EE535 Smart Grids

Lecture No: 1 and 2

Syed Abdul Rahman Kashif
University of Engineering and Technology Lahore

Course Outline

Lecture Schedule	Wednesday 10am-1pm	Semester	Fall 2015
Credit Hours	Three	Pre-requisite	**Power Engineering (UG)**
Instructor	Syed Abdul Rahman Kashif	Contact	**abdulrahman@uet.edu.pk**
Office	Ground Floor, EE Department	Office Hours	**Friday 1:30 to 3:00 PM 08:00 am – 10:00am**
Teaching Assistant	None	Lab Schedule	**N/A**
Office	N/A	Office Hours	**N/A**
Course Description	**This course will examine not just the smart grid technologies, but the transformational impacts of the smart grid on the industry. Students in this course will learn the fundamentals of the smart grid and its architectures, basics of power system analysis and simulations, integration of renewable energy, load and demand side management, smart grid communication; measurement and control, micro-grids, system reliability and ancillary services**		
Expected Outcomes	**Upon completion of this course, students will: -Various aspects of smart grid: Technologies, Components, Architectures and Applications -How a smart grid can be designed to meet the needs of a utility, including: Meeting utility's objectives, helping to adopt new technologies into the grid and creating a framework for power engineers to operate the grid more effectively -The issues and challenges that remain to be solved.**		
Textbooks	**Text: Ali Keyhani and Muhammad Marwali, "Smart Power Grids 2011", Springer, 2011**		

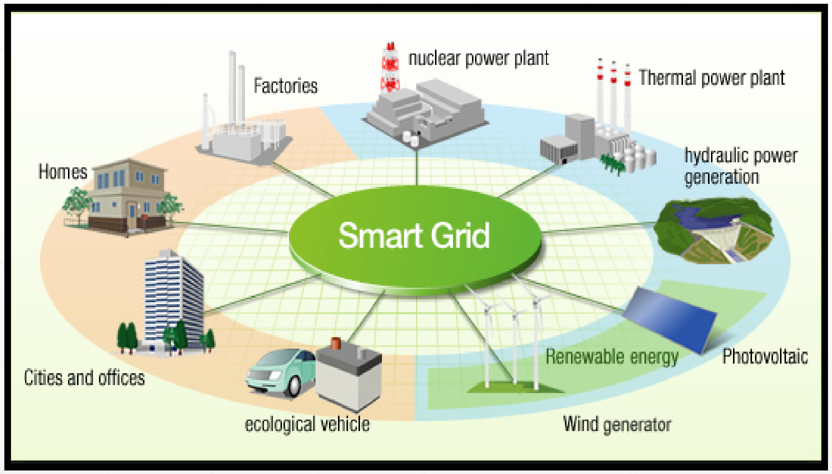
Course Overview

Question

What is Smart Grid??

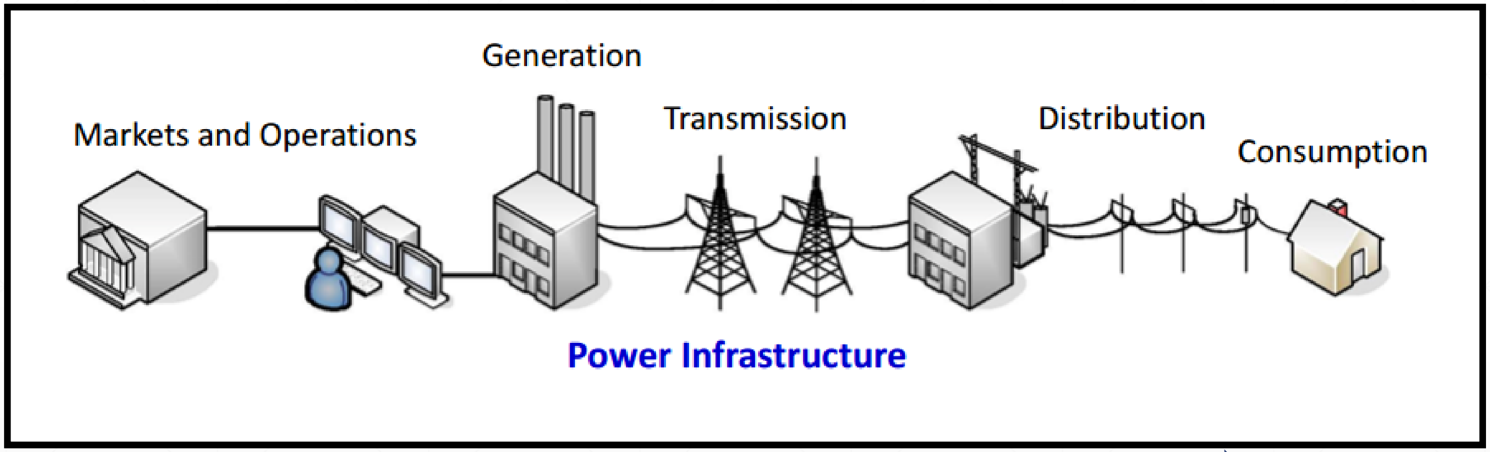
Short Answer

Smart Grid
=
IT + Electric Grid



What is Smart Grid?

- Traditional Power Grid



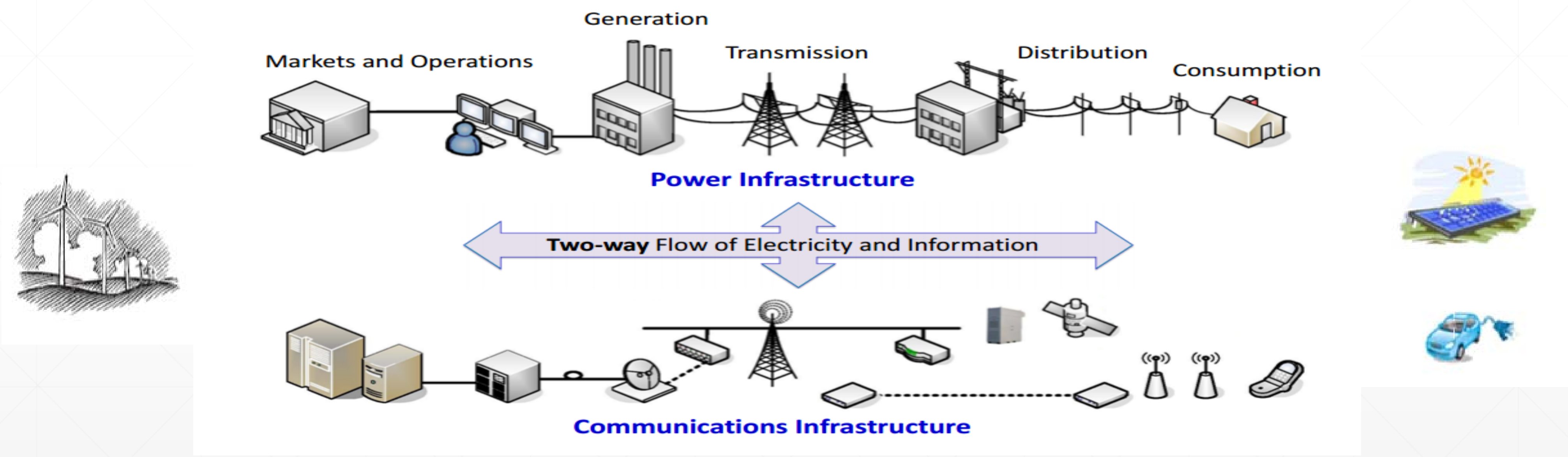
Centralized, Bulk Generation Limited Automation

One way flow of Electricity

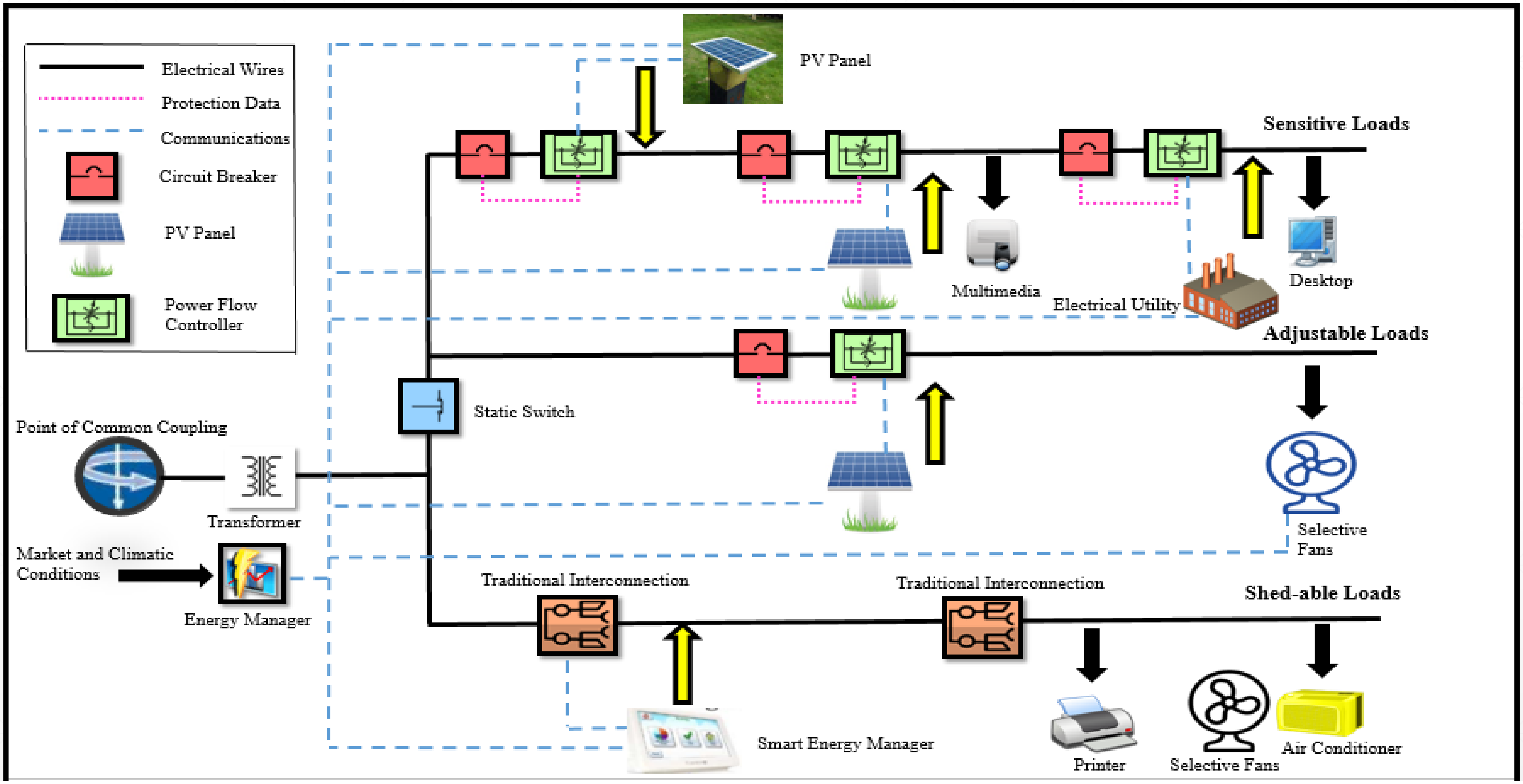
Consumers can't manage energy usage

What is Smart grid Cont'd

- Future Smart Grid



Concept of Smart Grid Architecture/Micro Grid



Chapter 1 : Smart Power Grids

"The optimum operation and control of power grid systems where every energy user can be energy user and energy producer may be designated as a smart power grid."

Fossil Fuels: Hazardous for environment

Integration of Renewable and Green Energy resources

Amin coined the word "Smart Grid" in 2005

Depletion of Limited Energy Resources

Global Warming

1.2 & 1.3 Solar and Wind Power Energy

- Insolation refers to exposure to the rays of the sun, i.e., the word "insolation" has been used to denote the solar radiation energy received at a given location at a given time.

Factors affecting Insolation

Location, Season, Humidity, Temperature, Air Mass, Hour of Day

- Local effects on wind include the differential heating of the land and the sea, and topography such as mountains valleys. The average wind speed determines the wind energy potential at a particular site.

Wind is described by its Speed and Direction

The speed is the angular speed of rotation and then translated into linear speed

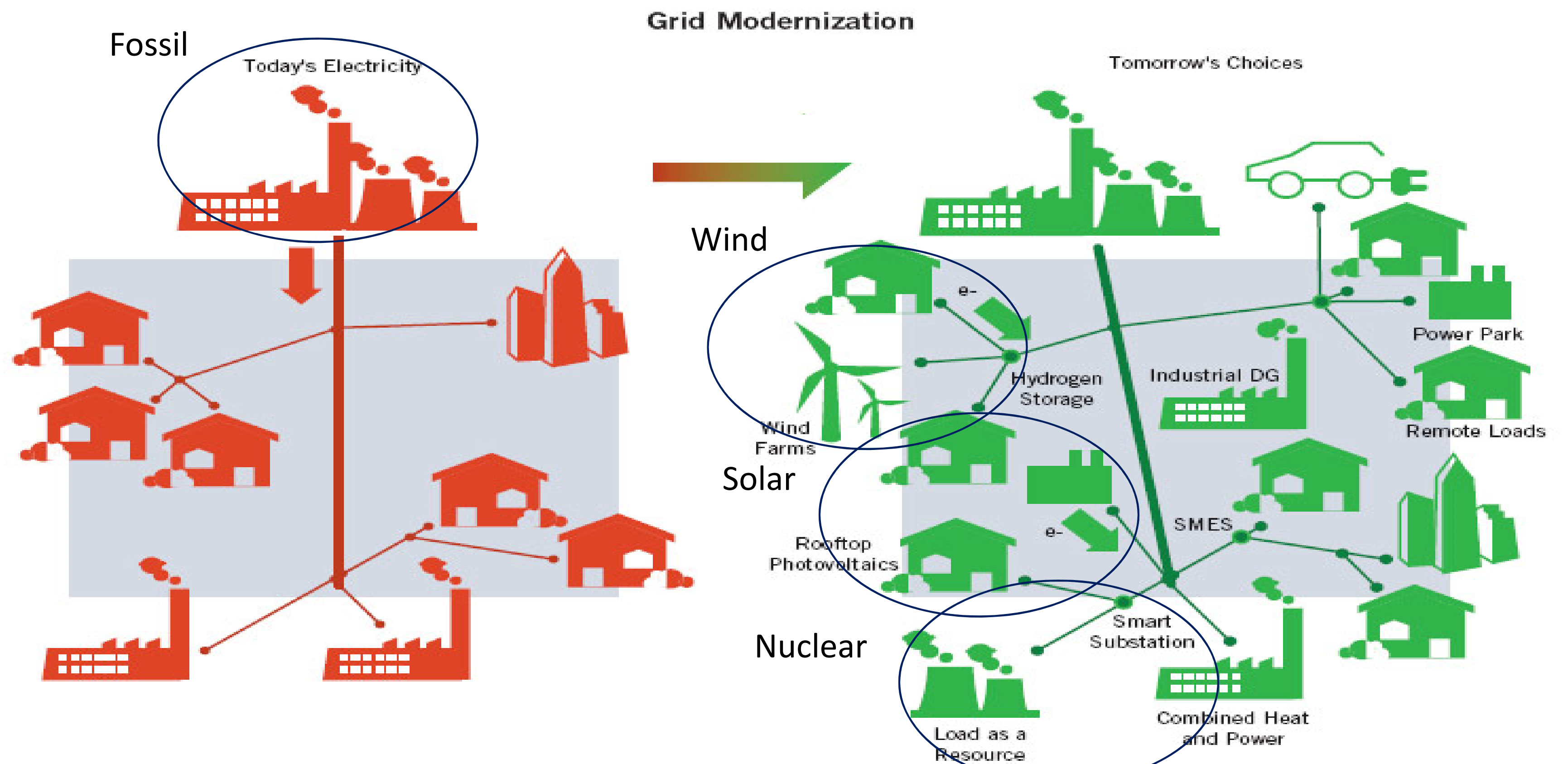


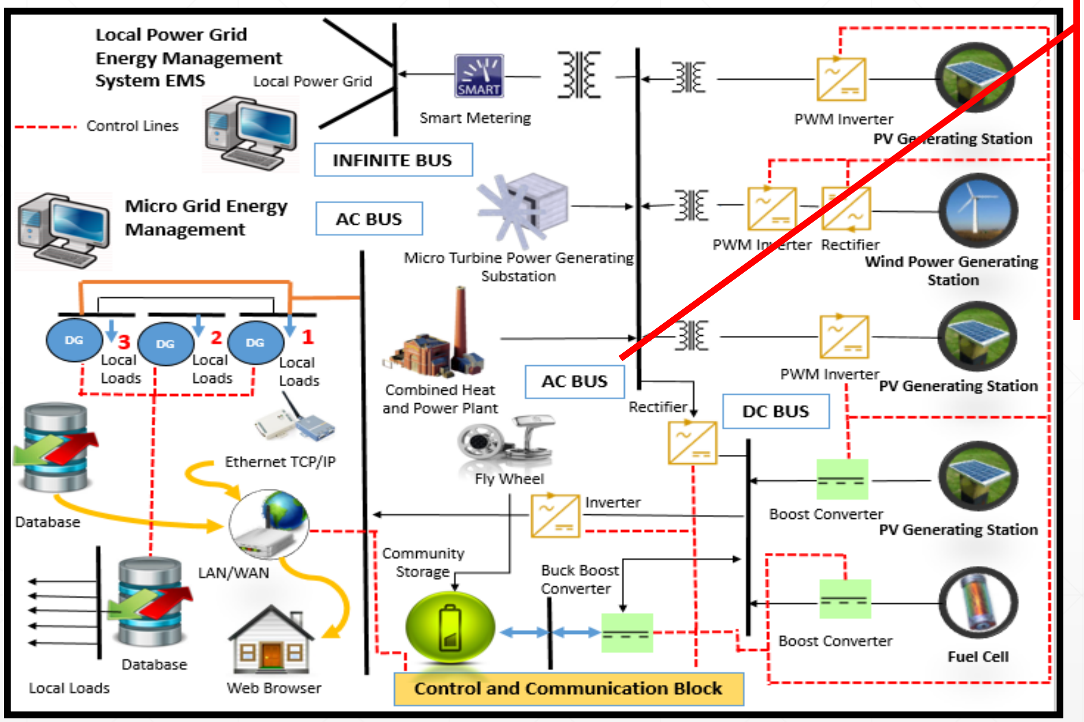
Fig. 1. The IEEE's version of the Smart Grid involves distributed generation, information networks, and system coordination, a drastic change from the existing utility configurations.

http://powerelectronics.com/power_systems/smart-grid-success-rely-system-solutions-20091001/

1.4 Micro-grid of Renewable and Green Energy (MRG) Power Grids

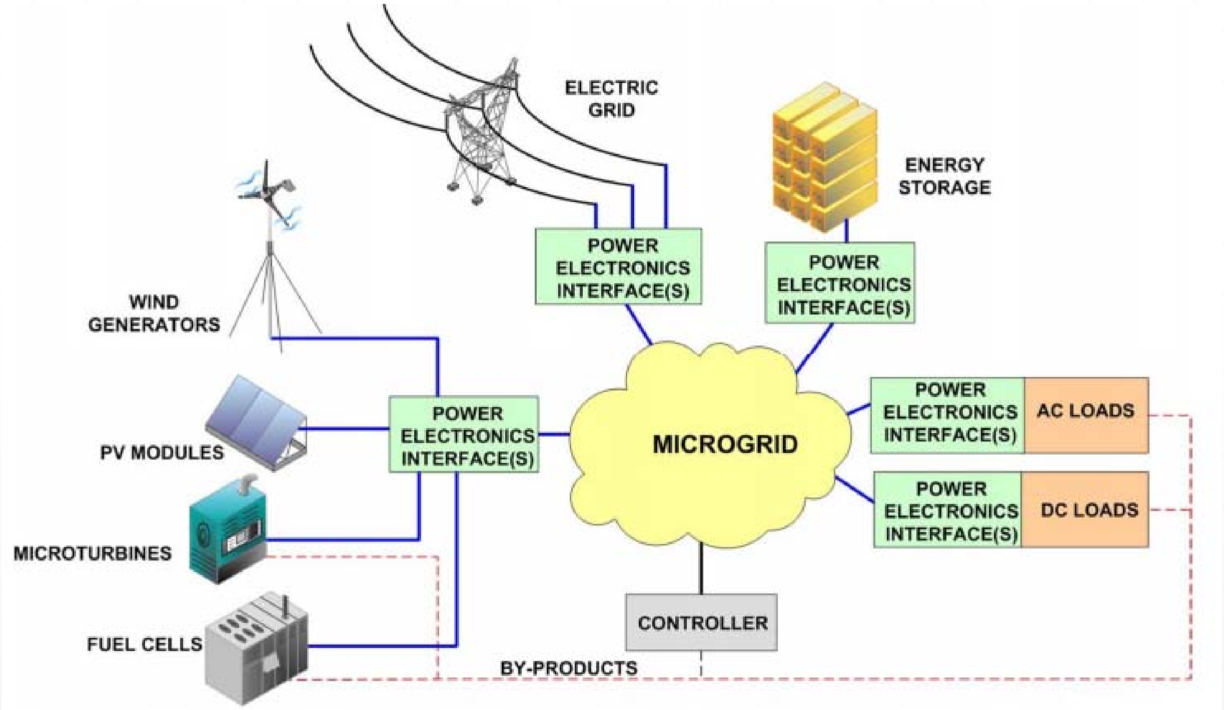
MRG Energy Systems

Energy Sources
• PV
• Wind Power
• Green Energy Sources (fuel cells, high speed micro-turbine generating stations)



When MRG systems are synchronized to AC bus of the local power grids, the AC bus voltage and frequency are controlled by the local power grid's energy management.

Concept of Micro Grid



1.5 Control Operation of Interconnected Network Bulk Power Grids

Step 1: As new green energy resources are adopted, converters must be integrated

Step 2: Schedule power generation to supply the system loads

Step 3: All resources must be managed and synchronized to satisfy the load demand of the power grid.

Step 4: Energy resources must be optimized to satisfy the peak demand of each load cycle.

Step 5: Tie lines are controlled to import or export power according to set agreed contracts

$$ACE = \Delta P_{TL} - \beta \Delta f$$

$$\Delta P_{TL} = P_{Sch} - P_{Actual}$$

$$\Delta f = f_S - f_{Actual}$$

P_{Sch} : The scheduled power flow between two power networks

P_{Actual} : The actual power flow between two power networks

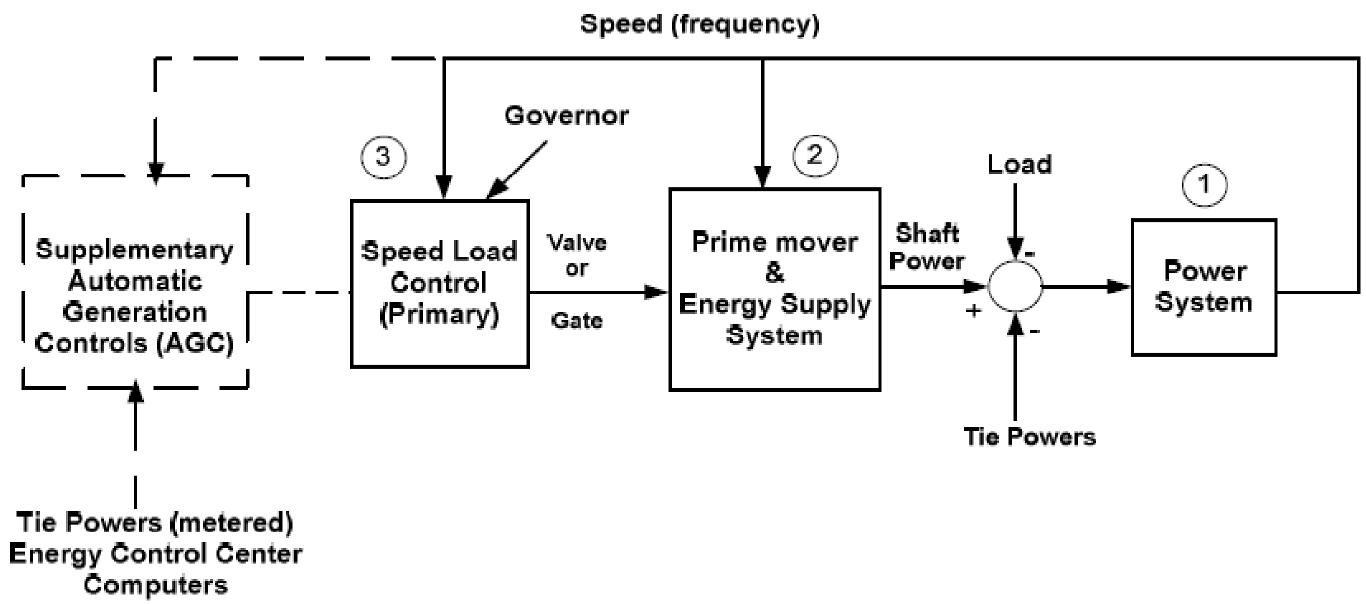
f_s : The reference frequency, i.e., the rated frequency

f_{actual} : The actual measured system frequency

β : The frequency bias

Area Control Error Concept

Automatic Generation Control



1.6 Smart Power Grid

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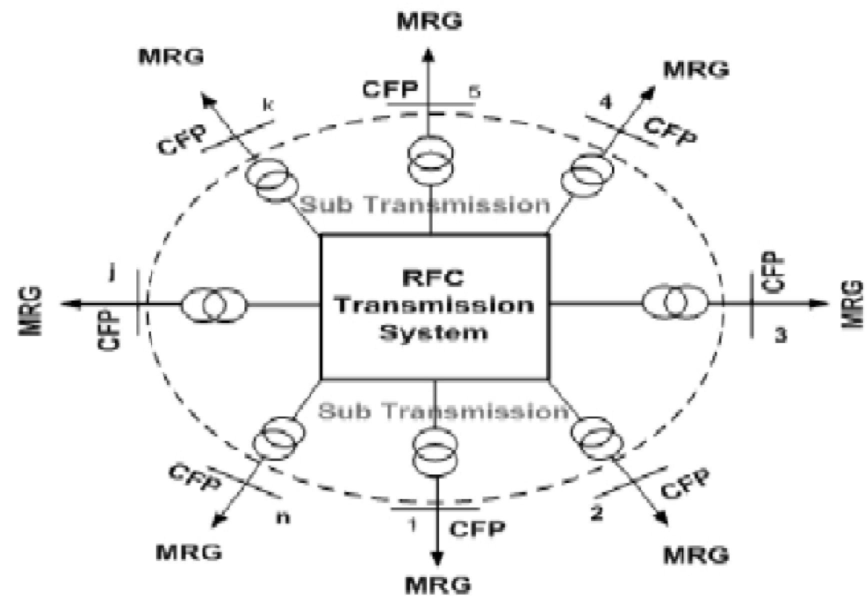
Comparison

	Current Grid	Smart Grid
System communications	Limited to power companies	Expanded, real-time
Interaction with energy users	Limited to large energy users	Extensive two-way communications
Operation & maintenance	Manual and dispatching	Distributed monitoring and diagnostics, predictive
Generation	Centralized	Centralized and distributed, substantial renewable resources, energy storage
Power flow control	Limited	More extensive
Reliability	Based on static, off-line models and simulations	Proactive, real-time predictions, more actual system data
Restoration	Manual	Decentralized control
Topology	Mainly radial	Network

Cyber Controlled Smart Grids

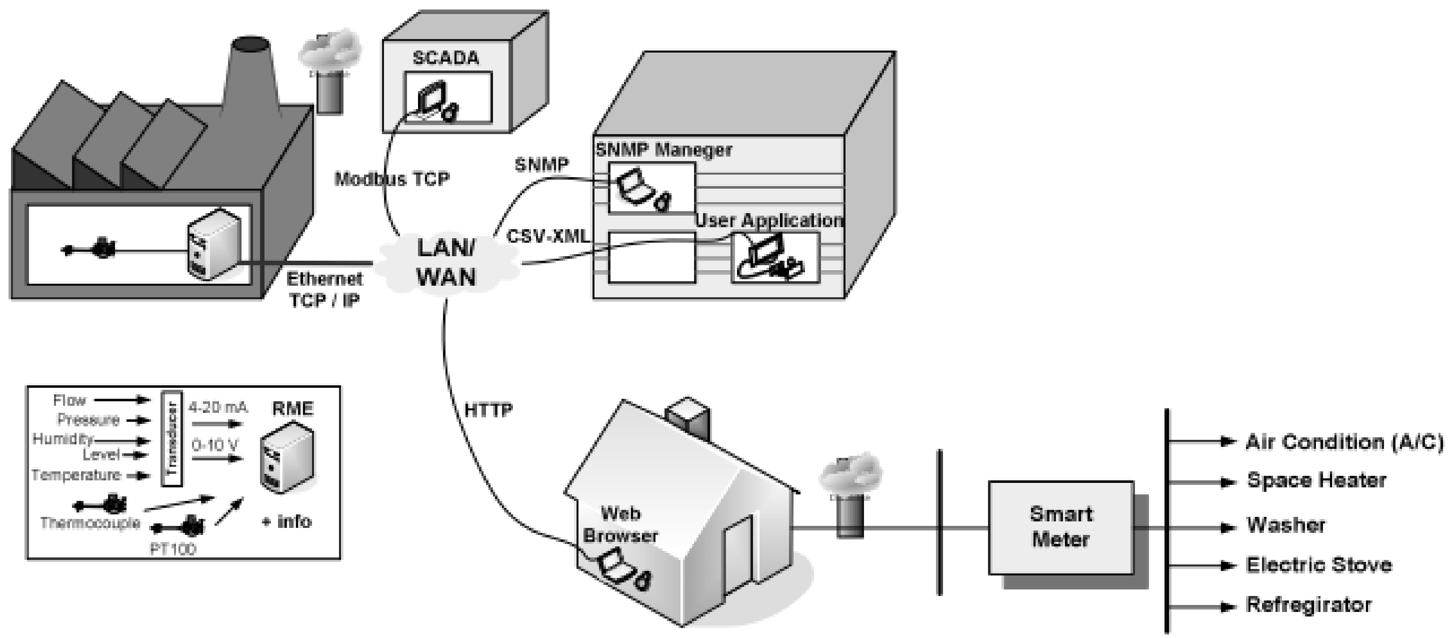
- CFP
- Role of CFP
- Two way communication
- Energy Management System (Local and smart grid)
- Master and slave control
- Active and reactive power flow control
- Role of real time pricing
- Intelligent control



CFP: Cyber Fusion Point

MRG: Micro-grid Renewable Green Energy System

Energy Management System



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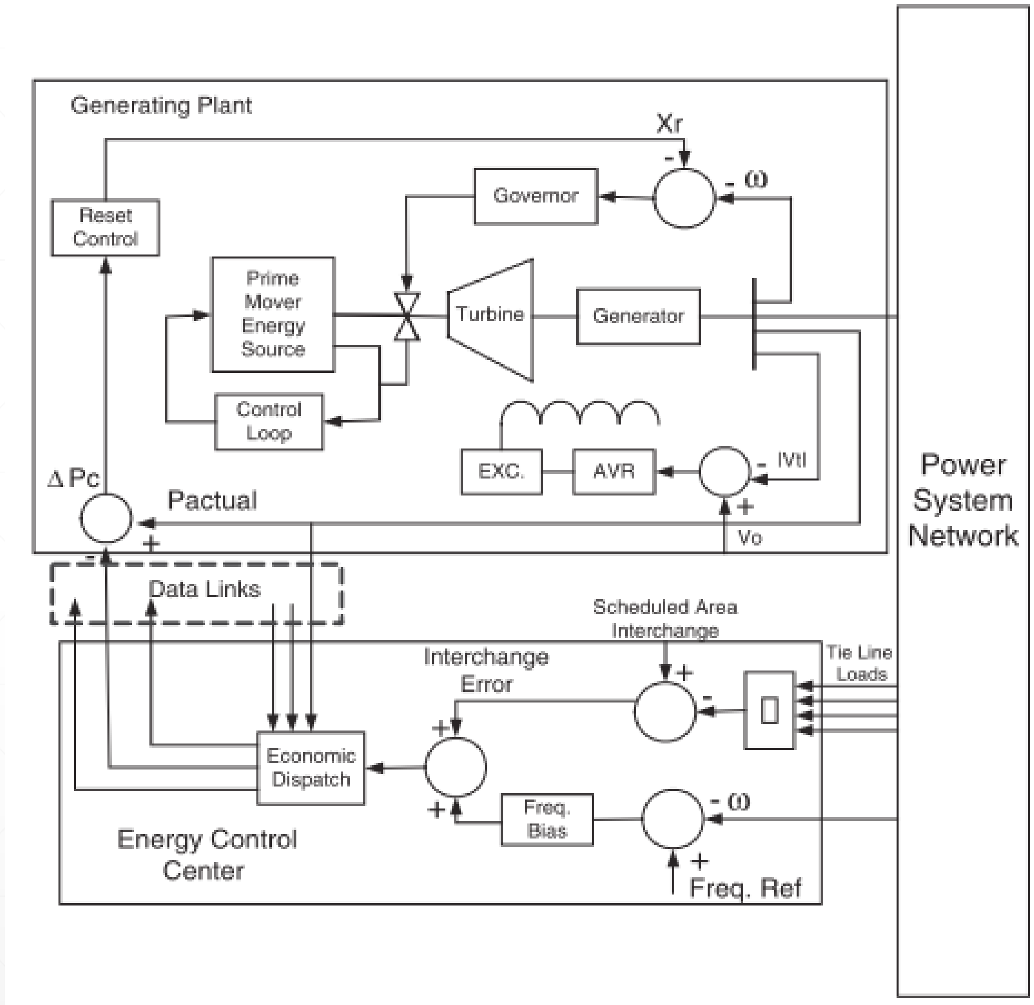
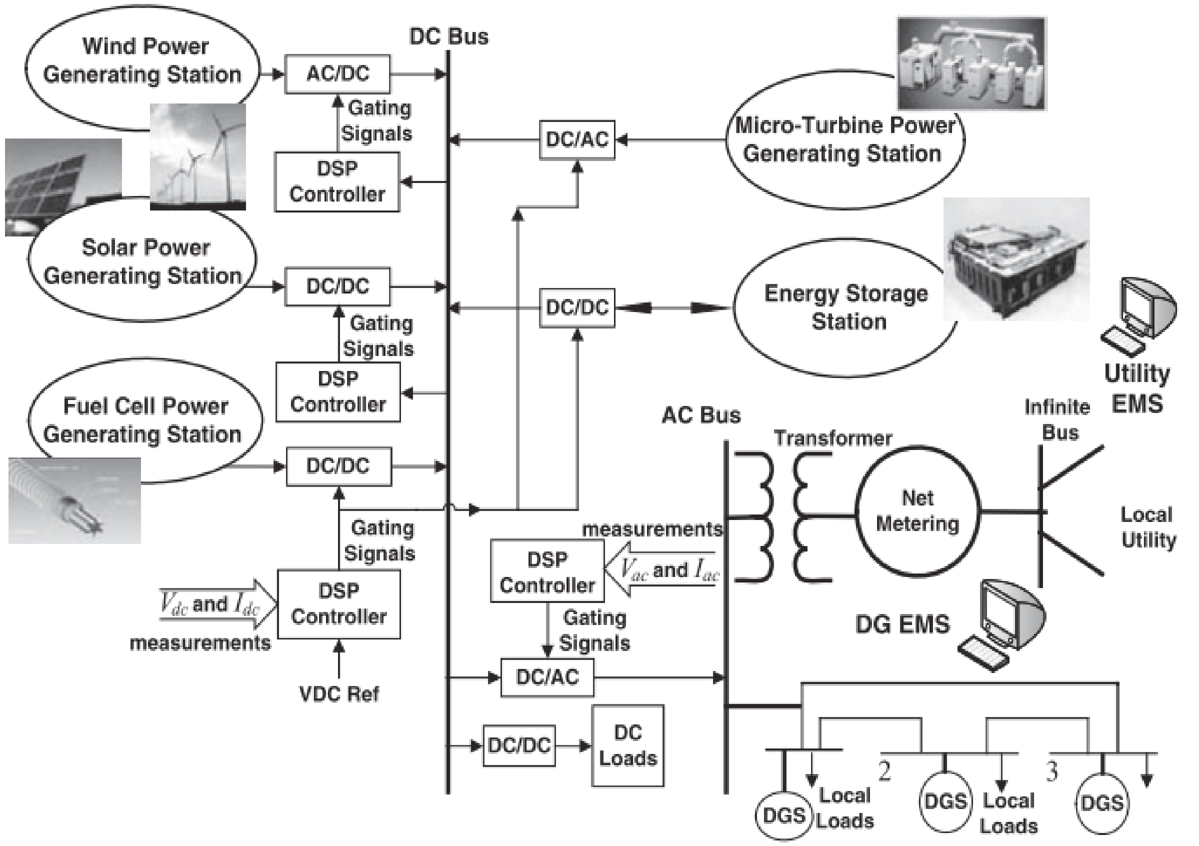
Energy Management System

a. Voltage Control
b. Frequency Control



Dc and AC Architecture of a Smart Grid with DG



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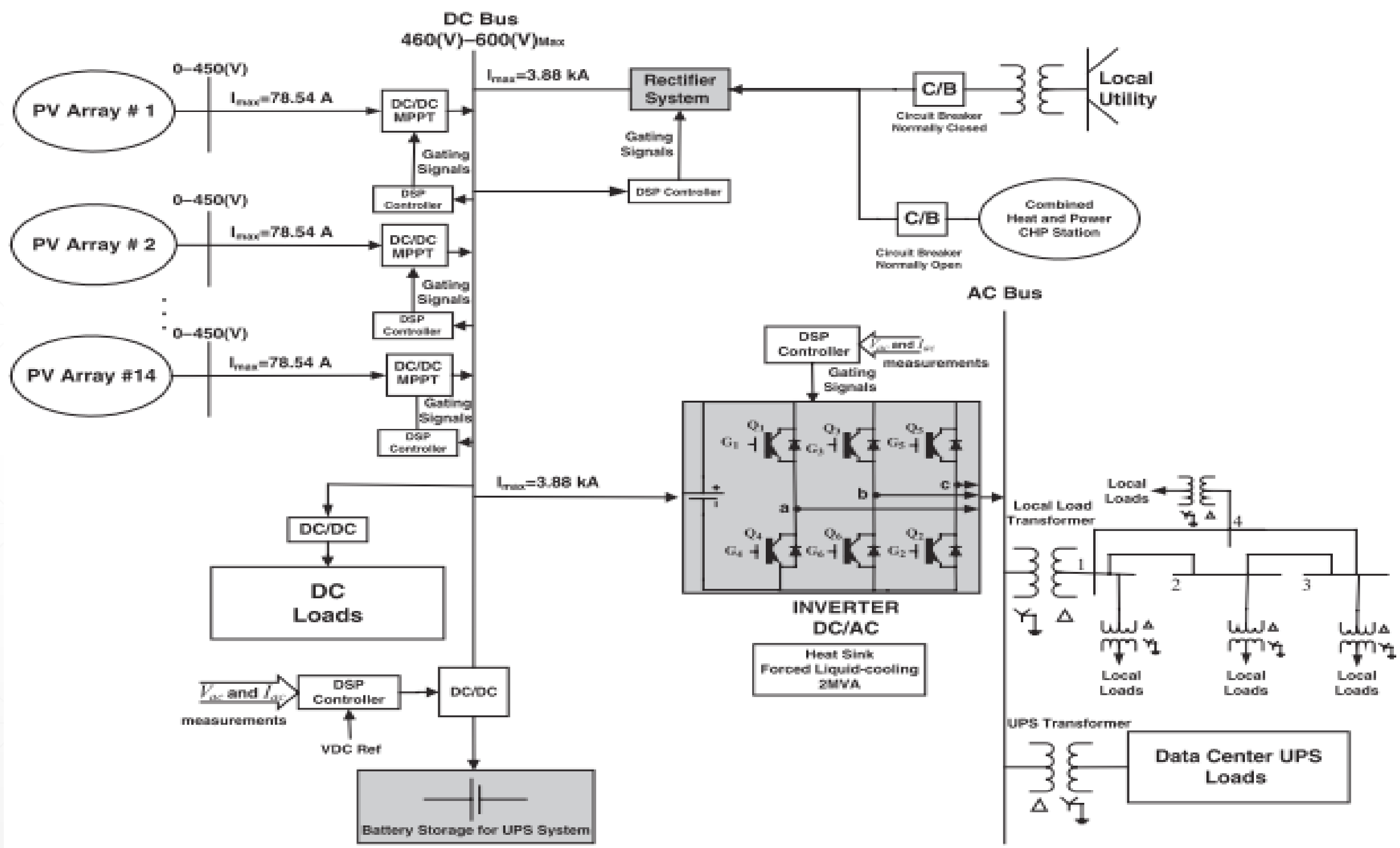
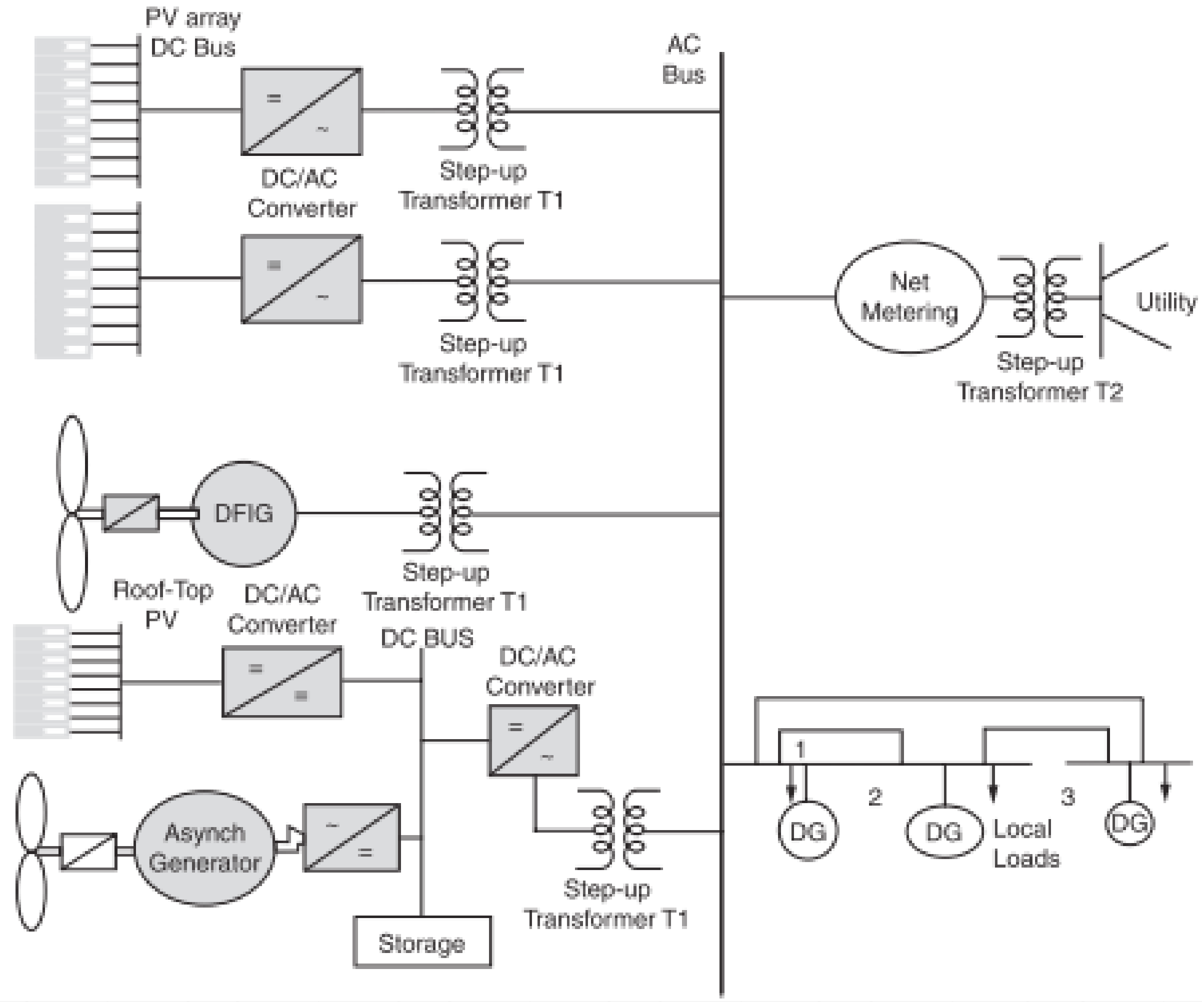
DC Architecture of a 2-MVA PV Station



Architecture for the Design of 2 MVA System

Solar and Wind Energy Combination



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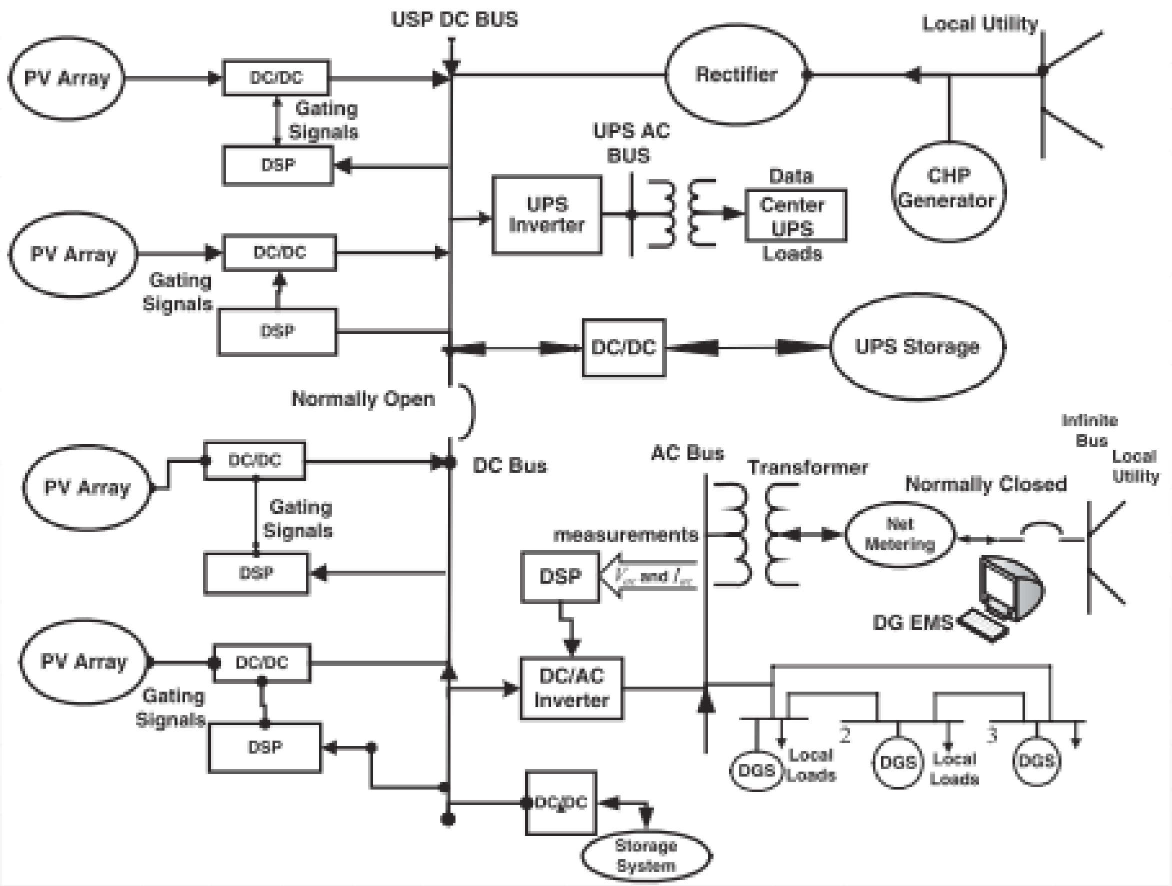
The split DC BUS UPS-PV smart grid system



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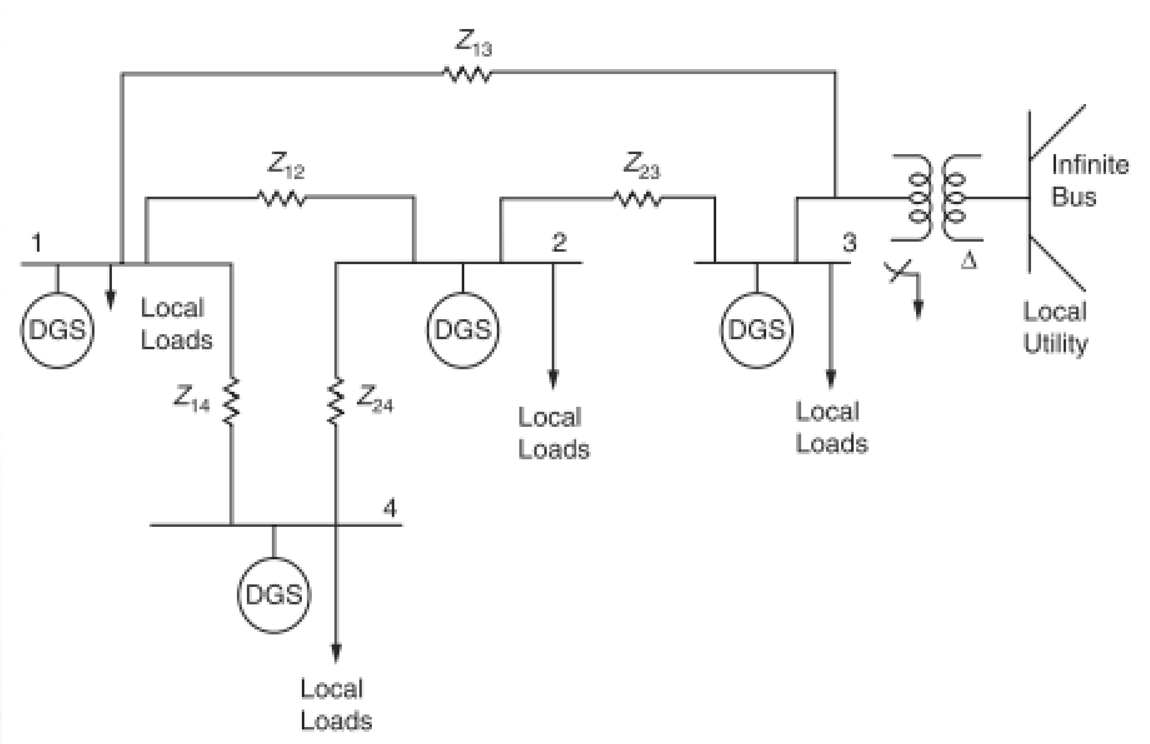
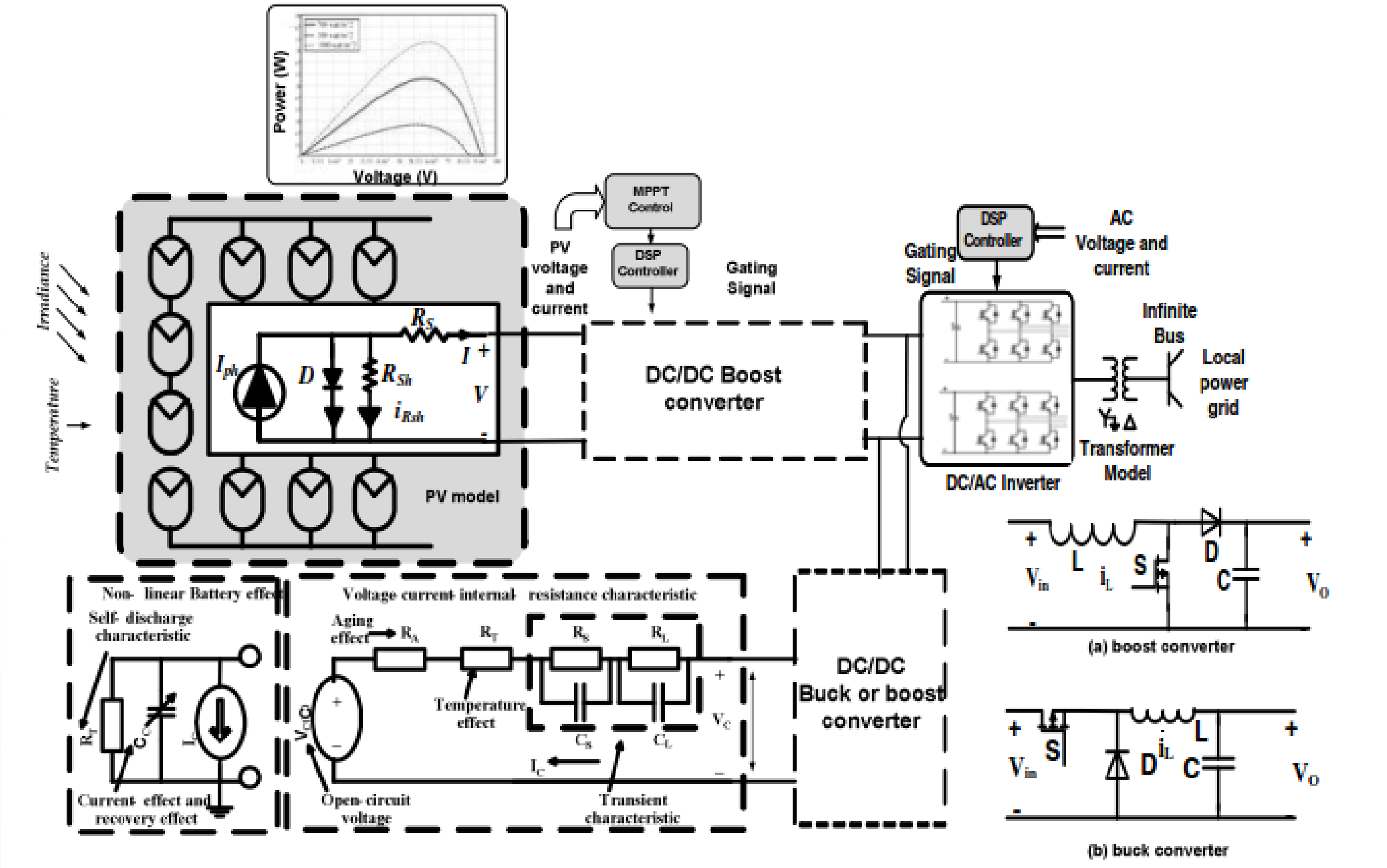
One Line Diagram of a System



Integration of Photo Voltaic System with Grid



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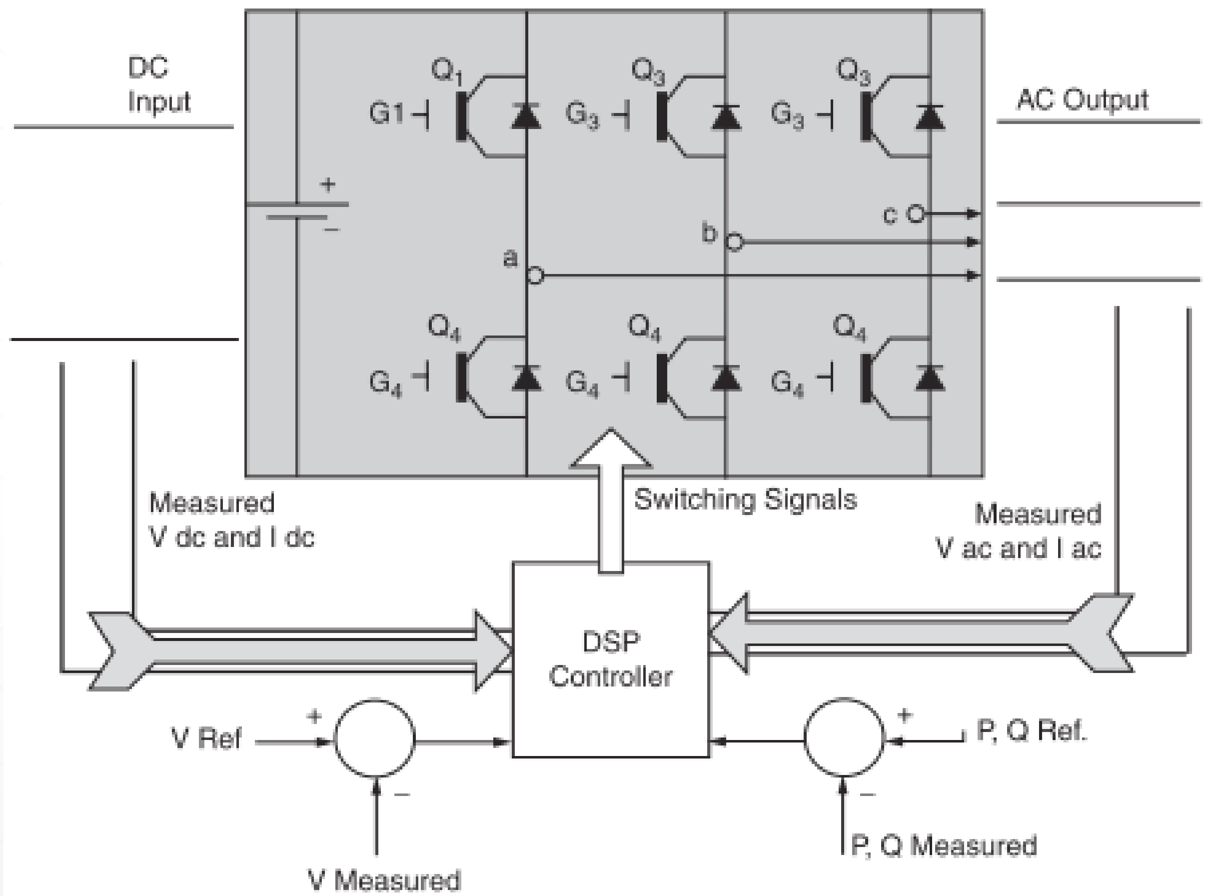
The Operation of an Inverter – Multi Quadrant Operation



Offset current blending function of inverter

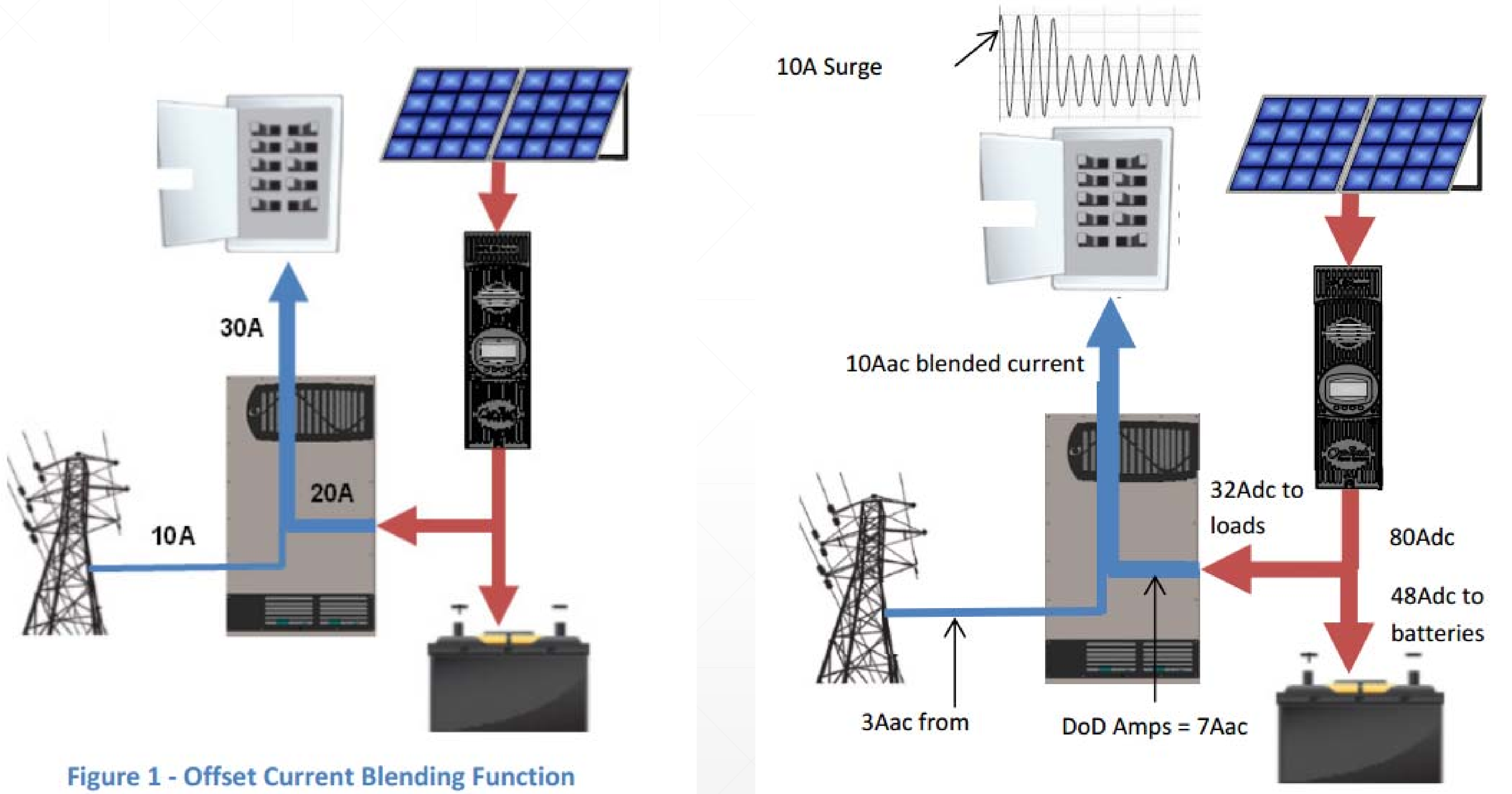


Figure 1 - Offset Current Blending Function

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Selling Excess Power to the Grid – Only Supply

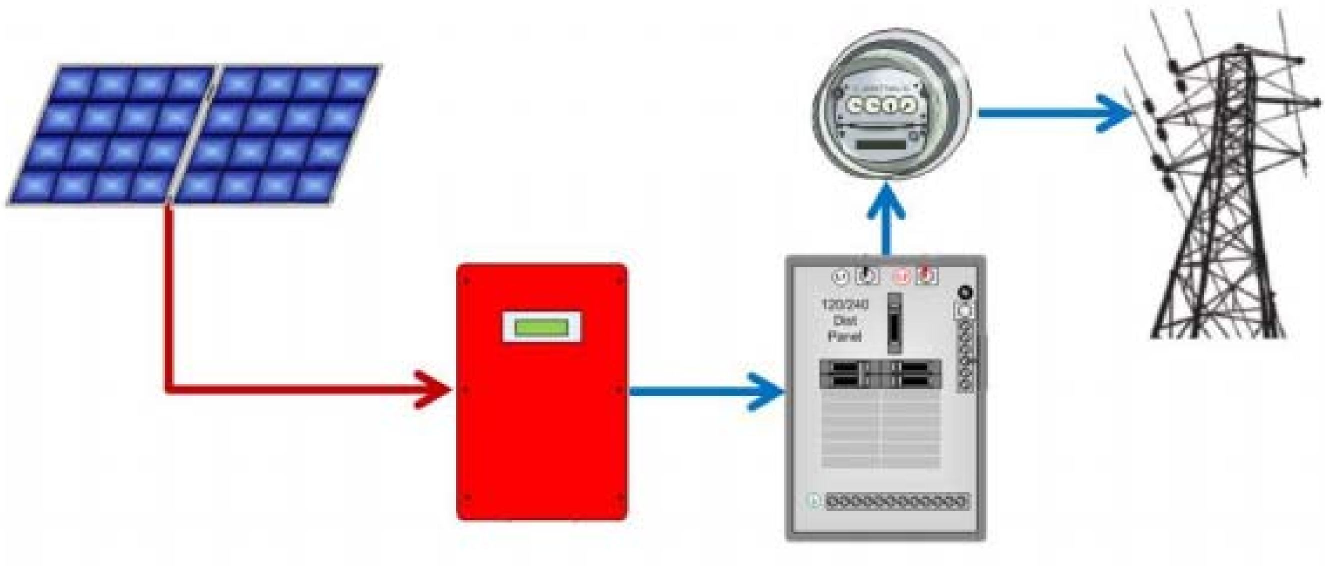


Figure 2 - Grid Tied Inverter Current Flow

Grid Hybrid Inverter

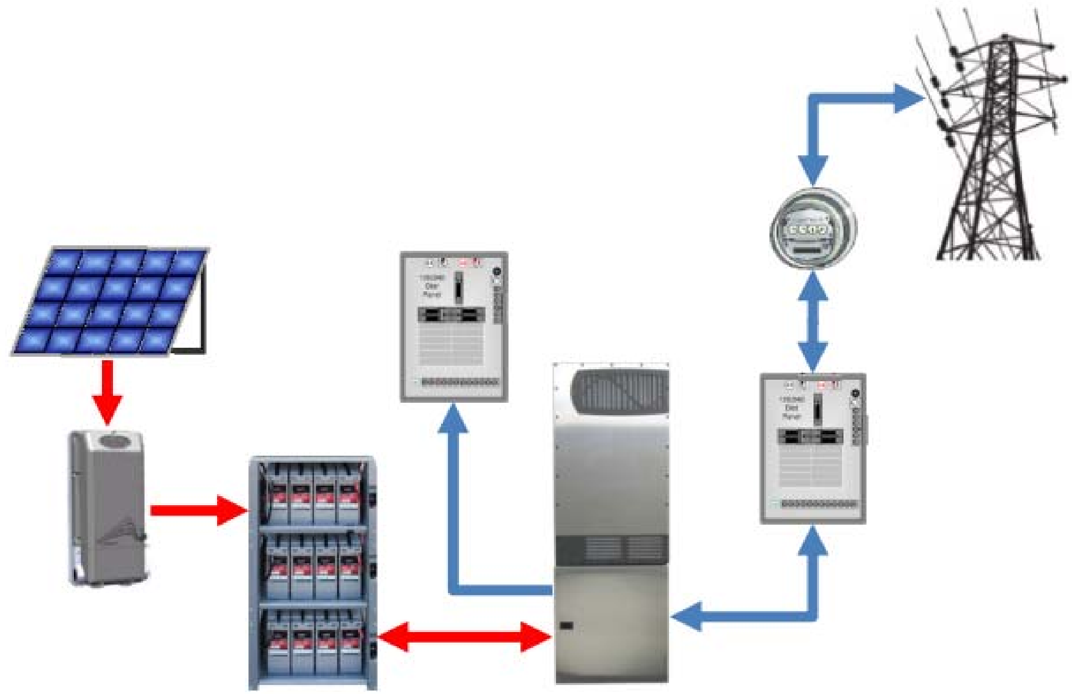
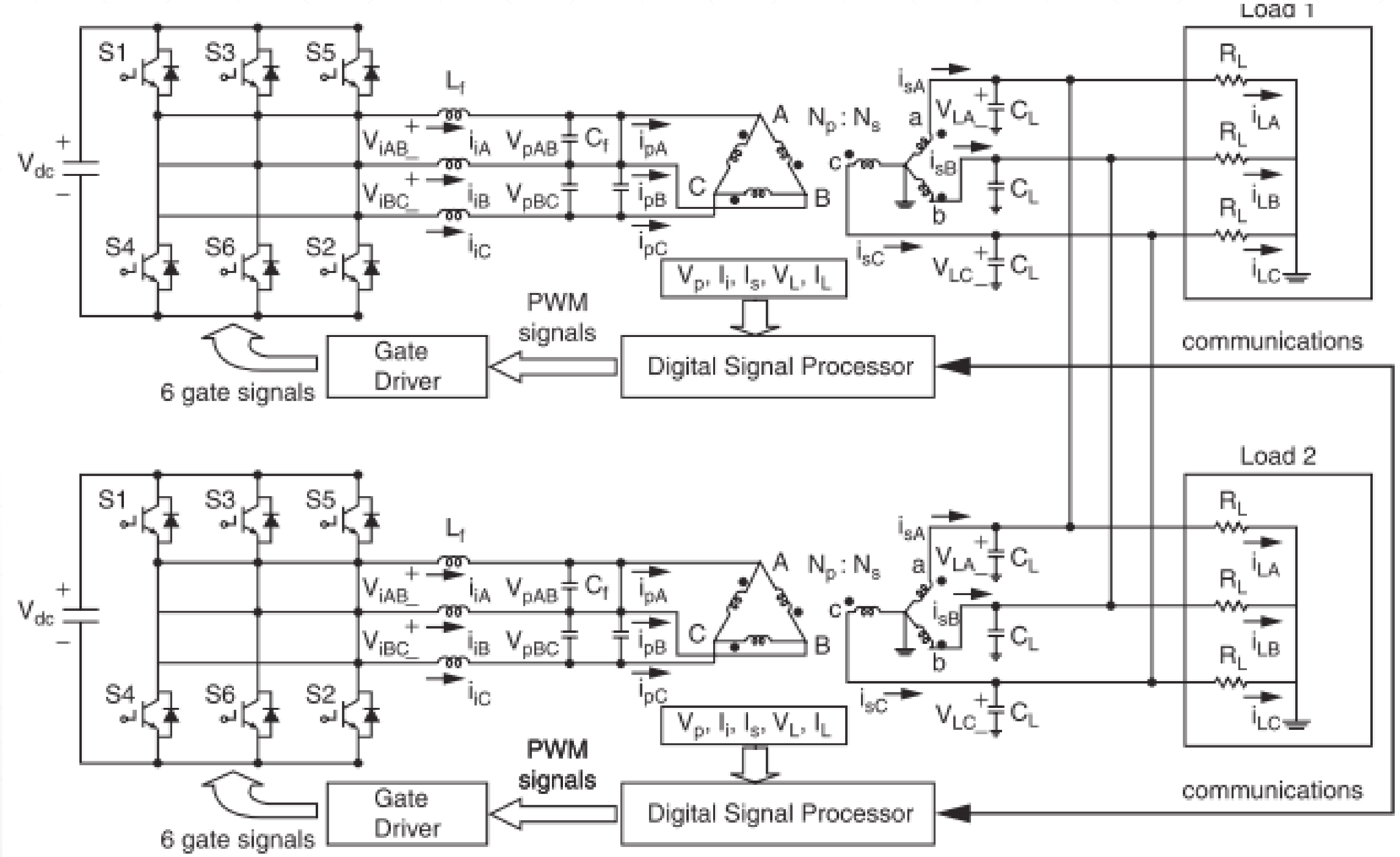
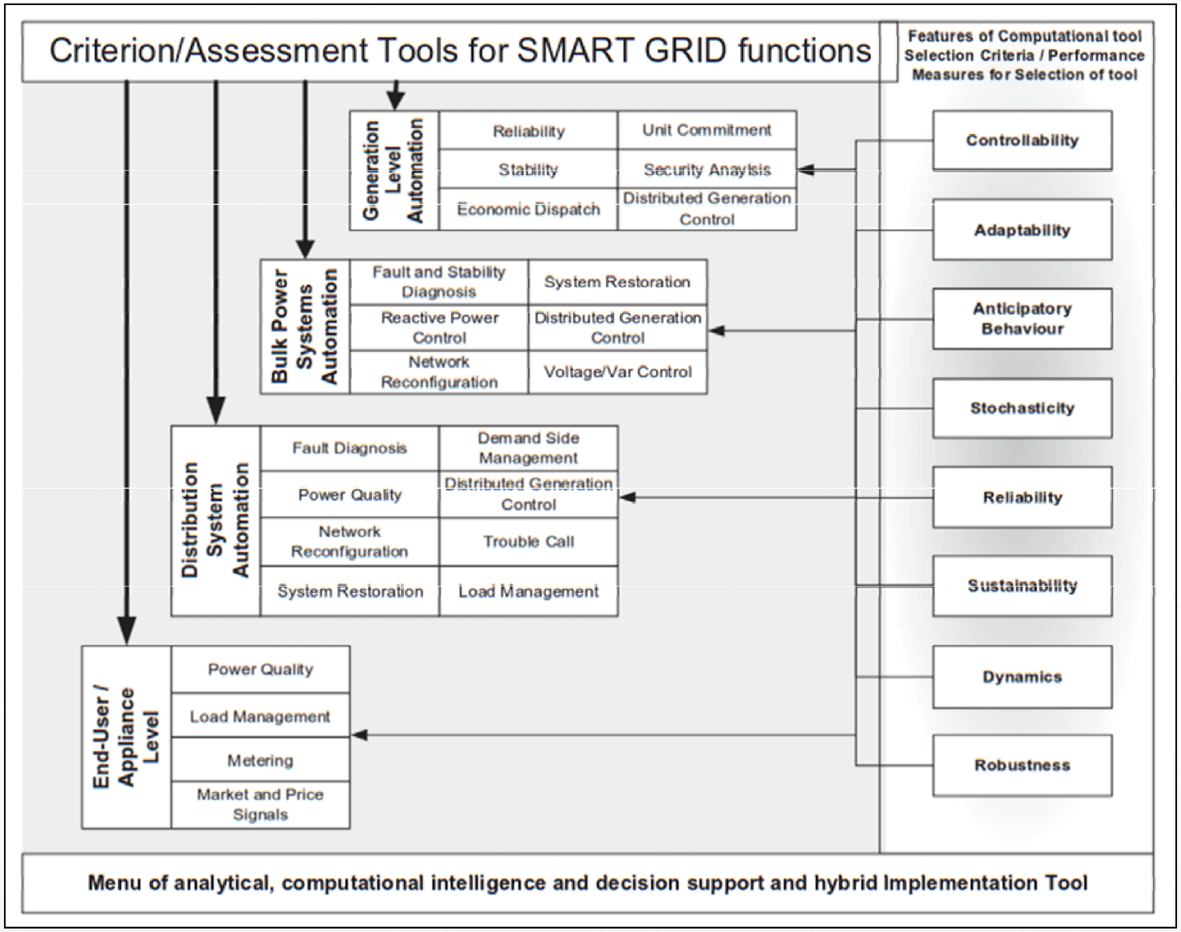


Figure 3 - Grid Hybrid Inverter Current Flow

Parallel Operation of Inverters



Assessment Tools for Smart Grid



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Communication Technologies

- 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 Internet technology
- Broadband over Power Lines (BPL): power line communication with Internet access
- Wi - Fi: commonly used wireless local area network
- Additional technologies include optical fiber, mesh, and multipoint spread spectrum.
- The five characteristics of smart grid communications technology are: High bandwidth, IP - enabled digital communication (IPv6 support is preferable), Encryption, Cyber security, support and quality of service and voice over internet protocol.

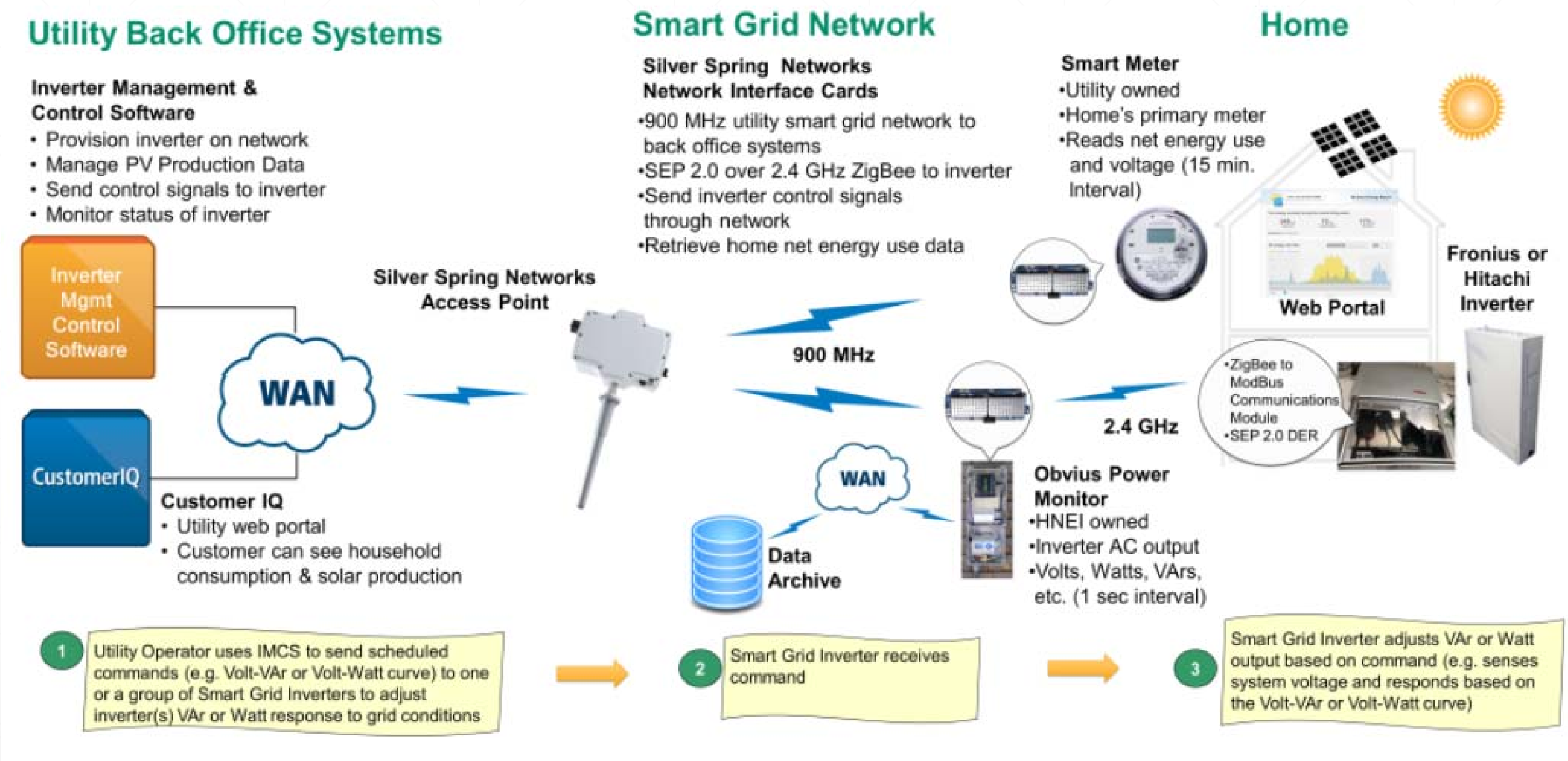
Smart Meters

- 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.
- Automated data reading is an additional component of smart meters
- Two way communication between customers and utilities to control bidirectional power flow is a key component in future smart grids
- 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.

Future 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 program 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 and can be made smart with intelligent control.
- 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.

An Example of Smart Metering Network



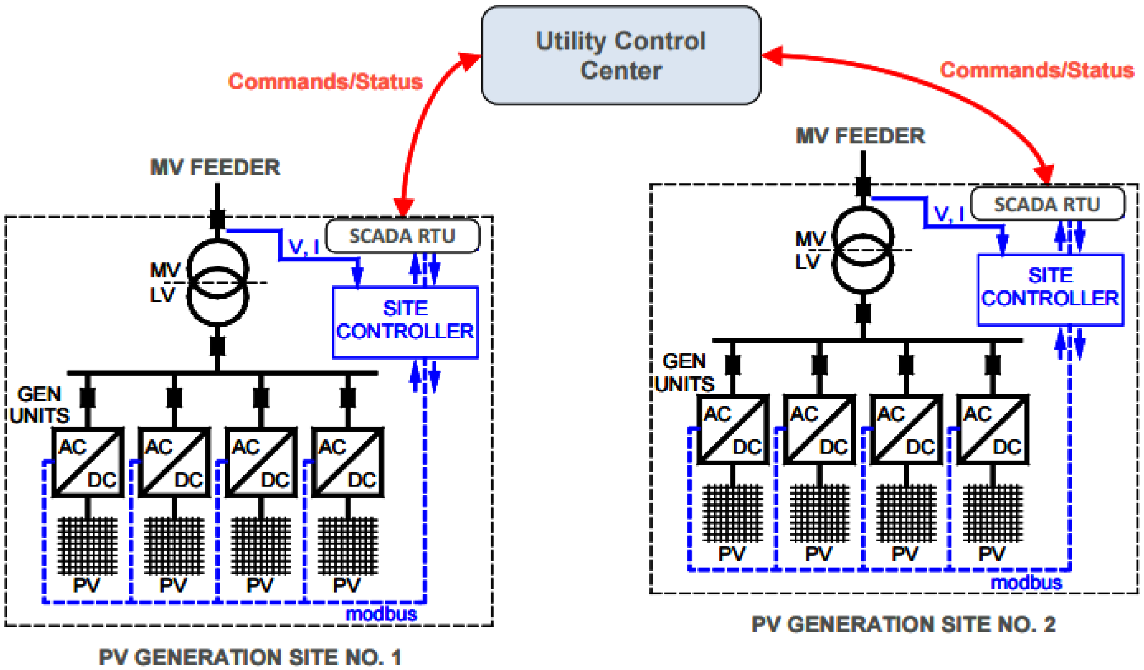
Advanced Metering Infrastructure (AMI)

- 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.

Major Functions of AMI

- **Market applications:** serve to reduce/eliminate labor, transportation, and infrastructure costs associated with meter reading and maintenance, increase accuracy 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;. An extension of AMI is a smart meter

Communication



Site controller generates real and reactive power management commands for multiple inverters in utility-scale PV projects.

Review Questions

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- What are smart grids?
- What are the important components of a smart grid?
- What are Cyber Physical Systems (CPS)?
- What is an Internet of Things (IoT)?
- What is a Network Control System? (NCS)
- What type of problems in power management can be solved by a smart grid?

- What do you mean by an Energy Management System?
- What is the role of power electronics converter in a smart grid?
- What are the physical model for a smart grid?
- What is the difference between a distributed parameter and a lumped parameter model?
- How do we model distributed parameter system?

- How do we model lumped parameter system?
- How do we solve distributed parameter models in a computer?
- What are the advantages and disadvantages of a complicated and simple models?