Interactions Between Information Systems and Electric Power Systems: The Vasa Redux

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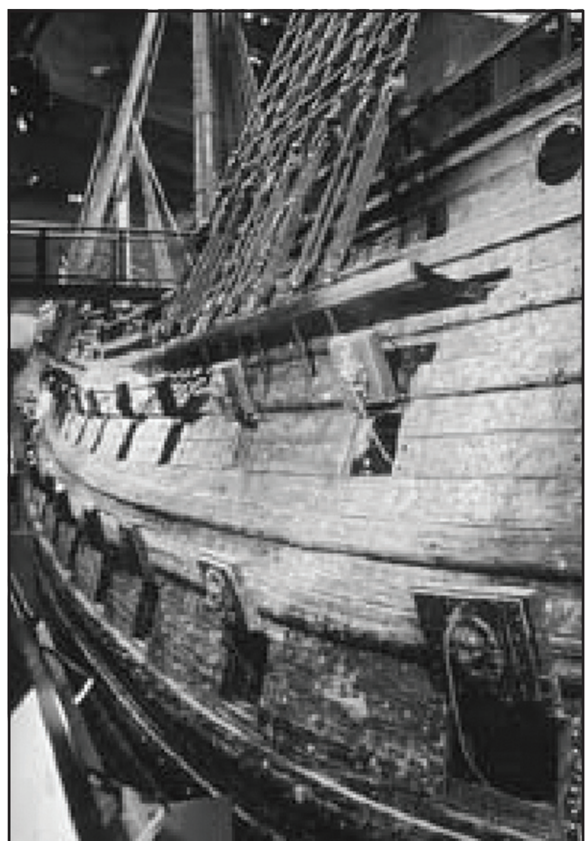
Background

The Interoperability Context-Setting Framework Draft does an excellent job of laying out interoperability in complex systems from an information-theoretic viewpoint. In this paper I address the single question that I find troubling about this approach: limiting the definition of interoperability to one between subsystems exchanging "data" in a conventional sense vs. interoperability (and the ensuing interactions and system dynamics) between information systems and electric power systems.

Interoperability leads to interactions—in complex systems, even interactions between deterministic subsystems lead to chaotic (unpredictable) system behavior. In electric power systems, one has to account for interoperability and interactions at two different levels: i) interoperability and interactions between subsystems as proposed in the framework document (data-driven), and ii) interactions between subsystems that occur indirectly through the dynamics of the interconnected power system (electromagnetic-driven) arising from actions taken by subsystems.

The Vasa Redux



On a trip to Stockholm a couple of years back I visited the Vasa museum that is a tribute to the Scandinavians' sea faring skills in the 17th century. I was a bit taken aback to learn that much of the hullabaloo was about a ship that sank on its maiden voyage. As I reflected on the framework paper, the Vasa story kept coming back to me as a metaphor for that nagging worry in the back of my mind about information-centric interoperability in power systems.

Here is the Vasa story in a nutshell (mostly pilfered from the results of a Google search of course): A great Swedish king who ruled Scandinavia in the early 17th century had to have a fleet of warships to patrol the Baltic and ordered 4 new galleons. One was to be the royal mighty battle galleon called Vasa, greater than any ship ever built at that time. It had two gun decks and held 64 bronze cannons. Timbers of the bow were steamed (to curve them) and fixed, and the close-set ribs were clad with heavy timber walls. A web of masts and spars rose from the deck and the top gallant on the main mast soared to 190 ft. The Vasa's rudder stood over 30 feet tall. Carvings were attached on the bow and round the high stern castle. Stern ornaments painted red, gold, and blue of gods, demons, kings, knights, warriors, cherubs, mermaids, and weird animal shapes–all meant to scare enemies and symbolize power and courage. It took 3 years to build Vasa, turning her into a floating work of art and a weapon of war. Vasa's ballast equaled 120 tons of stone. She carried additional weight of cannon balls, gunpowder, ancillary firearms, food in casks, officers and a crew of 133 sailors.

Vasa began her maiden voyage August 10, 1628 from Stockholm harbor. There was a light breeze from the southwest. She had only sailed for less than a nautical mile when there was a sudden squall, her gun ports were still open having just fired farewell, and she listed heavily to port, the gun ports sank below water level and water gushed in. In only a few moments she sank to the bottom of the Baltic sea, less than 100 yards from the shore. Unintended interactions between diverse subsystems got the better of her on her maiden voyage.

Implications for the Interoperability Framework

As we ponder the weighty issue of interoperability among disparate energy resources, electric networks, actors, organizations, and markets, we are clearly laying the framework for a rejuvenated electromechanical vessel (already labeled the largest man made machine) with all the information-centric equivalents of timber bows, close-set ribs, multiple masts, sails, cannons and carvings, to be admired and adopted by all. If we are successful, all the pieces will fit together beautifully no matter who made them or where they were built—any competent systems integrator will be able to put it together without too much difficulty. The problem however, is that we have no idea how this vessel will behave in swells or squalls much less a hurricane or typhoon. Multiple modes of interactions between its myriad sub-systems will result in a complex system whose dynamics would be unpredictable at best, electrically unstable at worst.

If data-driven information is the glue that holds the system together (with the interoperability framework providing the blueprint for assembling the system), then the wrong types of interactions (not predictable within the framework) between subsystems or with the environment (Information System–Electric System (IS-ES) interactions) will pull the system apart and send us to the bottom faster than we can say "interoperability."

Example: Consider three services offered in some area of a power system: i) An internal service implemented by utility operations personnel with a tap changing transformer for voltage correction on a radial feeder with voltage reading from the end of the feeder being used to implement automated tap changer operation at the substation, ii) DG for reactive power services (a service purchased by a trader from DER owners to aggregate and sell reactive power on the ancillary services market) where the DER owner is paid monthly on the basis of the number of events supported and the duration of the events with the DER unit programmed to supply/absorb VARs as soon as an automated signal is received, and iii) wind farm owner in the area that purchases VAR balancing on the open market to self provision ancillary services required for grid-interconnection.

The three subsystems (tap changer, DG, WT and associated services) now interact with each other through the dynamics of the power system influencing each other's operations. It is not difficult to envision how the operation of one subsystem not only impacts the operation of another subsystem, but can also feed back on itself as the other subsystem responds. Real-time wind turbine compensation affects VAR market influencing DG operations that impact tap changer settings in turn affecting WT ancillary services needs. Worst case situation could result in VAR oscillations that could trip out DG and WTs further impacting system stability causing a rapid slide down the infamous nose curve. The example can of course be refined—but you get the picture…

The behavior of the system is no longer predictable although the behavior of any of the subsystems is deterministic. As the number of sub-systems responding automatically with a localized point of view increases, the ability to design sub-systems with predictable system-wide behavior rapidly goes down. Currently, data, services, and software agents can proliferate within an information-centric framework, but as that happens, there is no way to guarantee that the power system remains within some acceptable stability boundary due to ensuing IS-ES interactions.

Extending the interoperability framework to address IS-ES interactions

The issue at hand is that the draft interoperability framework offers no guidance on handling IS-ES interactions. Section 4.7 briefly touches on this issue, simply stating that parties transacting business through their interfaces must consider the potential impact of their actions on the health of the system. This is simply not possible since parties to the majority of grid-transactions will have limited visibility over the range of ongoing activities to determine the "goodness" of their own actions. Further, this "goodness" metric will change depending on actions taken by others. This issue is not simply a "cross cutting" issue similar to say, security and privacy where models from other domains can be successfully adapted for the needs of the power system. I believe this is a foundational issue that needs to be directly addressed by the framework to instill confidence in the approach and foster broad adoption.

Where to from here?

The solution (still in the category of thinking out loud) is to extend the interoperability framework to ensure that appropriate methods exist for modeling, exposing, validating, and auditing subsystem interactions within the context of power system dynamics. The alternative is that the entire interoperability framework is relegated to services that are decoupled from power system dynamics—such as AMR or day ahead demand response—no actions are taken that touch the power system without human intervention. This limited approach, I believe, is insufficient to make the transition to the smart grid of the future that all of us envision. If a framework layer can be developed that acts as a "services filter" that can in some sense "guarantee" that system dynamics remains within acceptable bounds, then we would have the beginnings of a solution.