Introduction to Smart Grids*

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

CHAPTER 1:

SMART GRID ARCHITECTURAL DESIGNS

INTRODUCTION

Today's electric grid was **designed to operate** as a **vertical structure** consisting of

- Generation,
- Transmission
- Distribution

Today's electric grid was **supported** with controls and devices **to maintain**

- Reliability
- Stability
- Efficiency

INTRODUCTION

However, **system operators** are now facing **new challenges** including:

- the penetration of renewable energy resources (RER) in the legacy system
- rapid technological change
- different types of market players and end users

INTRODUCTION

The next iteration, **the smart grid**, will be equipped with

- communication support schemes
- real-time measurement techniques

INTRODUCTION

The **new grid** will be **capable of**:

- Handling uncertainties in schedules and power transfers across regions
- Accommodating renewables
- Optimizing the transfer capability of the transmission and distribution networks
- Meeting the demand for increased quality and reliable supply
- Managing and resolving unpredictable events and uncertainties in operations and planning more aggressively

TODAY'S GRID VERSUS THE SMART GRID

Table: Comparison of Today's Grid versus Smart Grid

Preferred Characteristics	Today's Grid	Smart Grid
Active Consumer Participation	Consumers are uninformed and do not participate	Informed, involved consumers — demand response and distributed energy resources
Accommodation of all generation and storage options	Dominated by central generation—many obstacles exist for distributed energy resources interconnection	Many distributed energy resources with plug-and-play convenience focus on renewables
New products, services, and markets	Limited, poorly integrated wholesale markets; limited opportunities for consumers	Mature, well-integrated wholesale markets; growth of new electricity markets for consumers
Provision of power quality for the digital economy	Focus on outages—slow response to power quality issues	Power quality a priority with a variety of quality/price options —rapid resolution of issues

TODAY'S GRID VERSUS THE SMART GRID

Table: Comparison of Today's Grid versus Smart Grid (continued)

Preferred Characteristics	Today's Grid	Smart Grid
Optimization of assets and operates efficiently	Little integration of operational data with asset management—business process silos	Greatly expanded data acquisition of grid parameters; focus on prevention, minimizing impact to consumers
Anticipating responses to system disturbances (self-healing)	Responds to prevent further damage; focus on protecting assets following a fault	Automatically detects and responds to problems; focus on prevention, minimizing impact to consumers
Resiliency against cyber attack and natural disasters	Vulnerable to malicious acts of terror and natural disasters; slow response	Resilient to cyber attack and natural disasters; rapid restoration capabilities

RATIONALE FOR THE SMART GRID

- Identification and lowering of unreasonable or unnecessary barriers to adoption of smart grid technologies, practices, and services options.
- Provision to consumers of timely information and control options.
- Increased use of digital information and controls technology to improve reliability, security, and efficiency of the electric grid.
- Development and incorporation of demand response, demand-side resources, and energy-efficiency resources.
- Deployment and integration of advanced electricity storage and peak-shaving technologies, including plug-in electric vehicles, and thermal-storage air conditioning.

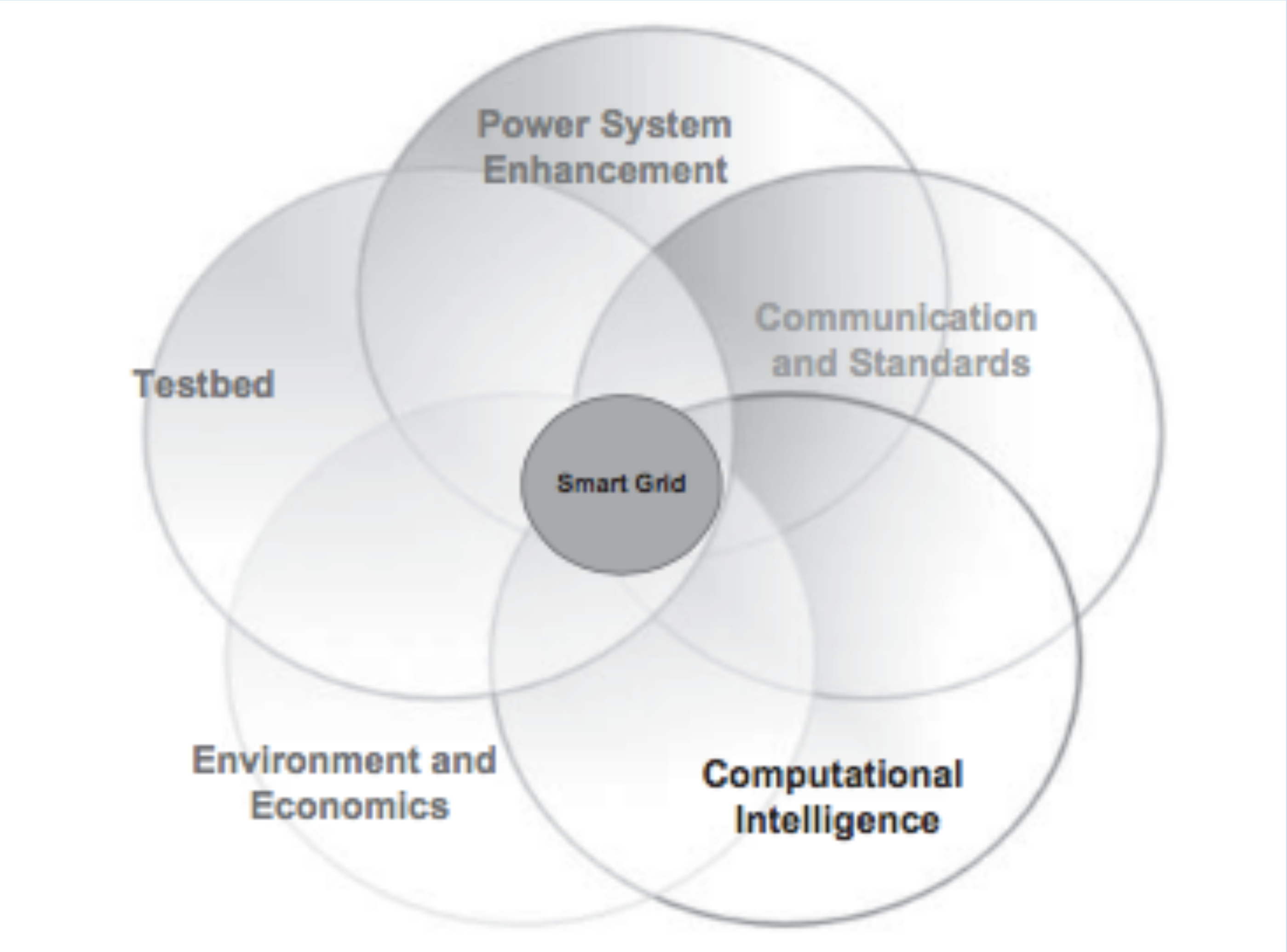
The features needed to facilitate the development of an energy-efficient and reliable system

RATIONALE FOR THE SMART GRID

- Dynamic optimization of grid operations and resources, with full cyber-security.
- Deployment and integration of distributed resources and generation, including renewable resources.
- Integration of "smart" appliances and consumer devices.
- Development of standards for communication and interoperability of appliances and equipment connected to the electric grid, including the infrastructure serving the grid options.
- Deployment of "smart" technologies (real-time, automated, interactive technologies that optimize the physical operation of appliances and consumer devices) for metering, communications concerning grid operations and status, and distribution automation.

The features needed to facilitate the development of an energy-efficient and reliable system

FIVE KEY ASPECTS



Five key aspects of smart grid development and deployment

1. COMPUTATIONAL INTELLIGENCE

Computational intelligence is the term used to describe the advanced analytical tools needed to optimize the bulk power network

The toolbox will include:

- Heuristic
- Evolution Programming
- Decision Support Tools
- Adaptive Optimization Techniques

FIVE KEY ASPECTS

2. POWER SYSTEM ENHANCEMENT

Policy-makers assume greatly expanded use of renewable energy resources will:

- help to offset the impacts of carbon emissions from thermal and fossil energy
- meet demand uncertainty
- increase reliability of delivery

3. COMMUNICATION AND STANDARDS

Since planning horizons can be short as an hour ahead, the smart grid's advanced automations will generate **vast amounts of operational data** in a rapid decision-making environment.

New algorithms will help it become adaptive and capable of predicting with foresight.

In turn, **new rules** will be needed for:

- managing
- operating
- marketing networks.

4. ENVIRONMENT AND ECONOMICS

When **fully developed the smart grid system** will allow:

- customer involvement
- enhance generation and transmission with tools to allow minimization of system vulnerability, resiliency, reliability, adequacy and power quality

The training tools and capacity development to manage and operate the grids and hence crate new job opportunities is part of the desired goals of the smart grid evolution

FIVE KEY ASPECTS

5. TEST-BED

The smart grid evolution which will be tested using test-bed.

To achieve the rapid deployment of the grids test bed and research centers need to work across disciplines to build the first generation of smart grid.

GENERAL VIEW OF THE SMART GRID
MARKET DRIVERS

To improve efficiency and reliability, several market drivers and new opportunities suggest that **the smart grid must**:

- Satisfy the need for increased integration of digital systems for increased efficiency of the power system. In the restructured environment, the deregulated electric utility industry allows a renovation of the market to be based on system constraints and the seasonal and daily fluctuations in demand. Competitive markets increase the shipment of power between regions, which further strains today's aging grid and requires updated, real-time controls.

GENERAL VIEW OF THE SMART GRID MARKET DRIVERS (continued)

To improve efficiency and reliability, several market drivers and new opportunities suggest that **the smart grid must**:

- Handle grid congestion, increase customer participation, and reduce uncertainty for investment. This requires the enhancement of the grid's capability to handle demand reliably.
- Seamlessly integrate renewable energy systems (RES) and distributed generation. The drastic increase in the integration of cost-competitive distributed generation technologies affects the power system.

STAKEHOLDER ROLES AND FUNCTION

As in the legacy system, **critical attention** must be paid to the **identification of the stakeholders** and how they function in the grid's development.

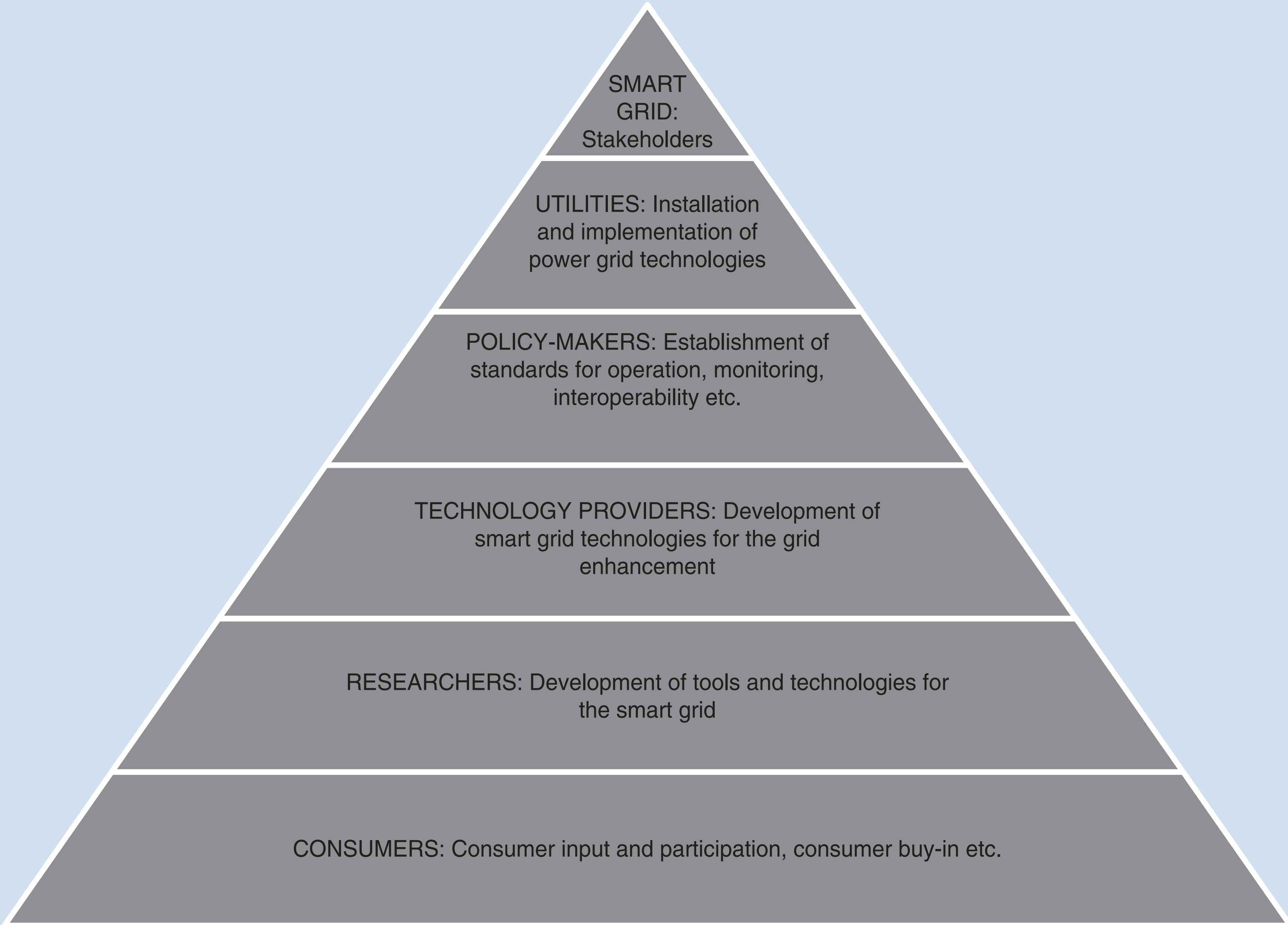
Stakeholders range from utility and energy producers to consumers, policy-makers, technology providers, and researchers.

An important part of the realization of the smart grid is the complete buy-in or involvement of all stakeholders.

Policy-makers are the state regulators responsible for ensuring the cohesiveness of policies for modernization efforts and mediating the needs of all parties.

The **primary benefit** of smart grid development to these stakeholders concerns the mitigation of energy prices, reduced dependence on foreign oil, increased efficiency, and reliability of power supply.

STAKEHOLDER ROLES AND FUNCTION



Stakeholders and their functions

Key Characteristics of the Intelligent Power Grid

The key characteristics are:

- **Grid equipment** and assets contain or are monitored by intelligent IP-enabled devices (digital processors)
- **Digital communication networks** permit the intelligent devices to communicate securely with the utility enterprise and possibly with each other
- **Data** from the intelligent devices and many other sources are consolidated to support the transformation of raw data into useful information through advanced analytics
- **Business intelligence and optimization tools** provide advanced decision support at both the automatic and human supervisory level

WORKING DEFINITION OF THE SMART GRID

A **working definition** should include the following **attributes**:

- **Assess grid health** in real time
- **Predict behavior**, anticipate
- **Adapt to new environments** like distributed resources and renewable energy resources
- **Handle stochastic demand** and respond to smart appliances
- **Provide self-correction**, reconfiguration, and restoration
- **Handle randomness** of loads and market participants in real time
- **Create** more **complex interactive behavior** with intelligent devices, communication protocols, and standard and smart algorithms to improve smart communication and transportation systems.

WORKING DEFINITION OF THE SMART GRID

The working definition becomes:

The smart grid is an advanced digital two-way power flow power system capable of self-healing, and adaptive, resilient, and sustainable, with foresight for prediction under different uncertainties

It is equipped for interoperability with present and future standards of components, devices, and systems that are cyber-secured against malicious attack