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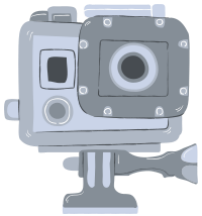
DEPARTMENT OF ELECTRICAL & ELECTRONICS ENGINEERING

UNIT 3

SMART GRID TECHNOLOGIES – MICRO GRIDS

19EEE308 – SMART GRIDS
III year / VI Semester

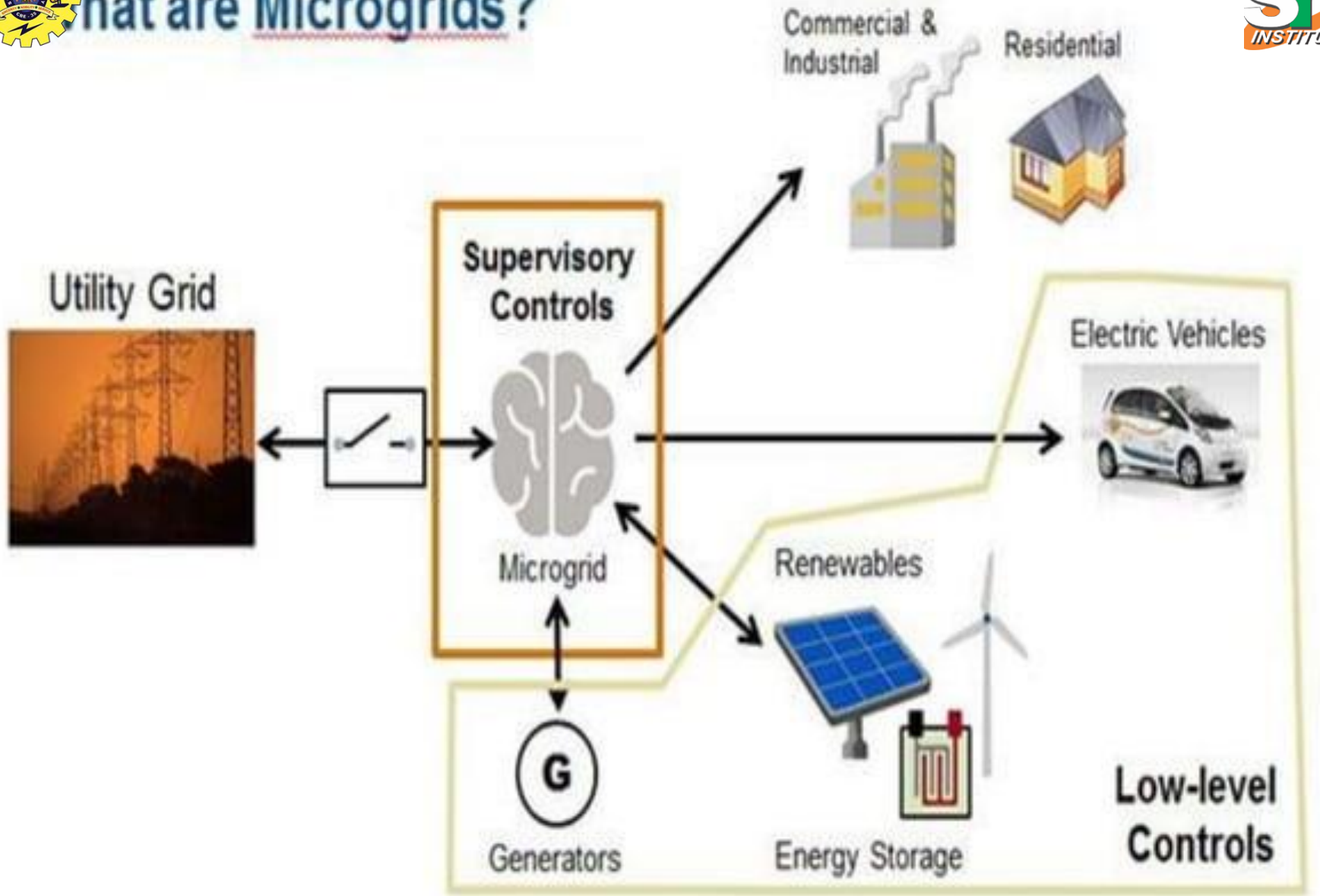


What is a microgrid system?

- A microgrid is a small-scale power grid that can operate independently or collaboratively with other small power grids. The practice of using micro-grids is known as distributed, dispersed, decentralized, discrete or embedded energy production.

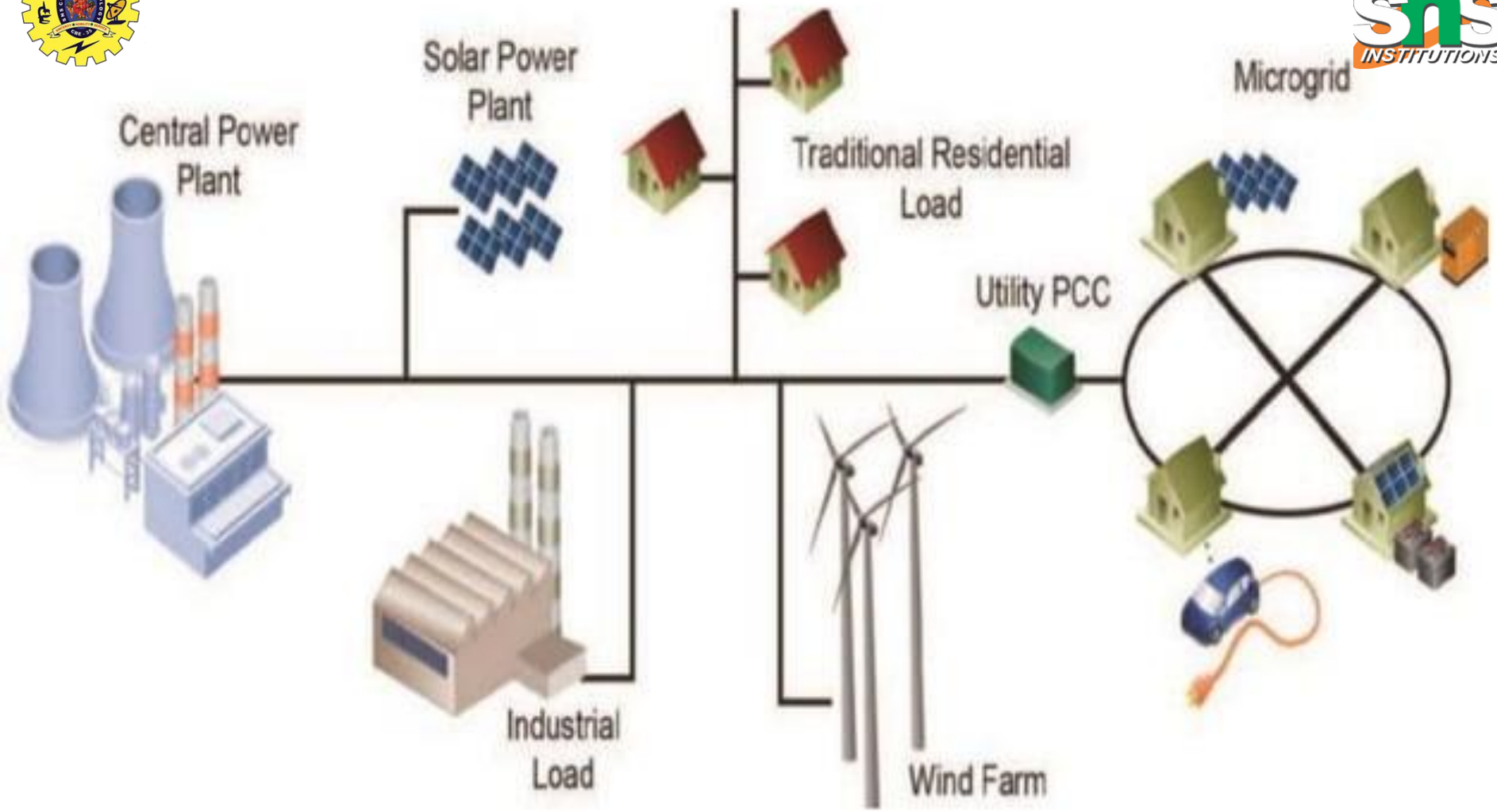
Any small-scale, localized power station that has its own generation and storage resources and definable boundaries can be considered a microgrid. If the microgrid can be integrated with the area's main power grid, it is often referred to as a hybrid microgrid.

What are Microgrids?



Continue....

- Micro-grids are typically supported by generators or renewable wind and solar energy resources and are often used to provide backup power or supplement the main power grid during periods of heavy demand.
- A microgrid strategy that integrates local wind or solar resources can provide redundancy for essential services and make the main grid less susceptible to localized disaster.
- A microgrid is a local energy grid with control capability, which means it can disconnect from the traditional grid and operate autonomously.


Central Power Plant
Solar Power Plant
Traditional Residential Load
Microgrid
Utility PCC
Industrial Load
Wind Farm

Continue...

- Microgrid is an integration platform for supply-side (micro-generation), storage units and demand resources (controllable loads) located in a local distribution grid.
- A microgrid should be capable of handling both normal state (grid-connected) and emergency state (islanded operation)
- The difference between a microgrid and a passive grid penetrated by the micro-sources lies mainly in terms of management and coordination of available resources


Other
Renewables
Generator
Backup
User
Utility
Grid
Microgrid
system
controller
User
User
Solar
Energy
User
Battery
Storage

How does a microgrid works?

In order to work, micro-grids must include three essential components:

- **Locally produced energy** to ensure they can operate independently in the event they are disconnected (photovoltaic panels, wind turbines, cogeneration, heat pumps, biomass plants, hydroelectric turbines, etc.) and an additional back-up supply of energy (power generators). In theory indeed, microgrids can go completely off the grid, but so far this rarely occurs in practice;
- **A storage system**: batteries, a supply of water for pumped-storage hydroelectricity and, in the future, super-capacitors and a chemical-based latent-heat storage system;
- **A smart management system** to ensure the continuous balance between electricity generation and demand.

How does a microgrid connect to the grid?

- A microgrid connects to the grid at a **point of common coupling** that maintains voltage at the same level as the main grid unless there is some sort of problem on the grid or other reason to disconnect. **A switch** can separate the microgrid from the main grid automatically or manually, and it then functions as an island.

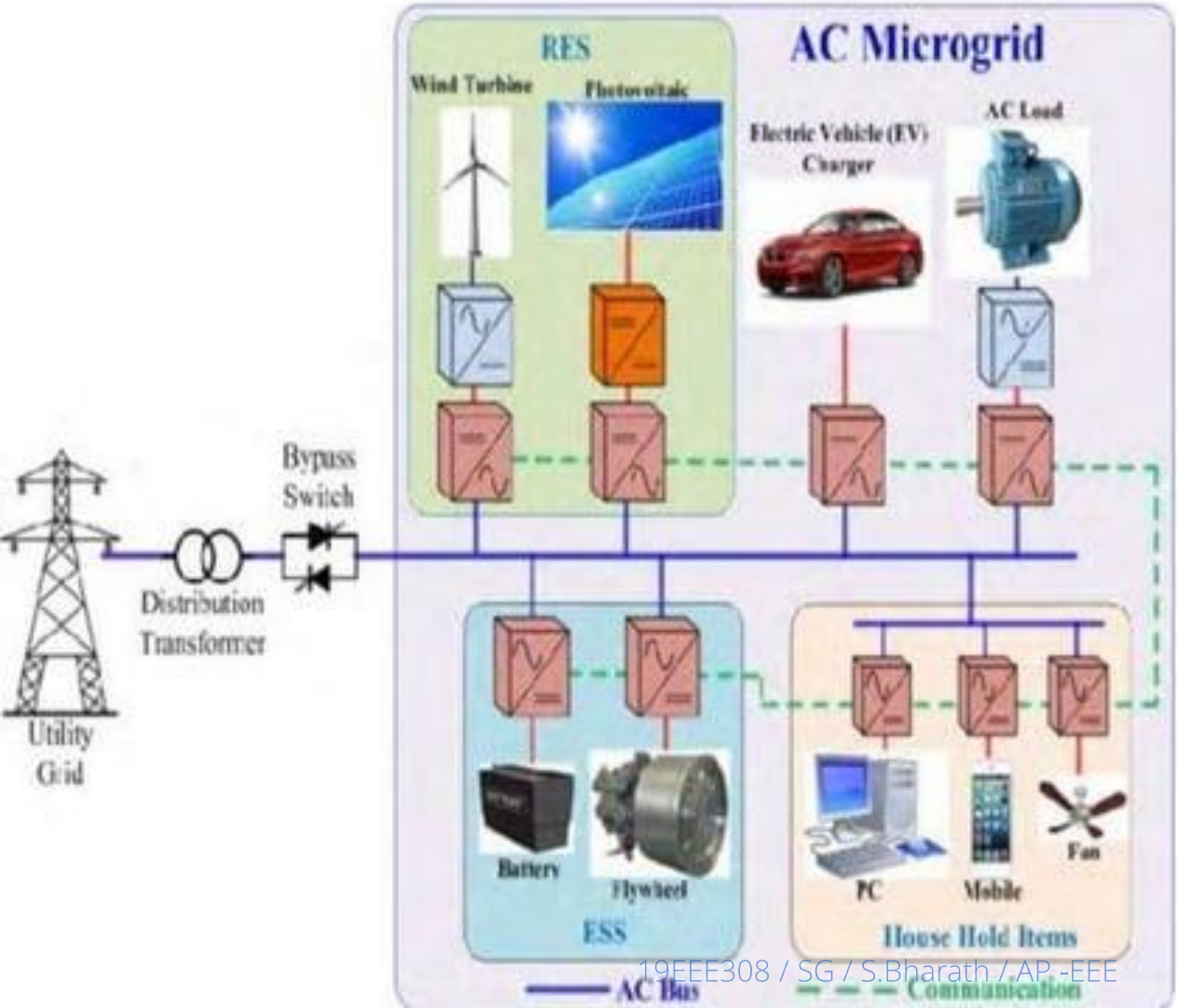
Microgrid benefits?

- Provides power quality, reliability, and security for end users and operators of the grid
- Enhances the integration of distributed and renewable energy sources
- Cost competitive and efficient
- Enables smart grid technology integration
- Locally controlled power quality
- Minimize carbon footprint and green house gas emissions by maximizing clean local energy generation
- Increased customer (end-use) participation

Composition of microgrid

- **DG:** It can be various types of new energy such as PV, Energy storage (ES), Wind, Fuel cell; or combined heat and power (CHP), combined cooling, heat and power (CCHP).
- **Loads:** It includes common load and critical loads.
- **ES:** It includes physical, chemical, and electromagnetic forms, for storage of renewable energy, load shifting, and black-start of microgrid
- **Control Devices:** They constitute the control systems for DGs, ESs, and transfer between grid connected mode and islanded mode, facilitating real time monitoring and energy management

assification: Type-1 AC microgri



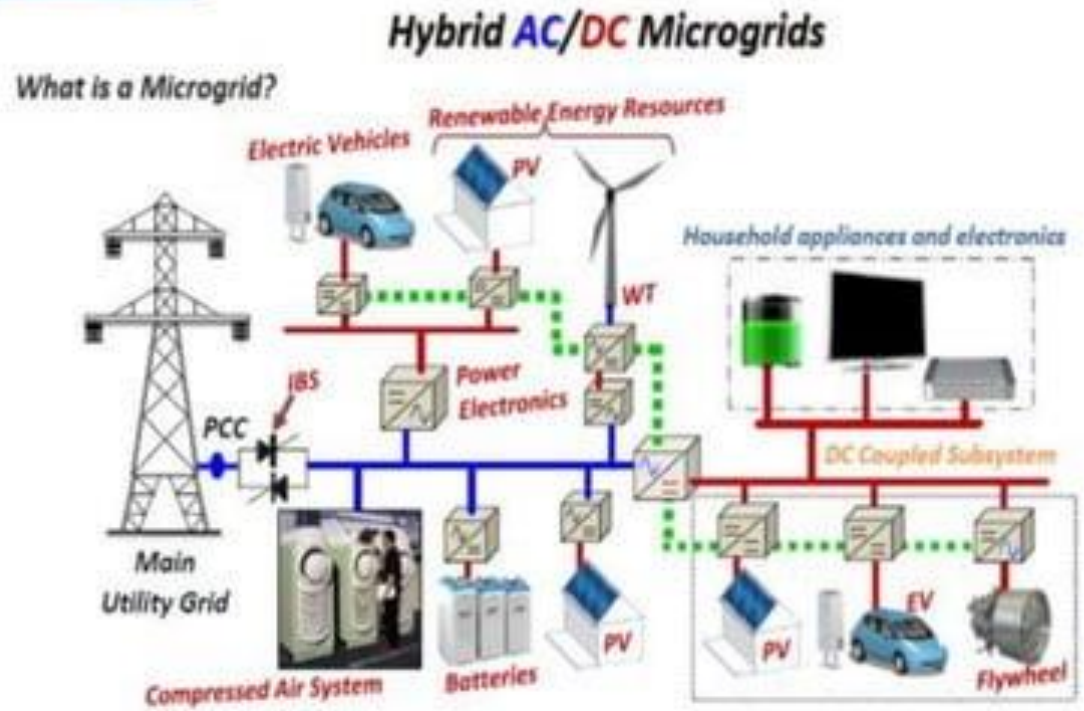
- ✓ An AC microgrid connects to the distribution network via an AC bus
- ✓ ES and DG are connected to the AC bus via inverter
- ✓ No inverter is required for power supply to AC loads
- ✓ Control and operation are difficult

assification: Type-2 DC microgr

- ✓ In a DC microgrid, DG, ES, and DC load are connected to the DC bus via a converter and the DC bus is connected to AC loads via an inverter to power both DC and AC loads
- ✓ As DG control solely depends on DC voltage, it is easier to realize coordinated operation of the DGs
- ✓ DG and load fluctuations are compensated by ES on the DC side
- ✓ Compared with an AC microgrid, a DC microgrid is easier to control, does not involve synchronisation among DGs, and thus it is easier to suppress circulating current
- ✓ Inverters are required for power supply to AC loads

Classification: Type-3 AC-DC microgrid

General aspects of a Microgrid: "Definition and Operation"



- ✓ An AC/DC hybrid microgrid is a microgrid consisting of an AC bus and a DC bus
- ✓ AC bus and DC bus allow for direct supply to AC loads and DC loads

Classification of microgrid by capacity

- Simple microgrid: <2 MW
- Corporate microgrid: 2-5 MW
- Feeder area microgrid: 5-20 MW
- Sub-station area microgrid: >20 MW
- Independent microgrid: Depending on the loads on an island, a mountainous area or a village

Classification of microgrid by function demand

- **Simple microgrid**: A simple microgrid contains only one type of DG, has simple functions and design, and is intended for use of CCHP or continuous supply of continuous loads
- **Multi-DG microgrid**: A multi-DG microgrid is composed of multiple simple microgrids or multiple type of complementary, coordinated DGs. Compared with a simple microgrid, the design and operation of such a grid are much more complicated. Some loads need to be identified as sheddable loads in case of emergency to maintain power balance in an emergency.
- **Utility microgrid**: All DGs and microgrids that meet specific technical conditions can be integrated into a utility microgrid. In such a microgrid, loads are prioritized based on users requirements on reliability, and high priority loads will be powered preferentially in an emergency.

ntegration voltage class

Micro-grids can be integrated into grids at the following three voltages:

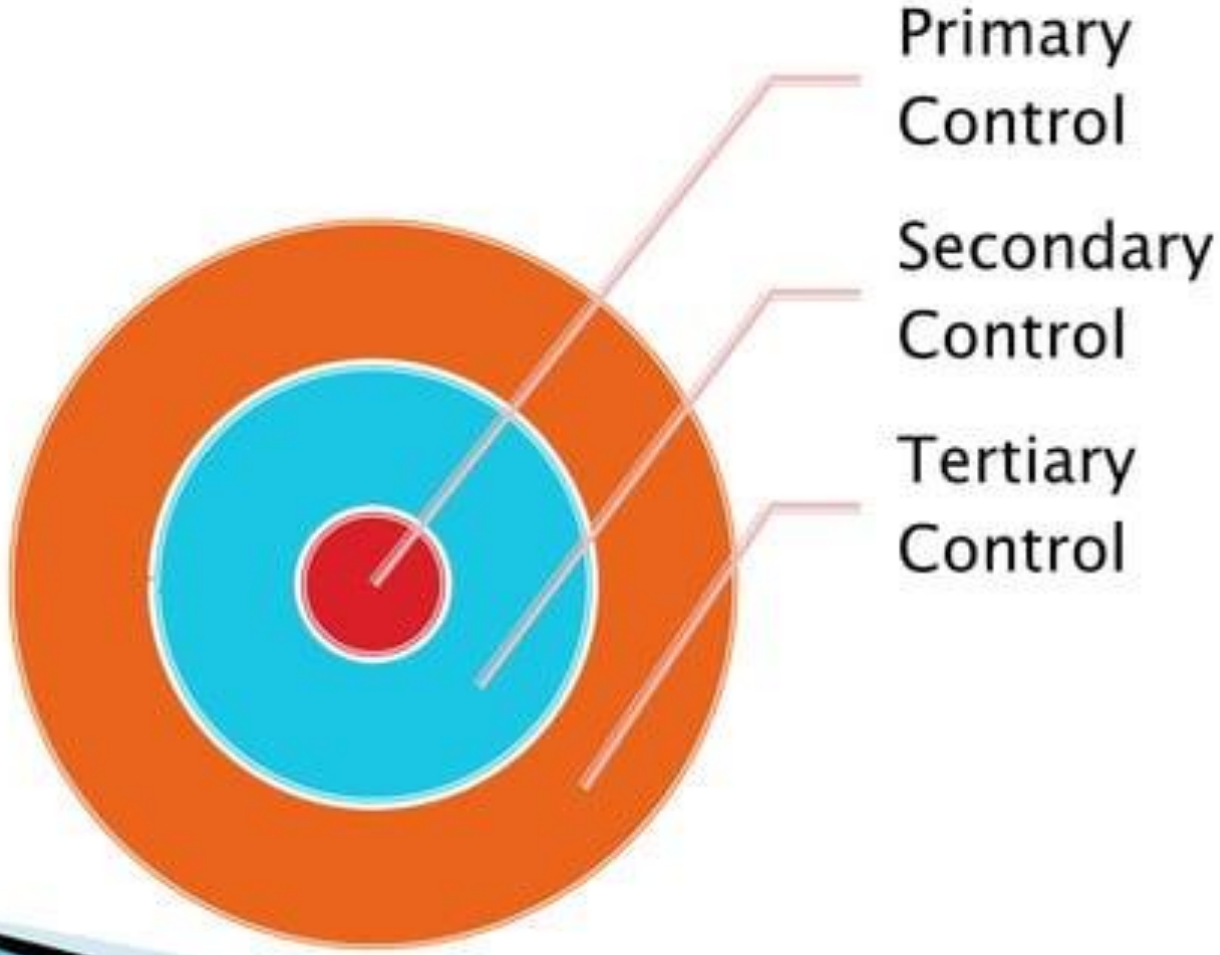
1. 380 V
2. 10 KV
3. A hybrid of 380 V and 10 KV

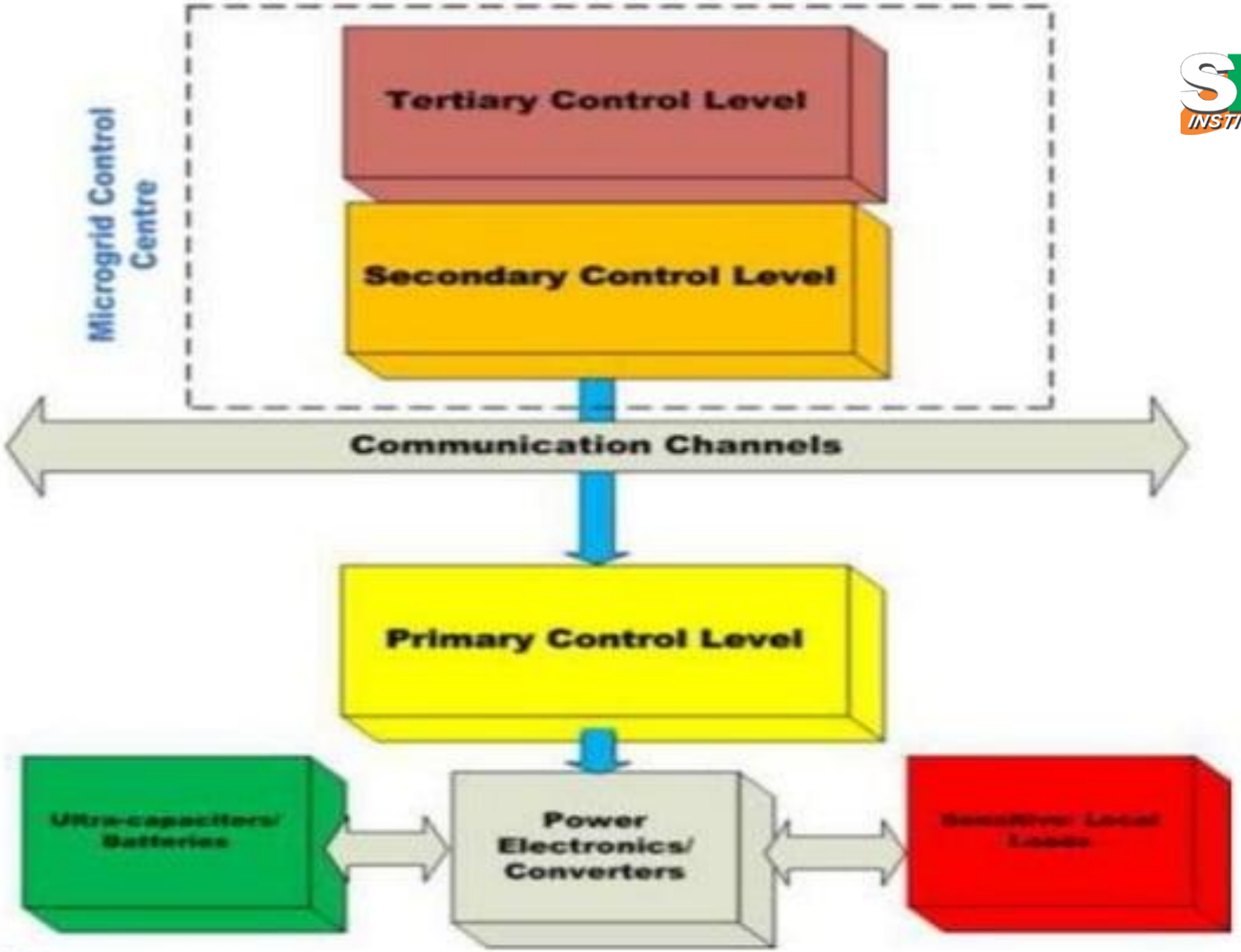
tructure

The principal roles of the microgrid control structure are:

- Voltage and frequency regulation for both operating modes;
- Proper load sharing and DER coordination;
- Microgrid resynchronization with the main grid;
- Power flow control between the microgrid and the main grid;
- Optimizing the microgrid operating cost.

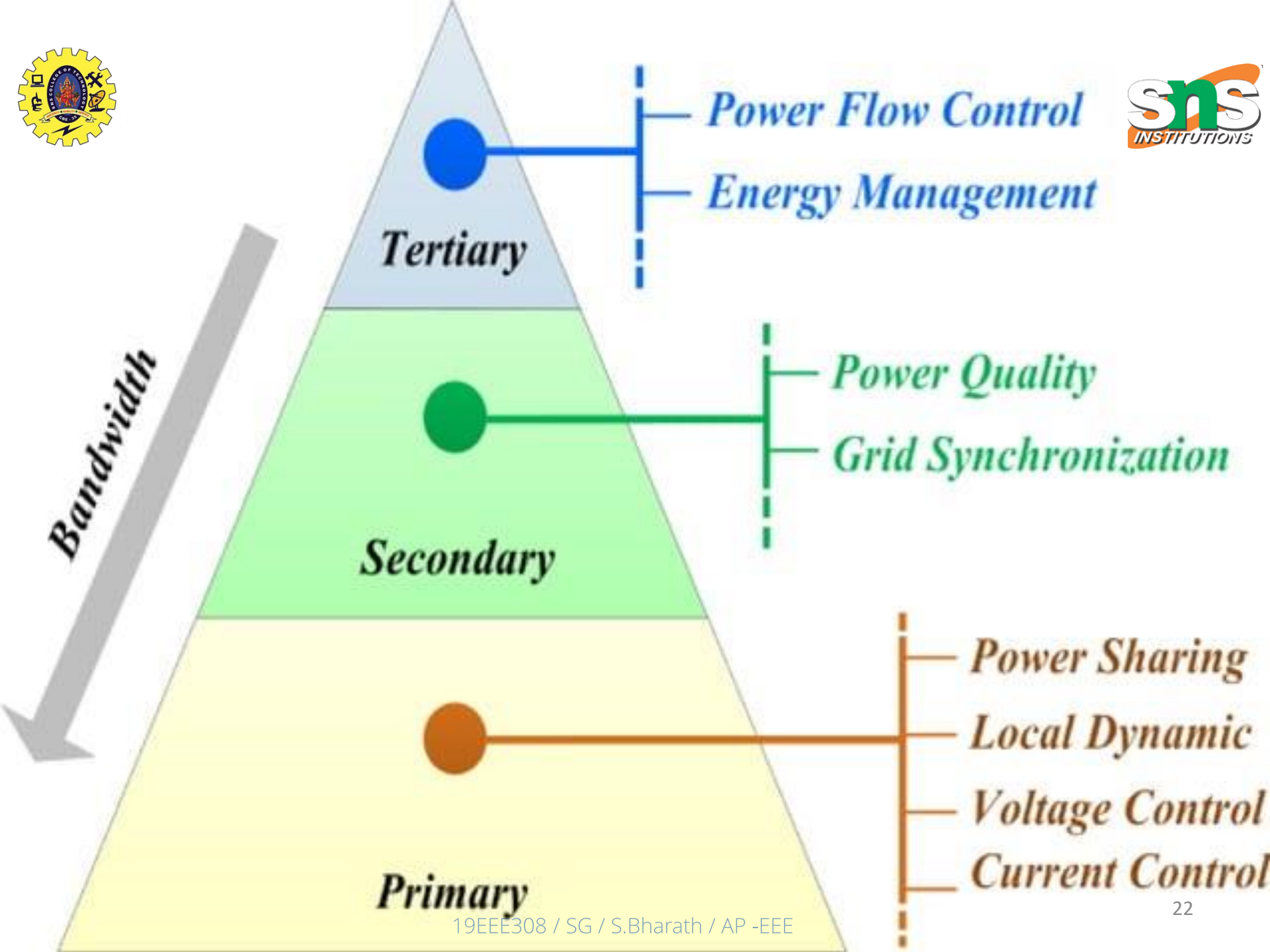
Hierarchical control levels of a microgrid




Microgrid Control Centre
Tertiary Control Level
Secondary Control Level
Communication Channels
Primary Control Level
Ultra-capacitors/ Batteries
Power Electronics/ Converters

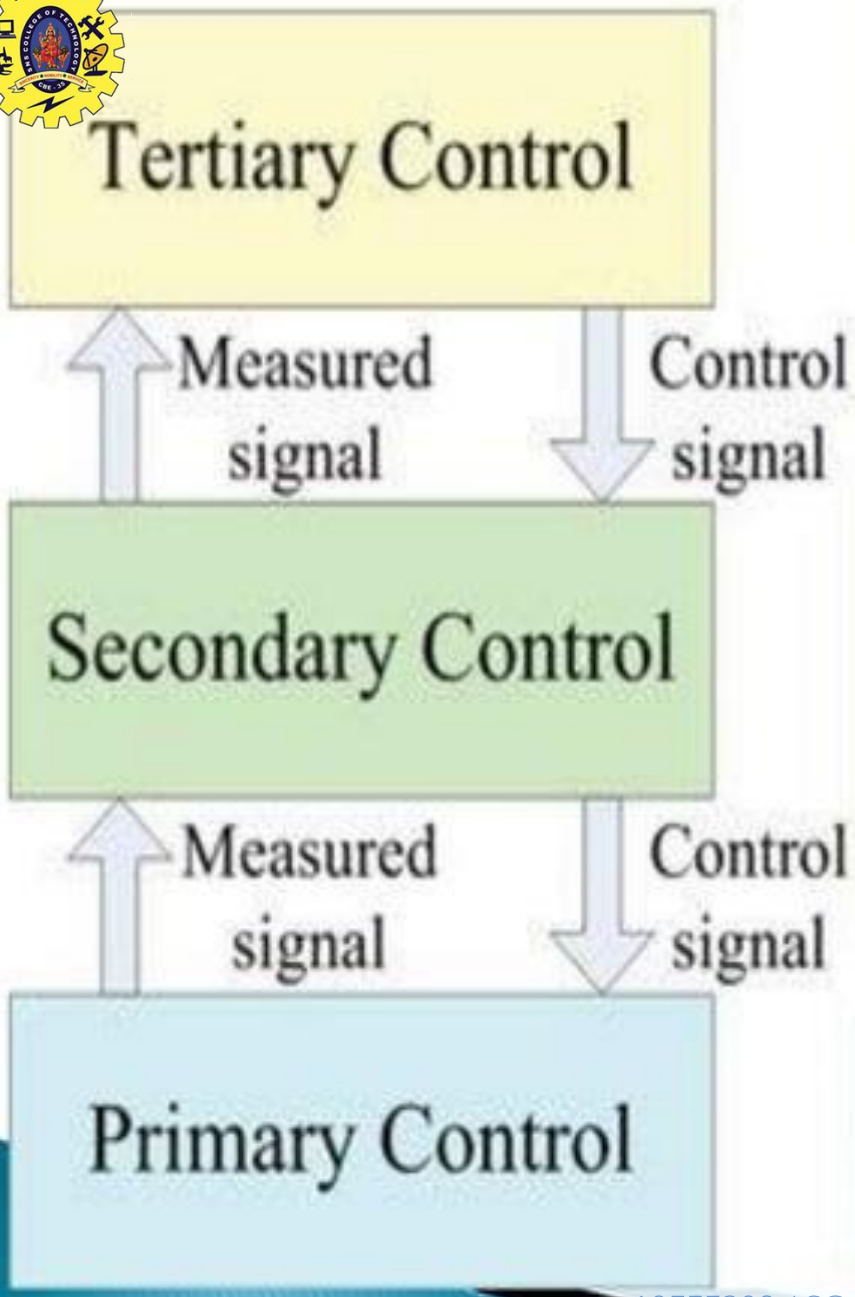
Primary control

- The primary control provides the reference points for the voltage and current control loops of DERs. These inner control loops are commonly referred to as zero-level control. The zero level control is generally implemented in either PQ or voltage control modes.
- The primary control is designed to satisfy the following requirements:
  - To stabilize the voltage and frequency. Subsequent to an islanding event, the microgrid may lose its voltage and frequency stability due to the mismatch between the power generated and consumed.
  - To offer plug and play capability for DERs and properly share the active and reactive power among them, preferably, without any communication links.
  - To mitigate circulating currents that can cause over-current phenomenon in the power electronic devices and damage the DC-link capacitor.


Power Flow Control
Energy Management
Tertiary
Power Quality
Grid Synchronization
Secondary
Bandwidth
Power Sharing
Local Dynamic
Voltage Control
Current Control
Primary

econdary control

- Primary control, may cause frequency deviation even in steady state.
- Although the storage devices can compensate for this deviation, they are unable to provide the power for load–frequency control in long terms due to their short energy capacity.
- The secondary control, as a centralized controller, restores the microgrid voltage and frequency and compensate for the deviations caused by the primary control.
- This control hierarchy is designed to have slower dynamics response than that of the primary, which justifies the decoupled dynamics of the primary and the secondary control loops and facilitates their individual designs.



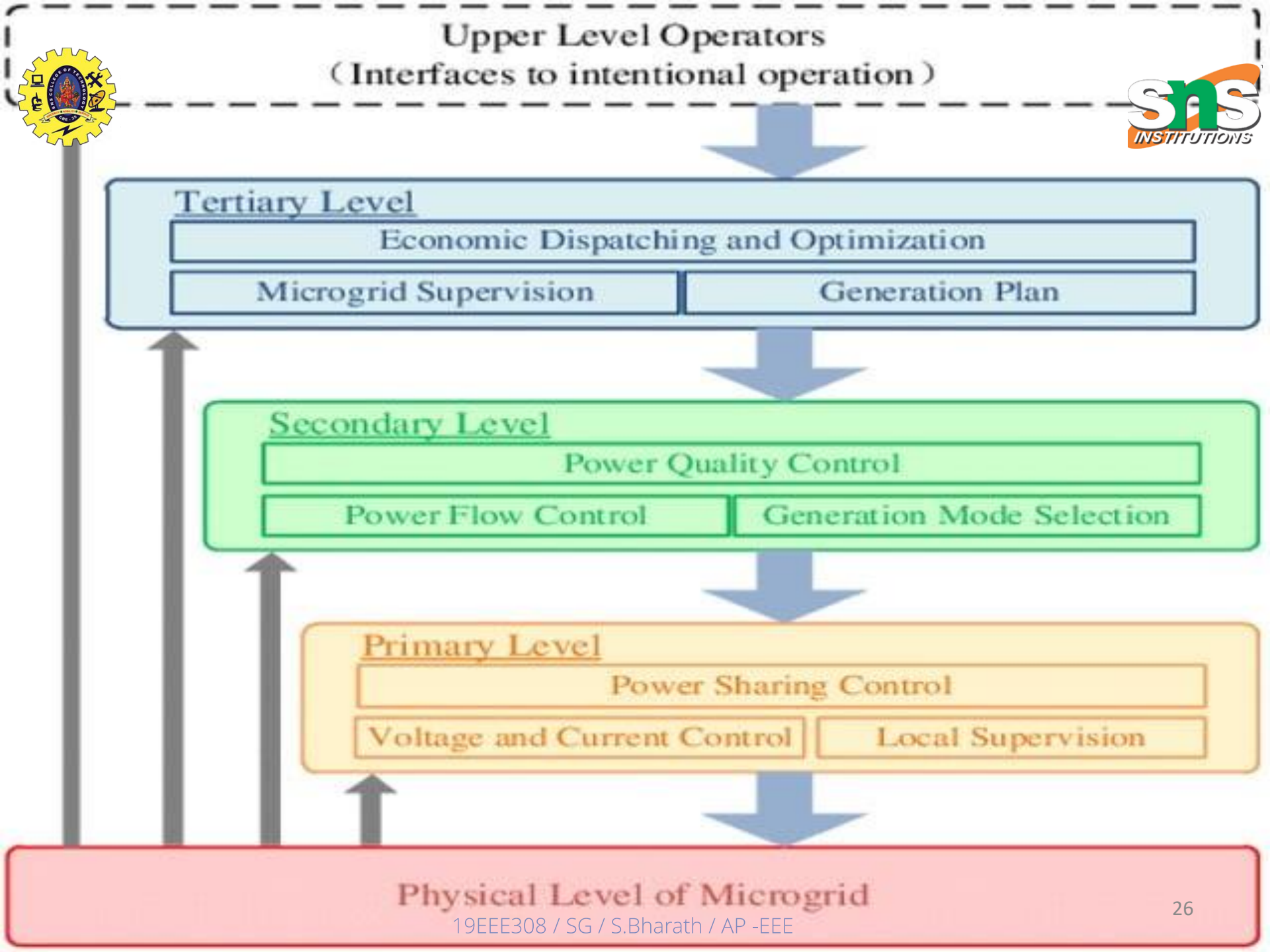
Economic dispatch
Unit commitment
Optimal power flow
Voltage var control
Time frame: seconds to minutes

Real-time load management
Secondary load-frequency control
Secondary voltage control
Automatic generation control
Time frame: 100s of milliseconds

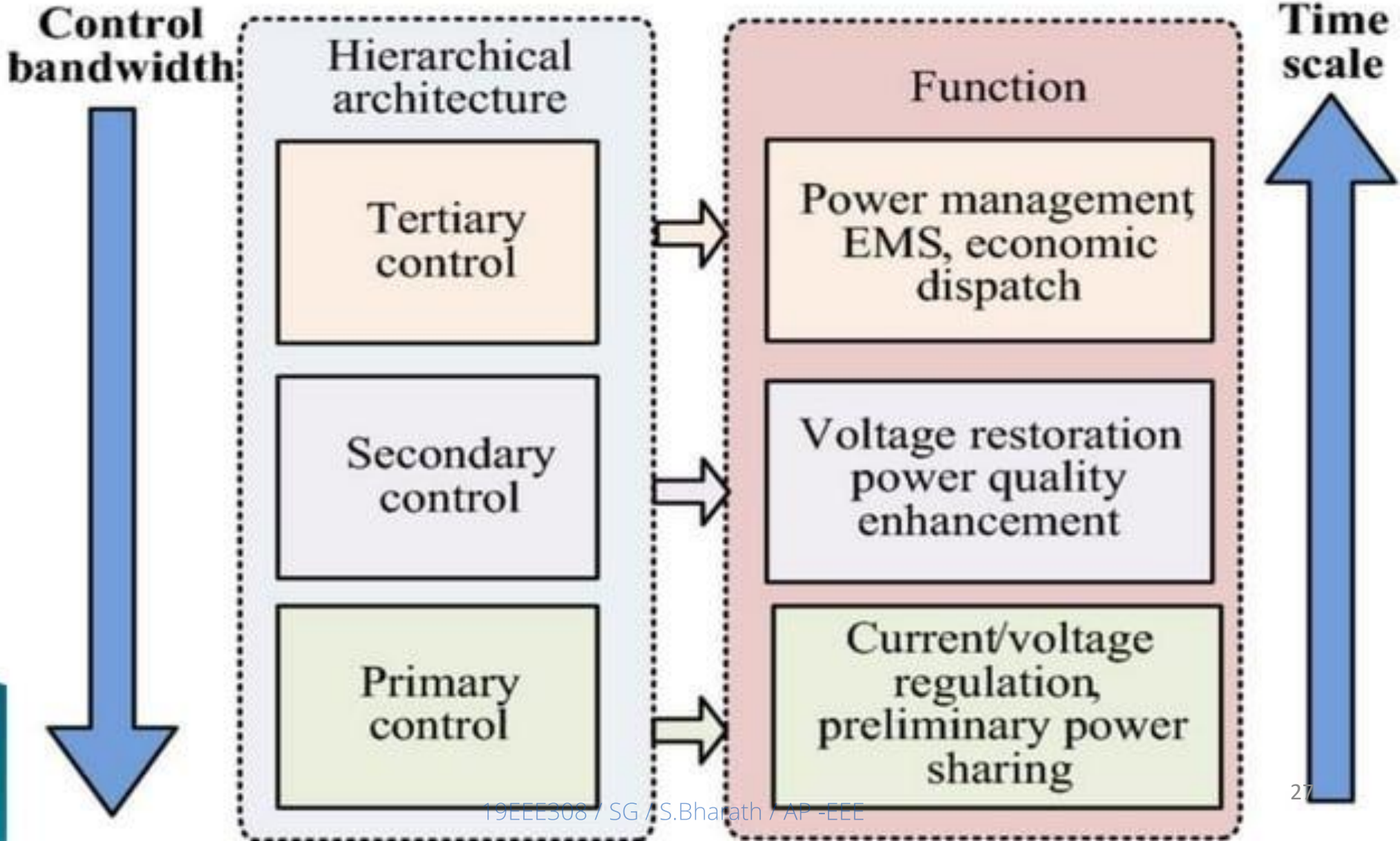
Droop control
Local protection control
Time frame: 10s of milliseconds

Tertiary control

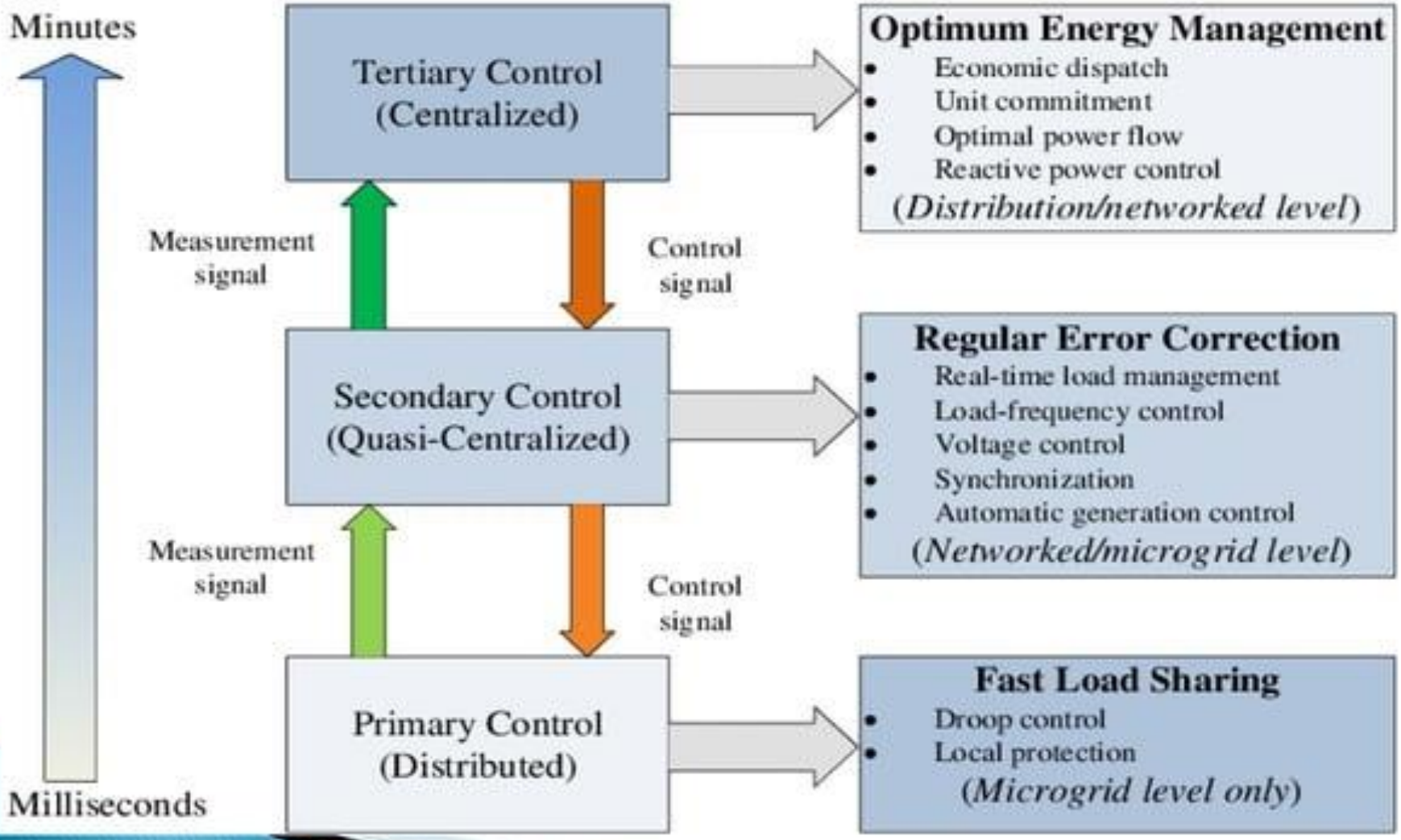
- Tertiary control is the last (and the slowest) control level that considers the economical concerns in the optimal operation of the microgrid, and manages the power flow between microgrid and main grid.
- In the grid-tied mode, the power flow between microgrid and main grid can be managed by adjusting the amplitude and frequency of DERs voltages.


Upper Level Operators
(Interfaces to intentional operation)
Tertiary Level
Economic Dispatching and Optimization
Microgrid Supervision
Generation Plan
Secondary Level
Power Quality Control
Power Flow Control
Generation Mode Selection
Primary Level
Power Sharing Control
Voltage and Current Control
Local Supervision
Physical Level of Microgrid

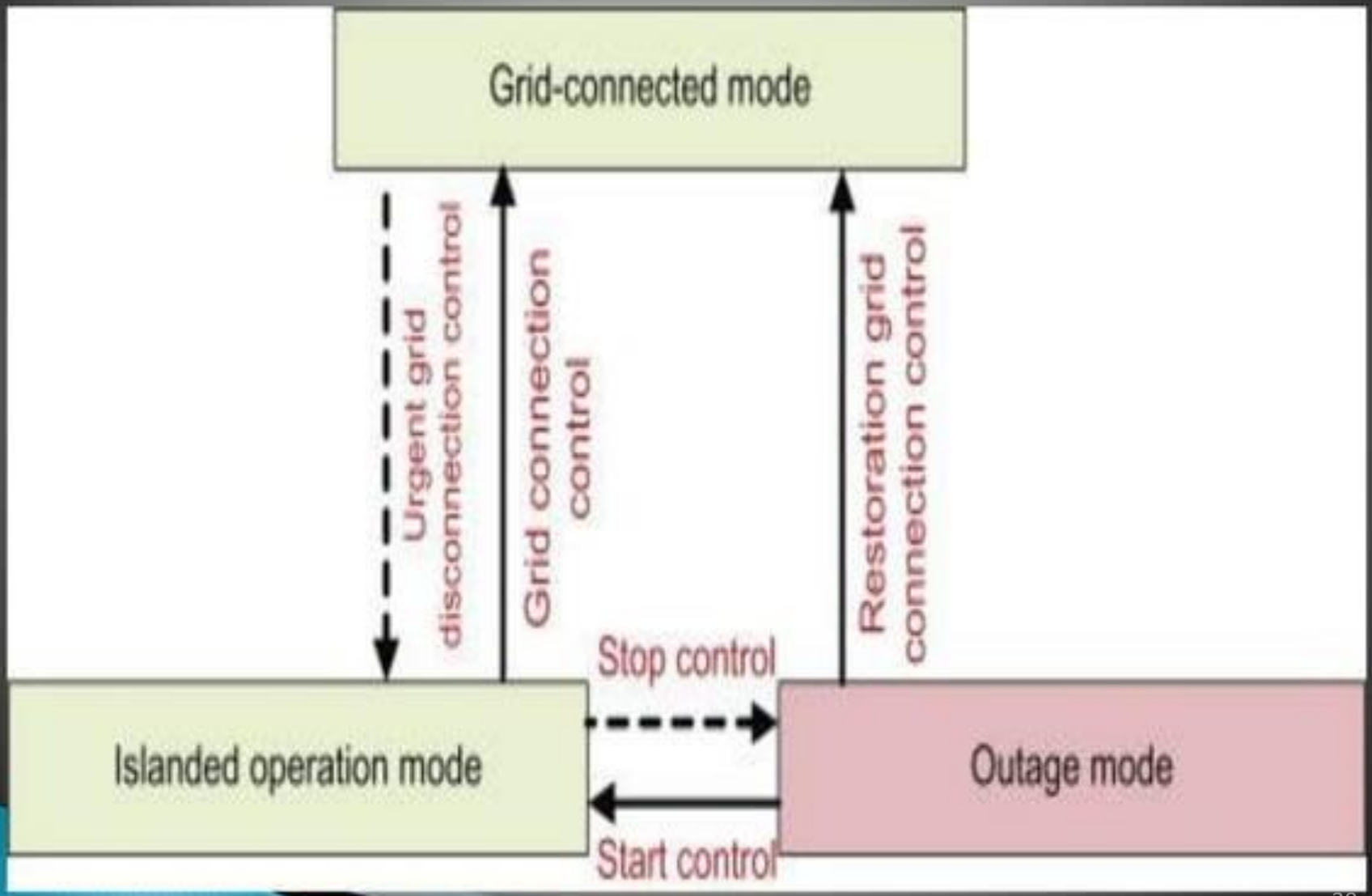
Control bandwidth analysis of Hierarchical control levels of a microgrid



Time scale analysis of hierarchical control levels of a microgrid

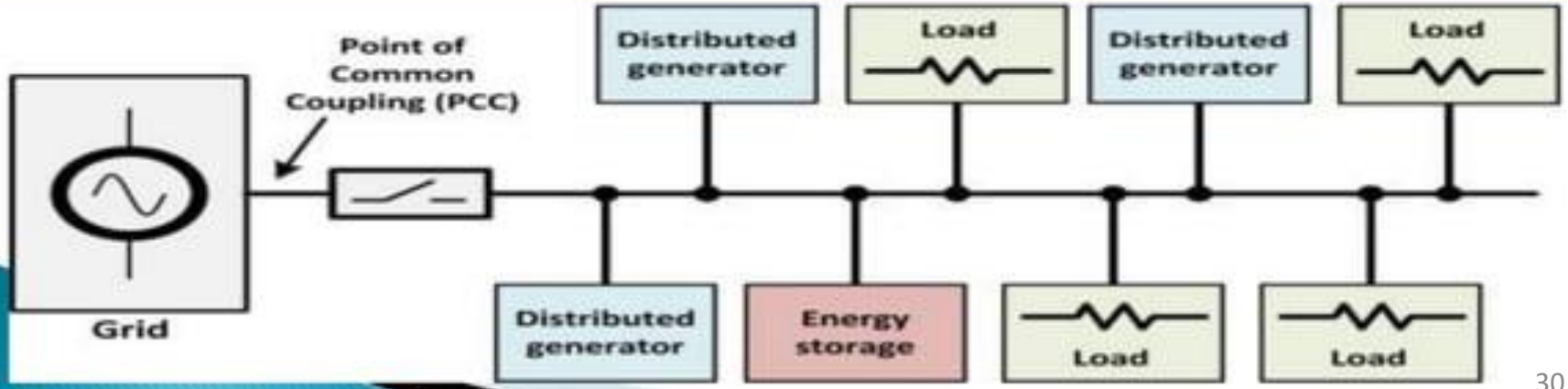


Microgrid operating modes



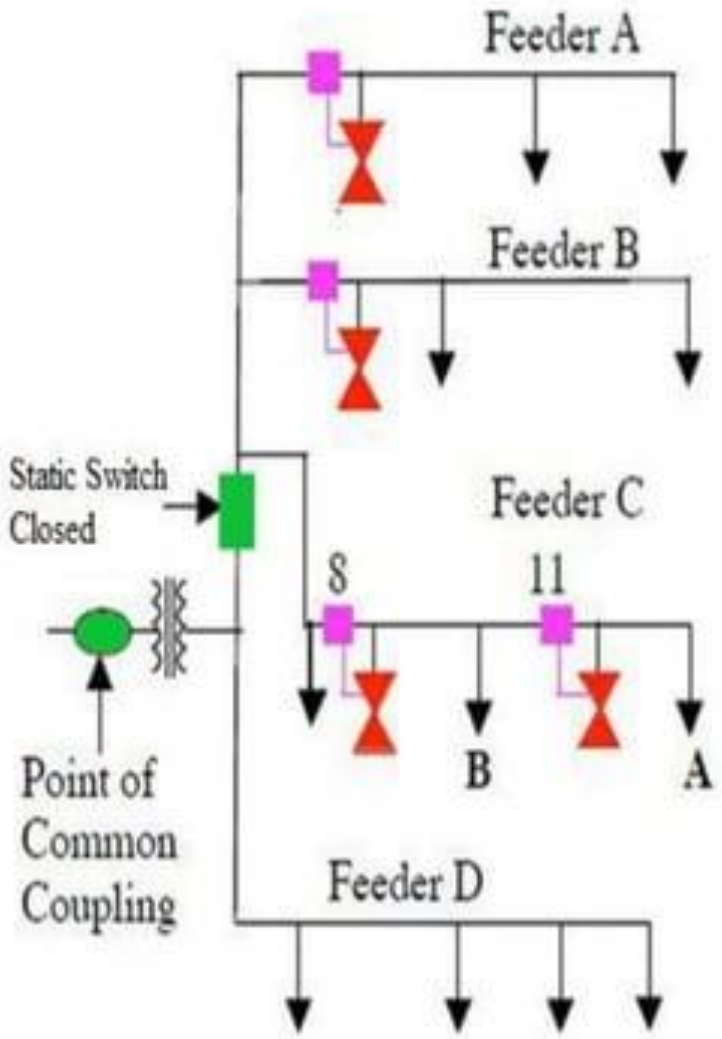
Operation modes continue...

- Microgrid may operate either in grid connected or in islanded mode
- Grid connected mode of operation is further divided into power matched operation and power mismatched operation according to power exchange.
- The microgrid is connected to the distribution network via a PCC



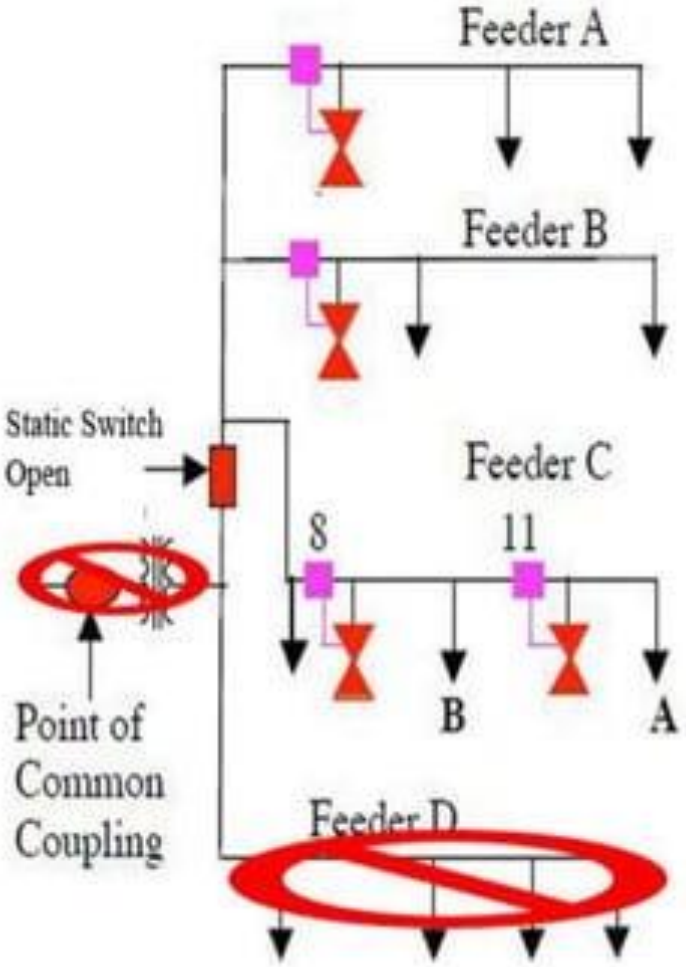
Grid connected operation

- In grid connected mode, the microgrid is connected to and exchanges power with the distribution system of the utility grid via PCC
- Utility grid is active
- Static switch is closed
- All the feeders are supplied by the grid
- Adopt P–Q control



Islanded operation

- Islanded operation means that the microgrid is disconnected from the distribution system of the main grid at the PCC following a grid failure or as scheduled, and that the DGs, Ess, and loads within the microgrid operate independently.
- Static switch is open
- Feeder A,B,C are supplied by micro-sources
- Feeder D is dead.
- Adopts V-f control mode



Conventional grid vs microgrids

- Efficiency of conventional grid is low compared to microgrid.
- Large amount of energy in the form of heat is wasted in conventional grid.
- Power sources in the microgrid are small and located close to the load.

Types of distributed resources

- Distributed resources (DRs) that can be connected to the power grid can be grouped as:

1. **Electronically interfaced generators**
2. **Rotating machine interfaced generators**

- Electronic interfaced DRs are inverter-based units.
- Rotating machine interfaced DRs are induction or synchronous generator based units.

Advantages of microgrid

- Microgrid generation resources can include fuel cells, wind, solar, or other sustainable energy sources.
- Multiple dispersed generation sources and ability to isolate the microgrid from a larger network provides highly reliable electric power.
- By product heat from generation sources such as micro turbines could be used for local process heating or space heating, allowing flexible trade off between the needs for heat and electric power.
- Generate power locally to reduce dependence on long distance transmission lines and cut transmission losses.

Disadvantages of microgrids

- **Voltage, frequency and power quality** are the three main parameters that must be considered and controlled to acceptable standards whilst the power and energy balance is maintained.
- **Electrical energy needs to be stored** in battery banks or as mechanical energy in flywheels thus requiring more space and maintenance.
- **Resynchronisation** with the utility grid need to be made carefully.
- **Microgrid protection** is one of the most important challenges facing the implementation of micro-grids

Virtual power plant

- A Virtual Power Plant is a network of decentralized, medium-scale power generating units such as wind farms, solar parks, and Combined Heat and Power (CHP) units, as well as flexible power consumers and storage systems.
- The interconnected units are dispatched through the central control room of the Virtual Power Plant but nonetheless remain independent in their operation and ownership.

  The objective of a Virtual Power Plant is to relieve the load on the grid by smartly distributing the power generated by the individual units during periods of peak load.
- Additionally, the combined power generation and power consumption of the networked units in the Virtual Power Plant is traded on the energy exchange.

Continue...

- Virtual power plants- a term frequently used interchangeably with micro-grids - rely upon software systems to remotely and automatically dispatch and optimize generation or demand side or storage resources in a single, secure Web-connected system.
- In short VPPs represent an 'Internet of energy', trapping existing grid networks to tailor electricity supply and demand services for the customer, maximizing value for both end user and distribution utility through software innovations.
- *The beauty of the VPP is that it can optimize the entire system without the need for large capital investments in infrastructure.*

Microgrids versus VPPs

- Microgrids can be grid-tied or off-grid remote systems (VPPs are always grid-tied)
- Microgrids can 'island' themselves from the larger utility grid (VPPs don't offer this contingency)
- Microgrids typically require some level of storage (whereas VPPs may or may not feature storage)
- Microgrids are dependent upon hardware innovations such as inverters and smart switches (whereas VPPs are heavily dependent upon smart meters and IT)
- Micro-grids encompass a static set of resources in a confined geography (whereas VPPs can mix and match among a diversity of resources over large geographic regions).
- Consumer interest: A microgrid focuses on the satisfaction of local consumption. (while VPP deals with consumption only as a flexible resource that participates in the aggregate power trading via DSI remuneration)

Continue...

- Microgrids typically only tap DER at the retail distribution level (whereas VPPs can also create a bridge to wholesale markets)
- Microgrids still face regulatory and political hurdles (whereas VPPs can, more often than not, be implemented under current regulatory structures and tariffs)
- Size: The installed capacity of microgrids is typically relatively small from few KW to several MW (While the VPPs power rating can be much larger)
- Locality: In a microgrid, DER are located within the same local distribution network and they aim to satisfy primarily local demand. (In a VPP, DERs are not necessarily located on the same local network and they are coordinated over a wide geographical area. The VPP aggregated production participates in traditional trading in normal energy markets)

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Questions

- Differentiate between microgrids and virtual power plants?
- What are the two modes of operation of microgrid?
- Classify the microgrid in terms of function, capacity, and source type.
- Explain the structure of microgrid in terms of control?