Wind and Solar Forecasting

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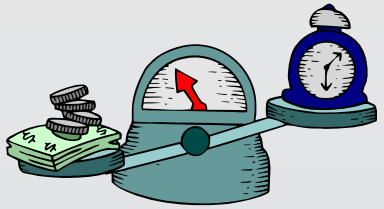
Renewable Challenges

- Aggressive 33% by 2020 RPS goal
  - 100% penetration at Distribution level
  - Current flow reversals
  - LADWP 40% RPS goal

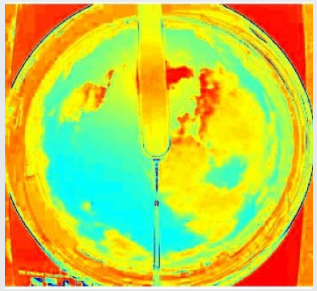
- Wind and solar variability sometimes correlated, sometime independent
  - Wind and solar are fastest growing renewable energy sources
  - Solar forecasting has lagged wind forecasting but solar is catching up
  - PV ramp rate variability can be more severe than wind ramp rate since wind tends to have an inertia component
- Renewable forecasting effects range from economics to transmission and distribution electrical system design to long range planning to social engineering
- California climate zones highly variable
- Best solar/wind sites far from living areas drives bulk generation and transmission impacts

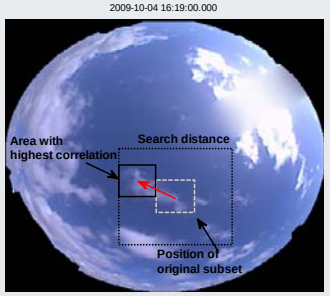
Multiple Forecasting Time Frames

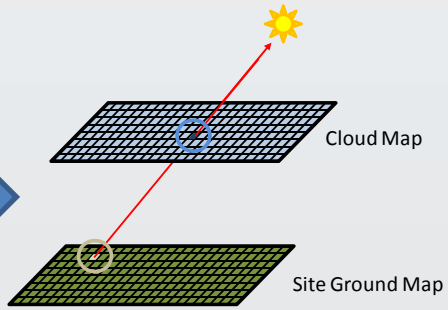
- Seconds, minutes, hours, and days ahead of time
- CAISO day ahead
  - Hour ahead
  - Moving to 15 minute ahead benefits solar/wind
- Utility (Scheduling, operations, planning)
  - Yearly, day ahead, hour ahead
- Utility scale generation
  - 2.75 hours ahead
  - Day head

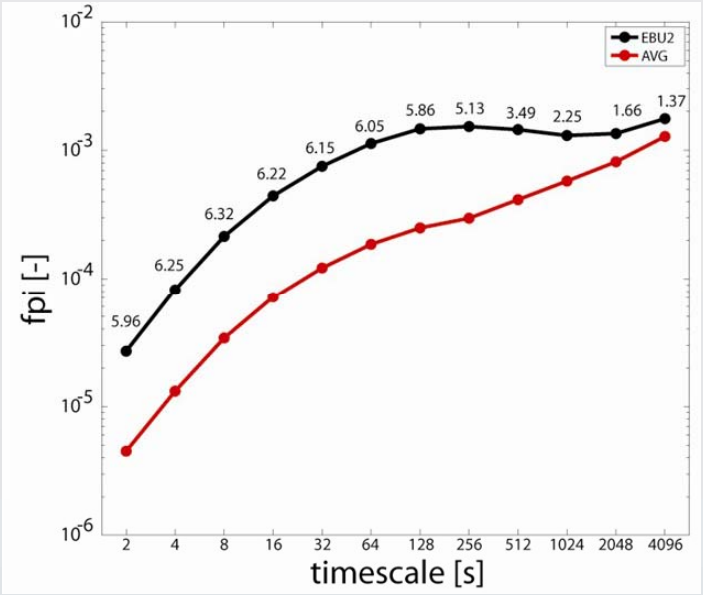


Solar Forecasting Technique









Solar Forecasting Levels of Complexity

- Selection of best set of measurable variables is important
  - Cross-correlation of variables must be considered
  - Cost and complexity of algorithms
  - Measurable, accurate data must be available

- Selection of methodology and algorithms important
  - Persistence
  - Predicted weather, historic generation, static
  - Cloud motion vector calculations
    - Real-time as opposed to static
    - Does not factor in real-time corrections
  - Real-time multi-variable analysis adds settable correction factors (location, season)
  - Kalman Filtering adds real-time prediction updates (storms, unusual weather)

Solar Forecasting Power and Ancillary Capabilities

- Currently standards limit ability of solar inverters to contribute to power quality
  - IEC 1547 limits ability of inverters
  - 1547 updates in progress will remove restriction
  - Ancillary services will be permitted in updated IEEE 1547

Future Renewable Energy Research Possibilities

- In terms of economic value, determine optimal
  - Location and size of storage to backup renewable generation
  - Location of distributed versus centralized renewable resources for T&D and installation costs
  - Electricity market design which reward Distributed Energy ***and*** ancillary services
  - Grid system changes to handle increased cycling of traditional generation plants
- Determine T&D upgrades required to serve 100% renewable generation in order to maintain/increase reliability
- Determine grid effects of asynchronous generation with some synchronous generation vs. current state of mostly synchronous generation
  - Grid dynamics not well understood
  - Mitigation strategies need to be modeled to ascertain best approaches
  - Use of demand side management

Future Research Solar

- Combine Kalman Filter and cloud vector solar forecasting methods
- Add cloud density estimates to motion vector estimates
- Effect of IEEE 1547 inverter standard changes on economic value of DER and grid reliability
- Selection of best statistically optimal variables

Future Research Wind

- Incorporate off shore wind generation
  - Close to load in many cases
  - Suitable to larger, more efficient turbines
  - Significant technical challenges to overcome