Probabilistic Integrated Resource Planning Tool (pIRP)
Introductions

- **Dr. Hisham Othman**
  - *Vice President, Transmission & Regulatory*
  - Areas of expertise include power system dynamics and control, hybrid microgrids, grid integration of renewables and storage, economic analysis
  - PhD, Electrical Engineering, University of Illinois, Urbana
  - Over 30 years of technical and managerial experience in the electric power industry

- **Dr. Salman Nazir**
  - *Senior Engineer, Advisory Services*
  - PhD from the University of Michigan, Ann Arbor
  - Areas of interest include DERs, demand response, electricity markets, and advanced analytics and algorithms for integrating DERs into power systems.
Motivation

- A robust response from utilities and corporations to climate change culminated in NetZero carbon reduction goals to reach 100% between 2030 and 2050.

- Integrated resource planning (IRP) processes and tools have served the industry well over the past 30 years. However, they are increasingly challenged:
  - Increased uncertainties in load development, electrification, technology, and grid development.
  - Reliability concerns of high penetration of inverter-based resources (IBRs) not modeled.
  - Dependence of resource development on availability of T&D hosting capacities, not co-optimized.
  - Resilience requirements associated with intermittent resources and grid vulnerabilities not modeled.
  - Energy storage capacity (i.e., hours) are pre-selected and not optimized.
  - Energy storage value is often restricted energy balancing, and the full stack of benefits not exploited.

- Probabilistic IRP (pIRP) project between Quanta Technology and Sandia has a goal of addressing these challenges and creating a tool that can be accessed by researchers and practitioners through Sandia’s QuEST platform.
## Carbon Reduction Plans (NetZero)

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- NetZero decarbonization goals set at most major utilities and corporations over next 10-30 years
- This is prompting a profound change in the energy resource mix towards inverter-based resources (IBRs) in the form of solar, wind, and energy storage, in addition to clean dispatchable sources (e.g., hydrogen).
# Traditional Probabilistic IRP - Study Process

## Policy Drivers
- GHG Targets
- Electrification
- Coal Retirement
- Price Stability
- Reliability
- ...

## Resource Strategy
- Biz As Usual
- In-State Supply/Demand
- DG
- Mini/Micro Grids
- Regional Integration
- ...

## Study Scenarios

<table>
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<tr>
<th>Scenarios</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
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## Resource Optimization
- Technology Cost
- Import Prices
- Fuel Prices
- Fuel Security
- DSM Level
- Load Growth
- RPS Increase
- ...

## Uncertainties & Sensitivities
- 25 yr Cost NPV
- 10 yr Rev Req NPV
- Resilience Risk
- GHG Risk
- Investment Timing Flexibility
- ...

## Metrics (costs, Benefits, Risks)

## Pathways

### Financial Capital (Resources, Grid)
- LCOE
- LCOE Risk
- Price Stability
- Curtailment Risk

### Reliability
- Resilience Risk
- Res. Adequacy Risk
- Grid Integration Risk

### Environmental
- Emission Level
- GHG Reduction Risk
Probabilistic IRP Formulation

Optimize Goals

- Capacity
  - LOLE
  - LCRs
  - Reserves

- Energy Balancing
  - Load Forecast
  - Time Profiles

- T&D Grid
  - Zonal
  - T-Hosting
  - D-Hosting
  - Expansion

- IBRs
  - Penetration
  - Ramp Rates
  - FFR needs
  - PFR needs

Uncertainties

Monte Carlo and Real-Option Analysis

Capacity Expansion Portfolios & Performance Statistics

Objectives:
- Affordable
- Clean
- Resilient

Constraints:
- Demand by Zone
- Resources: Capacity, Asset Life, Buildout Rates, Total Buildout
- Power dispatch:
  - Resources
  - Tie-lines between Zones
  - Energy Storage
  - Renewable Production Profiles
  - Curtailments
- Renewable targets
- Emissions
- Local Capacity Requirements (LCR)
- T&D hosting capacities
- Reserves
- Ramping Flexibility: 1-min and 10-min
- Intermittent power penetration limits
- Resilience – Supply Interruption
Role of Energy Storage within an IRP

- Gen Resource:
  - Capacity and Reserves
  - Daily energy balance
  - Firm and shape solar and wind profiles
  - Fast ramping
  - Fast Frequency Response (FFR) and Primary Frequency Response (PFR)
  - Multi-day resilience

- T&D Grid Resource
  - Non-Wire T&D Solution (NWS)

- Model Reliability and Resilience Attributes/Metrics of Resources:
  - Dispatchability
  - Predictability
  - Dependability (e.g., Supply Resilience, firmness)
  - Performance Duration Limits
  - Flexibility (e.g., ramping speed, operating range)
  - Intermittency (e.g., intra-hr and multi-hr ramping)
  - Regulating Power
  - VAR support
  - Energy Profile (e.g., capacity credit / ELCC)
  - Inertial Response
  - Primary Frequency Response
  - Minimum Short Circuit Ratio
  - Locational Characteristics (e.g., deliverability, resilience to grid outages)
  - Black start and system restoration support
How deep should the storage reservoir be?

- **Sub-hour (Gen)**
  - Fast and Flexible Response to control Frequency
  - Intermittency of VERs (e.g., Solar/Wind)

- **4-10 hours (Gen)**
  - Integrated Resource Planning (Capacity, Reserves, Energy)
  - Peaker Plants Combined Storage+Renewable

- **2-8 hours (T&D)**
  - Address Grid Security Constraints (e.g., NERC TPL Standards)
  - NWA solutions

- **Hours to Days (Gen)**
  - High Renewable Targets (50%+) using low-capacity factor resources
  - Balance Supply and Demand
  - Mitigate Interruption Supply Risks

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VER: Variable Energy Resources
NWA: Non-Wire Alternative Solutions
RE: Renewables

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Modeling Time Buckets

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Default values for seasons:
- Spring: 03/20 to 06/20
- Summer: 06/21 to 09/21
- Fall: 09/22 to 12/20
- Winter: 12/21 to 03/19

Default values for peak and off-peak hours:
- Day off-peak: 0 to 05
- Day peak: 06 to 11
- Night off-peak: 00 and 22-03
- Night peak: none
Modeling T&D Hosting Capacity and Grid Expansion - Zonal Model

Tie-Lines (Import/Export)
T- Hosting
D- Hosting Capacity

Available MW
Upgrade MW
Upgrade Cost/MW

Zonal Constraints:
- LCR
- Resilience
- Load
- Uncertainty
Modeling Supply Resilience

- Objective: Provide backup to resources that can be interrupted under extreme conditions (e.g., hurricane).

- How much backup duration is required? depends ...
  - Interruption season and number of consecutive days
  - Capacity credit of all affected resources (e.g., solar/wind)
  - Load Profile

- Backup size increases with affected resource size, capacity credit, and number of consecutive interruption days:
  - Peak load of 1000MW.
  - 500MW solar PV with a capacity credit of 100MW (20%), or 10% of peak load.
  - 2 consecutive rainy days
  - Backup size is 1200MWh (or 12 hours of 100MW capacity). This can be energy storage or a 100MW generator running on renewable fuel.
  - However, if the solar capacity credit is 60% (30% of peak load), the backup size will increase to 6000MWh (or 20 hours of 300MW capacity).
Modeling Grid Resilience

- Protect Critical Load and/or Vulnerable Communities
  - Create special zones for critical loads within the T&D grid
  - Determine capacity credit curves of renewable resources relative to the hourly profile of critical load
  - For resources within special zones:
    - Impose a minimum local capacity requirement constraint to ensure closeness of resources to critical load
    - Impose energy adequacy constraints
    - Impose supply resilience constraints
    - Select if resources should be connected to T or D or both
Within each zone, optimize multiple storage systems, with different energy capacities:
  • (e.g., 1h, 2h, 4h, 6h, 12h).

Model operational constraints:
  • daily energy balance constraints: daily charging = daily discharging plus losses
  • Energy reservoir constraints

Model storage value stack:
  • capacity benefit curve
  • Fast Frequency Response capability
  • Ramp Rate capability (1min, 10min)
Roadmap

2019
- Conceptual Dev.
- MATLAB Prototype

2020
- More Features:
  - Resilience
  - Uncertainty
  - Scalability

2021
- Python Porting
- QuEST integration
- Usability/Dashboard
- Additional Capability
Sample Outputs
Uncertainty Sampling - Latin Hypercube

- LogNormal distribution - fuel cost
- Uniform distribution - zonal load
- Normal distribution - Cap Credit
- Weibull distribution – Profile (W+BESS-E10)

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Sample Outputs

Study C: 50-75% Renewables by 2040

Resilience Impact:
- Storage capacity requirement increased by 17.5%
- LCOE increased from 45.7 $/MWh to approximately 48.9 $/MWh
Storage energy capacity requirements increase with time:

- **Freq Response:**
  - ESS-1hr

- **Capacity & Energy Balance:**
  - ESS-5hr
  - ESS-10hr

- **Capacity & Energy:**
  - S+S-5hr
  - W+S-10hr
Storage Requirements range between 41-69GW, with a mean of 60GW.

90% probability the storage requirements will exceed 50GW; 95% probability will not exceed 62GW.
To reach carbon-neutral, 165GW peak load (LF 60%) will require a resource mix that grows from 200GW to 800GW in 20 years at a high total cost of $667B (LCOE=$77/MWh), and significant grid investments.
To reach carbon-neutral 165GW peak load (LF 60%) will require a resource mix that grows from 200GW to 350GW in 20 years at a moderate total cost of $331B (LCOE = $38/MWh) and small grid investments.
Adding Renewable Fuel (e.g., Hydrogen) to the Resource Mix

- To reach carbon-neutral 165GW peak load (LF 60%) will require a resource mix that grows from 200GW to 320GW in 20 years at a moderate total cost of $313B (LCOE = $36/MWh) and small grid investments.
Thank you!

Office Locations

Quanta Technology
2300 Clayton Road, Suite 970
Concord, CA 94520

Quanta Technology
905 Calle Amanecer, Suite 200
San Clemente, CA 92673

Quanta Technology
720 East Butterfield Rd., Suite 200
Lombard, IL 60148

Quanta Technology, LLC (HQ)
4020 Westchase Blvd., Suite 300
Raleigh, NC 27607

Quanta Technology Canada, Ltd.
2900 John Street, Unit 3
Markham, Ontario, L3R 5G3

(919) 334-3000
quanta-technology.com
info@quanta-technology.com
LinkedIn.com/company/quanta-technology

Join us on LinkedIn and visit our website for live Knowledge Sharing Webinars and more!

Dr. Hisham Othman
HOTHMAN@Quanta-Technology.com