White Paper

Renewable Integration

Need for curtailment risk assessment

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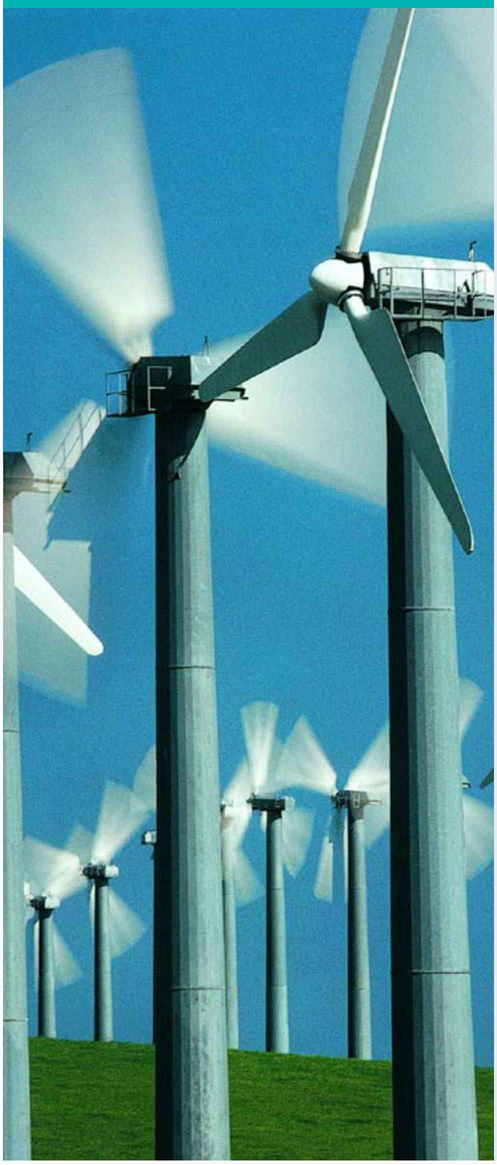


Shareables

- Curtailment of Renewable Energy (RE) is a real risk and this risk is likely to increase as more RE generation comes in to the system.
- Curtailment risk is a function of the mismatch between the load profile and the generation mix. Availability of flexible generation and regulatory preparedness of the state are key to mitigating this risk.
- Investors and lenders need to assess and quantify curtailment risk in their models, especially when bidding and/or acquiring assets.

Key questions for stakeholders

- Is the system ready to absorb all the RE generation that must run?
- What levels of curtailment may be expected if adequate steps are not taken in time?
- Which states are more vulnerable to curtailment?
- Which indicators can stakeholders look at to assess curtailment risk?

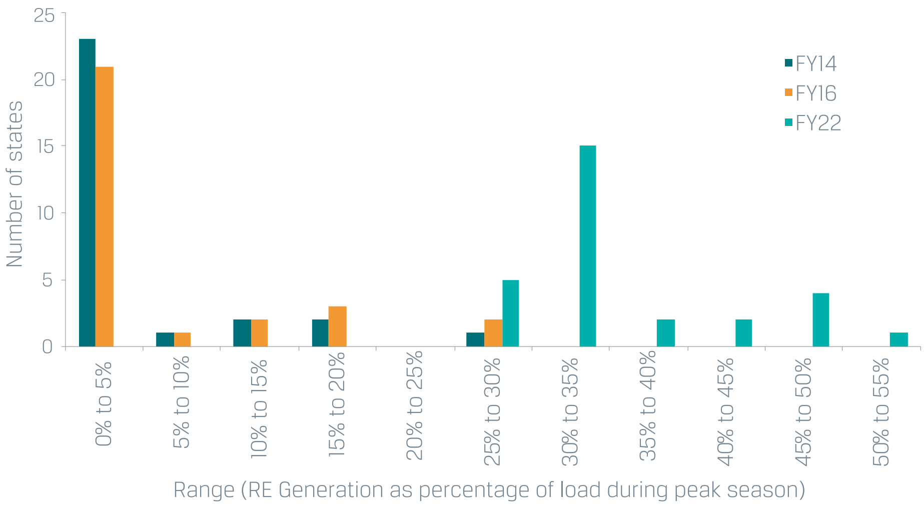
RE deployment has witnessed explosive growth globally, and India is poised to witness this growth in the next few years. The ratification of the Paris Accord by India further highlights the country's resolve towards timely deployment of renewables. The Government of India (GoI) plans to achieve target of 175 GW of RE by end of FY22. This large infusion of intermittent renewable generation has raised some challenges in managing the grid and integrating the intermittent power. While system operators are developing mechanisms to tackle these issues, curtailment of RE may continue, as an unavoidable option to manage the grid, until technological solutions are devised and best integration practices are adopted. Wind and solar curtailments have been seen in some states in the recent past, highlighting increased uncertainty and risk to project revenue.

What is Curtailment? When the transmission system operator orders the RE generator to reduce or stop generation, even though the RE resource is available.

Why is it important to undertake detailed assessment of RE curtailment risk?

Until now, share of RE generation as a percentage of load has been low in most states. With aggressive capacity addition targets, by FY22 (green bar graph in Exhibit 1 below), that **RE generation is estimated at more than 25% of load during peak RE seasons in all states.** In FY14, only one state (Tamil Nadu) and in FY16 only two states (Tamil Nadu and Rajasthan) had similar ratios. As the ratio of RE generation to load increases, the risk of curtailment also increases substantially.

EXHIBIT 1. RE AS A % OF LOAD FOR DIFFERENT STATES (2014, 2016 AND 2022)



How to assess curtailment risk?

While assessing network curtailment risk, ICF recommends a two-pronged approach: site-specific analysis and state-wide load flow analysis.

- **Site-specific analysis** is required to address power evacuation capability of the sub-station at which connection is planned. The analysis is required to assess how much capacity can be further connected at the current structure configuration of the sub-station. The analysis includes:

1. Number of transformers, their average loading and voltage levels
2. Proposed expansion (if any)
3. Bay space availability (number of connecting lines and total capacity of bay)
4. Connected generation capacity and predicted future generation capacity
5. Transmission line connecting in/out of sub-station (including their capacity, line loading and future expansion or upgrade plan and connecting sub-station on the other side)
6. Availability of stand-by transformers
7. Overview of how transmission contingency has been handled in the past, and availability of extra circuit or route to evacuate power.

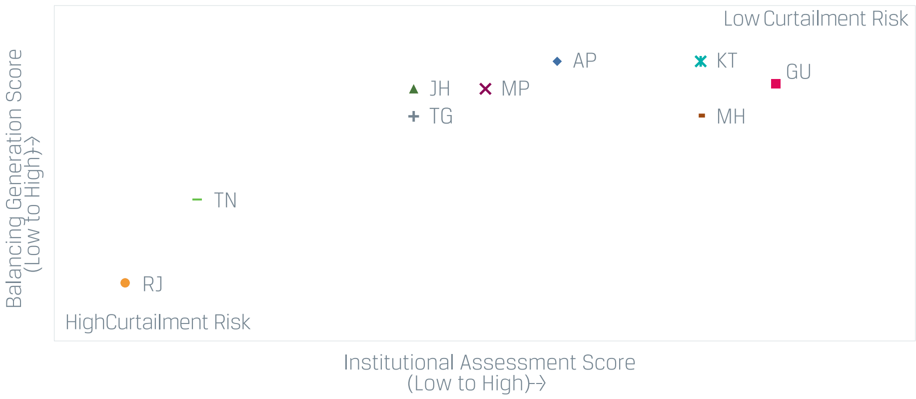
- **State analysis** is required to provide broad overview of state's ability to absorb RE generation. It includes analysis of:

1. State's load profile and RE generation profile
2. State's generation mix
3. Technical minimum of power plants dispatching in the state,
4. Share of flexible generation like gas, and storage hydro in the overall generation mix
5. Regulatory, operational, infrastructural, and institutional enablers
6. State's behavior in sale/purchase of power during excess/deficit at exchange, in bilateral market, and in UI
7. Detailed load flow analysis of state

    - **Institutional assessment** is necessary as different states have different risk profiles when it comes to RE curtailment. States like Gujarat have a defined step-by-step process of managing variability of RE sources, while others have not formally adopted any such process. Each state also have different load and generation profile/ mix. States with larger share of storage based hydro and lower share of RE (as percentage of total demand) have lower risk of curtailment.

Exhibit 2 provides a summary of risk for RE curtailments in some key states:

EXHIBIT 2. RISK PROFILE OF KEY STATES



- **Network assessment** is equally important, conducting detailed load flow analysis of the state network to assess RE curtailment risk. Positive Sequence Load Flow models are used to assess transmission flows in the system for both normal (N-0) and selected (N-1) contingency conditions when possibility of RE curtailment is the highest (e.g. when the ratio of RE generation to load is highest, or during periods of high RE generation). The model can quantitatively assess the amount of RE curtailments that can happen with a changing load and generation pattern.

ICF recommends a detailed assessment of curtailment risk by all the stake holders–investors, lenders, utilities, and regulators. Stakeholders then need to work together to minimize the risk of curtailment, which requires developing strategies and action plans for reducing curtailment risk and building the capacity of system operators to implement the plans.

About ICF

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ICF's key areas of expertise in renewable markets:

Regulatory & Policy

- Analysis of central and state level policies, regulations and incentives, policy advocacy
- Expected RPO trajectories
- Trends in FiT, APPC and other charges including OA and CSS

Market Analysis

- Energy demand-supply balance, expected RE contribution and power sale options
- Performance review of existing plants, asset valuation

Technology Trends

- International scenario- innovations and new developments
- Pilots for new energy access business models in telecom, irrigation, micro grids, hybrids

Transmission & System

- Strategies and solutions for sustainable RE, including wind integration and flexible options
- Grid availability, curtailment issues

Project Financing & Contracts

- Bid support & PPA Structuring
- Financing tool kits for RE project development including risk assessment

Portfolio Development

- RE potential, resource assessment, site identification and clearances
- Project structuring for meeting RPO targets for industrial and Open Access consumers
- Net back price estimation

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