power Systems.*

[2] J. Cochran et al. 2012. *Integrating Variable Renewable Energy in Electric Power Markets: Best Practices from International Experience, Summary for Policymakers.*

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Greening the Grid provides technical assistance to energy system planners, regulators, and grid operators to overcome challenges associated with integrating variable renewable energy into the grid.

FOR MORE INFORMATION

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