# Abstraction and Layering for Electricity Industry

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## 1 Background

Power networks are sophisticated large cyber-physical systems the control of which needs a deep and synergistic integration of new design ideas, computational algorithms and physical components.

The difficulty in the control of the electricity networks comes from their special features, such as the integrated flow of electricity governed by the KVL and KCL laws, the inability to store electrical energy, the transmission network limits, ramping constraints, the inelasticity of demand which needs to be met in real time and unpredictability of demand.

Any approach to control the system should consider all these constraints and will be complex by nature. As an example, system operators who are responsible for the performance and stability of electricity grid, are well known for their complex algorithms and procedures. The integrity of physical constraints to any problem, not only makes the analysis of the system complicated, but also hinders comprehensive design for the system; hence, most current algorithms including dispatch, ancillary services and expansion of the network are complicated and to some extent approximations based on numerical results.

In order to overcome this situation, we need to introduce abstractions to the electricity networks and divide the problems into parts by layering the system. The abstraction helps to disintegrate the physical limits and higher level decisions. Layering helps to define appropriate communication between consequent layers (or among layers if they are not in a hierarchical order).

Abstraction and layering has been applied successfully to communication networks, i.e. application layer, network layer, data layer and physical layer. Power networks are however different from communication networks. Two main differences are that first, one unit of electricity energy is the same across electricity network and not packetized to packets with distinct information and second, the electricity flows are integrated through the network.

Some ideas of layering the electricity industry can be found in existing works like ISO/PX of California. These works disintegrate the physical layer from market layer in order to run the market without network constraints, and make the control of the system tractable. In this position statement we particularly focus on the abstraction and layering of the electricity and try to consider the whole system.

## 2 Proposed Research/Work

This research will provide abstractions for the electricity industry. Layers will be defined based on these abstractions. The input and output for each layer will also be defined.

Any abstraction of the industry should be with a view to the future of the industry and emerge of the new technologies. For example, the emerge of measuring technologies will help demand shaping. In the same way the increase in the number of producers and consumers in the smart grid will effect the protocols in the system.

Moreover, the abstraction should be flexible for future progressions based on changes in technology and needs; otherwise, the Internet ossification which has happened in communication networks may occur in the electricity industry.

Following is a basic view toward layering of the industry.

- Application layer: In this layer the consumer manages its applications.

  For a simple household, this applications can be daily use of electricity like cooking, ironing, heating system, refrigerator etc. As a vision to future, the household can have a software which helps her organize these applications and set priority for them.

  For a supplier, this could be how to run different utilities it has including wind, solar, gas turbine, etc.

- Market layer: The market layer, takes the total amount of demand/supply at every instance from the application layer and tries to buy/sell it in the market. It sends the price to the application layer to be considered to manage the priority of applications.

- Transmission layer: The transmission layer takes the outcome of the market layer and tries to dispatch electricity considering physical constraints. It sends the result to the market layer including modifications needed to made in the trades.

## 3 Potential Impact in/to CPS

Applying abstraction and layering to electricity industry will change the paradigm of design and analysis of the network. It will help to model the system, develop new designs and diagnose the system. The new electricity systems will be more flexible to changes. The abstraction and layering will provide a base for new algorithms of the system design. They also help modular design of the system where every algorithm developed for a particular layer can remain in practice regardless of changes made in other layers like changes in the physical layer.

Abstracting and layering the electricity industry should be with a view to the emerge of smart grids including smart demand and supply and new resources. This way, it will pave the way for progression of the smart grids.

We believe introducing abstraction to electricity industry is necessary to provide a similar ground for different models of the system and help different algorithms and designs of the electricity system to add together in a synergistic way.