Identifying Architectural Modularity in the Smart Grid
An Application of the Design Structure Matrix Methodology

Architecture Track – Innovative Architectural Models Session

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“Technical skill is mastery of complexity, while creativity is mastery of simplicity.”

- Sir Erik Christopher Zeeman, Mathematician
What is an Accidental Architecture?

An accidental architecture\(^1\) is the organization of a system resulting from numerous point-to-point integrations between various applications to achieve near-term objectives.

Point-to-point integrations are not scalable and often create unintended ripple effects on downstream applications.

The result is a unique and customized system that becomes increasingly difficult to maintain and update.

Modularity is a general systems concept, typically defined as a continuum describing the degree to which a system’s components may be separated and recombined.¹ It refers to both the tightness of coupling between components, and the degree to which the “rules” of the system architecture enable the mixing and matching of components.


- Wikipedia article on modularity
12/5/2011
What is modularity?

Modularity in systems architecture is the degree to which elements of a system can be grouped with minimal dependency across groups.
What is Design Structure Matrix?

The design structure matrix (DSM) is a modeling tool that represents the relationships and dependencies between components of a system, product, or process. The DSM captures coupling and dependency relationships between the components of a system in a graphical matrix.

How can DSM help identify modularity?

Clustering is a process applied to a DSM by which elements of a system are arranged and grouped in order to minimize interdependency across groups.
Where to start?

Start by mapping the relationships and dependencies of the system.

NISTIR Logical Reference Model

Then translate those dependencies into a DSM matrix.

DSM Representation of the NISTIR Logical Reference Model
How to find modularity?

Clustering is more an art than a science. A clustering algorithm can give a good starting point, but “manual” organization is typically needed.
A pattern emerges in complex systems.

Clustering complex systems almost always results in a “Hub & Spoke” configuration.

Identifying the appropriate hub elements allows for the creation of modular spokes.

Without identifying and grouping the most central, cross-cutting elements...high levels of dependency would exist across the spokes, and little modularization can be achieved.
Varying levels of dependency may be allowed. It’s up to the architect to determine the most appropriate configuration.
DSM can be applied for specific implementations.

This is the planned architecture for a federally funded smart grid demonstration project.

NRECA's Demonstration Architecture: Physical and Logical Architecture for Enterprise Application Integration

DSM can be applied for specific implementations.

High densities of dependencies and of whitespace generally indicate a more modular organization.

DSM Representation of NRECA’s Demonstration Architecture
Different organizations may emerge.

But you never know what might emerge...such as two independent hubs in this case.
Different organizations may emerge.

Or a “daisy chain” of dependency in an alternate configuration.
• Modularization can help combat accidental architectures by isolating groups of dependency allowing them to be treated as an independent sub-system. Modular systems can evolve more elegantly because modular organization is more easily respected.

• Hubs identify the most cross-cutting elements of a system. Prioritizing these elements and acknowledging their centricity will reduce the complexity of the system.

• DSM is a useful approach to visualizing and structuring complex systems, such as those in a smart grid.
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