

Energy Technologies Area

Lawrence Berkeley National Laboratory

Models Used for Transmission Planning Their Focus, Strengths, and Limitations for Various Purposes, and How They Can be Improved

Models to Inform Planning for the Future of Electric Power in the US

Committee on Future of Electric Power in the US

National Academies of Sciences, Engineering, Medicine

Irvine, CA

February 3, 2020

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Opening Perspectives



"Plans are worthless, but planning is everything"

Dwight Eisenhower

Opening Perspectives



"Plans are worthless, but planning is everything"

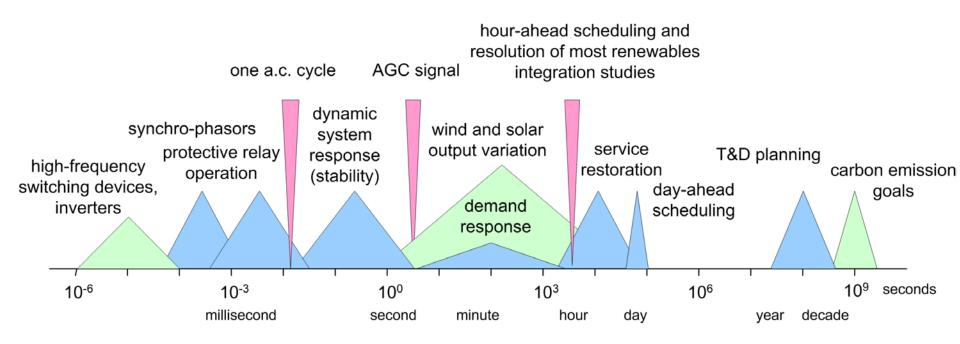
Dwight Eisenhower

"For utility CEO's, blackouts considered fire events, because when blackouts occur, the CEO gets fired"

Terry Boston

Reliable Operation of the Electric Transmission System Involves Management Over Multiple Time Scales





Distinct classes of planning tools are used to support operations over each of these time scales – most are used "off-line" long in advance of operations; some are used "on-line" during real-time operations

Transmission operations



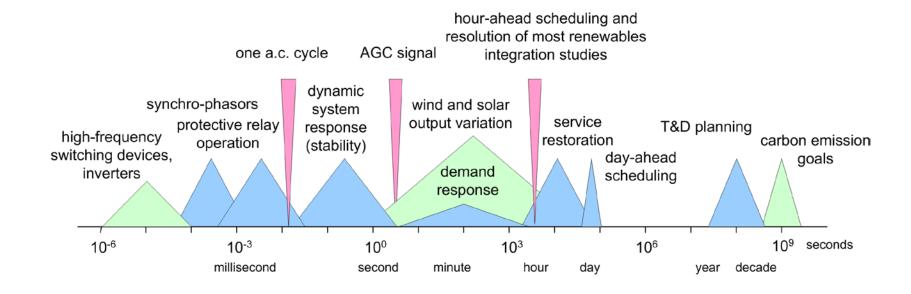
Operations Protection

Automatic Controls

Operator Actions

Generation Dispatch

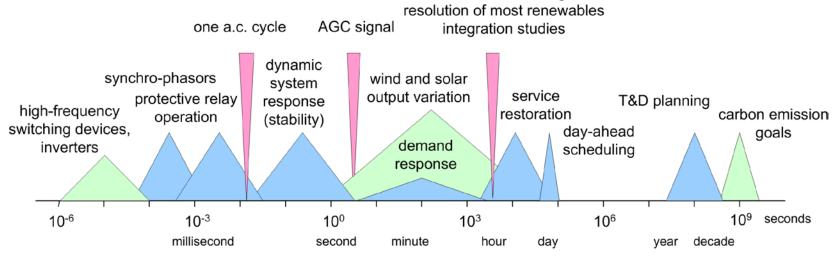
Investment



Transmission planning tools



Operations	Protection	Automatic Controls	Operator Actions	Generation Dispatch	Investment
Planning Tools	Short-circuit, Electromagnetic Transient	Steady-State and Dynamic Power Flow	Real-time Contingency Analysis, Short-term Forecasting	Optimal Power Flow, Production Cost Simulation	Generation and Transmission Expansion



Transmission planning challenges



Operations	Protection	Automatic Controls	Operator Actions	Generation Dispatch	Investment		
Planning Tools	Short-circuit, Electromagnetic Transient	Steady-State and Dynamic Power Flow	Real-time Contingency Analysis, Short-term Forecasting	Optimal Power Flow, Production Cost Simulation	Generation and Transmission Expansion		
Planning Challenges	Changing Resource Mix, Digital Technologies	Based on Synchronous Generation	Multiple Contingencies, Resource Variability	Market Structure and Behavior	Technological Change, Public Policies		
hour-ahead scheduling and resolution of most renewables one a.c. cycle AGC signal integration studies							
synchro-phasors protective relay high-frequency switching devices, inverters dynamic system response (stability) wind and solar output variation service restoration day-ahead scheduling carbon emission day-ahead scheduling							

Source: A. von Meier, "Challenges to the Integration of Renewable Resources at High System Penetration," California Energy Commission, May 2014

 10^{0}

second

10⁻³

millisecond

10-6

minute

 10^{3}

hour

day

10⁶

 10^{9}

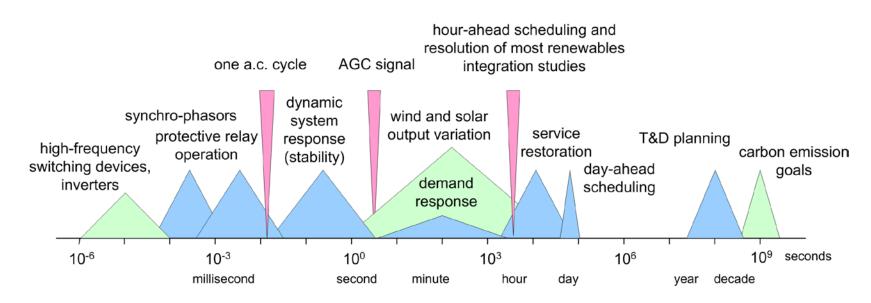
decade

year

seconds

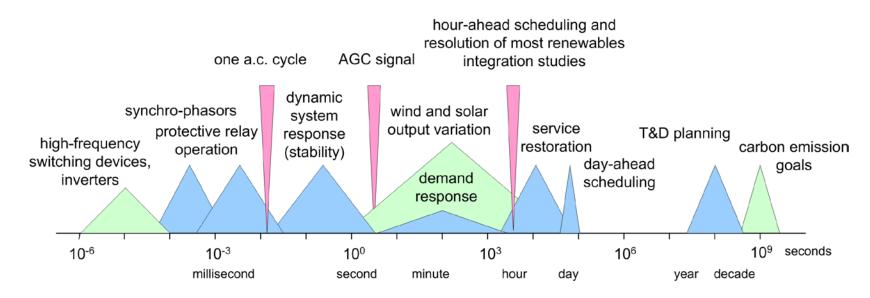


Variable Renewable Generation



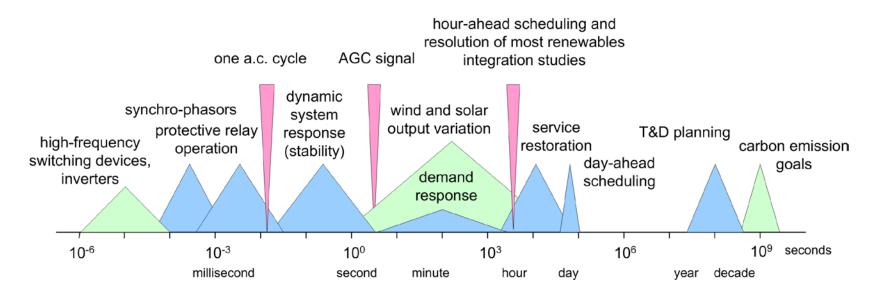


- Variable Renewable Generation
- Integrated Transmission and Distribution System Planning





- Variable Renewable Generation
- Integrated Transmission and Distribution System Planning
- Cyber and Physical Security





- Variable Renewable Generation
- Integrated Transmission and Distribution System Planning
- Cyber and Physical Security
- Interdependencies with Natural Gas and Communications

