EH2750 Computer Applications in Power Systems, Advanced Course.

Lecture 1b – August 2012

Professor Lars Nordström, Ph.D.
Dept of Industrial Information & Control systems, KTH
larsn@ics.kth.se

Outline of the lecture

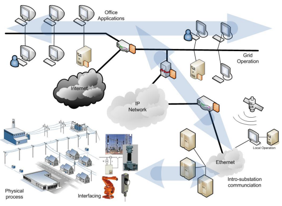
Course Philosophy
Course Administration
Lab Tour

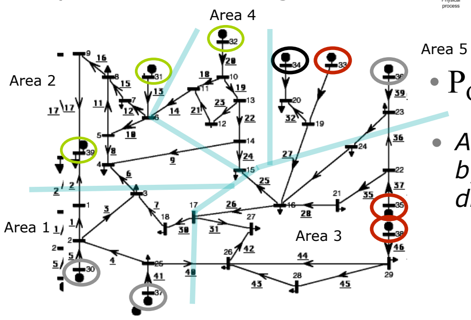
Break

Computer Applications in Power Systems
Smartgrids a bit of history
The NIST report

Integrated Infrastructures

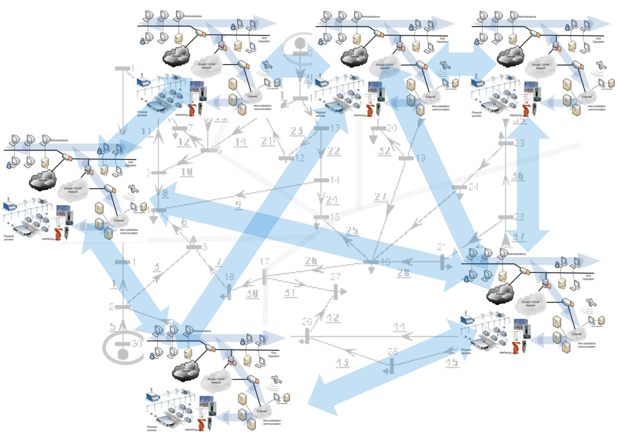
- *ICT systems are essential for power system planning, operation, control & optimisation.*
- *The ICT Architecture is a system in its own right.*





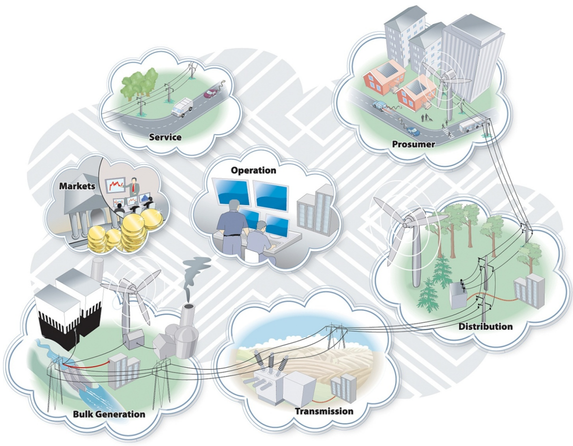
- $P_{Gen} = P_{Load} + P_{Loss}$
- *A power system is managed by separate entities with differing agendas.*

Integrated² Infrastructures



- *More or less well understood*
- *Managed by gradually developed systems & processes*
- *Largely hierarchical based on national borders and collaboration*

Enter – the Smart grid



-12%

Possibilities with Smartgrids

- Direct communication of price signals between consumer and producer
- Possibility to shift load over time
- Interconnection of intelligent appliances in the Smart Household
- Enable the producing consumer – the Prosumer with microgeneration
- Integration of large scale intermittent production – wind power
- Use of electric storage in large fleets of electric vehicles

Priority Areas across the System

- Wide-area situational awareness
- Demand response and consumer energy efficiency
- Energy storage
- Electric transportation
- Cyber security
- Network communications
- Advanced metering infrastructure
- Distribution grid management

Outline of the lecture

Course Philosophy
Course Administration
Lab Tour

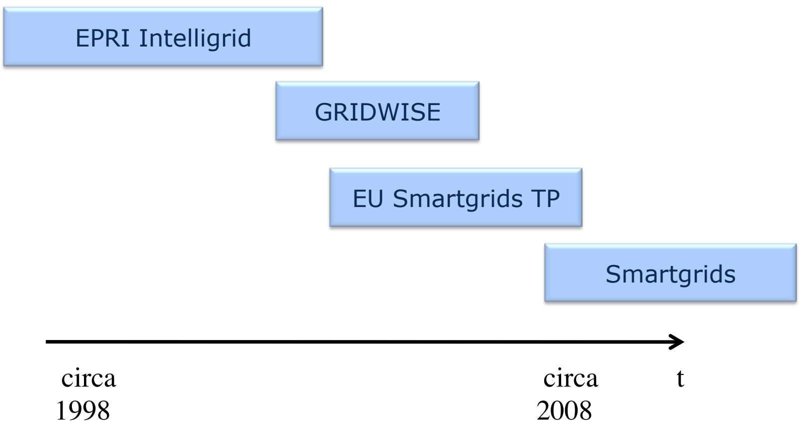
Break

Computer Applications in Power Systems
Smartgrids - a bit of history/perspective
The NIST report

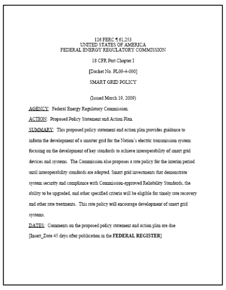
Where it all began (this time around)

- Security of Supply
- 4,5 Billion USD are available in subsidies for building the Smart electricity grids.

From Intelligrid to Smartgrid



FERC – Smartgrid Policy


126 FERC ¶ 61,253
UNITED STATES OF AMERICA
FEDERAL ENERGY REGULATORY COMMISSION

18 CFR Part Chapter I

[Docket No. PL09-4-000]

SMART GRID POLICY

(Issued March 19, 2009)

AGENCY: Federal Energy Regulatory Commission.

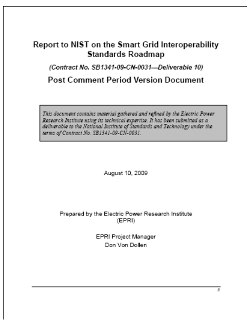
ACTION: Proposed Policy Statement and Action Plan.

SUMMARY: This proposed policy statement and action plan provides guidance to inform the development of a smarter grid for the Nation's electric transmission system focusing on the development of key standards to achieve interoperability of smart grid devices and systems. The Commission also proposes a rate policy for the interim period until interoperability standards are adopted. Smart grid investments that demonstrate system security and compliance with Commission-approved Reliability Standards, the ability to be upgraded, and other specified criteria will be eligible for timely rate recovery and other rate treatments. This rate policy will encourage development of smart grid systems.

DATES: Comments on the proposed policy statement and action plan are due [Insert_Date 45 days after publication in the **FEDERAL REGISTER**]

- *"Once interoperability standards are completed, the Commission will consider making compliance with those standards a mandatory condition for rate recovery of jurisdictional Smart Grid investments"*

NIST Roadmap for Smartgrids


Report to NIST on the Smart Grid Interoperability Standards Roadmap

(Contract No. SB1341-09-CN-0031—Deliverable 10)

Post Comment Period Version Document

This document contains material gathered and refined by the Electric Power Research Institute using its technical expertise. It has been submitted as a deliverable to the National Institute of Standards and Technology under the terms of Contract No. SB1341-09-CN-0031.

August 10, 2009

Prepared by the Electric Power Research Institute (EPRI)

EPRI Project Manager
Don Von Dollen

ii

- *Project within NIST (performed by EPRI et.al.) to identify areas that need to be standardised*

But wait - Possible is not Sufficient

BEA Systems, Inc. (Nasdaq: BEAS), the E-Commerce Transactions Company(TM), announced that [redacted] one of the largest energy companies in Europe, is using BEA's WebLogic product family of industry --leading e-commerce transaction servers, along with BEA components, to build an integrated network A network that supports both data and voice and/or different networking protocols for providing 'smart building' subscription services throughout Sweden. The services let customers remotely monitor their refrigerators, ovens, electricity consumption and power mains status, and control their burglar alarms and heating and air conditioning air conditioning, mechanical process for controlling the humidity, temperature, cleanliness, and circulation of air in buildings and rooms. [redacted] estimates that, before the end of next year, 150,000 Swedish households will be using the new services, and hopes to add 200,000 new customers a year en route to a customer base of one million households within five years.

Yesterday's news

- K.J. Åström "Modeling and identification of Power Systems Components", In Proceedings of the Symposium on real-time control of Power Systems, Baden, Switzerland, 1971 Ed E. Handschin.
- T. Cegrell "A Routing Procedure for the TIDAS Message-Switching Network" IEEE Transactions on Communications, Vol 23 issue 6, Jun 1975
- L. Cederblad and T. Cegrell , "A new approach to security control of power systems - local protection coordinated with system-wide operation". In: *IFAC Symposium on Power System modelling and control applications* , 1988
- A.G. Phadke, J.S. Thorp, M.G. Adamiak "A new measurement technique for tracking voltage phasors, local system frequency, and rate of change of frequency", In IEEE Transactions on Power Apparatus and Systems, 1983

ROYAL INSTITUTE OF TECHNOLOGY

United States Patent [19] — [11] **4,240,030**

Bateman et al. — [45] **Dec. 16, 1980**

[54] **INTELLIGENT ELECTRIC UTILITY METER**

[76] Inventors: **Jess R. Bateman,** 1516 Esplanade Ave., Redondo Beach, Calif. 90277; **Robert L. Carpenter,** 12,032 Freeman Ave.; **Ross K. Smith,** 5435 W. 124th St., both of Hawthorne, Calif. 90250

[21] Appl. No.: **969,303**

[22] Filed: **Dec. 14, 1978**

[51] **Int. Cl.³** **G01R 1/00**

[52] **U.S. Cl.** .... **324/110;** 346/14 MR; 235/449

[58] **Field of Search** .... 324/51, 110, 113, 157; 364/483; 235/449, 493; 346/14 MR; 307/140

[56] **References Cited**

U.S. PATENT DOCUMENTS

2,019,866	11/1935	Morton	324/110
3,001,846	9/1961	Franceschini	346/14 MR
3,380,064	4/1968	Norris et al.	346/14 MR
3,778,637	12/1973	Arita	307/140
3,835,301	9/1974	Barney	235/61.11
4,019,135	4/1977	Lofdahl	324/110

Primary Examiner—Michael J. Tokar
Attorney, Agent, or Firm—Poms, Smith, Lande & Rose

[57] **ABSTRACT**

A conventional electric utility meter is equipped with special circuitry and components which work in conjunction with an inserted magnetic card to regulate the supply of electricity to the structure to which the unit is attached. In addition to including the conventional dials which indicate overall kilowatt hours, the exterior of the unit includes a receptacle for the card and additional displays which show the kilowatt hours, and corresponding dollar value thereof, for the current payment period. The special circuitry includes a microprocessor, a set of magnetic read/write/erase heads, and a power relay. The circuitry interfaces with the conventional meter components by means of a photocell positioned above apertures or notches in the rotating disk of the meter. In the primary mode of operation, a prepayment card is inserted containing a predetermined kilowatt hour credit. The special circuitry senses this amount and adds it to the amount of power the customer is entitled to receive. Also, the circuitry warns the customer when only a small electricity credit remains. In an alternative mode, a blank postpayment card is inserted into the unit and the amount of the electricity utilized during the current payment period is encoded on the card. The card is then sent to the utility company as the basis of a future billing. Finally, the unlocking of the meter unit case is controlled by a special card code.

15 Claims, 6 Drawing Figures

ROYAL INSTITUTE OF TECHNOLOGY

United States Patent [19] — [11] **3,980,954**

Whyte — [45] **Sept. 14, 1976**

[54] **BIDIRECTIONAL COMMUNICATION SYSTEM FOR ELECTRICAL POWER NETWORKS**

[75] Inventor: **Ian A. Whyte,** Churchill Borough, Pa.

[73] Assignee: **Westinghouse Electric Corporation,** Pittsburgh, Pa.

[22] Filed: **Sept. 25, 1975**

[21] Appl. No.: **616,711**

[52] **U.S. Cl.** .... **325/48;** 325/64; 340/310 A; 340/310 R

[51] **Int. Cl.²** **H04M 11/02**

[58] **Field of Search** .... 325/36, 47, 48, 55, 325/64; 179/2 E, 2.5 B, 41 A; 340/310 R, 310 A, 311, 312

[56] **References Cited**

UNITED STATES PATENTS

3,376,506	4/1968	Sontag	325/64
3,714,375	1/1973	Stover	179/2 E

Primary Examiner—Benedict V. Safourek
Attorney, Agent, or Firm—D. R. Lackey

[57] **ABSTRACT**

An arrangement of communication components to provide communications between a central control center and various customer load locations in an electrical power distribution system. Control or interrogation signals are originated at the control center and transmitted over a suitable facility, such as a telephone line, to an FM broadcast station. The control signals frequency modulate an ultrasonic subcarrier which modulates the FM broadcast transmitter simultaneously with the normal broadcast program material. Radio receivers at the customer load locations receive, filter, and decode the broadcast signals which are used to activate the control or logic circuits associated with the customer location. A reply signal is generated at the customer location and applied to the power lines by carrier techniques. The power line carrier reply signal is remotely detected by a suitable receiver and transferred over a suitable wire line facility which terminates at the control center.

8 Claims, 3 Drawing Figures

an electrical power distribution system. One type of communication system of growing importance is a system which transfers information between a central control station and the customer load location. Such a system can be used to selectively control the power consumption at the customer location, interrogate the customer's metering facility to produce signals which are responsive to the energy used, or for any other purpose requiring two-way communication facilities.

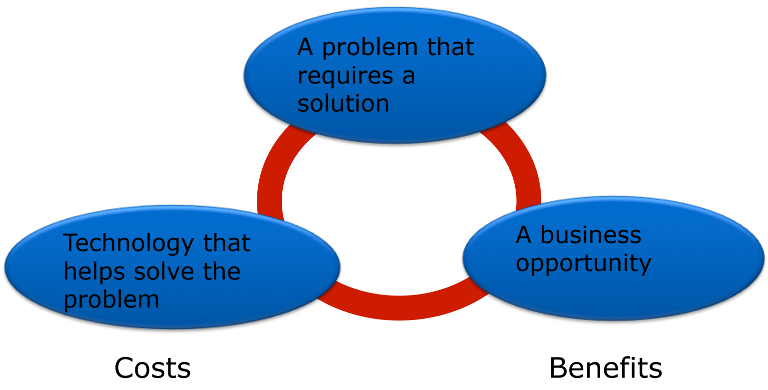
What is new this time?

- Experiences from 15 years of de/re-regulation
  - Regulators are making utilities cost focused
  - Projects are driven by a business case
  - Fewer Engineers are managers
- New types of production are entering the system
  - Large scale wind and solar power
- Aware and connected customers
  - Climate awareness
  - AMR rolled out, Broadband to the home, Internet,….
- Modernising the transport sector
  - Electric vehicles are being introduced in large scale
  - Market dynamics of a another industry is affecting the conservative power industry

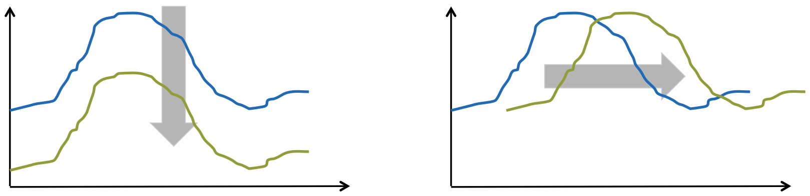
Challenges this time

- The 20/20/20 goals
- For the electric power system they have the following implications
  - Power Balancing
  - Managing DER
  - Energy efficiency

Necessity driven by business

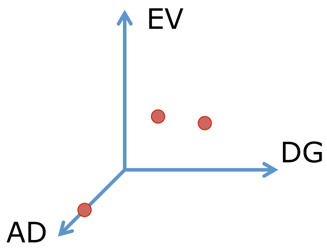


What is smart in this picture?



ROYAL INSTITUTE OF TECHNOLOGY

A structured approach to changes



- The Electric Power system is facing challenges in three dimensions.
  - Distributed (non-dispatchable) Generation
  - Active Demand
  - Introduction of Electric Vehicles
- The challenges vary from country to country, market to market.

ROYAL INSTITUTE OF TECHNOLOGY

Smartgrid ”summary”

- Surely the power system is facing challenges
- Many new technology features are offered as solutions
- Few discuss what the problem to solve actually entails

Outline of the lecture

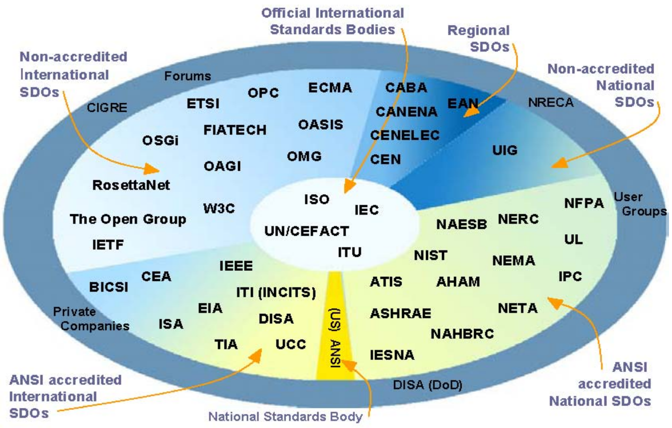
Course Philosophy
Course Administration
Lab Tour

Break

Computer Applications in Power Systems
Smartgrids a bit of history
The NIST report

The Problem with Standards

Standards-Related Organizations

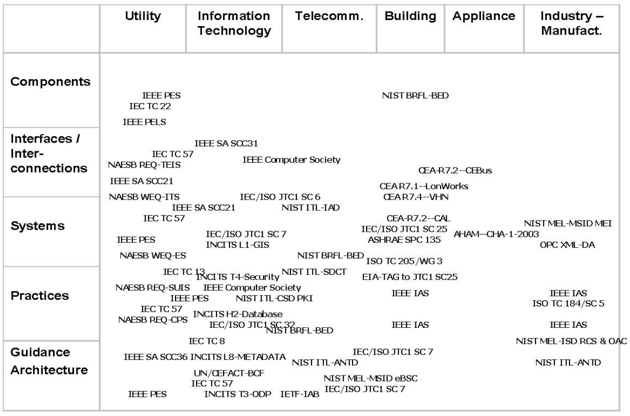


Source: GridWise Standards Mapping Overview by M.L. Bosquet, March, 2004

ROYAL INSTITUTE OF TECHNOLOGY

Standardisation Domains

Mapping Groups vs. Business Sectors



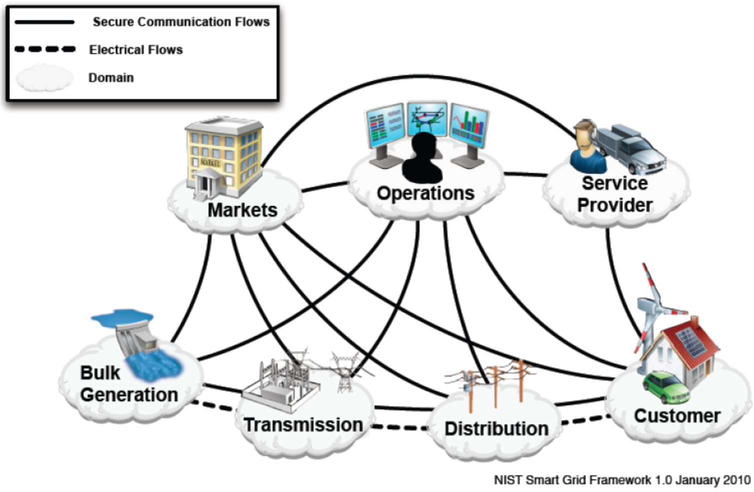
Source: GridWise Standards Mapping Overview by M.L. Bosquet, March, 2004

ROYAL INSTITUTE OF TECHNOLOGY

Some ongoing activities

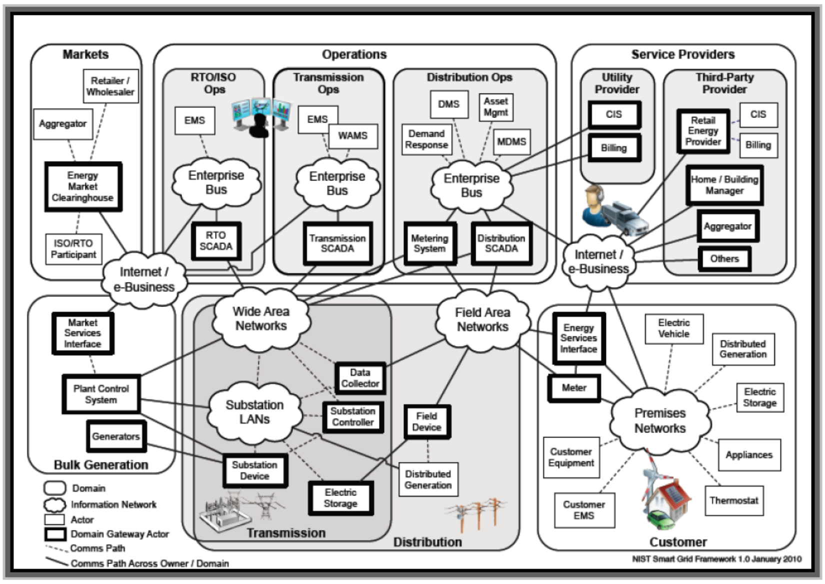
- IEC SMB Strategic group #3 ”Smartgrids”
- EU Mandate 490 - EU DG Energy TF on Smartgrids
- CENELEC/ETSI reference architecture for Smartgrids
- Mandate 441 – Smart Metering Coordination Group
- NIST SGIP – Smartgrids Interoperability Panel
- Mandate 468 –electric vehicle integration

NIST Smartgrids domains



Domain actors

Domain	Actors in the Domain
Customers	The end users of electricity. May also generate, store, and manage the use of energy. Traditionally, three customer types are discussed, each with its own domain: residential, commercial, and industrial.
Markets	The operators and participants in electricity markets.
Service Providers	The organizations providing services to electrical customers and utilities.
Operations	The managers of the movement of electricity.
Bulk Generation	The generators of electricity in bulk quantities. May also store energy for later distribution.
Transmission	The carriers of bulk electricity over long distances. May also store and generate electricity.
Distribution	The distributors of electricity to and from customers. May also store and generate electricity.



Customer Domain Details

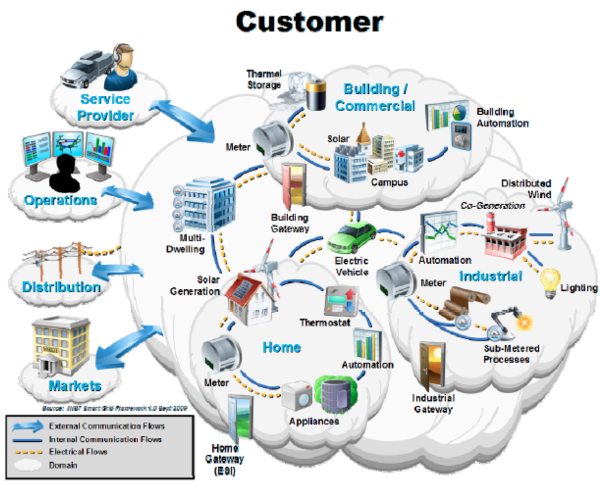


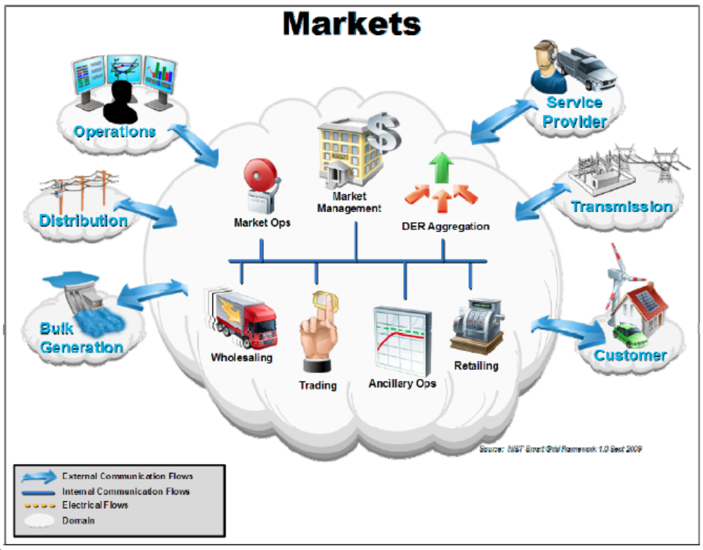
Figure 9-2. Customer Domain Diagram.

Customer Domain Details -II

Table 9-2. Typical Application Category in the Customer Domain.

Example Application Category	Description
Building or Home Automation	A system that is capable of controlling various functions within a building such as lighting and temperature control.
Industrial Automation	A system that controls industrial processes such as manufacturing or warehousing. These systems have very different requirements compared to home and building systems.
Micro-generation	Includes all types of distributed generation including; Solar, Wind, and Hydro generators. Generation harnesses energy for electricity at a customer location. May be monitored, dispatched, or controlled via communications.

Markets Domain Details

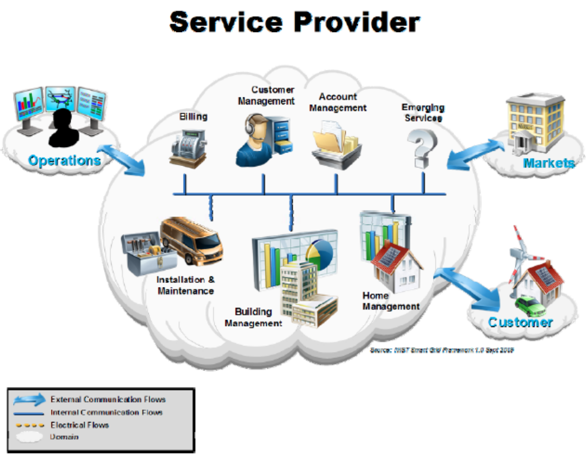


Markets domain details - II

Table 9-3. Typical Applications in the Markets Domain.

Example Application Category	Description
Market Management	Market managers include ISOs for wholesale markets or NYMEX/CME for forward markets in many ISO/RTO regions. There are transmission and services and demand response markets as well. Some DER Curtailment resources are treated today as dispatchable generation.
Retailing	Retailers sell power to end customers and may in the future aggregate or broker DER between customers or into the market. Most are connected to a trading organization to allow participation in the wholesale market.
DER Aggregation	Aggregators combine smaller participants (as providers or customers or curtailment) to enable distributed resources to play in the larger markets.

Service Provider Domain details – I

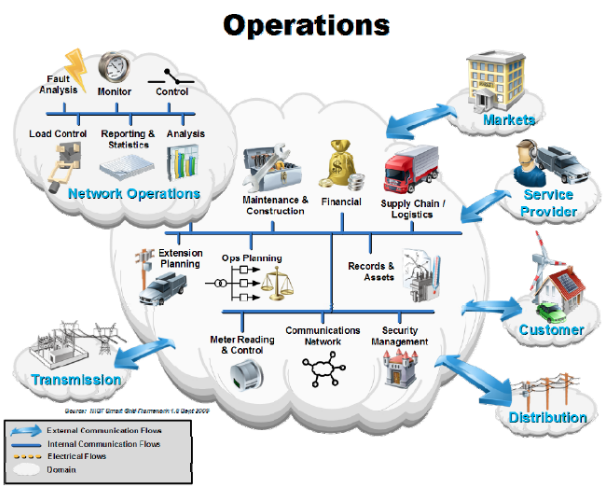


Service Provider Domain details – II

Table 9-4. Typical Applications in the Service Provider Domain.

Example Application Category	Description
Customer Management	Managing customer relationships by providing point-of-contact and resolution for customer issues and problems.
Installation & Management	Installing and maintaining premises equipment that interacts with the Smart Grid.
Building Management	Monitoring and controlling building energy and responding to Smart Grid signals while minimizing impact on building occupants.
Home Management	Monitoring and controlling home energy and responding to Smart Grid signals while minimizing impact on home occupants.

Operations Domain Details - I



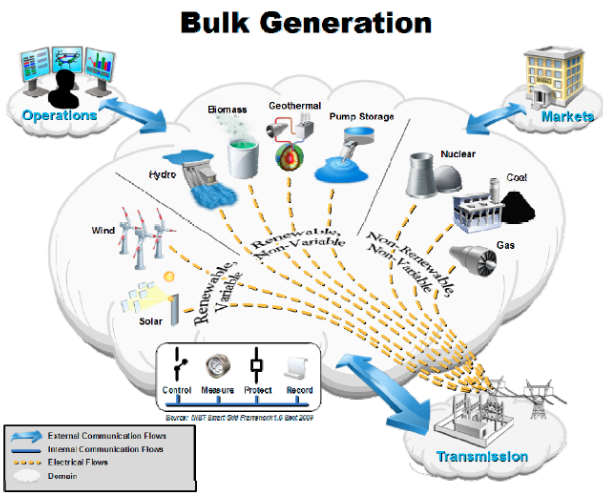
KTH VETENSKAP OCH KONST
ROYAL INSTITUTE OF TECHNOLOGY

Operations Domain Details - II

Example Application Category	Description
Monitoring	Network Operation Monitoring actors supervise network topology, connectivity and loading conditions, including breaker and switch states, and control equipment status. They locate customer telephone complaints and field crews.
Control	Network control is coordinated by actors in this domain, although they may only supervise wide area, substation, and local automatic or manual control.
Fault Management	Fault Management actors enhance the speed at which faults can be located, identified, and sectionalized and service can be restored. They provide information for customers, coordinate with workforce dispatch and compile information for statistics.

KTH VETENSKAP OCH KONST
ROYAL INSTITUTE OF TECHNOLOGY

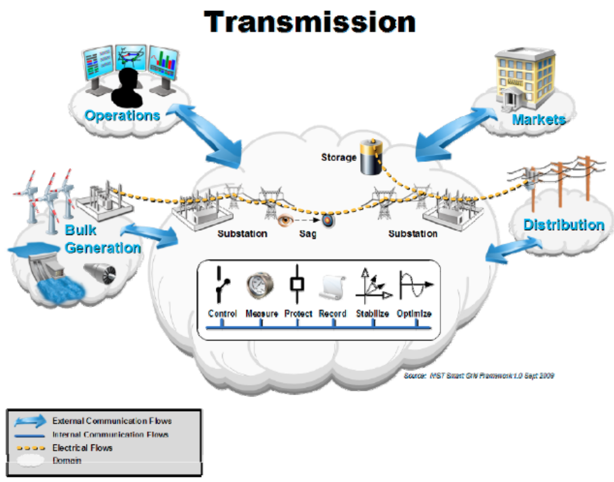
Bulk Generation Domain Details - I



Bulk Generation Domain Details - II

Example Application Category	Description
Control	Performed by actors that permit the Operations domain to manage the flow of power and reliability of the system. An example is the use of phase angle regulators within a substation to control power flow between two adjacent power systems
Measure	Performed by actors that provide visibility into the flow of power and the condition of the systems in the field. In the future, measurement might be found built into meters, transformers, feeders, switches and other devices in the grid. An example is the digital and analog measurements collected through the SCADA system from a remote terminal unit (RTU) and provide to a grid control center in the Operations domain.
Protect	Performed by Actors that react rapidly to faults and other events in the system that might cause power outages, brownouts, or the destruction of equipment. Performed to maintain high levels of reliability and power quality. May work locally or on a wide scale.

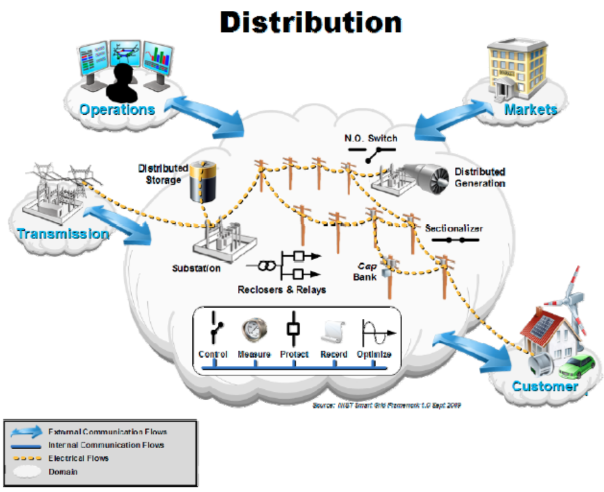
Transmission Domain Details – I



Transmission Domain Details – II

Example Application Category	Description
Substation	The systems within a substation.
Storage	A system that controls the charging and discharging of an energy storage unit
Measurement & Control	Includes all types of measurement and control systems to measure, record, and control with the intent of protecting and optimizing grid operation.

Distribution Domain Details - I



KTH VETENSKAP OCH KONST
ROYAL INSTITUTE OF TECHNOLOGY

Distribution Domain Details - II

Example Application Category	Description
Substation	The control and monitoring systems within a substation.
Storage	A system that controls a charging and discharging of an energy storage unit
Distributed Generation	A power source located on the distribution side of the grid.
Measurement & Control	Includes all types of measurement and control systems to measure, record, and control with the intent of protecting and optimizing grid operation.

KTH VETENSKAP OCH KONST
ROYAL INSTITUTE OF TECHNOLOGY

But what of all this will happen?

"Who" controls what in a distribution system?
Voltage?
Frequency?
Is there a price for storage?
Can production be curtailed?
Can the system supply itself?
Can the DSO shift load in time?

Is the ICT architecture secure?
Is the performance sufficient?
Are the measurements of high quality?
Can all the systems communicate?

m architecture
trol
,

Tools to manage this!?!

- A reference Architecture
  - What are the systems that will eb interacting?
  - What are their interfaces?
  - How does the power system interface the ICT system?
- Use Cases
  - Who are the actors that will use the systems?
  - What will they use it for?
  - Which systems will they interact with?
- Security and reliability
  - How do we maintain reliability
  - Security must not be compromised.
- Standards
  - How can systems be standardised?

Outline of the lecture

Course Philosophy
Course Administration
Lab Tour

Break

Computer Applications in Power Systems
Smartgrids a bit of history
The NIST report