Smart Markets for the Smart Grid: *Dynamic Forward Pricing*

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The Internet and the Smart Grid

- The electric grid connects hundreds of millions of customers and meters and billions of devices.
- Every electric device is connected on the grid and increasingly all devices and customers are connected on the Internet.
- The Internet connects billions of people, devices and everything else.
- The Internet supports communication and coordination at a level never thought possible.
- The Smart Grid would not be possible without the Internet.
- With smart meters, the Google PowerMeter and other display devices show how much you are using and paying for power.

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Price Signals

- Everybody's vision of the Smart Grid has a picture connecting large generators, transmission, distributed generators, appliances, battery storage, and plug-in vehicles.
- At the center is a system operator sending "price signals".
- Price signals will coordinate customer and supplier decisions to maximize efficiency, reduce costs, increase reliability and reduce green house gas emissions and allow more variable renewables on the grid.
- But what are these price signals?
- Typically, they are so undefined that they might as well be *smoke signals*.
- Proposing practical price signals for the Smart Grid is the purpose of this talk.
- But first some more foundation.

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Traditional Power Pricing

- Traditionally, the electric industry offered flat pricing or time-of-use pricing to retail customers.
- Wholesale real-time power prices in five minute intervals are volatile and can be $1000s of dollars per MWH and then drop to a negative price that is just as large.
- Prices in different locations can be very different when there is congestion on the grid.
- With large amounts of wind and solar, price volatility will increase.

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Long-Term and Real-Time Pricing

- Most visions of the Smart Grid propose real-time prices.
- Customers and suppliers do not want all power transacted at real-time prices.
- Utilities and power plant owners need long-term contracts to efficiently finance generation and transmission investments.
- Customers want to protect against the risks of high long-term costs of power with fixed prices for some amount of power.

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Both Long-Term and Real-Time Pricing

- Each customer buys a block of power for each time of day and season.
  - If the customer uses less than the block amount, he is credited at the real-time price for the power not used.
  - If the customer uses more than the block amount he pays the real-time price for the difference.
- All customers have the full incentive to respond to real-time prices and help create an efficient grid.
- The benefits of long-term contracts to customers and producers are retained .

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System Operator Pricing

- System Operators (ISOs and RTOs) and utilities are designed to dispatch large fossil generators.
  - To act on the real-time price you have to bid into the ISO's real-time markets.
  - The ISO may increase or decrease the output of your generator or device.
  - The ISO uses optimization software to decide how much to change the output of each generator or device before it computes the real-time prices.
  - Real-time prices for each 5-minute interval are published several minutes after each 5-minute interval passes.
- Aggregators help customers work with the ISO, but this costs money and the results are not ideal.
  - Aggregation is not necessary if the real-time price is offered to customers and their smart devices before each 5-minute interval.

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Complexity and the Smart Grid

- ISO software systems are straining under the complexity of their current mission.
- New ISO software systems in California and Texas are costing hundreds of millions each and up to ten years to complete.
  - We can't wait that long for the Smart Grid.
- Central dispatch of billions of customer devices by the ISO is too difficult.
  - The Smart Grid will collapse under the weight of its complexity if we take this path.
- We need robust distributed decision making and optimization.

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Dynamic Forward Pricing

- The key to a practical Smart Grid is *dynamic forward pricing*.
  - Forward real-time pricing means that an offer price for each 5-minute interval is published well before each 5-minute interval.
  - Smart devices and generators, buy or sell at this price and the transaction is binding.
- As grid conditions change the forward price will increase or decrease to balance supply and demand for the 5-minute interval.
  - Smart devices and generators may make additional transactions at these new prices to further improve their services and costs.

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Frequent, Small Adjustments

- A key attribute of dynamic forward pricing is that frequent, small price adjustments and binding transactions are made rather than single large transactions.
  - The Internet and smart devices will enable these transactions at low cost.
- Because many time intervals are in play at the same time, devices and generators will be offered prices for every 5-minute interval for the next hour or two and hourly prices for the next 24 hours.

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Smart Responses to Dynamic Forward Pricing

- Smart devices such as air conditioner thermostats will frequently receive the set of forward prices.
  - Knowing current and future prices, these smart thermostats will efficiently cool the building taking into account, weather, building thermal inertia, customer comfort preferences and more.
- As conditions on the grid change, such as an actual or forecast rapid drop in wind or solar generation, forward real time prices will change and smart devices such as air conditioners will change the timing of power use.
  - Customers will get paid for the changes at the new prices.
  - Fossil generators will then have time to start up to balance the grid if the wind and solar generation does not return soon.

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Storage Needs Dynamic Forward Pricing

- Distributed storage will be needed for integration of large amounts of wind and solar.
  - Each type of storage device has different power and energy ratings, charging losses, cycle life, and temperature limits.
  - Central dispatch of storage is impossible.
  - Dynamic forward prices will allow the smart storage controller to know how much to store and how much to deliver in each interval and to change its delivery instantly upon receipt of new forward prices.
- Plug-in vehicles with battery storage will use the dynamic forward pricing to charge according to customer preferences, state of charge, temperature, cycle wear and the price of fuel for hybrids.
  - Based on forward prices, a vehicle will be charged at low or negative prices and made ready for driving.
  - If prices are high the vehicle can discharge to return power to the grid.
  - If too many vehicles attempt to charge at the same time, the dynamic prices will increase.
  - This is the best and only practical way to manage the charging and discharging of millions of vehicles on the grid.

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The Simplicity of Dynamic Forward Prices

- Because smart devices are responding to dynamic forward prices we don't need complicated multi-part bids from the customers.
  - All we need from the customers are their transactions.
- Paying for all of these transactions is also simple.
  - The smart meter stores
    - prices and blocks of long-term power purchased, and
    - transactions carried out at forward prices.
  - Accumulating the costs gives the overall bill.
  - The bill can be paid at the smart meter without central billing.

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Benefits of Dynamic Forward Prices

- Congestion on the grid is managed by dynamic forward prices.
  - Prices on grid constraints will be adjusted dynamically.
  - Constraint price affect the prices at each location on the grid according to sensitivity factors computed by the grid operators.
  - Both transmission and distribution grid limits and congestion will be managed. Dynamic forward prices will be location based.
- Green house gas prices paid by fossil generators will increase generation the price of power when these generators are on the margin.
  - This will shift generation to intervals when wind or solar is available.
- The end result will be optimal coordination of all customer devices, distributed generation, central generation, and storage.
- Dynamic forward prices will provide very fast response to changes wind and solar generation and other grid conditions and enhance reliability.

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Implementing Dynamic Forward Pricing

- Dynamic forward pricing will reduce the complexity of the ISOs software systems.
  - Existing ISO and RTO software systems will be adapted to support dynamic forward pricing.
- Micro-grids will use dynamic forward pricing internally.
  - When micro-grid separates from the grid, the internal forward prices will increase to reduce electricity use and increase internal generation to balance the micro grid.
- Vertically integrated utilities can use dynamic forward pricing.
  - Open markets are not necessary to implement dynamic forward pricing.

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Conclusion

- There are many critical implementation details for dynamic forward pricing that I have avoided here so as to focus on the big picture. Feel free to contact me for further details.
- Dynamic forward pricing is the only practical way to provide Smart Grid price signals.
- Any other approach will fail to achieve the full promise of the Smart Grid and will collapse under the weight of its own complexity.
- Dynamic forward pricing *is* the key to Smart Markets for a Smart Grid.

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