Introduction to Smart Grids*

*SMART GRID
Fundamentals of Design and Analysis
by James Momoh, 2012

CHAPTER 2:

SMART GRID COMMUNICATIONS AND MEASUREMENT TECHNOLOGY

COMMUNICATION AND MEASUREMENT

High-speed, fully integrated, two-way communication technologies will allow the smart grid to be a dynamic, inter- active mega-infrastructure for real-time information and power exchange.

The technology exists for the measure, monitor, and control in real time in the Smart Grid, and this technology plays an essential role in the functioning of the Smart Grid.

COMMUNICATION AND MEASUREMENT

Obviously, existing measuring, monitoring, and control technology will have a role in smart grid capability.

Establishing appropriate standards, cyber security, and interoperability requires careful study, for example, formalizing the standards and protocols for the secure transmission of critical and highly sensitive information within the proposed communication scheme.

Moreover, open architecture's plug-and-play environment will provide secure network smart sensors and control devices, control centers, protection systems, and users.

COMMUNICATION AND MEASUREMENT

Possible wired and wireless communications technologies can include:

- Multiprotocol Label Switching (MPLS): high-performance telecommunications networks for data transmission between network nodes
- Worldwide Interoperability for Microwave Access (WiMax): wireless telecommunication technology for point to multipoint data transmission utilizing Inter net technology
- Broadband over Power Lines (BPL): power line communication with Internet access
- Wi-Fi: commonly used wireless local area network

COMMUNICATION AND MEASUREMENT

Additional technologies include optical fiber, mesh, and multipoint spread spectrum.

The five characteristics of smart grid communications technology are:

1. High bandwidth
2. IP-enabled digital communication (IPv6 support is preferable)
3. Encryption
4. Cyber security
5. Support and quality of service and Voice over Internet Protocol (VoIP)

MONITORING, PHASOR MEASUREMENT UNITS, SMART METERS, AND MEASUREMENTS TECHNOLOGIES

The smart grid environment requires the upgrade of tools for sensing, metering, and measurements at all levels of the grid.

These components will provide the data necessary for monitoring the grid and the power market.

Sensing provides outage detection and response,

evaluates the health of equipment and the integrity of the grid,

eliminates meter estimations, provides energy theft protection,

enables consumer choice, DSM, and various grid monitoring functions.

WIDE AREA MONITORING SYSTEMS (WAMS)

WAMS are designed by the utilities for optimal capacity of the transmission grid and to prevent the spread of disturbances.
WAMS give early warnings of system disturbances for the prevention and mitigation of system-wide blackouts.
WAMS utilize sensors distributed throughout the network in conjunction with GPS satellites for precise time stamping of measurements in the transmission system.
The integrated sensors will interface with the communication network. Phasor Measurements are a current technology that is a component of most smart grid designs.

PHASOR MEASUREMENT UNITS (PMU)

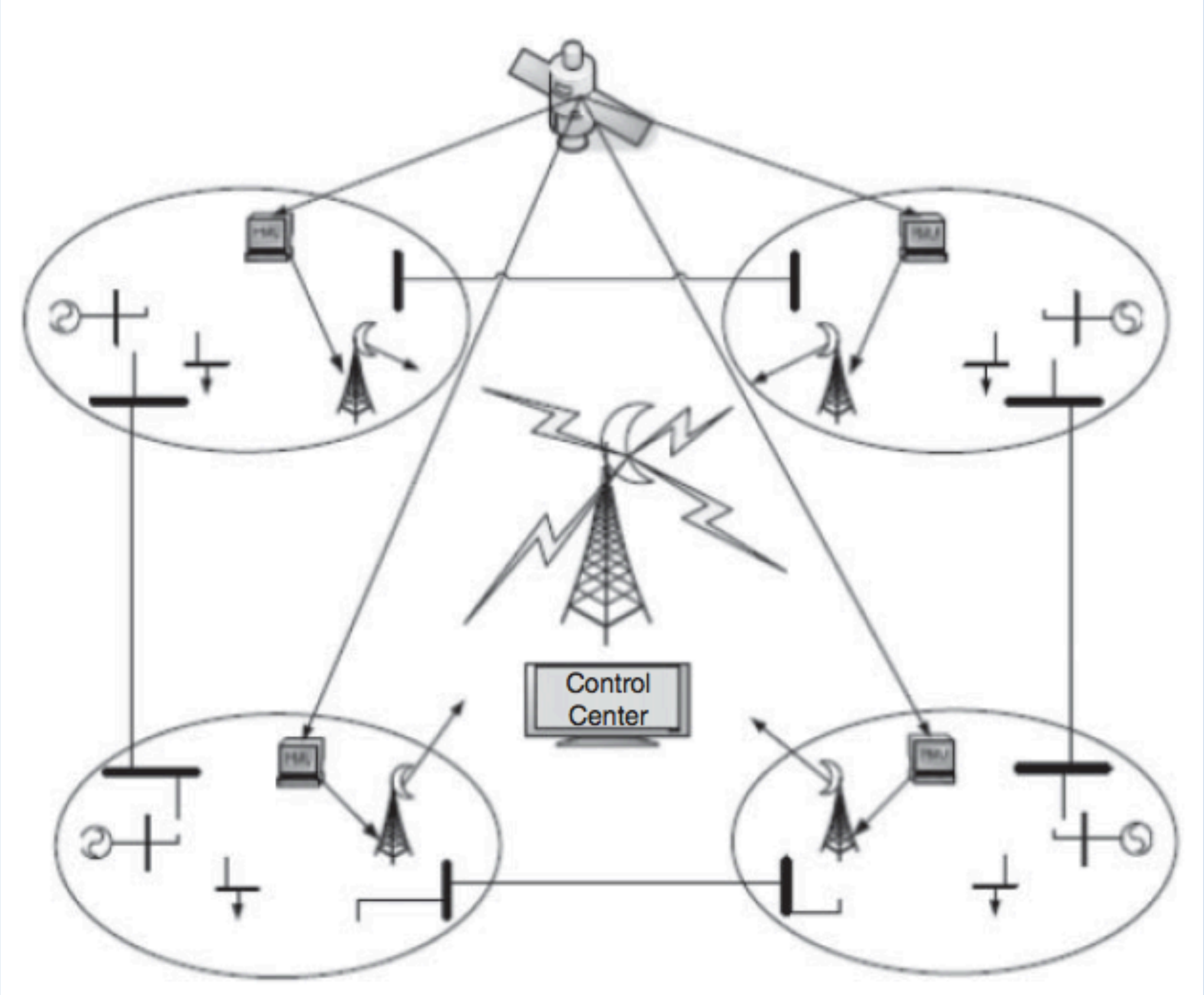
PMUs or Synchrophasors give operators a time-stamped snapshot of the power system.

The PMUs consist of bus voltage phasors and branch current phasors, in addition to information such as locations and other network parameters.

Phasor measurements are taken with high precision from different points of the power system at the same instant, allowing an operator to visualize the exact angular difference between different locations.

PMUs are equipped with GPS receivers which allow synchronization of readings taken at distant points.

PHASOR MEASUREMENT UNITS (PMU)



The PMU measurement system

SMART METERS

Smart meters have two functions:

- providing data on energy usage to customers (end- users) to help control cost and consumption
- sending data to the utility for load factor control, peak-load requirements, and the development of pricing strategies based on consumption information and so on Automated data reading is an additional component of both smart meters and two-way communication between customers and utilities. The development of smart meters is planned for electricity, water, and gas consumption.

SMART METERS

Smart meters equip utility customers with knowledge about how much they pay per kilowatt hour and how and when they use energy. This will result in better pricing information and more accurate bills in addition to ensuring faster outage detection and restoration by the utility. Additional features will allow for demand-response rates, tax credits, tariff options, and participation in voluntary rewards programs for reduced consumption. Still other features will include remote connect/disconnect of users, appliance control and monitoring, smart thermostat, enhanced grid monitoring, switching, and prepaid metering.

SMART APPLIANCES

Smart appliances cycle up and down in response to signals sent by the utility. The appliances enable customers to participate in voluntary demand response programs which award credits for limiting power use in peak demand periods or when the grid is under stress. An override function allows customers to control their appliances using the Internet.

Air conditioners, space heaters, water heaters, refrigerators, washers, and dryers represent about 20% of total electric demand during most of the day and throughout the year. Grid-friendly appliances use a simple computer chip that can sense disturbances in the grid's power frequency and can turn an appliance off for a few minutes to allow the grid to stabilize during a crisis.

ADVANCED METERING INFRASTRUCTURE (AMI)

AMI is the convergence of the grid, the communication infrastructure, and the supporting information infrastructure. The network-centric AMI coupled with the lack of a composite set of cross industry AMI security requirements and implementation guidance, is the primary motivation for its development. The problem domains to be addressed within AMI implementations are relatively new to the utility industry; however, precedence exists for implementing large-scale, network-centric solutions with high information assurance requirements. The defense, cable, and telecom industries offer many examples of requirements, standards, and best practices that are directly applicable to AMI implementations.

ADVANCED METERING INFRASTRUCTURE (AMI)

The functions of AMI can be subdivided into three major categories:

- **Market applications:** serve to reduce/eliminate labor, transportation, and infrastructure costs associated with meter reading and maintenance, increase accuracy GIS AND GOOGLE MAPPING TOOLS 23 of billing, and allow for time-based rates while reducing bad debts; facilitates informed customer participation for energy management

- **Customer applications:** serves to increase customer awareness about load reduction, reduces bad debt, and improves cash flow, and enhances customer convenience and satisfaction; provides demand response and load management to improve system reliability and performance

- **Distribution operations:** curtails customer load for grid management, optimizes network based on data collected, allows for the location of outages and restoration of service, improves customer satisfaction, reduces energy losses, improves performance in event of outage with reduced outage duration and optimization of the distribution system and distributed generation management, provides emergency demand response

GIS AND GOOGLE MAPPING TOOLS

GIS is useful for managing traditional electric transmission and distribution and telecom networks. It can also help to manage information about utility assets for data collection and maintenance.

Google's free downloadable Google Earth software offers geographical contextual information in an updated user-friendly platform that facilitates inquiry-based study and analysis. Users can create and share many types of dynamically-updating data over the Internet. Keyhole Markup Language (KML) allows them to overlay basic data types such as images, point data, lines, and polygons. Through satellite imagery, maps are available from space to street-level. The integration of GIS with Google Earth or other mapping tools will aid in understanding the relationship of the grid network to its surroundings, for example, determining the optimal location of rights of way, placement of sensors and poles, and so on. GIS technology will provide partial context to operators and planners, for example, real-time sensors that collect the data needed to reconfigure networks for reducing outages and equipment failures.

GIS AND GOOGLE MAPPING TOOLS

The **trends** in the development of the electric power system and the **expectation** of future demand suggest the following **needs**:

- Reducing outage time
- Preventing power theft which causes significant unaccounted losses
- Effective system for collection and billing system
- Expanding services for customers
- Effective asset management
- Improving reliability such as SAIDI (System Average Interruption Duration
- Index) and SAIFI (System Average Interruption Frequency Index) for distribution networks
- Improving analysis of customer complaint logs
- Enhancing load flow power quality analysis and fault study for current and anticipated problems
- Scheduling of actions such as load shedding and vegetation control

MULTIAGENT SYSTEMS (MAS) TECHNOLOGY

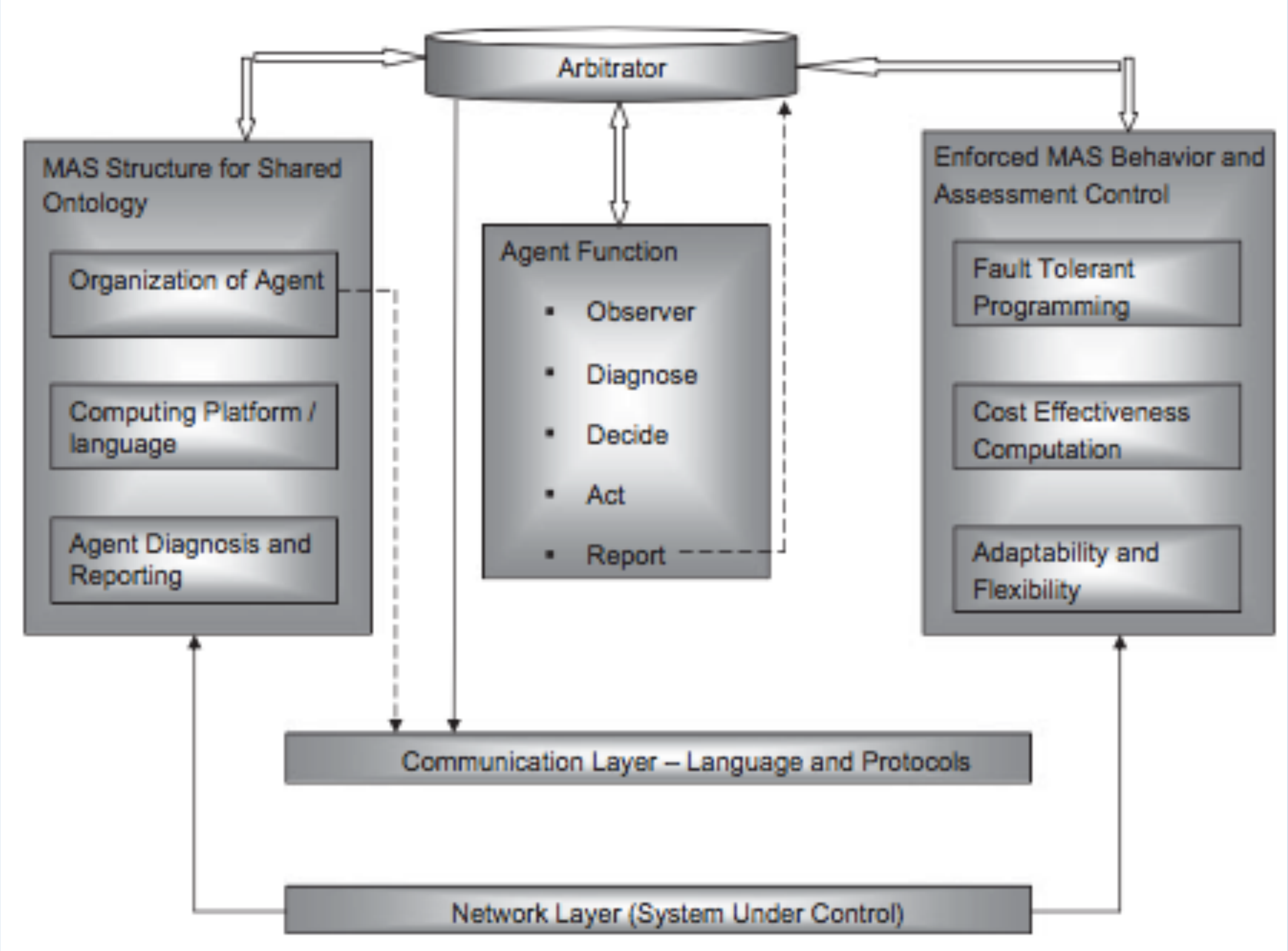
MAS are a computational system in which several agents cooperate to achieve a desired task.

Increasingly, MAS are the preferential choice for developing distributed systems. The development of monitoring and measurement schemes within the smart grid environment can be enhanced through the use of MAS architecture.

As an example, MAS have been utilized as a detection and diagnosis device and in system monitoring. Such architectures utilize a collection of agents such as Arbitrator Agents (AA), System Monitoring Agents (SMA), Fault Detection Agents (FDA), Diagnosis Agents (DA), a Judgment Index Agent (JIA), and a Scheduling Agent (SA).

Information passes between the agents about the appropriate actions to be taken. When implemented, the process repeats itself to constantly monitor the system so that management of system conditions can be implemented instantaneously.

MULTIAGENT SYSTEMS (MAS) TECHNOLOGY



Simplified multiagent architecture

Multiagent Systems for Smart Grid Implementation

A smart grid integrates advanced sensing technologies, control methods, and integrated communications into the present electricity grid at both transmission and distribution levels.

The smart grid is expected to have the following key characteristics:

- Self-healing
- Consumer friendly
- Attack resistant
- Provide power quality for 21st-century needs
- Accommodate all generation and storage option
- Enable markets
- Optimize assets and operate efficiently

Multiagent Specifications

The specifications of a control agent, a distributed energy resource (DER) agent, a user agent, and a database agent in the Intelligent Distributed Autonomous Power System (IDAPS) MAS are defined here.

Control agent: responsibilities include monitoring system voltage and frequency to detect contingency situations or grid failures, and sending signals to the main circuit breaker to isolate the IDAPS microgrid from the utility when an upstream outage is detected; receiving electricity price ($/kWh) signal from the main grid and publishing them to the IDAPS entities

Multiagent Specifications

DER (distributed energy resource) ***agent:*** responsibilities include storing associated DER information, monitoring and controlling DER power levels and connect/disconnect status; DER information to be stored may include DER identification number, type (solar cells, microturbines, fuel cells), power rating (kW), local fuel availability, cost function or price at which users agree to sell, DER availability, that is, planned maintenance schedule

Multiagent Specifications

User agent: acts as a customer gateway that makes features of an IDAPS microgrid accessible to users; responsibilities include providing users with real- time information on entities residing in the IDAPS system; monitors electricity consumption by each critical and noncritical load; allows users to control the status of loads based on user's predefined priority

Database agent: serves as a data access point for other agents as well as users; responsibilities include storing system information, recording messages and data shared among agents

Multiagent Technique

An agent of a MAS may be defined as an entity with attributes considered useful in a particular domain. In this framework, an agent is an information processor that performs autonomous actions based on information.

Common **agent attributes** include:

- ***Autonomy:*** goal-directedness, proactive and self-starting behavior
- ***Collaborative behavior:*** the ability to work with other agents to achieve a common goal
- ***Knowledge-level communication ability:*** the ability to communicate with other agents with language resembling human speech acts rather than typical symbol- level program-to-program protocols
- ***Reactivity:*** the ability to selectively sense and act
- ***Temporal continuity:*** persistence of identity and state over long periods

Multiagent Technique

MAS can be **characterized** by:

- Each agent has incomplete capabilities to solve a problem
- No global system control
- Decentralized data
- Asynchronous computation

MICROGRID AND SMART GRID COMPARISON

Basically, **a microgrid is a local island grid** that can operate as a stand-alone or as a grid-connected system. It is powered by gas turbines or renewable energy and includes special purpose inverters and a link for plug-and-play to the legacy grid. Special purpose filters overcome harmonics problems while improving power quality and efficiency.

The **microgrid is a local power provider**

- with limited advanced control tools

The **smart grid is a wide area provider**

- with sophisticated automated decision support capabilities