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Road Map for Advanced Power System Planning in Indian States With High Renewable Energy

Evolution of Power System Planning

Power system planning has evolved rapidly in recent years to keep pace with advancements in generation technologies, formation or interconnection of larger and more complex grids, and increasing consumer expectations. Load forecasting is an integral part of the planning process because it provides the bounds inside which the system must be planned. The traditional approach to power system planning is to ensure the system has adequate generation and transmission capacity to meet anticipated peak demand and annual or seasonal energy requirements. This is typically done in annual or biannual cycles and includes short-, medium-, and long-term projections for demand and the required generation mix, which is often categorized into "baseload," "intermediate," and "peaking" generation (REN21 2017). The variable cost and flexibility typically go up from baseload to peaking generation. Traditionally, transmission planning takes place after generation planning, in which power flow studies are conducted for peak and off-peak scenarios of different seasons to identify least-cost transmission options, ensuring reliability and security of the grid. With expansion of grids and increasing complexities and improvements in computational power, utilities around the globe have started to co-optimize generation and transmission investments based on least-cost planning approaches.

Why Does Power System Planning Need to Evolve?

The traditional approaches to planning were developed by utilities to serve a variable and somewhat uncertain demand with a supply that was able to be tightly controlled. There is an increasing thrust to adopt renewable energy (RE) around the world, and it is becoming more likely that future power systems will be dominated by these resources, making demand and supply both variable (REN21 2017). This is also true for India, where the government has set targets to achieve 175 GW RE by 2022 and 450 GW RE by 2030. In addition to RE, several studies for India, including the Central Electricity Authority's (CEA's) least-cost generation planning study, are projecting that energy storage devices will be cost-effective in the near term (CEA 2020). As the share of RE and storage increases in the grid and demand evolves to include a more diverse set of resources with vehicle and building electrification, the traditional idea of baseload and peaking resources may not hold the same meaning. It is more likely that a combination of RE, storage, and conventional generation will be coordinated with a more active demand-side participation to balance the system. These trends will require a different perspective toward long-term planning to account for the uncertainties and capabilities of new technologies, as well as changing power system needs.

Road Map to Advance Power System Planning in Indian States

Central Electricity Authority (CEA) is responsible for generation and transmission planning in India at the national level. CEA prepares a National Electricity Plan for generation and transmission in accordance with the National Electricity Policy once every 5 years (CEA 2018 and 2019). Additionally, CEA published a least-cost generation mix study for 2029–30, projecting 10 years into the future. States also conduct their own planning studies. State generation companies are responsible for generation planning within the state. In some cases, the state power procurement body is also involved in

this process. The responsibility of transmission planning at the state level lies with state transmission utility. The level of granularity in long-term planning approaches varies between states. Some states have started to explore optimization-based planning tools (Rose et al. 2021), whereas some states still use traditional approaches to planning of calculating generation needs then making transmission fit with that plan. These approaches will benefit from advancement as India reaches higher penetrations of RE and storage on the power system. This factsheet aims to provide a road map for Indian states to align their planning processes to the changing needs of the system. The road map provided below is based on the evolving needs of the system and best practices in long-term planning studies. This will not only help in achieving higher penetration of clean energy resources but also minimize costs over long-term planning horizons. **Figure 1** shows the institutional and modeling related action items of this road map grouped based on the implementation time frame and the level of effort or difficulty. This grouping is indicative and based on our understanding and experience of working in different Indian states. This grouping may be different for different states depending upon various factors such as existing planning practices, availability of tools & data, skilled workforce etc.

Highest Priority Actions

- **Engage with stakeholders:** Involvement of stakeholders is key to the success of the planning process. Regular consultations during the study and feedback on the draft plans are important in addressing the concerns of various stakeholders, thereby improving the results and acceptability of the plan.
- **Define and include planning reserve margin (PRM) and loss of load probability (LOLP) target:** Generation outages, as well as the potential for unforeseen demand, require PRM to be considered in planning studies. PRM ensures that extra resources can be called upon even in the most extreme foreseeable case of balancing the system. It is important to note here that PRM is different from spinning reserves margin. Spinning reserves are used to manage grid frequency on an operational timescale, while the PRM is a long-term capacity-planning metric. North American Electric Reliability Corporation- (NERC-) recommended PRM ranges from 13%–17% (Reimers et al. 2019). Sufficient PRM would ensure LOLP within acceptable range. One day in 10 years is an acceptable LOLP target in the industry (Ibanez and Milligan 2014). It is therefore important to define and consider PRM and LOLP target in planning studies.
- **Assign RE and storage capacity credit:** RE and storage can provide firm capacity and contribute toward PRM. Assuming no capacity credit or undervaluing the capacity contribution for these resources could lead to fewer investments of these resources and overinvestment in conventional resources that may not actually be necessary. The simplest approach could be to assign capacity credit based on the capacity factor during each specific periods of interest (e.g., during periods of peak electricity demand).
- **Update long-term plans frequently:** The changing policy landscape and technological advancements and their costs make it imperative for the planners to update long-term plans more frequently.
- **Study scenarios and sensitivities:** Scenarios and sensitivities focused on key assumptions polices,

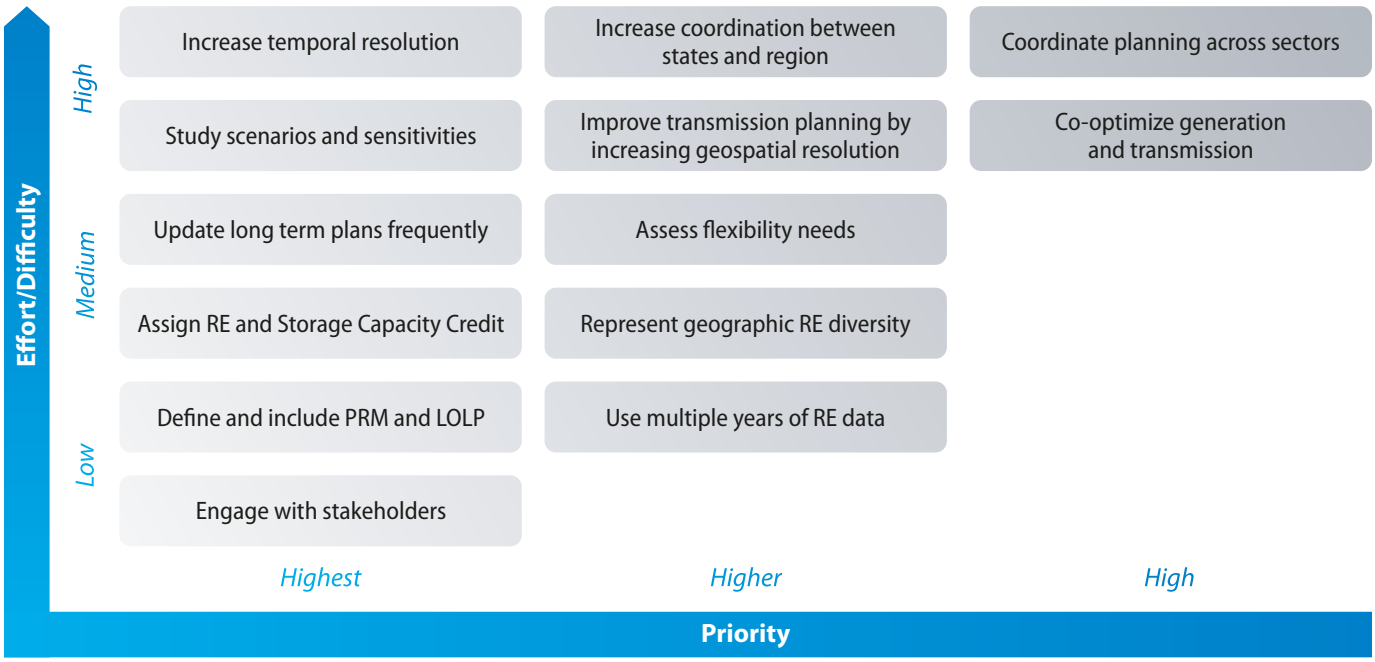

Figure 1. Road map to advance power system planning activities in Indian states

regulations, operating rules, market rules to enable system flexibility, etc., and inputs such as load growth, fuel prices, technology cost, etc., should also be studied to help stakeholders understand their impact on generation mix and transmission investments.

- **Increase temporal resolution:** Increasing temporal resolution by studying more time periods would allow planners to better capture the correlation of electricity demand and RE availability and help in assessment of flexibility needs.

Higher Priority Actions

- **Use multiple years of RE data:** Because RE generation is weather dependent, a single year of RE generation data cannot capture its interannual variability. It is therefore important to use multiple years of RE data. Exceedance probabilities could be calculated and 50% or 90% probability values based on multiple years (Joshi and Palchak 2020) could be used for generation estimates rather than generation based on only a year of data.
- **Improve transmission planning by increasing geospatial resolution:** Representing the system as multiple nodes, or balancing areas, would capture noncoincident load patterns between areas, differences in supply costs across the state, intrastate network congestion, and any policy, regulatory, or operating decisions that have geospatial components in transmission planning.
- **Assess flexibility needs:** Flexibility needs of the system are changing with addition of more RE. These needs can be assessed by increasing temporal resolution, studying net load, or conducting a production cost-modeling study of the planned power system.
- **Represent geographic RE diversity:** Higher-resolution representation of RE resources, connection costs, and site-specific RE profiles could help incorporate geographic diversity of RE in the planning process.
- **Increase coordination between states and region:** Coordinating long-term plans with neighboring states and regions may help in harnessing diversity in demand and RE variability, thereby optimizing resources and reducing cost.

High Priority Actions

- **Co-optimize generation and transmission:** Increasing uncertainties and complexities, in part brought about from increasing levels of RE and energy storage in the system, requires the use of advanced methods for long-term planning. It is therefore important for Indian states to build capacity in co-optimizing generation and transmission investments in the long term, incorporating best practices such as multiple-year weather data, and including emerging technologies such as demand-side flexibility in the planning process.
- **Coordinate planning across sectors:** The power sector is closely linked with other sectors such as transport, buildings, environment, water, fuels, industry, etc., and this linkage is expected to grow further with electrification of the economy. An integrated planning approach incorporating various sectors becomes essential in the long term.

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Learn More

Find out about NREL's power system planning activities in India: Supporting India's States with Renewable Energy Integration. Please contact SouthAsiaSupport@nrel.gov with any questions.

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