Architecture and Distributed Management for Reliable Mega-scale Smart Grids

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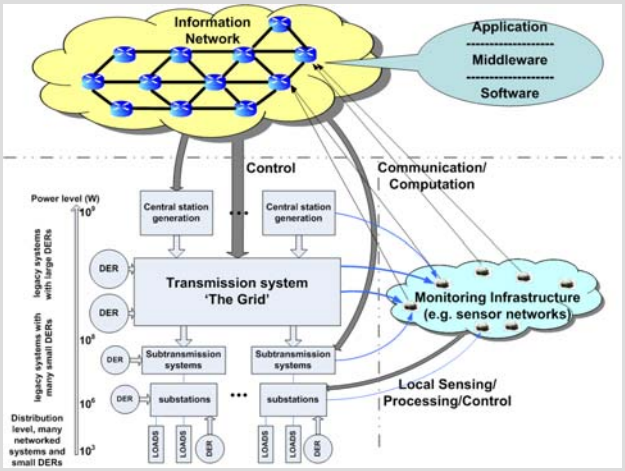
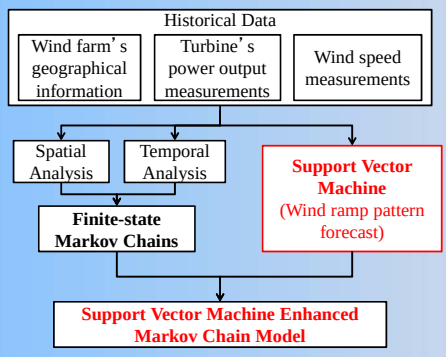
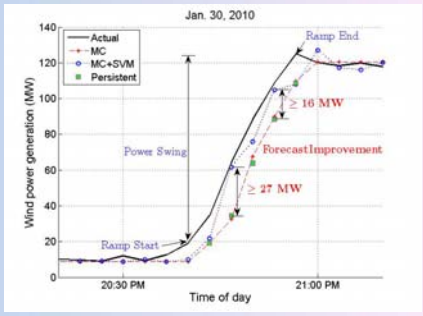
Vision of Cyber-Enabled Mega-scale Power Grid: Information Network Overlay Power System



Data Analytics Framework for MC-based Forecast of Wind Farm Generation (Zhang-Vittal)

➢SVM Enhanced Markov Chain Model for Wind Ramp Power Forecast





- Distributional forecast:

Forecast = Forecast_{SVM} x Belief + Forecast_{MC} x (1- Belief)

$$\Pr(P_{ag}(t+1) = P_{ag,j} | S(t) = S_k, x(t)) = \begin{cases} q_k, & \text{if } j = \hat{k} \\ (1-q_k)\frac{[Q]_{kj}}{\sum_{l \neq \hat{k}}[Q]_{kl}}, & \text{otherwise} \end{cases}$$

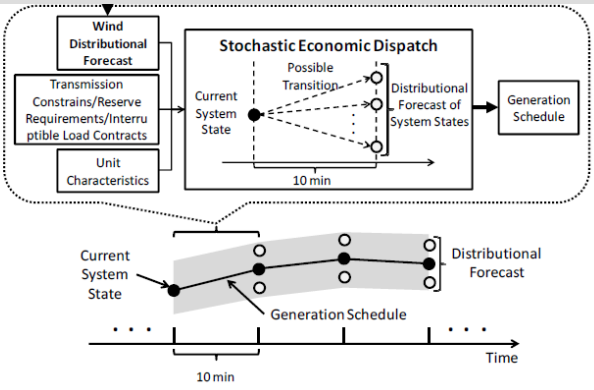
- Point forecast (conditional mean):

$$\hat{P}_{ag}(t+1) = P_{ag,\hat{k}} q_k + \sum_{j \neq \hat{k}} P_{ag,j}(1-q_k)\frac{[Q]_{kj}}{\sum_{l \neq \hat{k}}[Q]_{kl}}$$

Seamless Integration of Renewable Energy Sources (Vittal-Zhang-Kumar)

➢Technical approach:

1. Devise data analytics based models for wind generation forecast
2. Joint economic dispatch and interruptible load management for increased wind penetration



- Stochastic optimization

$$\mathbf{P1}: \min \sum_{g \in G} C_g^G(P_g^t) + \sum_{b \in B} C_b^I(P_b^t) + \sum_{w \in W} \mathbb{E}\{C_w^W(P_w^t)\}$$

Generation costs | Interruptible load service costs | Wind integration costs

$$\mathbb{E}\{C_w^W(P_w^t)\} = \sum_{j \in \mathcal{S}} Q_{S_w^{t-1},j} c_R(P_w^t - P_{w,j})^+$$

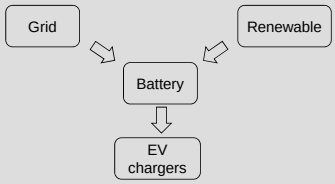
Distributional wind generation forecast

Cost of using reserve to compensate the forecast error

Wind Penetration Level		P1	P2	P3
10%	Total Cost (10^7 $)	73.19	74.21	77.51
	Improvement Ratio (%)		1.39	5.90
20%	Total Cost (10^7 $)	56.33	58.36	63.57
	Improvement Ratio (%)		3.61	12.85
30%	Total Cost (10^7 $)	42.96	48.23	52.45
	Improvement Ratio (%)		12.26	22.09

A Layered Architecture for EV Charging Stations Based on Time Scale Decomposition (Kumar)

Charging Station:



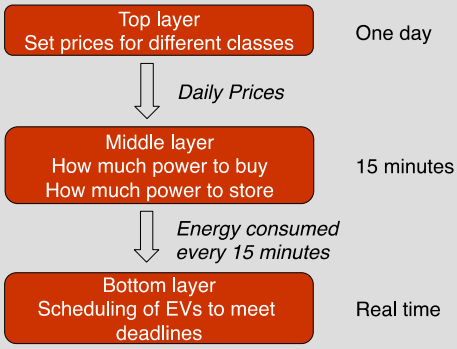
Complexities

Variability of grid power price
Peak grid power draw constraints
Intermittent availability of renewable energy
Battery capacity and round-trip energy loss
EV customer Energy reqmnt and Deadlines
Charging Demand Affected by Price charged

Exogenous processes: Grid power price and Renewable power supply

Control Variables:

Timing and purchase of grid power
Prices charged to customers
Scheduling to meet deadlines



Top Layer

Charge different prices to different customer classes: Deterministic Optimal Control Problem

Middle Layer: Minimize cost of meeting demand generated by top layer: MDP

Bottom Layer:

Stochastic scehduling of EV's to meet deadlines

Online Dynamic Security Assessment with Missing PMU Data (Zhang-Vittal)

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