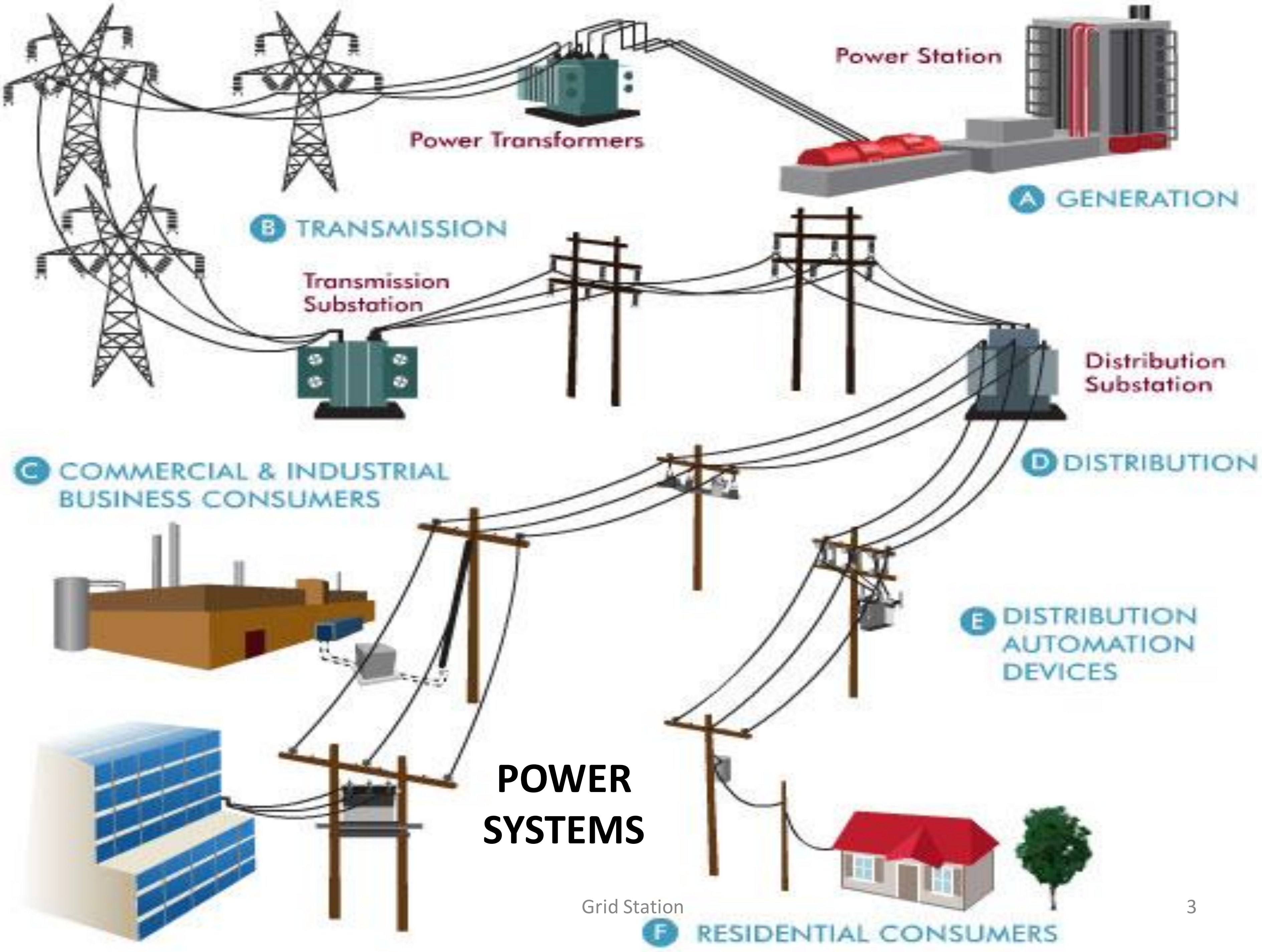
Asian Institute of Technology

(Introduction to Grid Station Operation and Management)

Dr. Sasidharan Sreedharan
www.sasidharan.webs.com

Contents

- Electrical Power System Fundamentals
- Power System SCADA
- Grid Station Fundamentals
- Components of grid station – Equipment and parameters
- Grid Station Operation and Control
  - Load Frequency Control
  - Reactive Power Control
- Grid Station Automation and SCADA
- Advancements in Grid Station Automation



POWER SYSTEMS

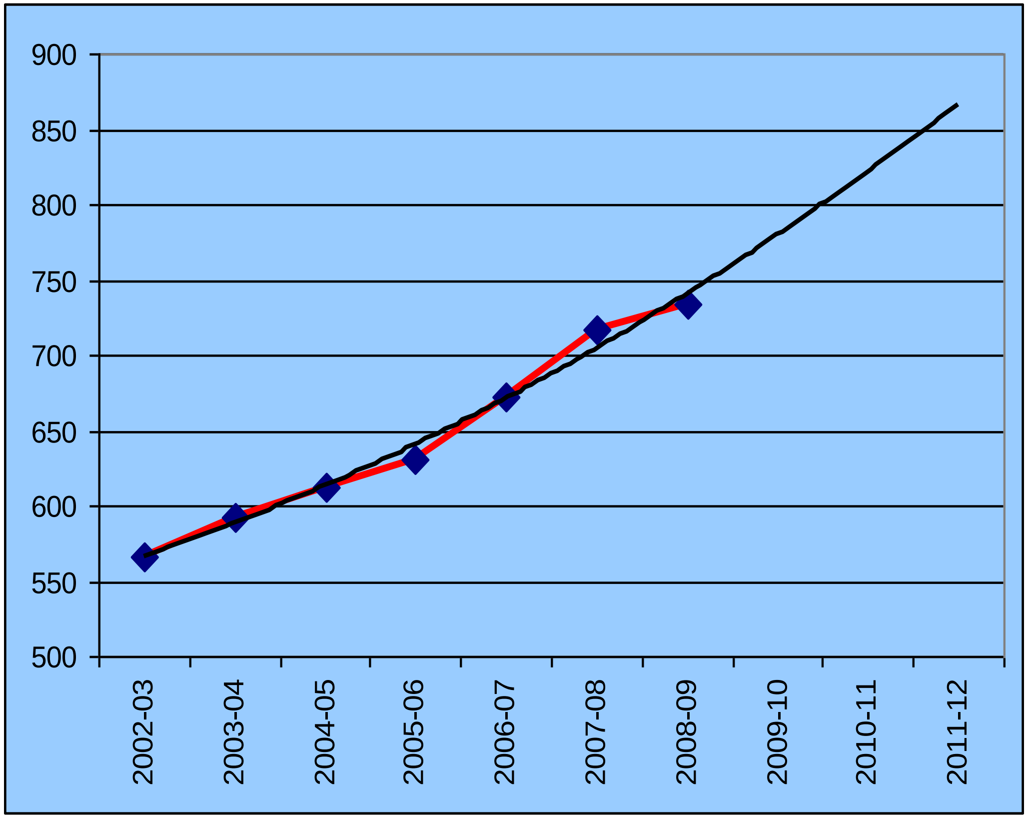
Power Sector - Milestones….

- Evolution
  - Small islanded utilities
  - Vertically integrated utilities
- Bifurcation into Regions
- Opening up for competition
- Generation companies
- Distribution licensees
- Transmission Utilities and Licensees
- Independent System Operator

Growth of Electric Power System

There is close correlation between GDP and per capita consumption

Growth of Economy – 7 to 8%
Power sector growth required – 10-12%
Per capita consumption 2012 – 900kWh



A typical Indian Case Study

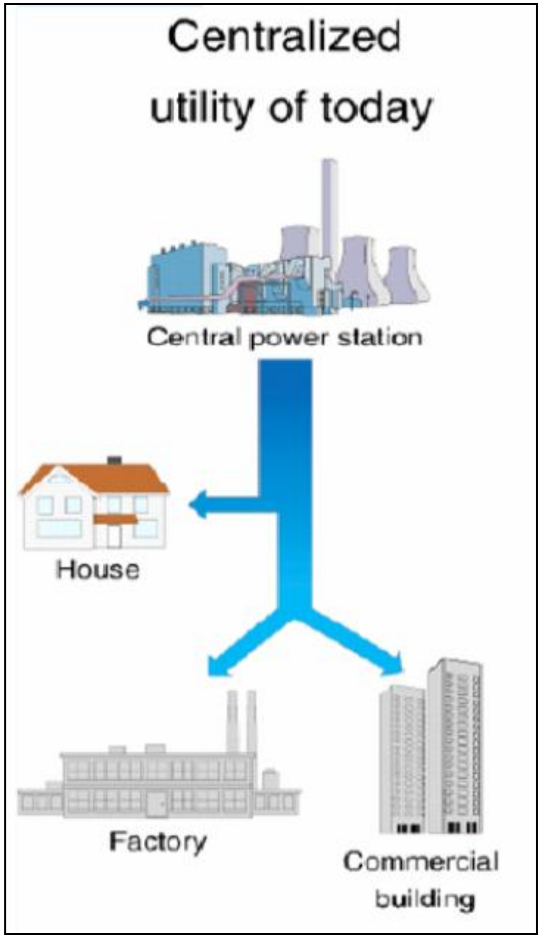
Power sector in nutshell

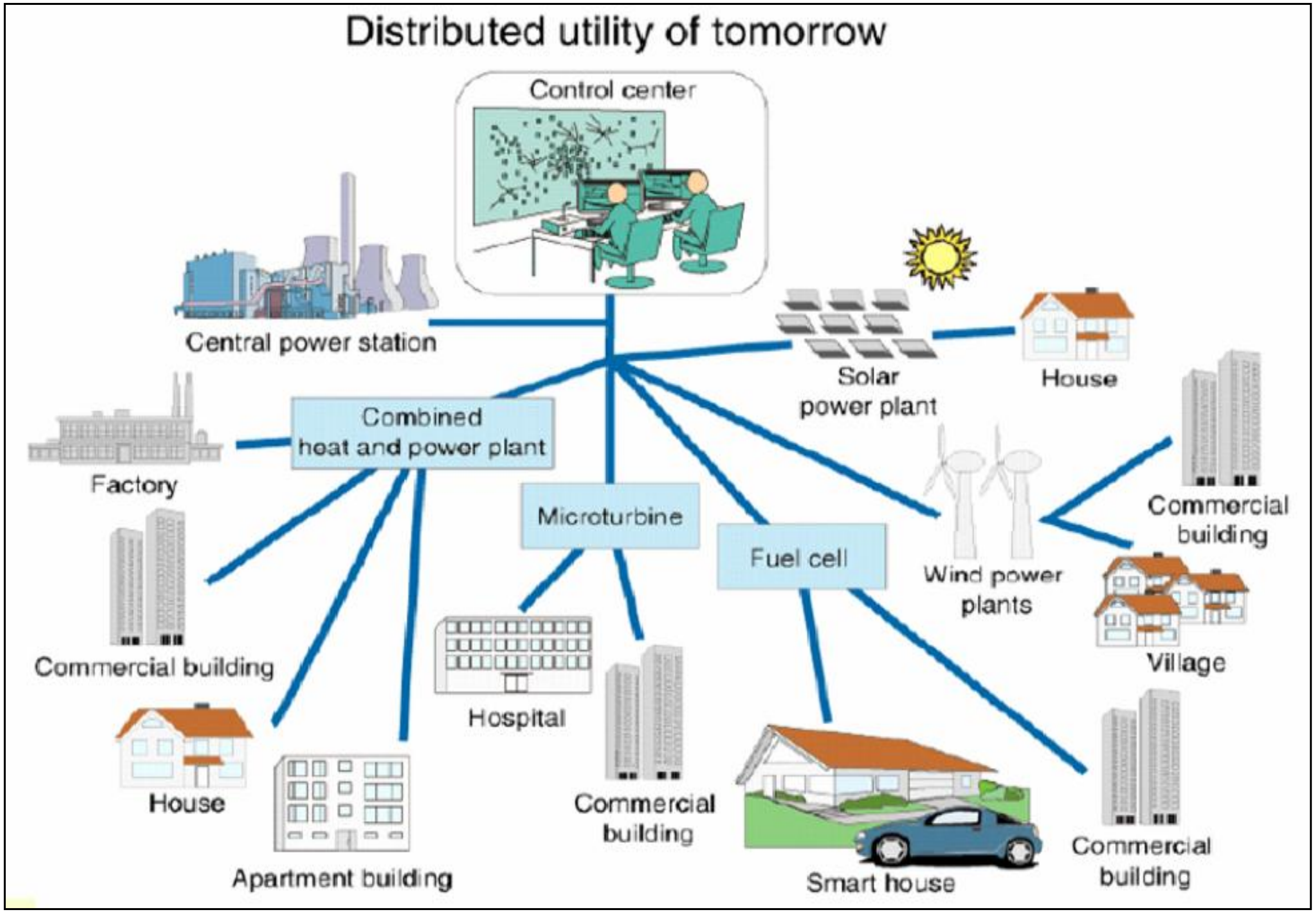
- Per capita consumption is a Key index to economic growth
- **Growth can be correlated to growth of GDP**
- **Per capita consumption – much low**
- **Restructuring and New Business models – world wide**
- Vibrant field
- Changes by regulations and acts

FUTRE

- **Decentralization of generation**
- **Micro grids, Smart grids**
- **Penetration of Renewable energy sources**
- **Power Quality and Custom Power**

Electric power System Today and Tomorrow





AIM OF POWER SYSTEM ENGINEERS

- EARLIER STATEMENT
  - To provide **Reliable, Stable** and **Secured Power supply** to the end user with **Least possible cost**

- PRESENT STATEMENT
  - **To provide *Reliable, Stable* and *Secured* Power supply to the end user with *Least possible cost* WITH *Maximizing profit* to all stake holders**

International Grid Operators Worldwide

Associations Worldwide

- **Very Large Power Grid Operators (VLPGO)**
- TSO-Comparison Group
- CIGRE - C2 and C5 committees
- International Interconnections - SAARC

Formation of the VLPGO

- A voluntary initiative of the world's largest Power Grid Operators
- Representing together more than 60% of the electricity demand in the world.
- Created in 2004
  - Not-for-profit organization
  - Followed several blackouts across the world
  - To investigate fundamental issues of common interest to its members
  - To develop joint action plans addressing the improvement of power system security.
- Formalized in 2009
- Specific Focus
  - **Issues related to Very Large Power Grids**
- Membership
  - **Size > 50 GW**

Very Large Power Grid Operators (VLPGO)

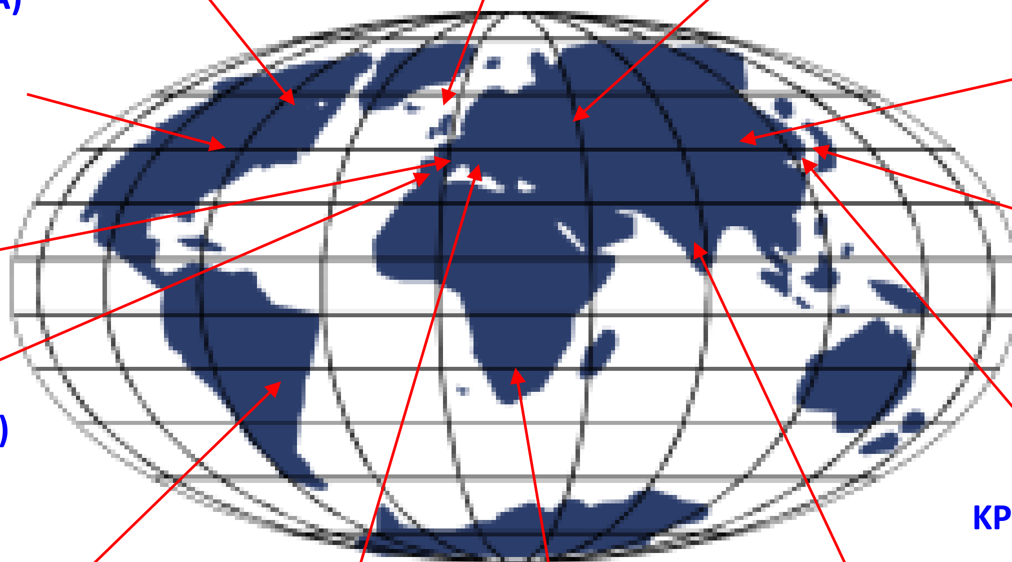
National Grid (UK)
68GW
Capita: 65m

PJM (USA)
165GW
Capita: 51m

SO - UPS (Russia)
146 GW
Capita: 144m

MidWest ISO (USA)
159GW
Capita: 40m

SGCC (China)
900GW
Capita: 1000m



RTE (France)
93GW
Capita: 65m

Tepco (Japan)
64GW
Capita: 45m

Red Electrica (Spain)
93GW
Capita: 47m

KPX (South Korea)
70GW
Capita: 49m

ONS (Brazil)
100GW
Capita: 170m

Terna (Italy)
57GW
Capita: 60m

Eskom
(South Africa)
43.5GW
Capita: 49m

PGCIL (India)
163GW
Capita: 1200m

http://www.vlpgo.org

Source: VLPGO, 2010

Website of System Operators Worldwide

Sl.No.	Name of the TSO	Country	Web Presence
1	ESKOM	South Africa	www.eskom.co.za
2	Red Eléctrica de España*	Spain	www.ree.es
3	Landsnet	Iceland	www.landsnet.is
4	Fingrid*	Finland	www.fingrid.com
5	Amprion*	Germany	www.amprion.net
6	Transpower NZ	Newzealand	www.transpower.co.nz
7	Saudi Electricity Company	Saudi Arabia	www.se.com.sa
8	TenneT	Netherlands	www.tennet.org
9	Statnett SF	Norway	www.statnett.no
10	PJM Interconnection**	PA,USA	www.pjm.com
11	National Grid Electricity Transmission*	UK	www.nationalgrid.com
12	CLP Power	Hong Kong	www.clpgroup.com.hk
13	ESB NG	Ireland	www.eirgrid.com
14	Transpower	Germany	www.transpower.de
15	Swisssgrid	Switzerland	www.swissgrid.ch
16	Rede Eléctrica Nacional	Portugal	www.ren.pt
17	Hydro Québec	Canada	www.hydroquebec.com
18	Svenska Kraftnät	Sweden	www.svk.se
19	PSE	Poland	www.pse-operator.pl
20	EWA	Bahrain	www.mew.gov.bh
21	China Southern Power Grid	China	www.eng.csg.cn
22	Power Grid Corporation of India Ltd.	India	www.powergridindia.com / www.nldc.in

VLPGO Aims and Objectives

- Work constantly to plan, monitor, supervise and control the energy delivered as a continuous process 24 hours a day
- Delivering the electricity that powers modern societies
- Critical role of Grid Operators includes
  - acting on behalf of Consumers, to **ensure quality** while **minimizing costs** and recognizing economic and societal dependence on electricity;
  - a **technical role** in planning, designing, and managing the Power Systems;
  - an **interface role** with generators, market participants and distributors, which are the most direct users of the transmission grid;
  - a **natural role** of interlocutors with power exchanges, regulators and governments.

Common Challenges for VLPGO

- Providing power system reliability and security
- **Smart Grid development**
- **Integration of Renewables**
- Integration of Electric Vehicles
- Capacity development and optimization including system renovation and development, equipment upgrading.
- Reducing CO2 emissions
- Improve productivity and energy efficiency
- Power system visualization
- **Demand Side Management**
- Interconnections
  - Development of new technologies and HVDC
- Establishment and coordination of new control centers

VLPGO 2011 Joint Activities

Working Groups

- *WG #1 – Wide Area Monitoring Applications*
- *WG #2 – Enhanced Security*
  - *WG 2a – Security vs. Operation Costs*
  - *WG 2b – Enhanced Network Restoration*
  - *WG 2c – Equipment Overstressing*
  - WG 2d –Security of Supply to large metro areas
- *WG #3 – Integration of Renewables*
- *WG #4 – Load Forecasting*
- *WG #5 – HVDC*
- *WG #6 – Electric Vehicles*
- *WG #7 – Storage*

Joint Projects

- *Visualization*

Workshops

- *WS #1 – KPIs*
- *WS #2 – Smart Grid (KPX)*

VLPGO Work plan … Road Ahead

VLPGO Workplan									
Driver	**No.**	**Activity**	**Owner**	**2010**	**2011**	**2012**	**2013**	**2014**	**Conclusion**
Renewables	1	WG Integration of Renewables	NGC						
	2	JP HVDC (Technology)	NGC						
	3	**WG HVDC (Op Experience)**	ONS						
	4	WG Storage	N/A		4	4	5	5	
SMARTer	5	WS Smart Grids	KPX						
	6	WG Smart Grids	N/A						
	7	WG Electric Vehicles	PJM						
	8	WG Frequency Response	N/A		6	6	6	6	
	9	**WG Load Forecasting**	REE						
Security of Supply	10	WG Operational Cost vs Risk	Terna						
	11	JP Monitoring & Automation	Tepco		Combine				TofRef
	13	WG Cyber Security	N/A		1				
New Technologies	14	WG Wide Area Monitoring Applications	PJM						
	15	WG Enhancing Network Capacity	N/A		6	6	7	7	
Efficiency	16	WS Operational KPIs	UPS						
	17	WG Enhanced Network Restoration	Terna						
	18	WG Overstressing	ONS						
	19	JP Asset Management	Tepco						
	20	JP Visualisation	SGCC						
	21	WG EMS Architechture	Sec		Combine				TofRef
		No. of Activities		**12**	**12**	**10**	**8**	**8**	

MAIN COMPONENTS OF GRID STATION SCADA

** Data Conversion Devices :- Transducers

** Field Data Collection Devices :- R T U

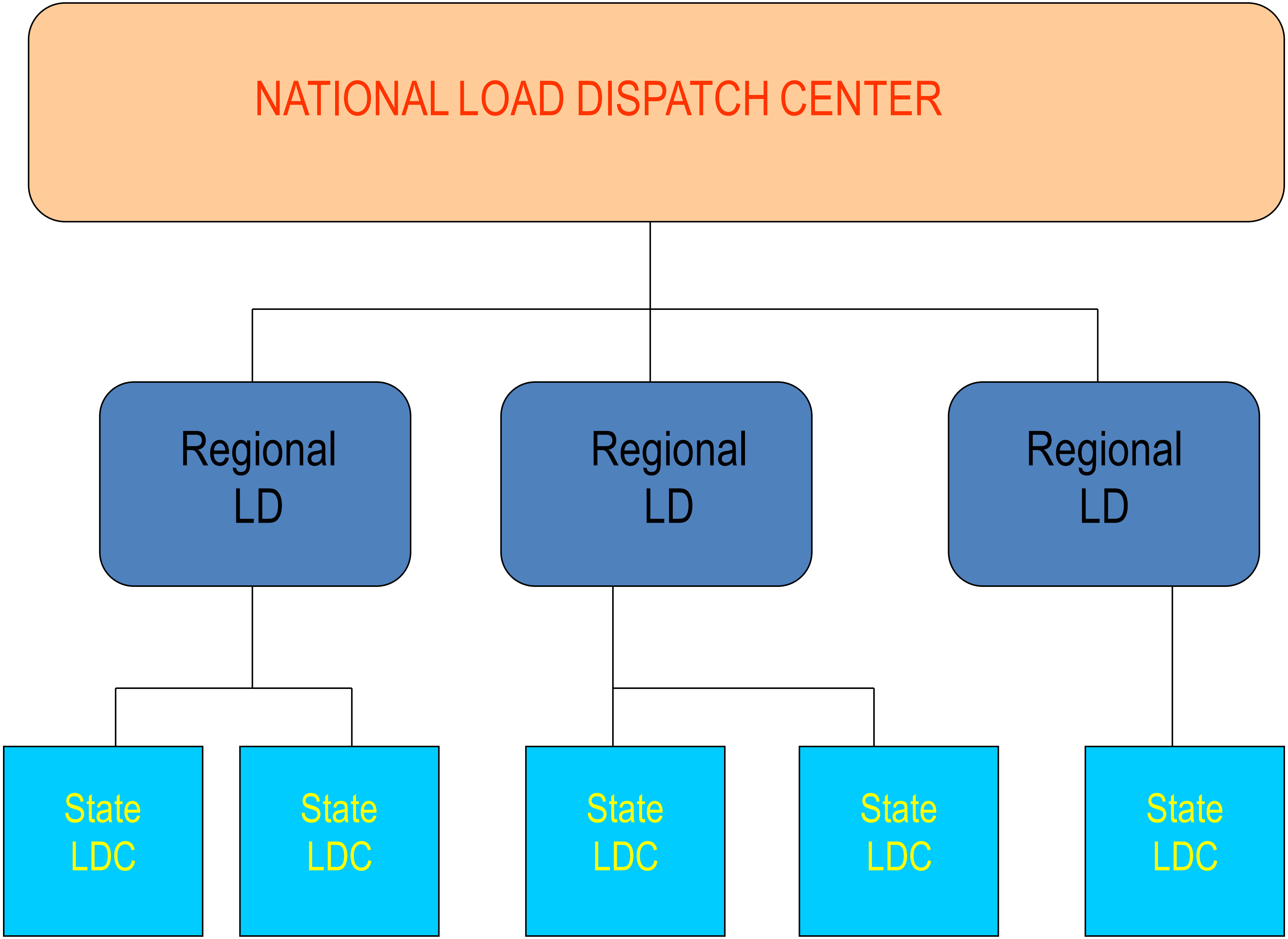
** Interfacing Devices :- MODEM

** Communication Media :- Different Modes

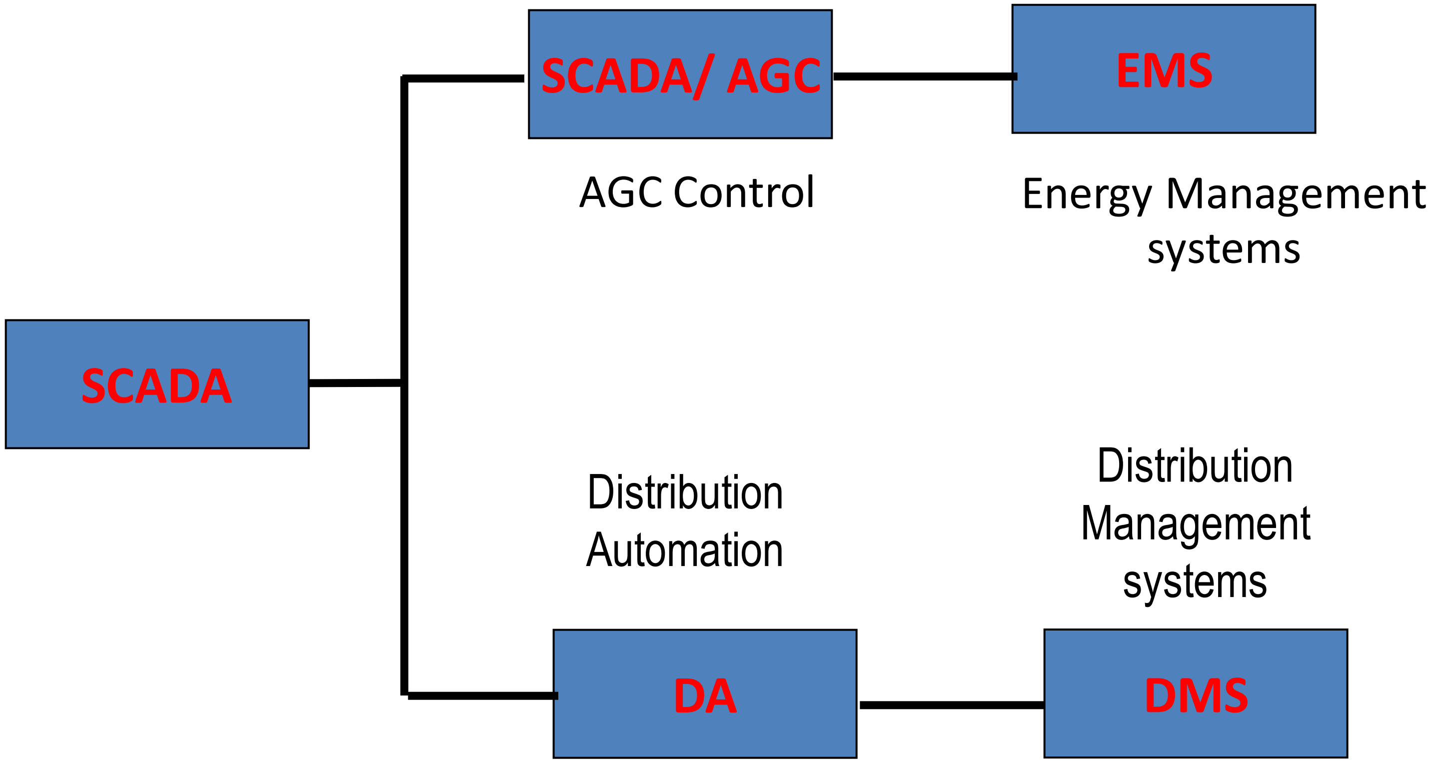
** Data Receiving Equipment :- FEP (Front End Processor)

** Processing and Distributing :- Computers, LAN etc

** Display Devices :- PC, Screen etc


NATIONAL LOAD DISPATCH CENTER
Regional LD
Regional LD
Regional LD
State LDC
State LDC
State LDC
State LDC
State LDC

Power System SCADA - Components



SCADA / AGC

- Automatic Generation Control
- Economic Dispatch Calculation/Hydro Allocator.
- Interchange Transaction Scheduling
- Transaction Evaluation (Area A and Area B)
- Unit Commitment
- Short-Term Load Forecasting

EMS

- Network Configuration/Topology Processor
- State Estimation
- Contingency Analysis
- Three Phase Balanced Operator Power Flow
- Optimal Power Flow
- Dispatcher Training Simulator

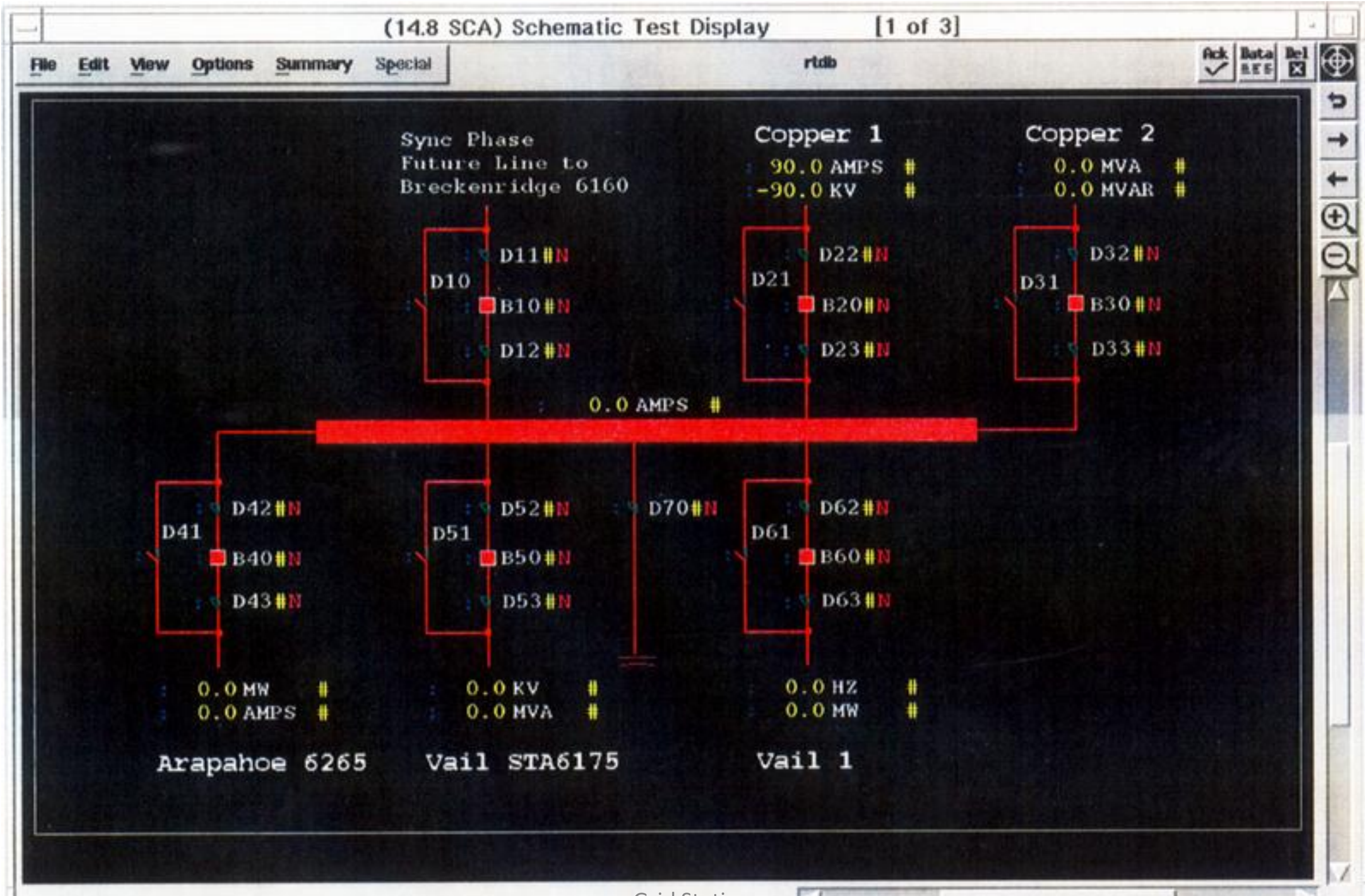
DA

- Voltage Reduction
- Load Management
- Power Factor Control
- Two-Way Distribution Communications
- Short-Term Load Forecasting
- Fault ID/Fault Isolation/Service Restoration
- Interface to Intelligent Electronic Devices (IEDs)

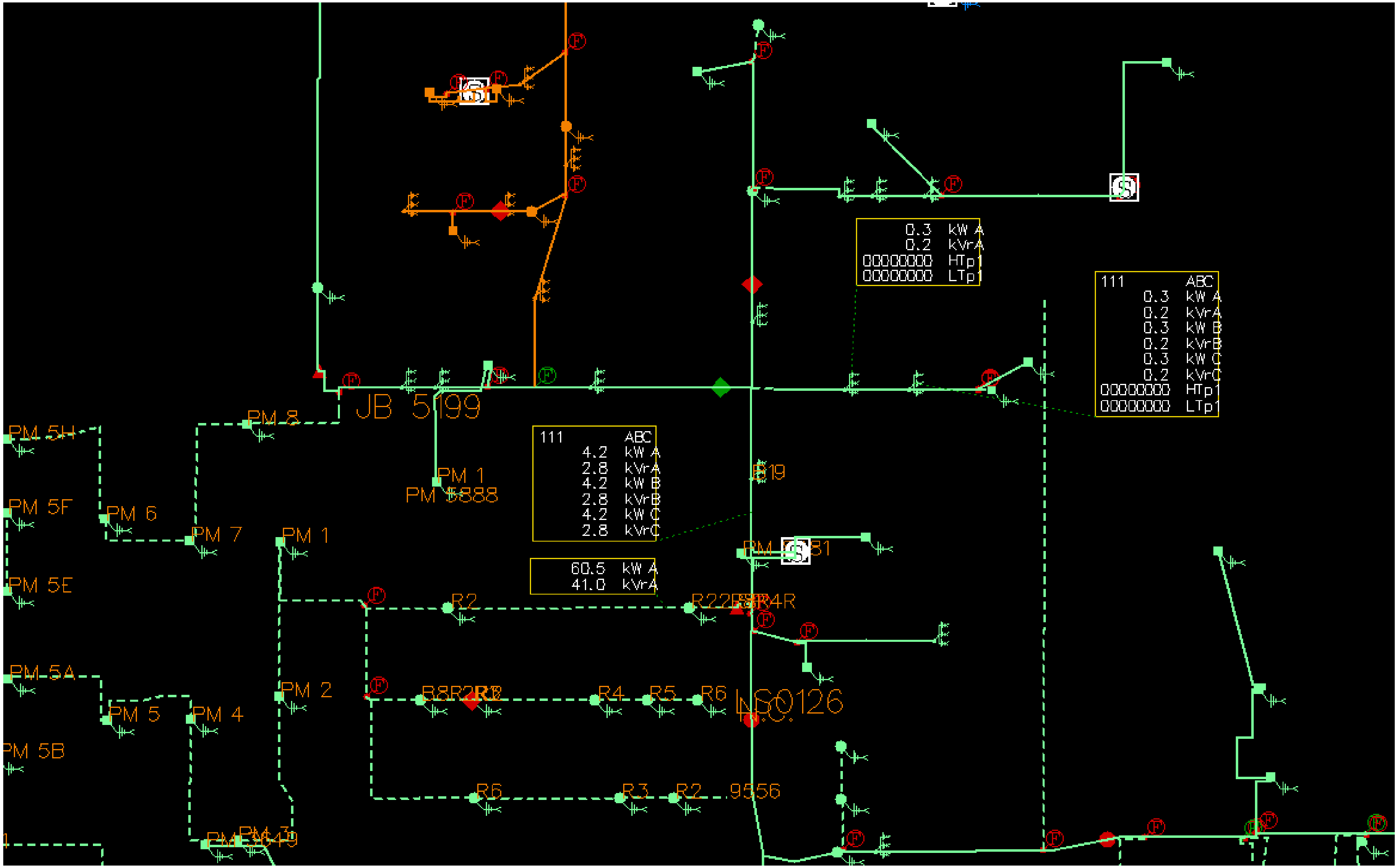
DMS

- Three Phase Unbalanced Operator Power Flow
- Interface To/Integration With Automated Mapping/Facilities Management (AM/FM)
- Interface To Customer Information System (CIS)
- Map Series Graphics
- Trouble Call/Outage Management

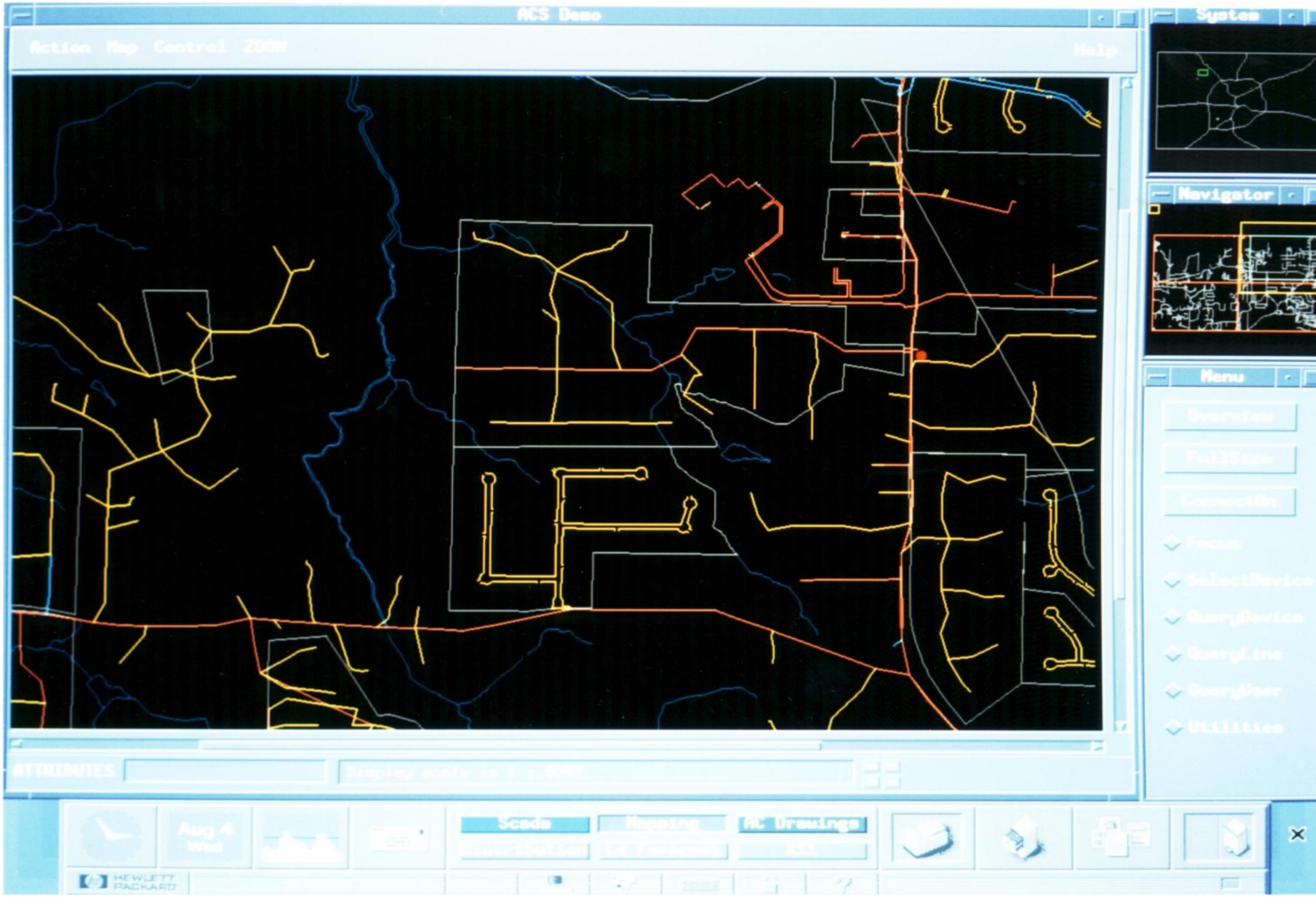
One Line Display



Feeder Map Display



Full Graphics (Feeder map)



Map board/Projection Screens

GPS Time Reference Unit

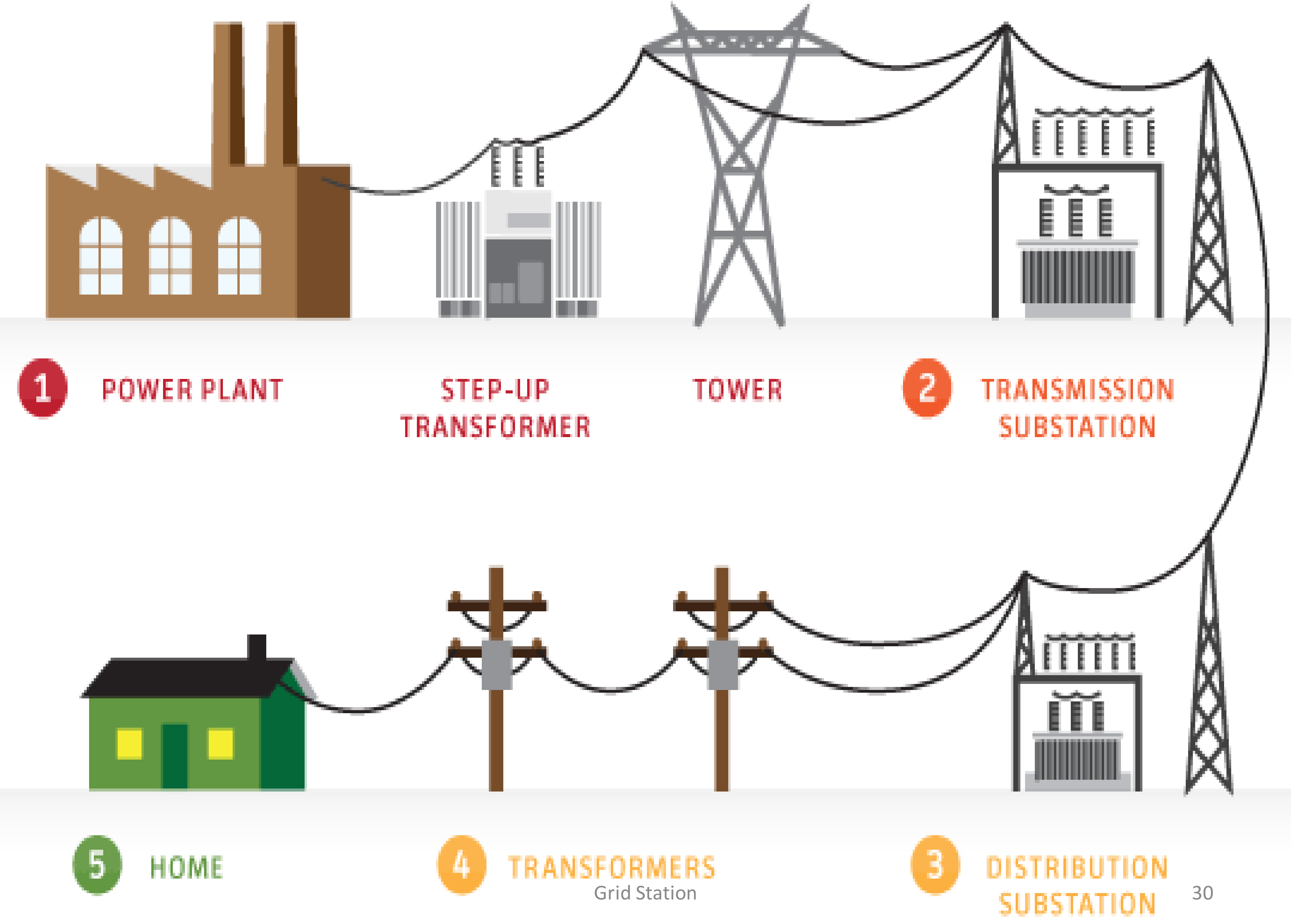
What is a Grid Station (GSS)

- Grid stations or grid sub stations are the stations which reduce the High Voltage to Low Voltage.

- It is also called by the name **transmission substation** which connects two or more transmission lines

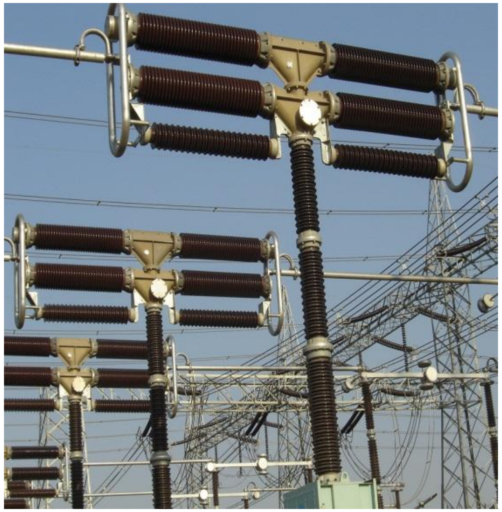
There are different kinds of Grid Stations as given below

- 132 KV Grid Station
- 220 KV Grid Station
- 500 KV Grid Station



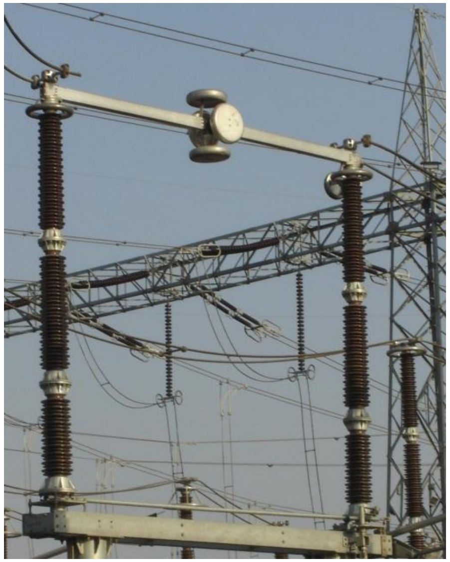
Grid Station

500kV Grid Station Bird's view

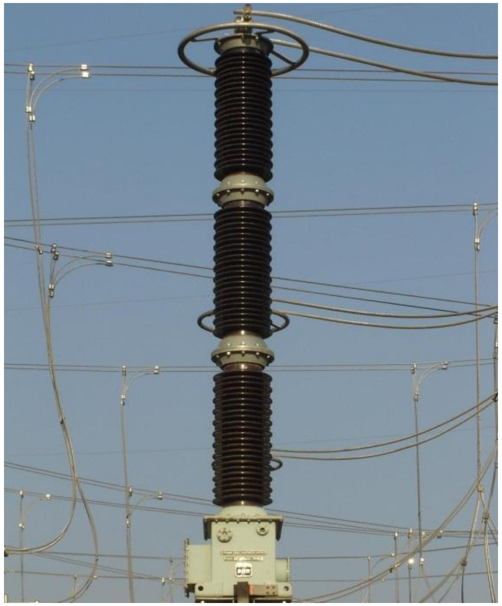


Circuit Breaker

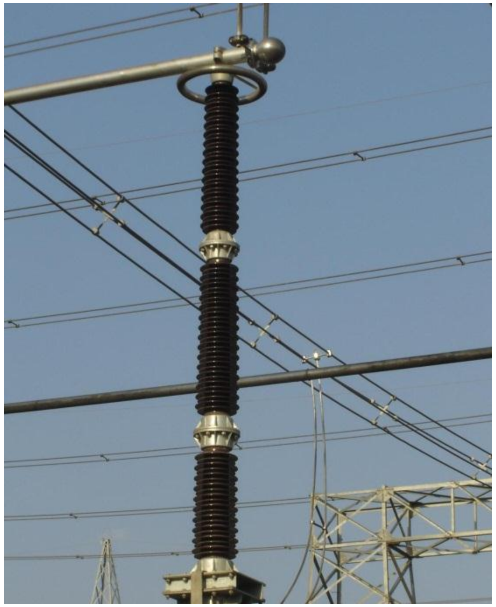
Current Transformer



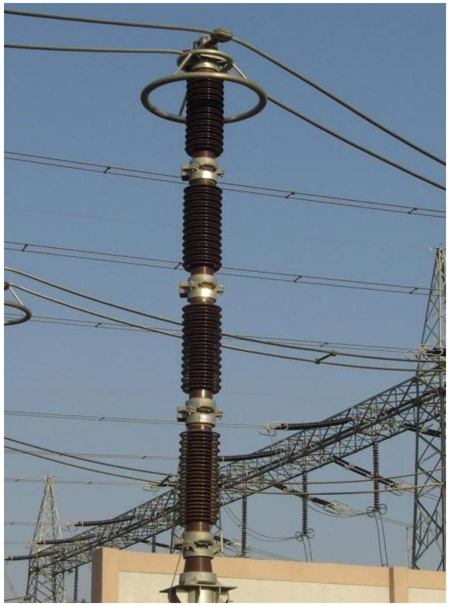
Isolator



CVT



Post Insulator

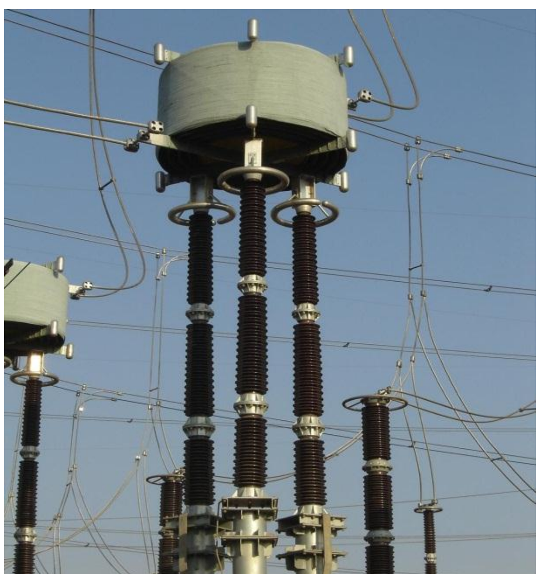


Surge Arrester

Shunt Reactor & NGR

400/220 kV Auto Transformer

Wave Trap



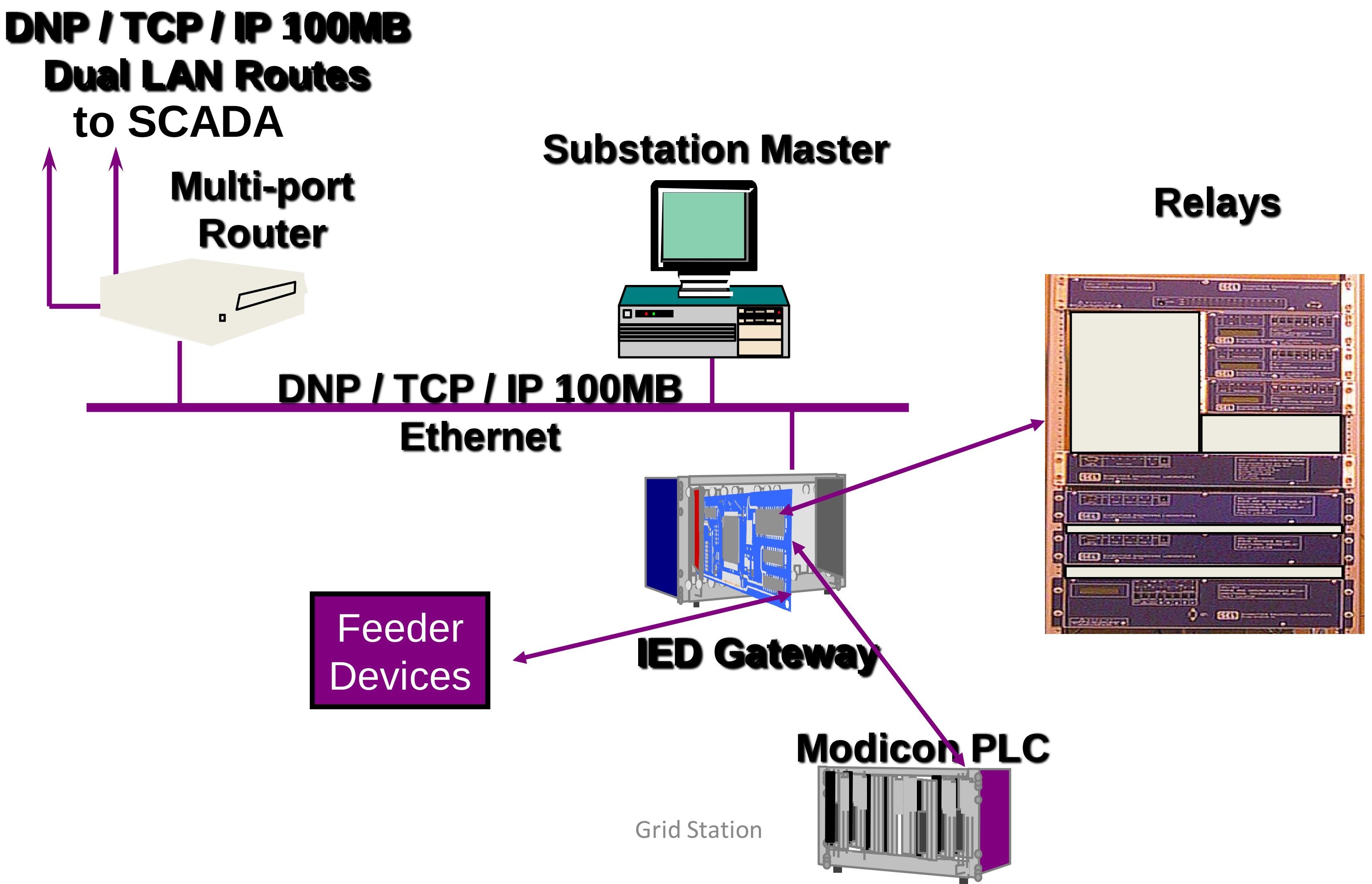
Spacers

Earthing Tower

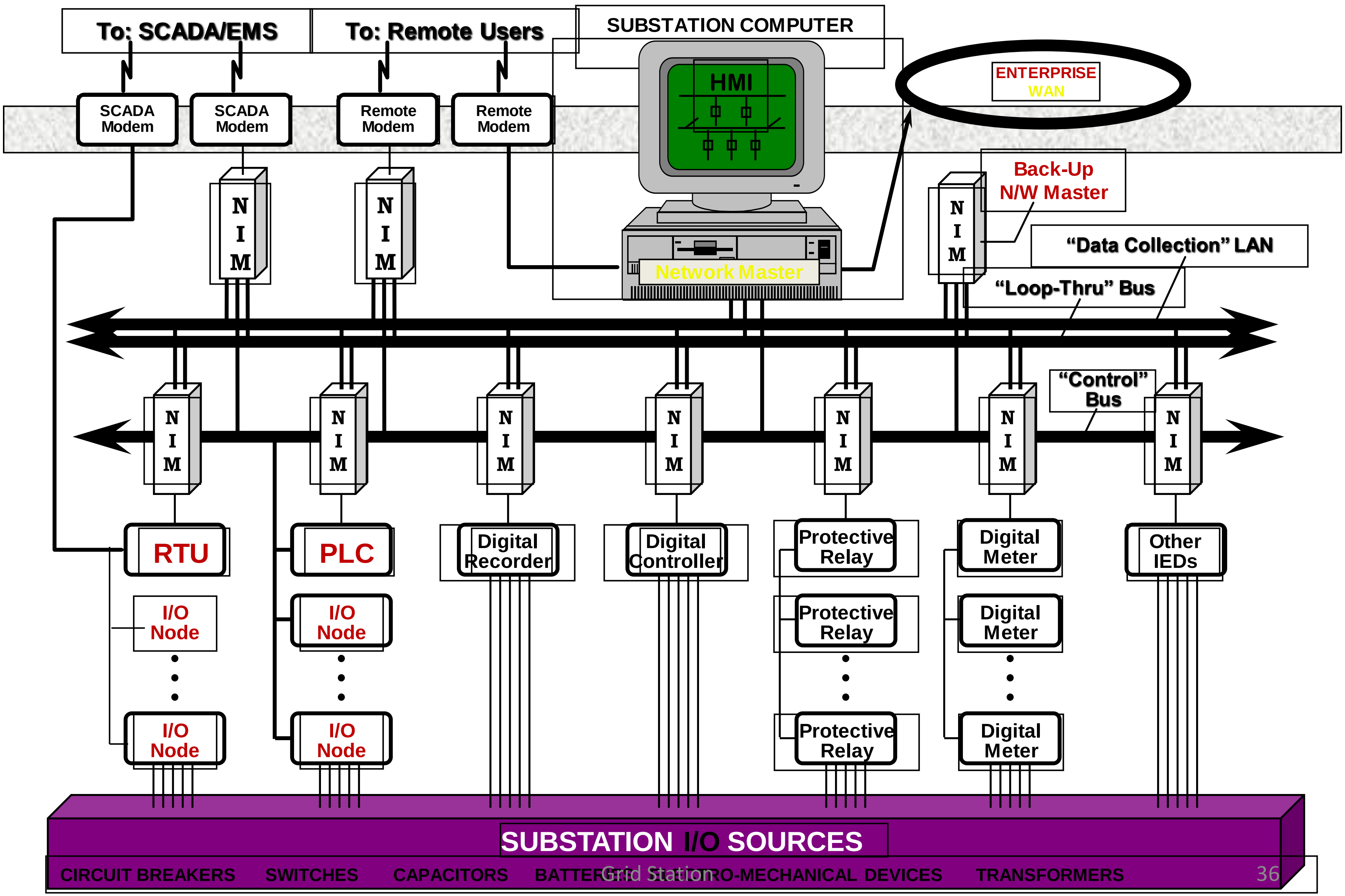
Grid station Local Area Network (LAN)

- The G/S LAN provides the means of connecting various components of the grid station to the SCADA System. Most important are
  - *IEDs (Intelligent Electronic devices)*
  - *Substation Host Processor*
  - *Interface to Wide Area Network*

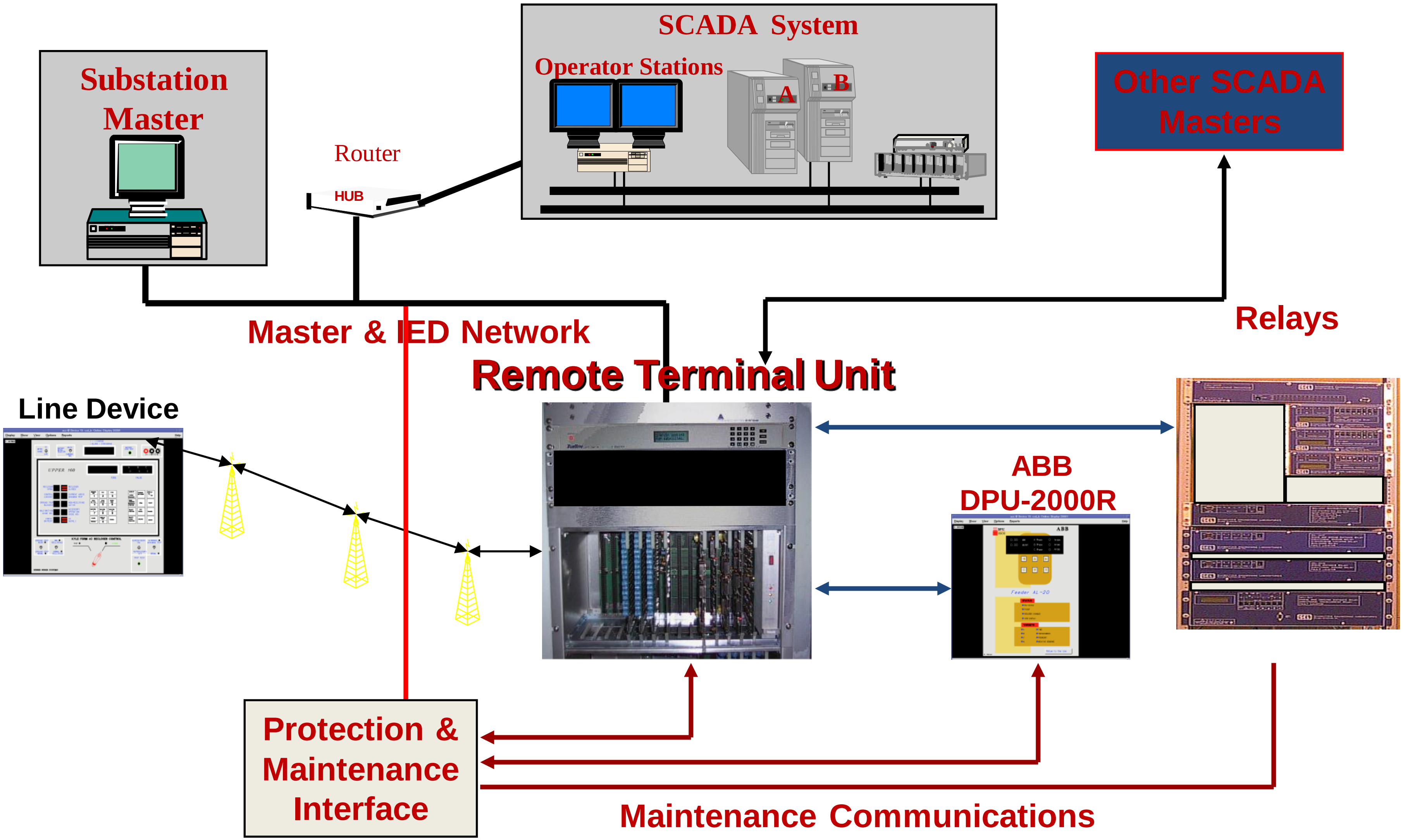
SA System for a Typical City



Substation Distributed LAN Architecture



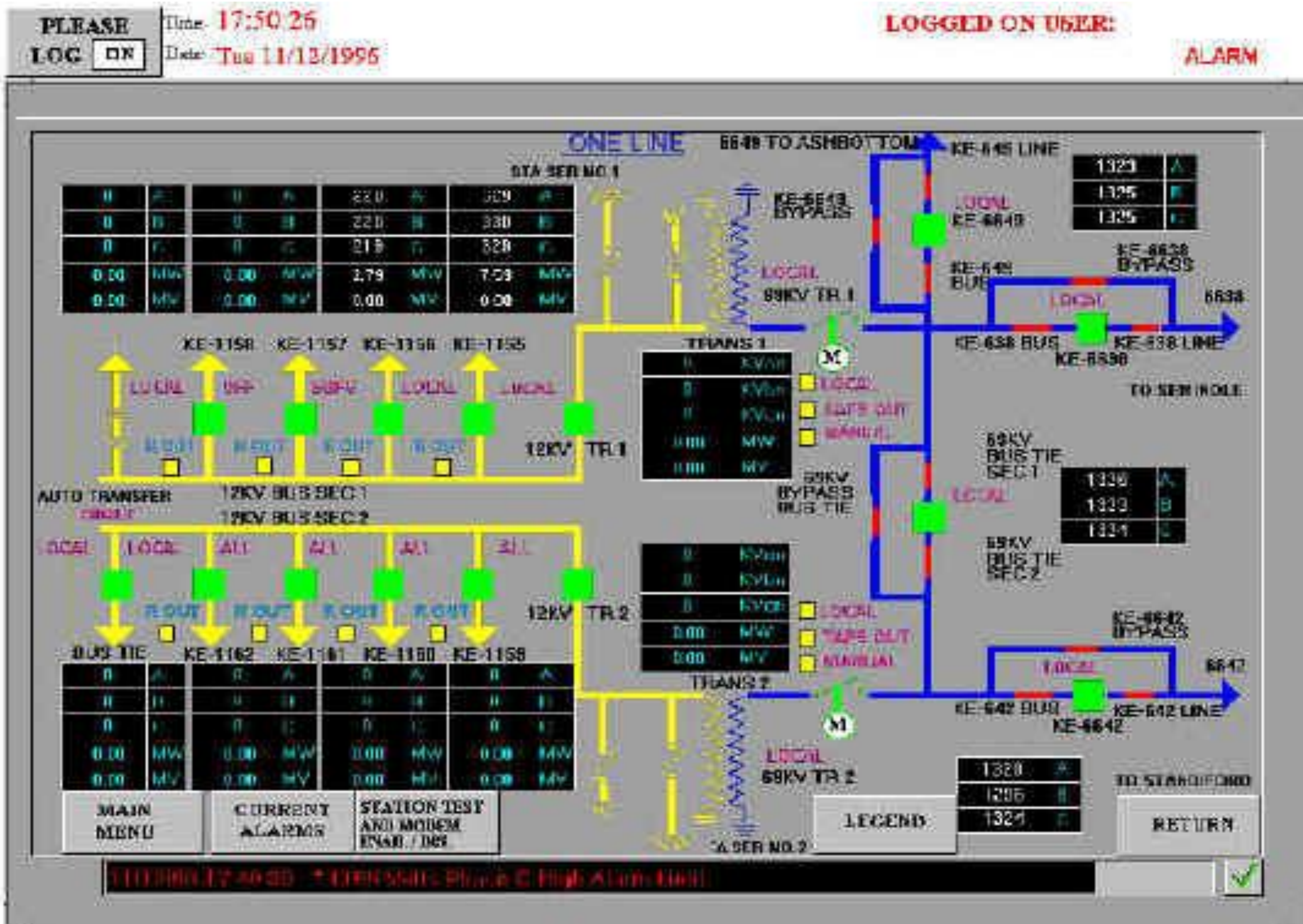
Substation RTU-Centric Architecture



Control Devices/User Interface

- Provides mechanism for:
  - Controlling substation equipment
    - circuit breakers
    - motorized disconnect switches
    - substation capacitor banks
    - load tap changer
  - Viewing/Changing settings
    - Protective relays
    - Programmable controllers

Substation One-Line Display



Intelligent Electronic Devices (IED)

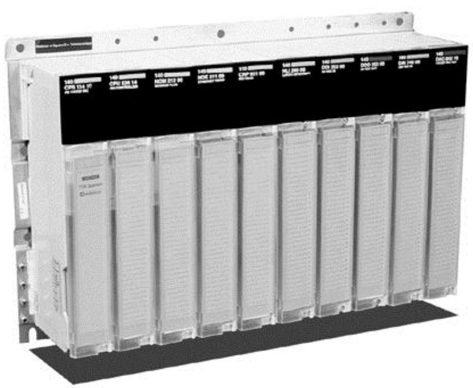
- ABB 2000R
  - *Protective Relays*

Intelligent Electronic Devices

- Bitronics Meter

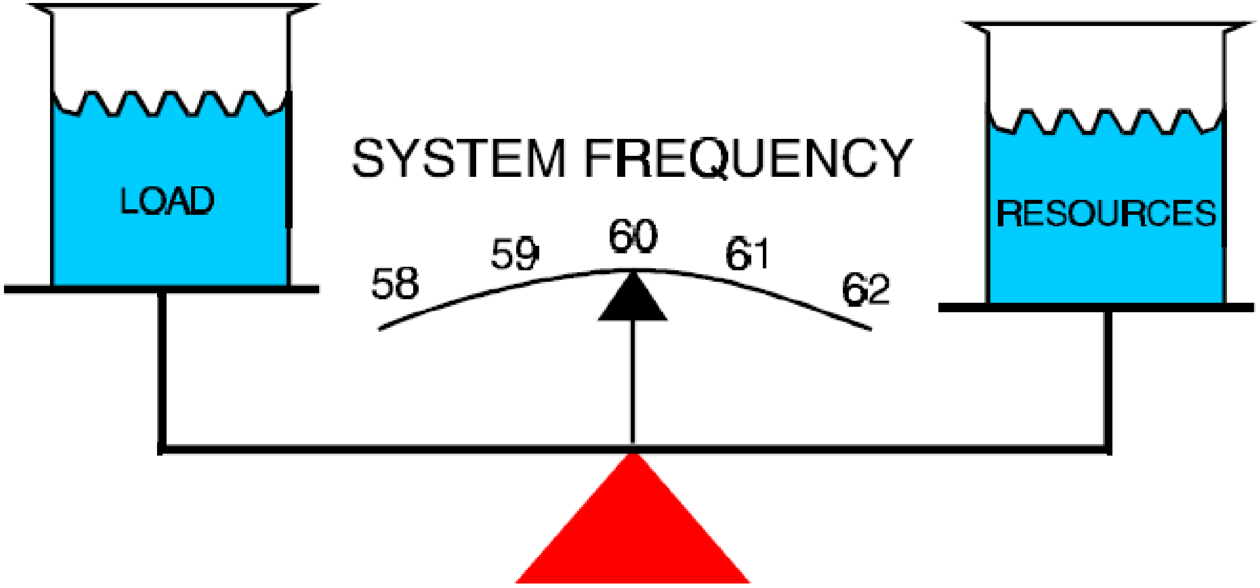
Intelligent Electronic Devices

- Programmable Logic Controller
  - *Acquires status inputs from devices that don't have IED interfaces (motor operated disconnects)*
  - *Performs control actions for devices that don't have IEDs*
  - *Performs sequenced control actions using ladder logic*



sModicon PLC

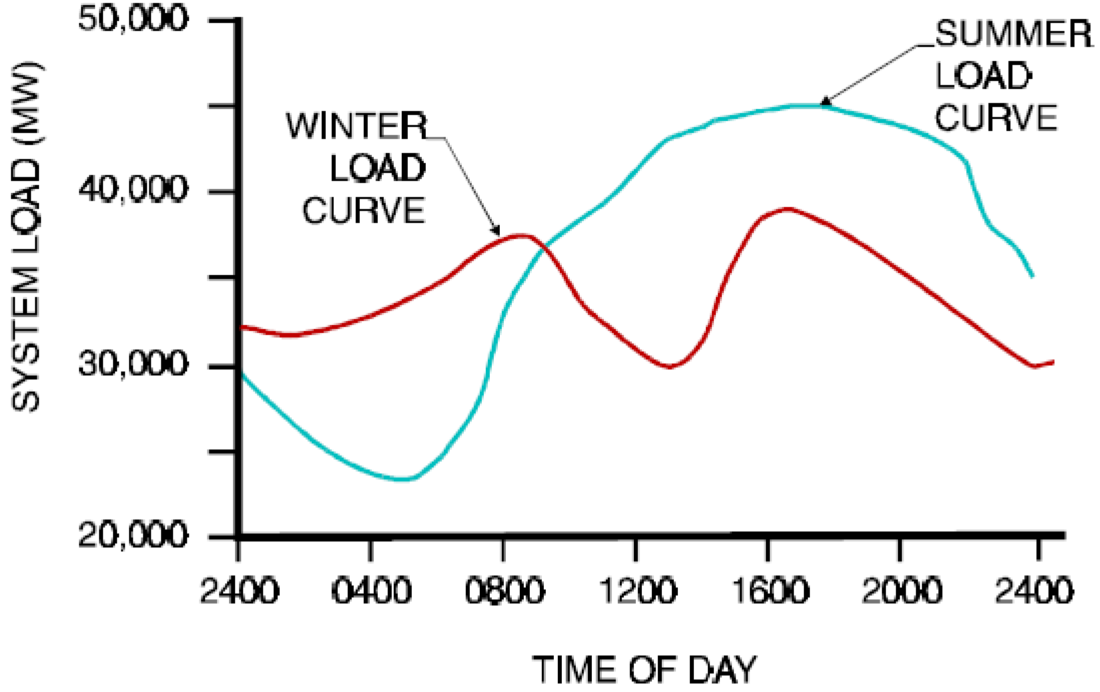
Load – Resources Balance



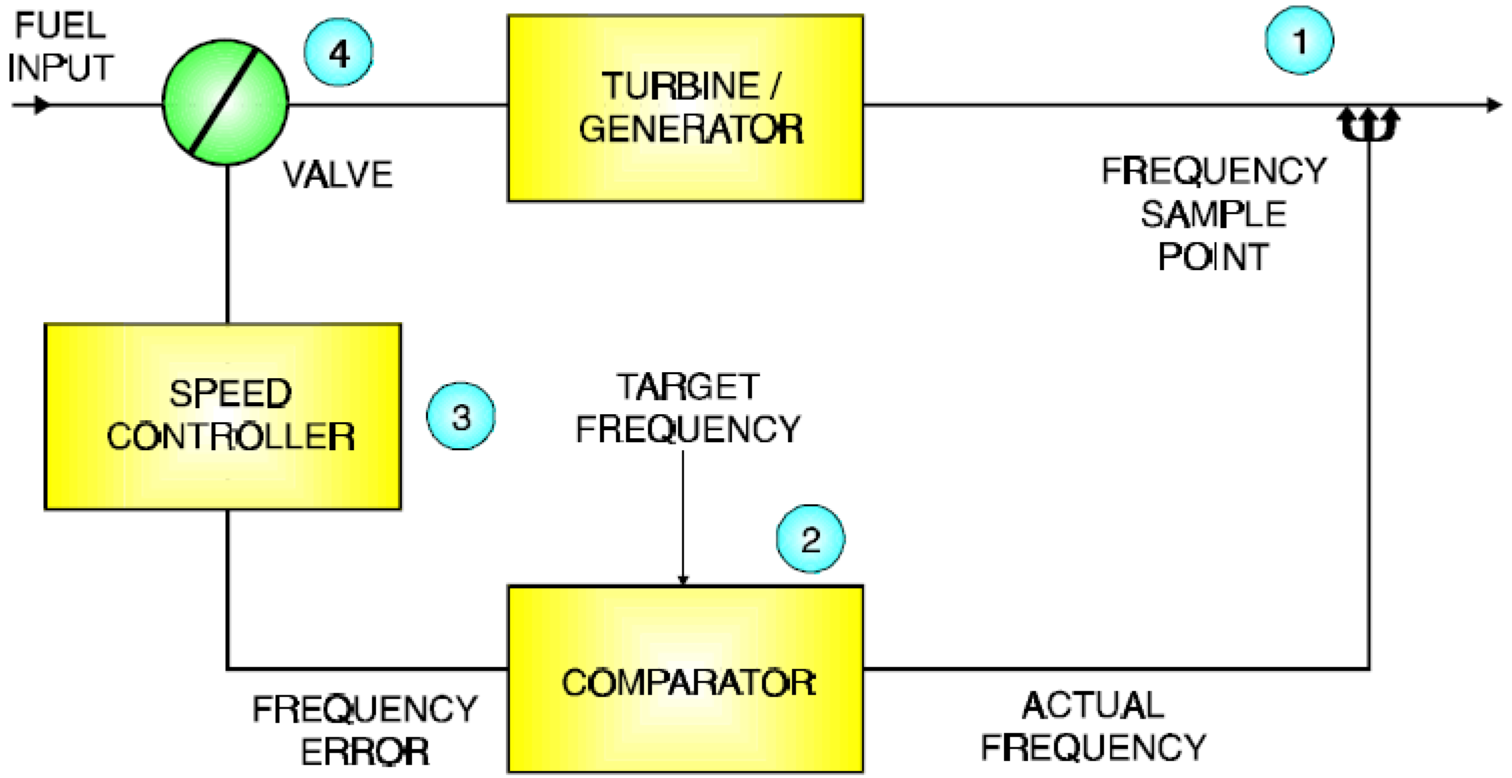
When resources exceed load, frequency will rise. When load exceeds resources, frequency will drop.

System Frequency Balance @60 Hz

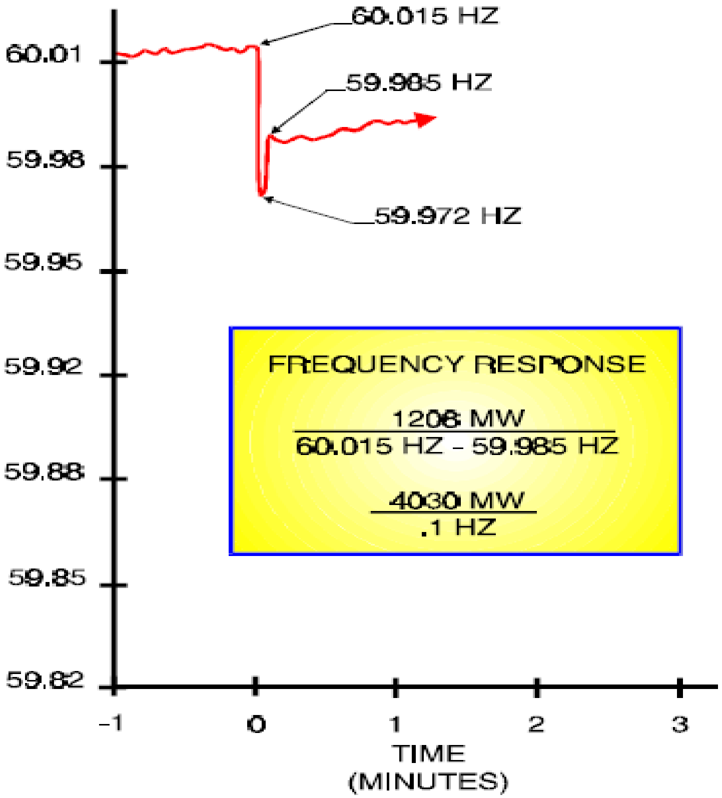
Load Frequency Effect
load is constantly changing



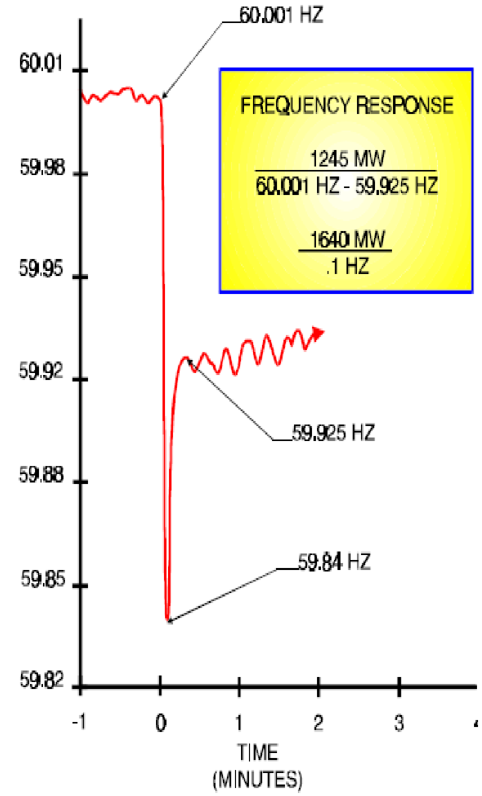
Simple Frequency Control System



Frequency Response

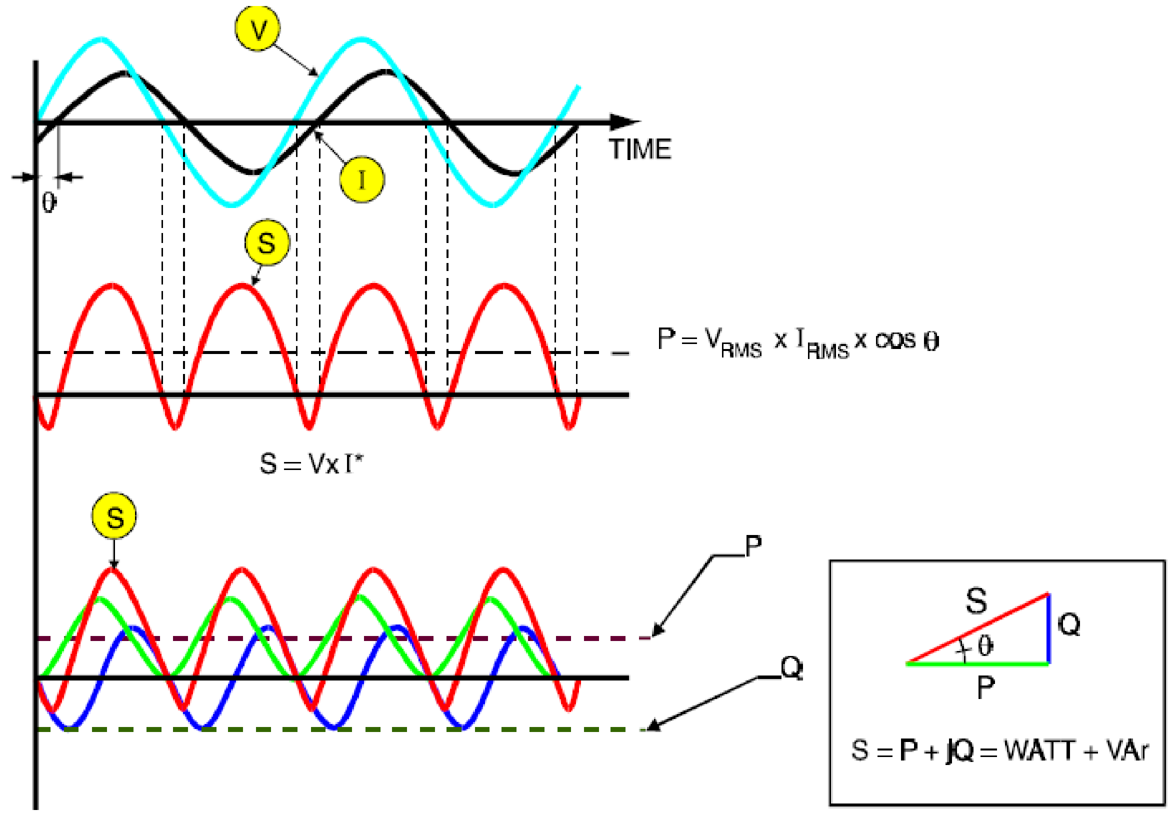


Large System

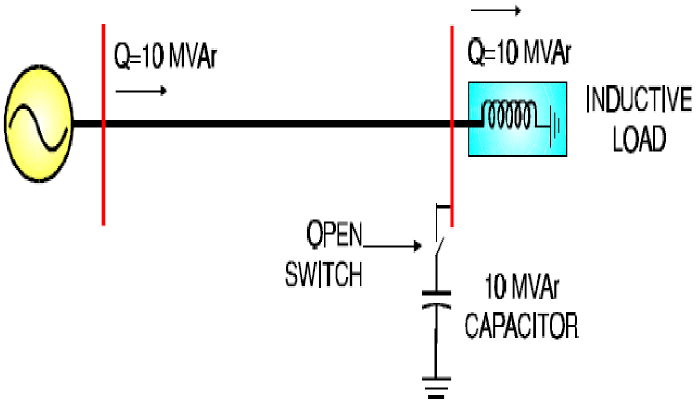


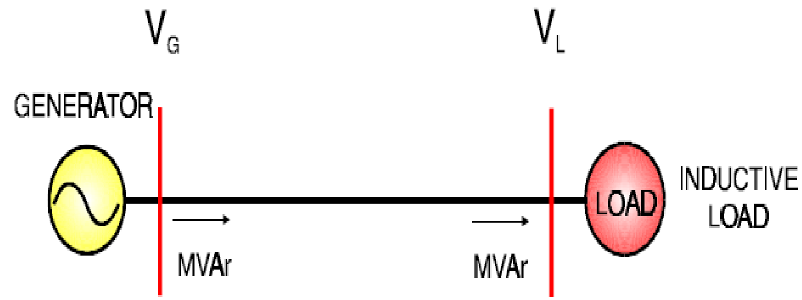
Small System

Active, Reactive and Complex Power



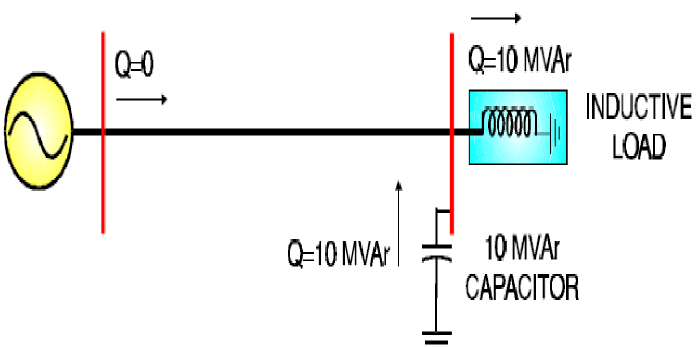
Voltage Reactive Power Balance

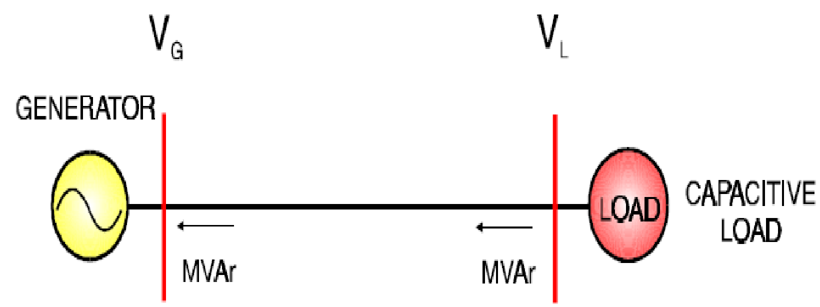




LAGGING GENERATOR

REACTIVE Power have to be supplied locally



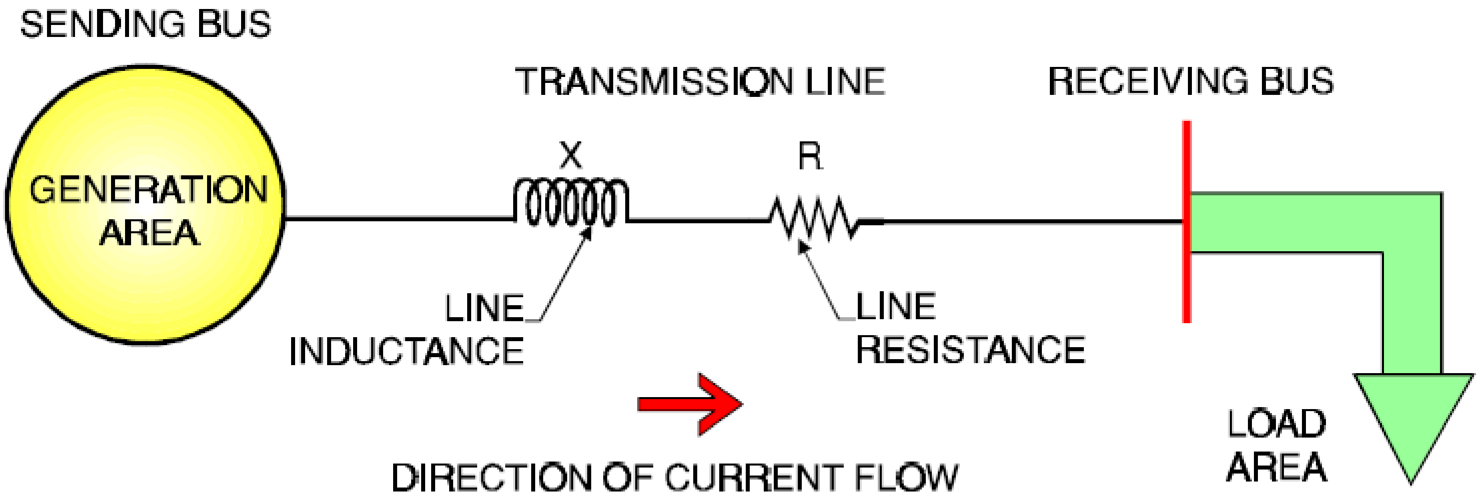


LEADING GENERATOR

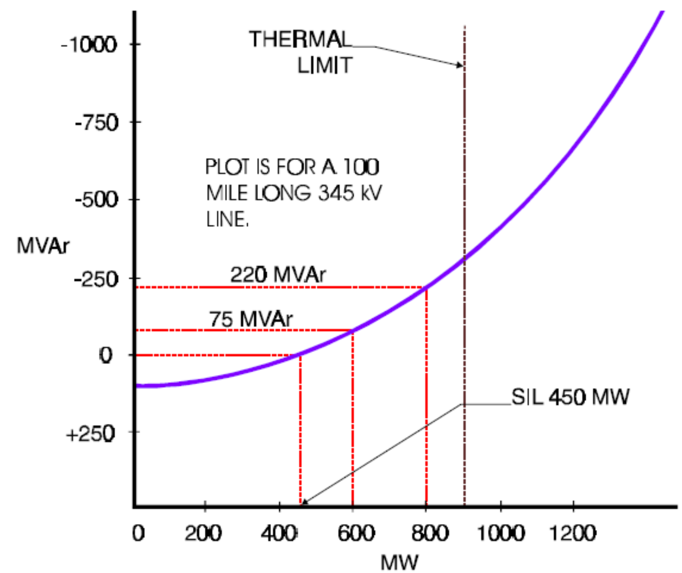
Cause of low voltage

- The root cause of low voltage is deficiency of reactive power. It may be due to
  - Heavy power Transfer
  - Transmission line outage
  - Reactive equipment outage
  - Failure to get ahead of voltage
  - Motor stalling

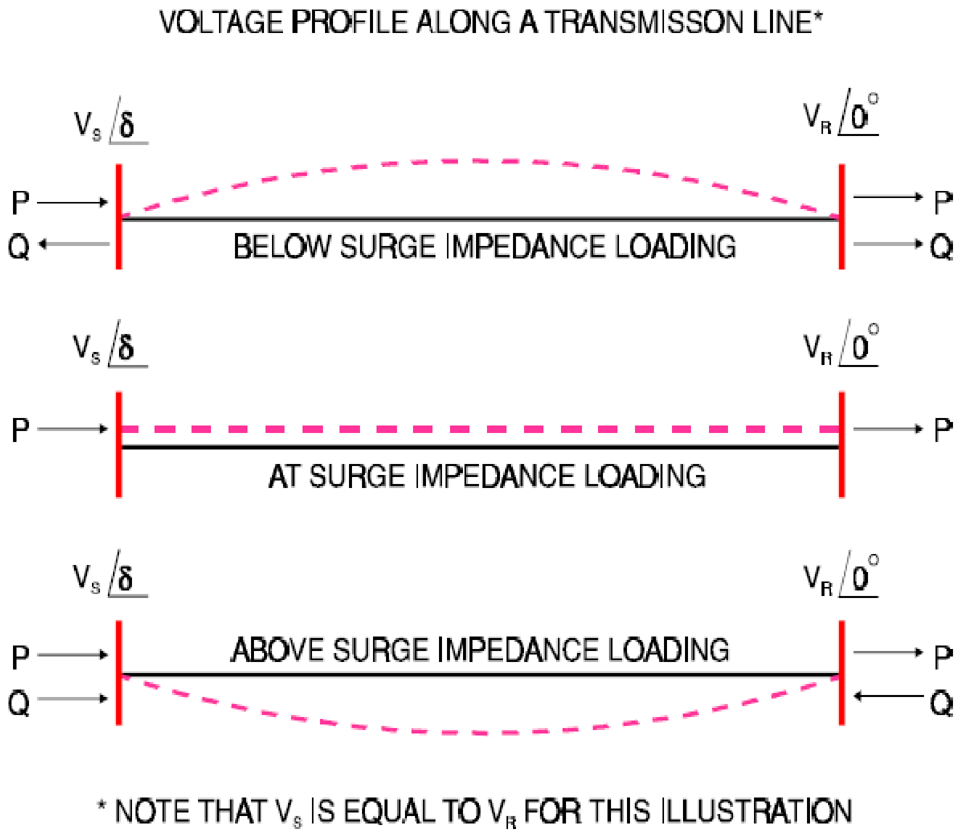
Heavy power Transfer on radial feeder



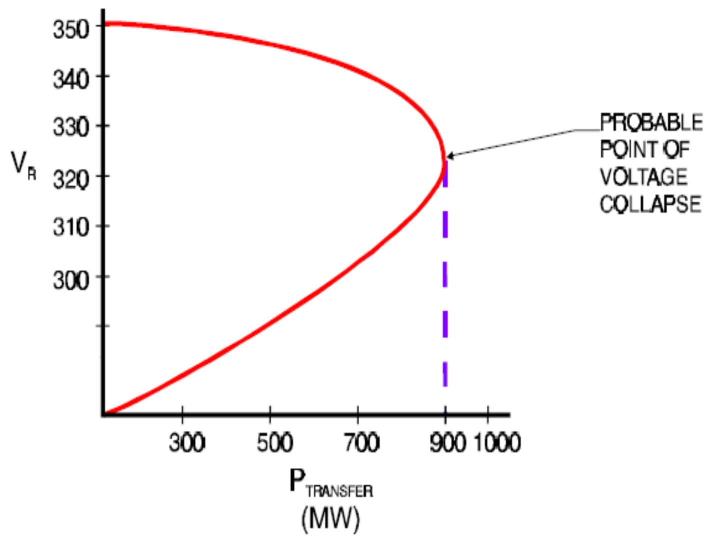
Mvar required to maintain constant voltage



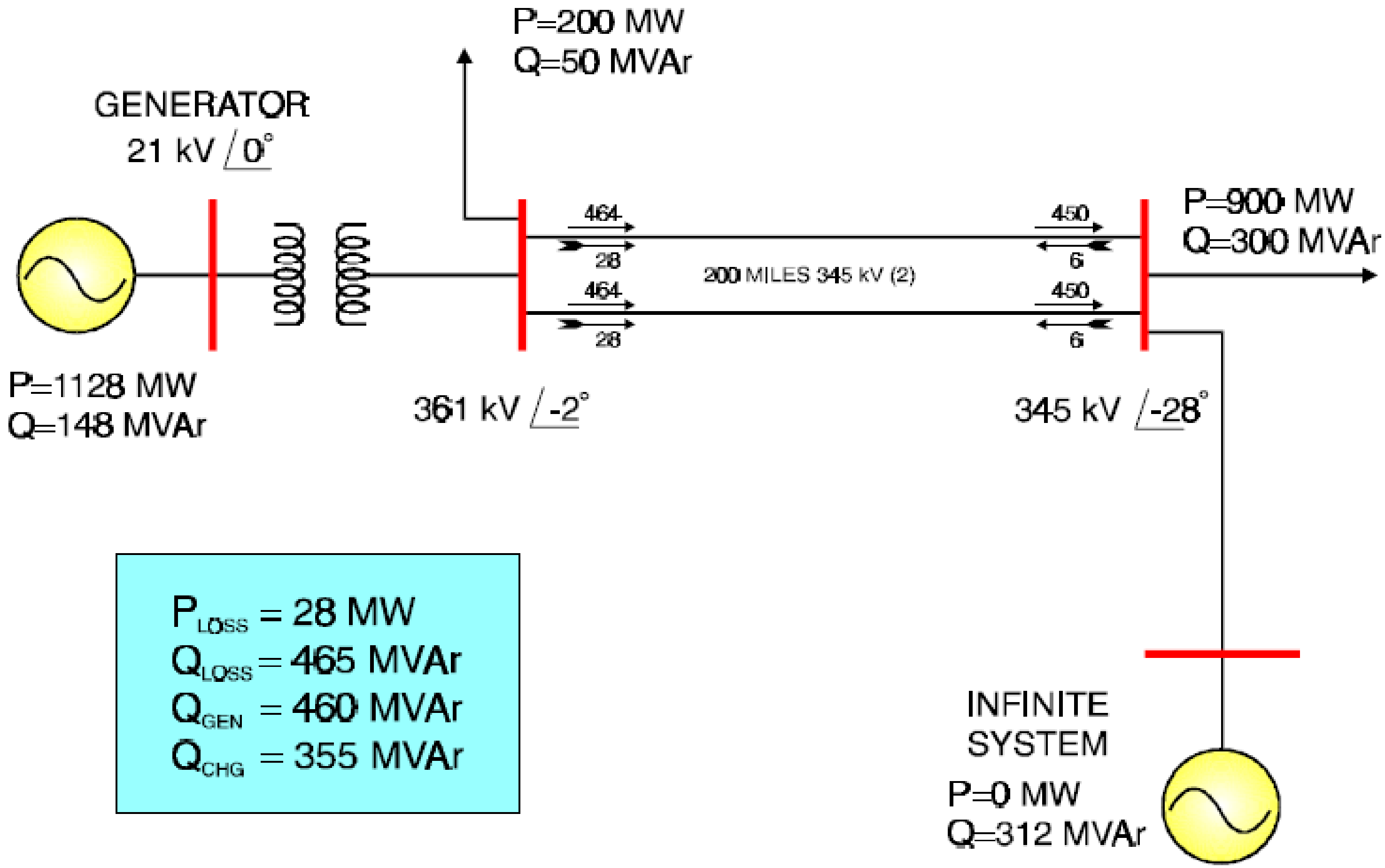
Transmission line loading

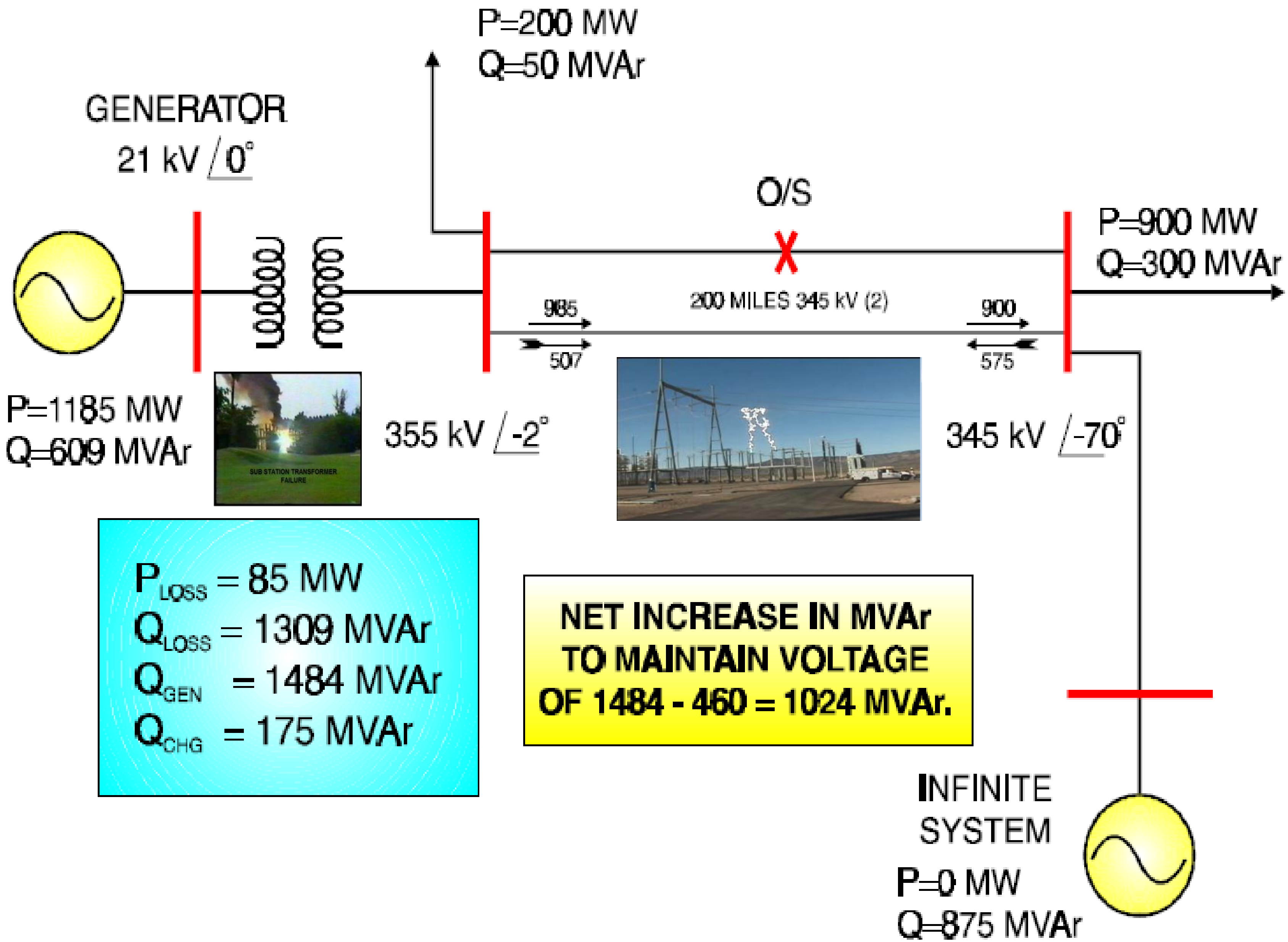


PV Curve

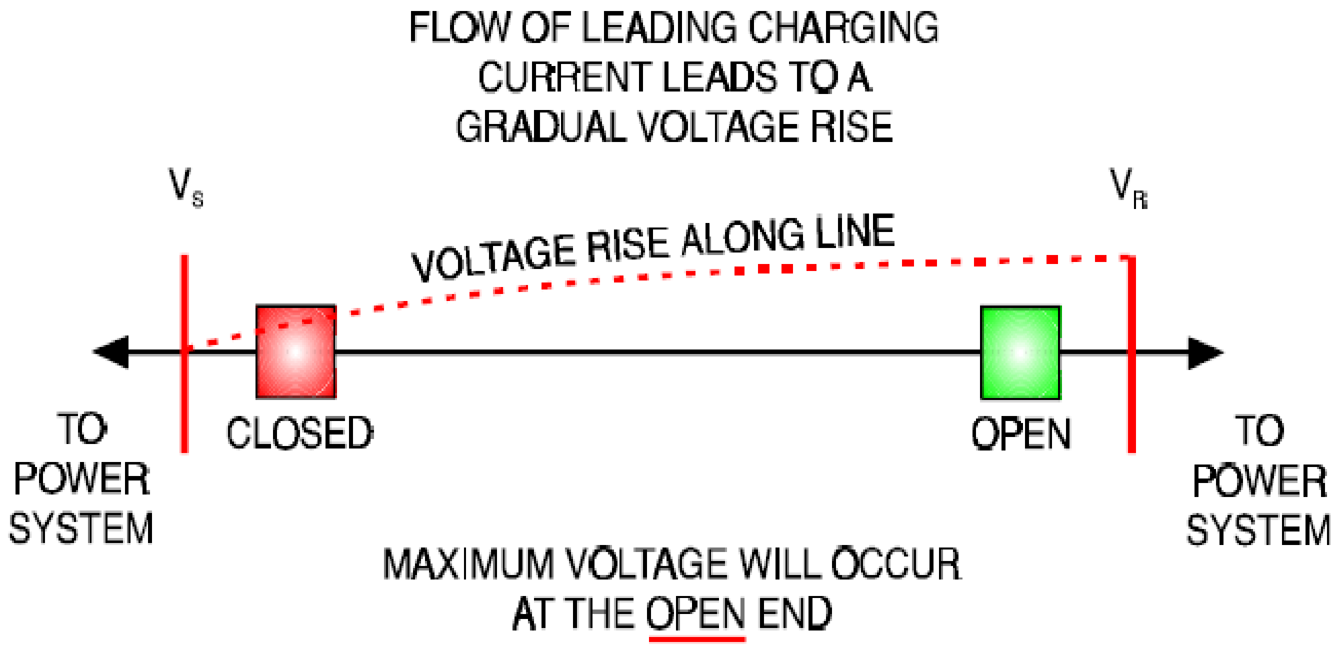


Transmission line outage




P=200 MW
Q=50 MVAr
GENERATOR
21 kV /0°
O/S
P=900 MW
Q=300 MVAr
985
200 MILES 345 kV (2)
900
507
575
P=1185 MW
Q=609 MVAr
SUB STATION TRANSFORMER FAILURE
355 kV /-2°
345 kV /-70°
P_{LOSS} = 85 MW
Q_{LOSS} = 1309 MVAr
Q_{GEN} = 1484 MVAr
Q_{CHG} = 175 MVAr
NET INCREASE IN MVAr TO MAINTAIN VOLTAGE OF 1484 - 460 = 1024 MVAr.
INFINITE SYSTEM
P=0 MW
Q=875 MVAr

Cause of high voltage



Definition of Smart Grid

Plenty of definitions; some of them are

- **The Smart Grid is the roadmap for enhancing the infrastructure of every segment of the energy delivery system. This includes generation, transmission, distribution and consumption**

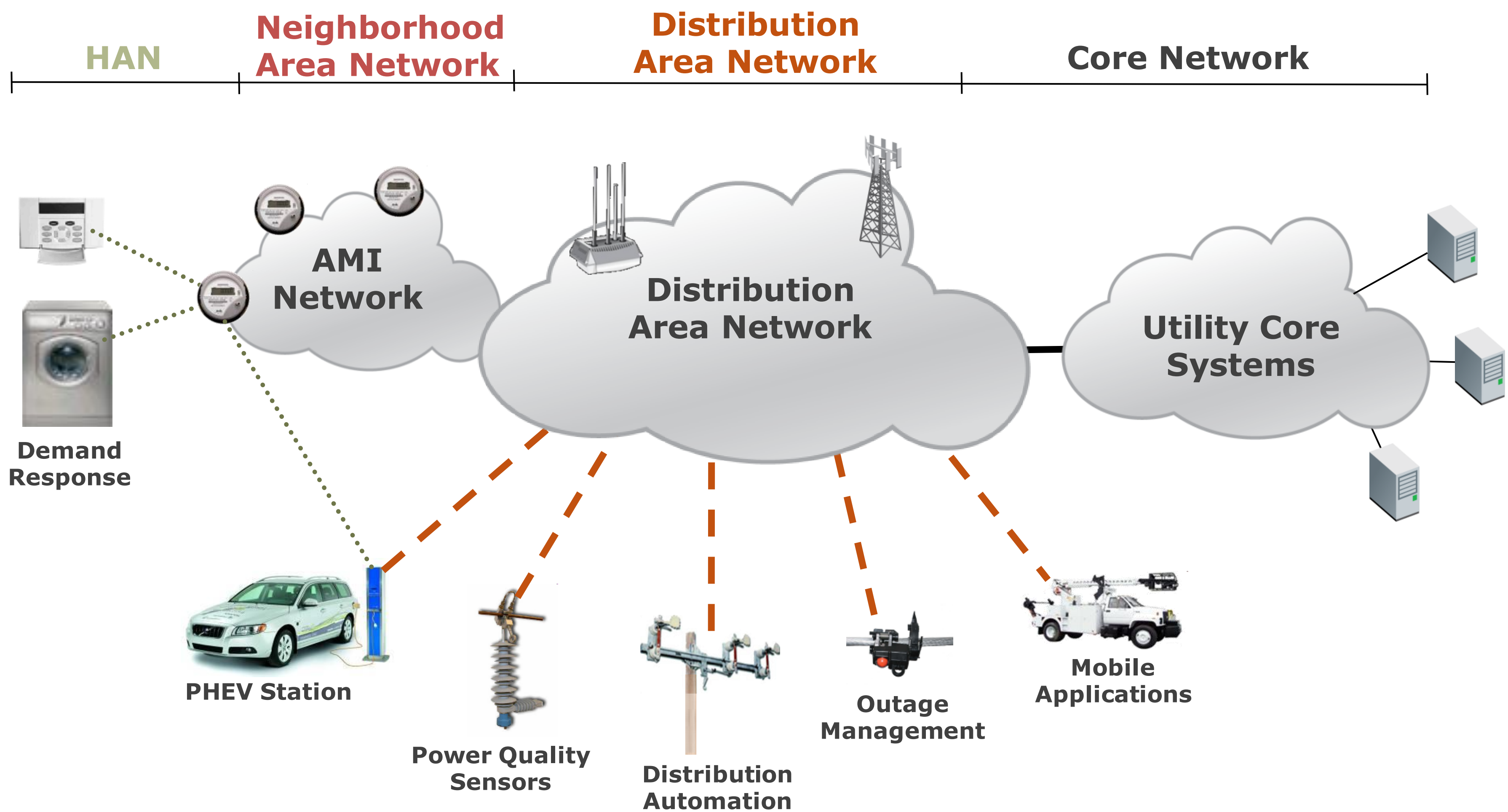
- **Smart grid is a generic label for the application of computer intelligence and networking abilities to a dumb electricity distribution system.**

- **Smart grid is about the application of technology to energy networks so that networks can run more intelligently and more efficiently.**

*www.**smartgrid**news.com*

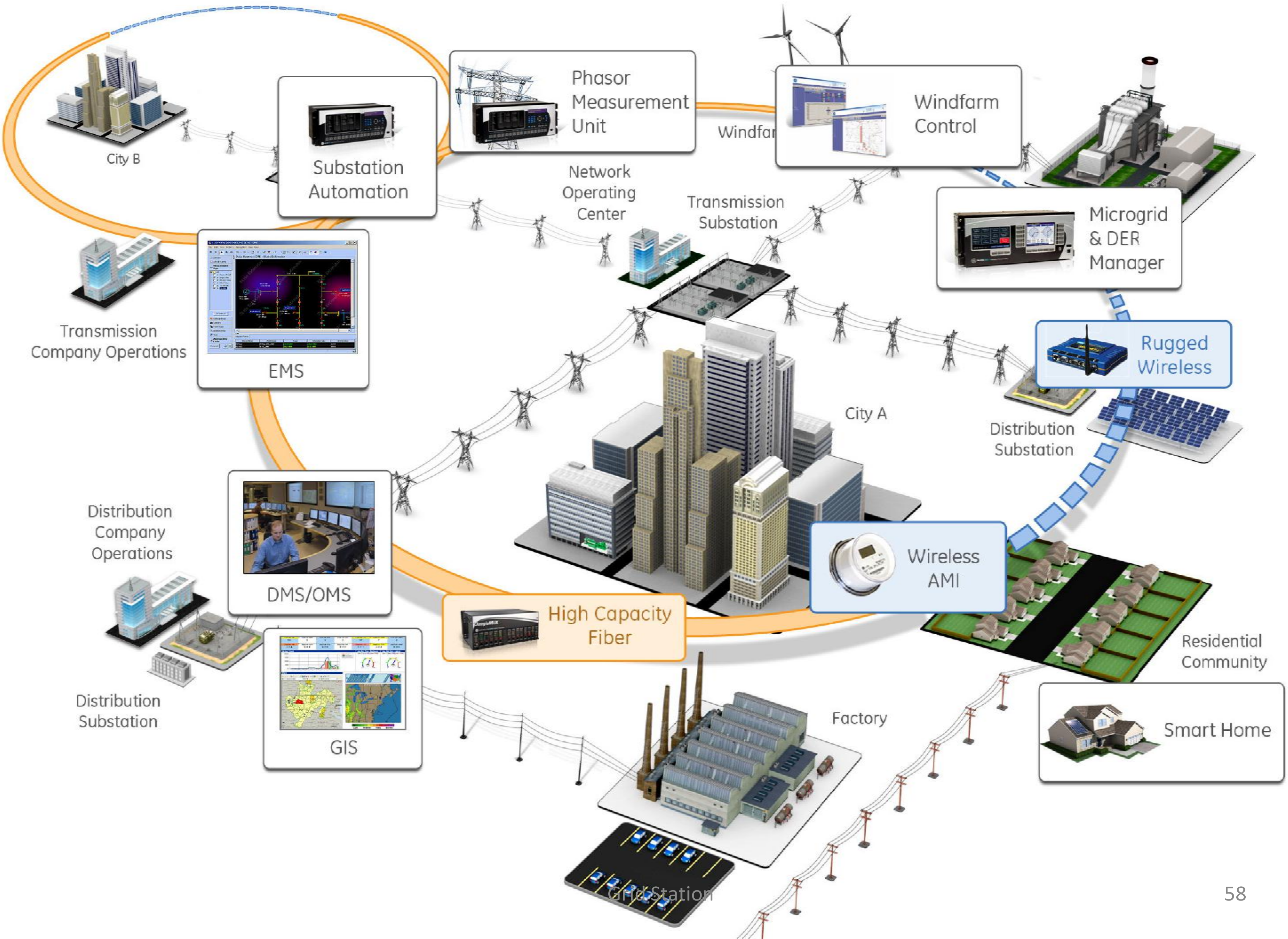
www.smartmeters.com

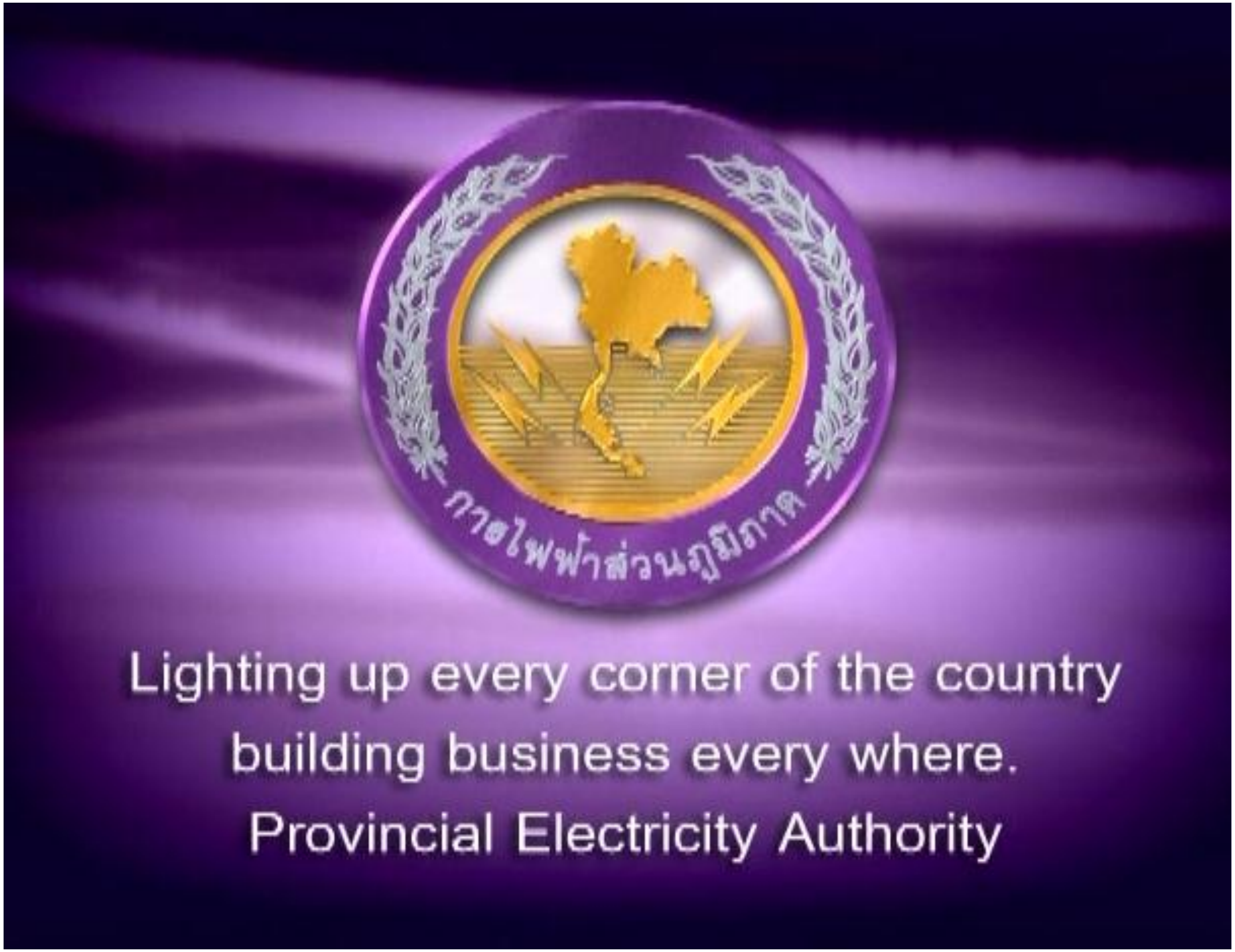
SmartGrid = Network of Networks



Why Smart Grid?

- Integrate isolated technologies : Smart Grid enables better energy management.
- Proactive management of electrical network during emergency situations.
- Better demand supply / demand response management.
- Better power quality
- Reduce carbon emissions.
- Increasing demand for energy : requires more complex and critical solution with better energy management


City B
Substation Automation
Phasor Measurement Unit
Windfarm Control
Network Operating Center
Transmission Substation
Microgrid & DER Manager
Transmission Company Operations
EMS
Rugged Wireless
City A
Distribution Substation
Distribution Company Operations
DMS/OMS
High Capacity Fiber
Wireless AMI
Residential Community
Distribution Substation
GIS
Factory
Smart Home


การไฟฟ้าส่วนภูมิภาค
Lighting up every corner of the country
building business every where.
Provincial Electricity Authority

Pillars **of Smart Grid**

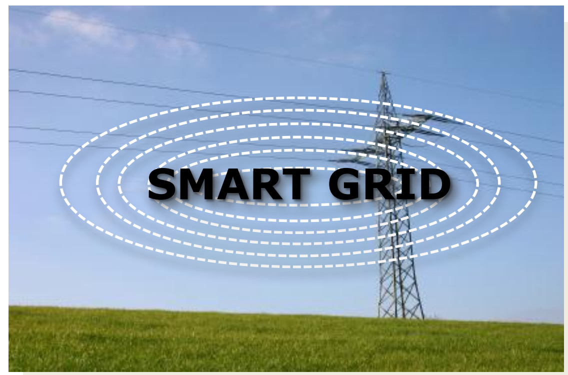
- Transmission Optimization
- Demand Side Management
- Distribution Optimization
- Asset Optimization

Demand Response

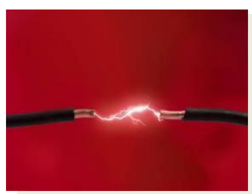
AMI

Renewable Integration

Field Data Applications

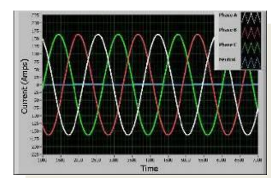


Distribution Automation



Outage Management

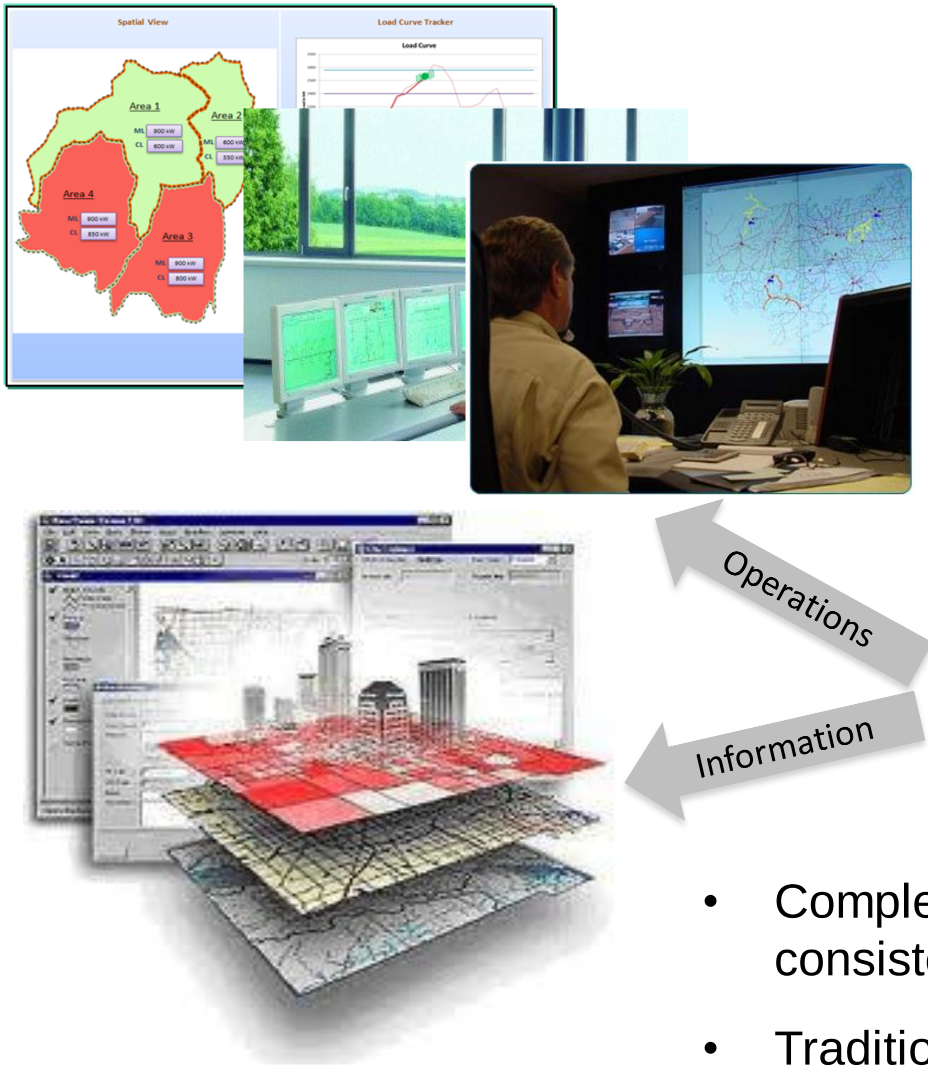
PHEV Management

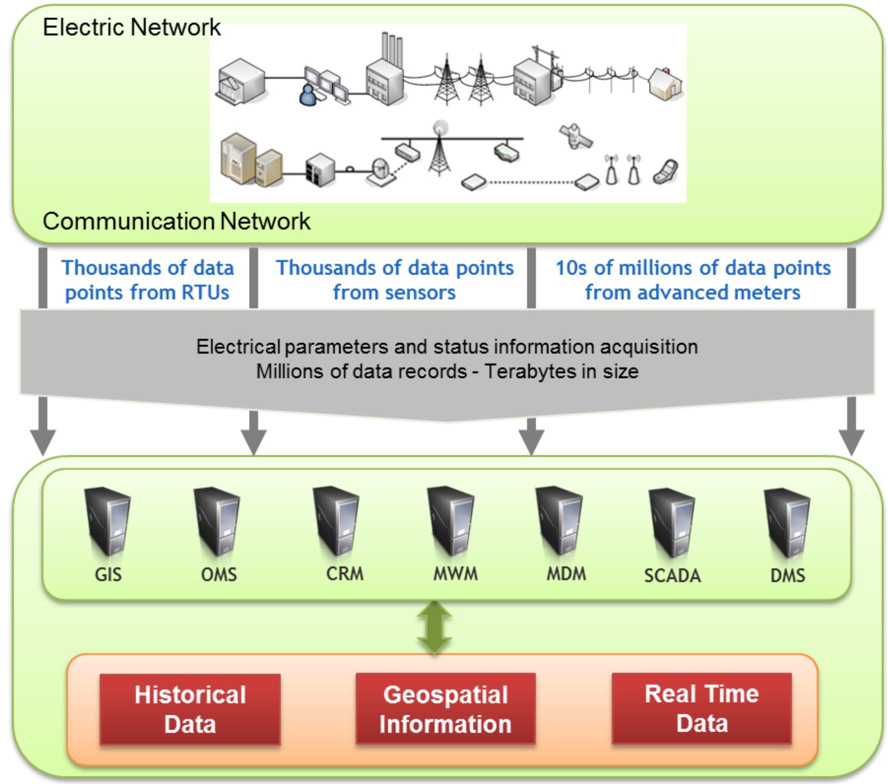


Power Quality and Planning

Distributed Intelligence, Automated Controls, Broadband Communications

Foundation for Smart Grid – Spatial Information





- Complete, positional accurate, connected, consistent, up-to-date geospatial information
- Traditional way of looking at spatial information needs to change

Smart Grid in Power Sector

- Transmission
  - •Asset Management
  - •HVDC and UHVAC etc.
- Distribution
  - •Advance Metering Infrastructures
  - •Asset Management etc.
- System Operations
  - •Self Healing Grids
  - •WAMS
  - •Adaptive Islanding etc.

Smart Grid in Distribution

- Distribution Automization
- Demand Optimization - Selective Load Control
- Operation –Islanding of Micro-grids

Distribution Automation/Optimization

- **Managing Distribution Network Model**
- **Outage management and AMI Integration**
- **DMS & Advanced Switching Applications**
- **Integrated Voltage / VAR Control**

Demand Optimization

- **Demand Response – Utility**
- **Demand Response – Consumer**
- **Demand Response Management System**
- **In Home Technology enabling**

Demand Optimization: Advanced Web Portal

- **Energy Usage Information**
- **Utility Communication**
- **Consumer Enrollment**
- **In Home Technology- Availability & Purchase , Device Provisioning**

Control Center with Service Oriented Architecture (BUS)

- **Having**
  - GIS (geo-spatial Information Systems),
  - AMI (Automatic Meter Interface)
  - SAP (ERP)
  - OMS (Outage management System),
  - DMS (Distribution Management System),
  - EMS (Energy Management System),
  - DRMS (Demand Response management System).

- **Model manager synchronizes GIS data with OMS, DMS & EMS.**

Micro grids Defined

A Microgrid is:

- a group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid.
- a microgrid can connect and disconnect from the grid to enable it to operate in both **grid-connected or island-mode**.

Microgrid Key Attributes (Defining Characteristics):

- Grouping of interconnected loads and distributed energy resources
- **Can operate in both island mode or grid-connected**
- Can connect and disconnect from the grid
- Acts as a single controllable entity to the grid

Microgrid Benefits:

- Enables Grid Modernization
- Enhances the integration of Distributed and Renewable Energy Sources
- Meets End User Needs
- **Supports the Macrogrid**

The Power Grid of the Future requires advanced tools to coordinate distributed energy resources

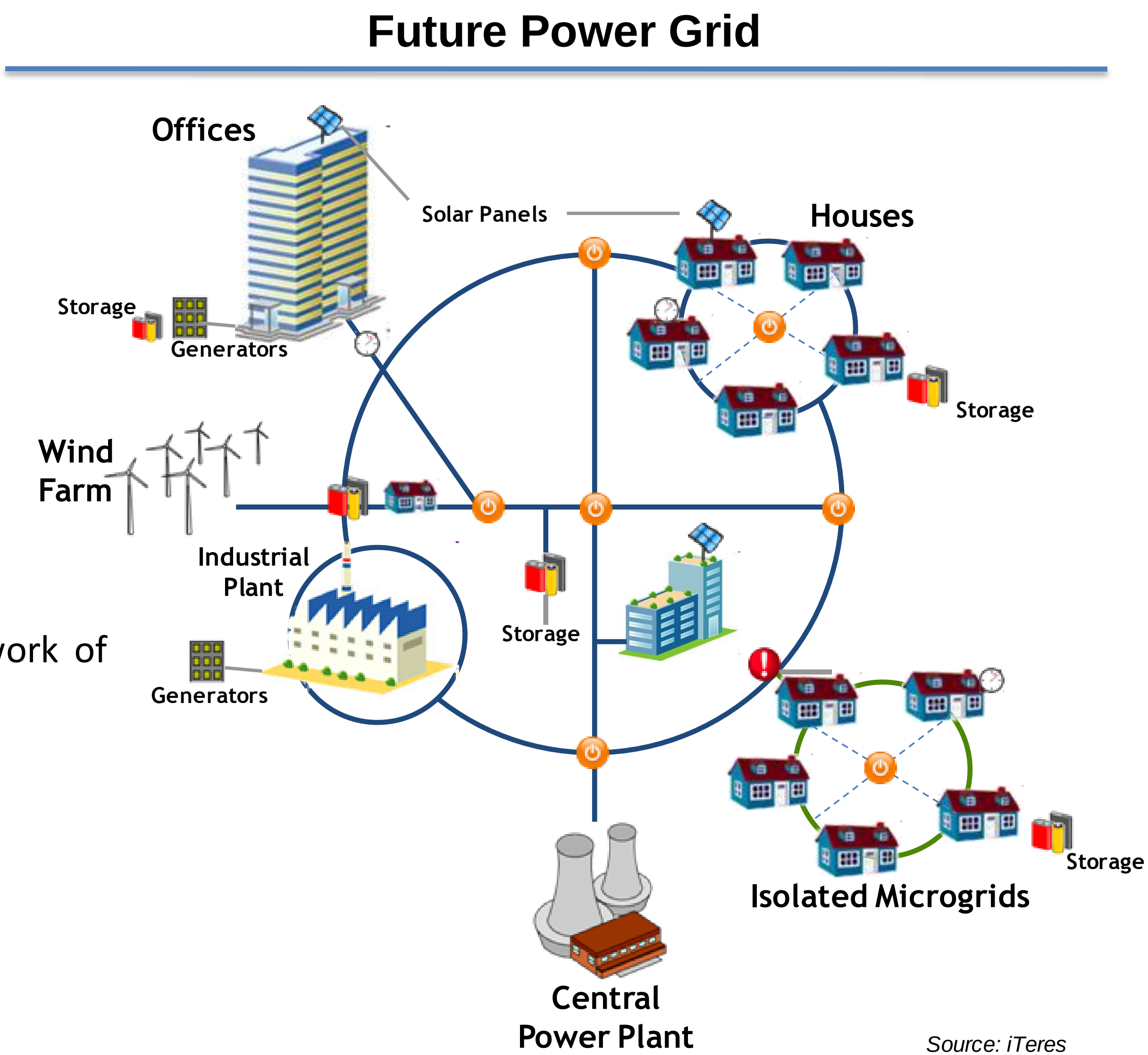
Global proliferation of distributed energy resources:

- Distributed generation
- Distributed storage
- Controllable load

Clusters of these distributed resources organized in microgrids

The Power Grid becomes a network of microgrids capable of:

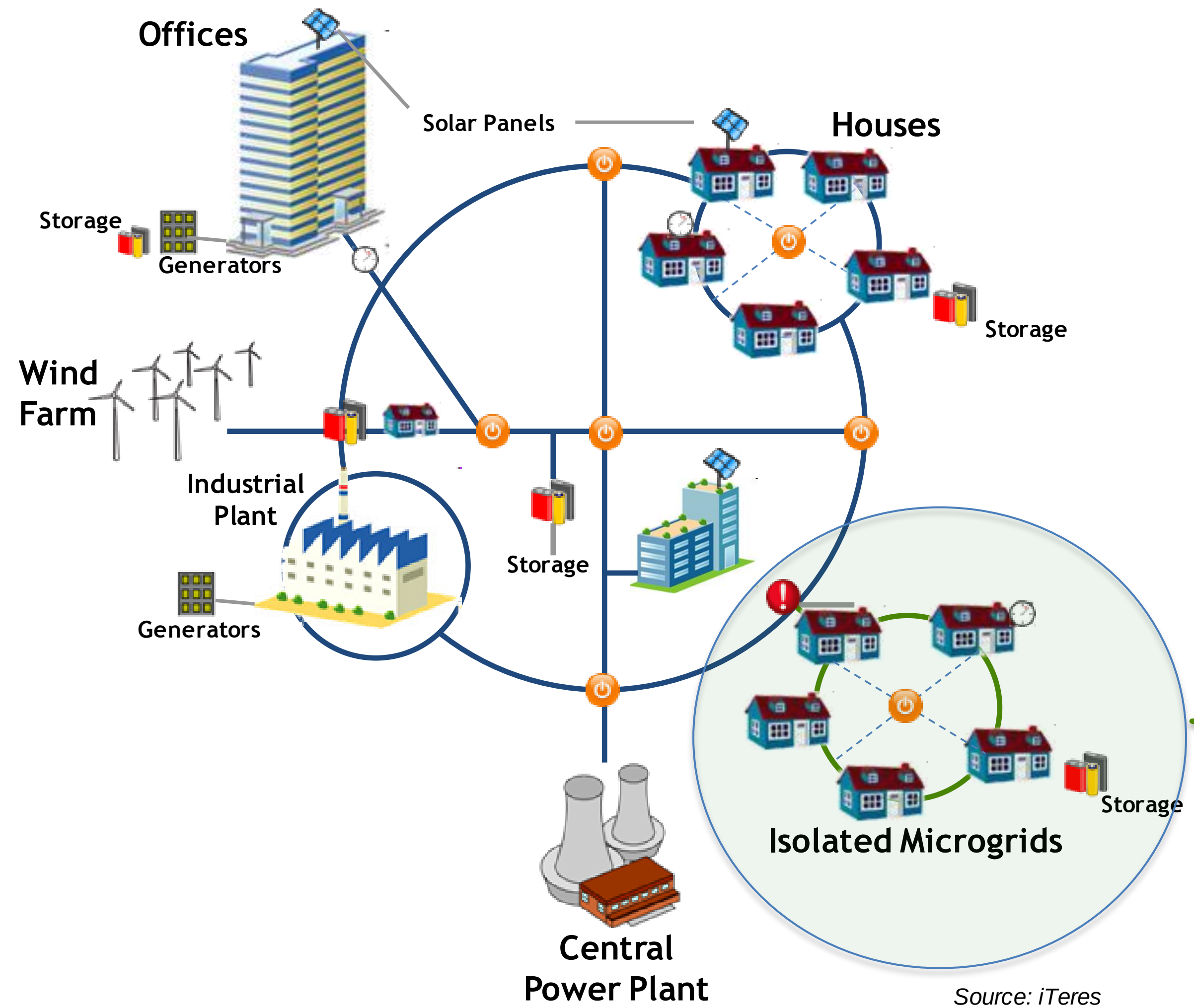
- Self-healing
- Self-coordination
- Self-scheduling



Source: iTeres

Micro grids will transform power distribution, enabling new levels of system reliability and efficiency

Focus on: Microgrid Intelligence



Source: iTeres

Grid Station

Self-healing

- Responds to system disturbances automatically
- Capable of operating as an "island" off of the regional grid

Self-coordination

- Coordinates real-time demands of energy users, distributed resources, microgrid operations and distribution system integrity

Self-scheduling

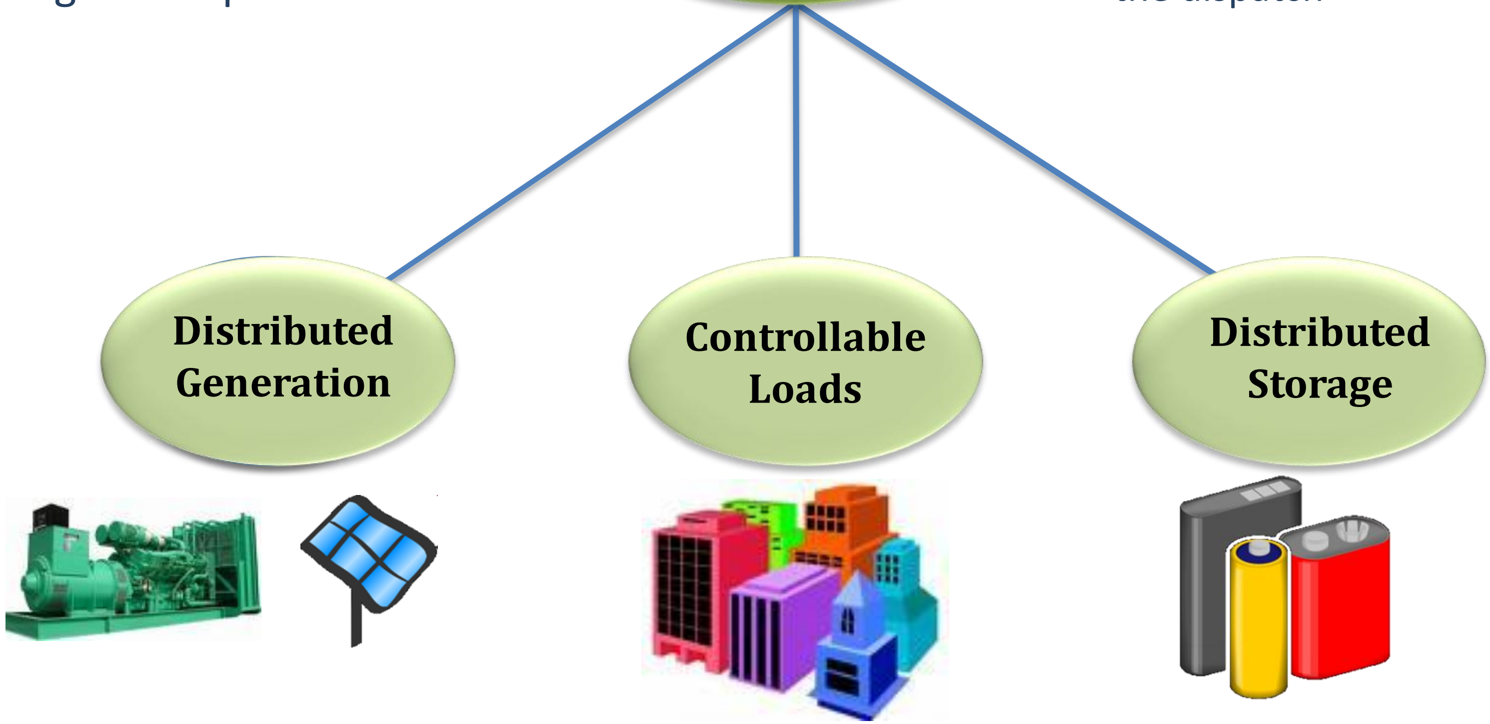
- Schedules dispatch of distributed energy resources using decisioning tools to optimize overall grid operational performance

Micro grids require a “central nervous system” to direct the operations of distributed resources within their zone

The **Microgrid Master Controller** regulates the power distribution infrastructure within the microgrid footprint

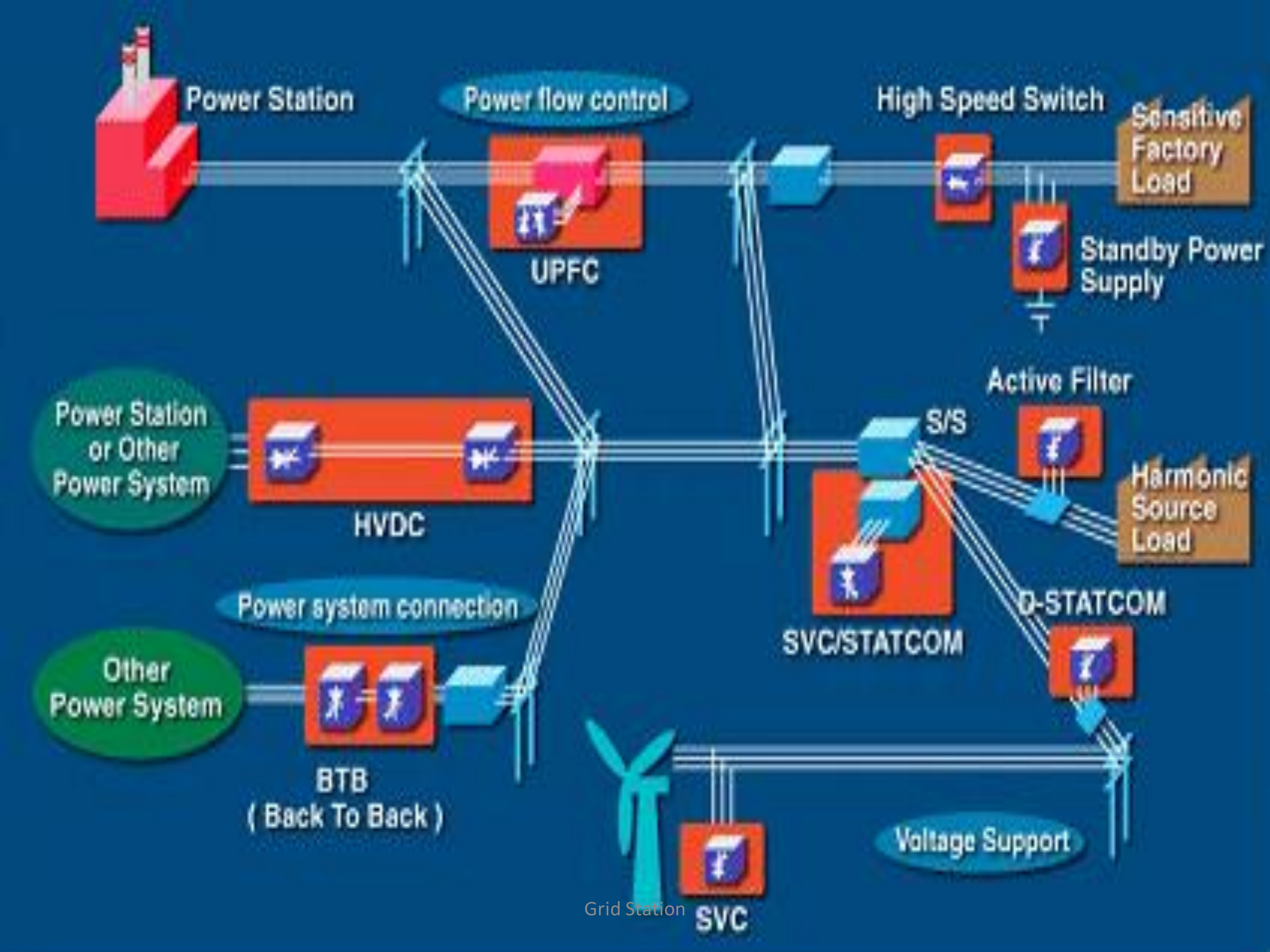
Distributed resources need to be combined and optimized

The resources must appear to the system operators as a “virtual generator” that is integrated into the dispatch



Distributed Resources

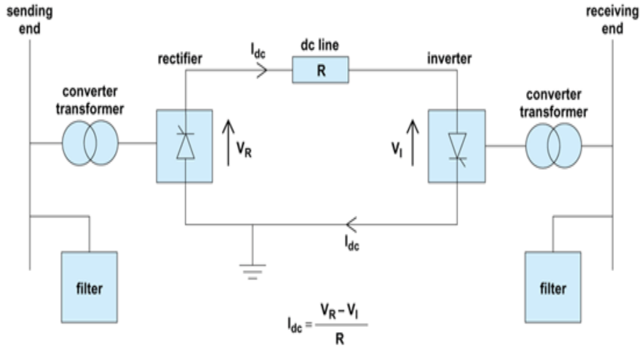
Grid Station



Grid Station

Salient Features of HVDC Transmission System

Advantages



Basic high-voltage direct-current (HVDC) system. (*ALSTOM*)

- Voltage transformation
- Asynchronous Tie /Link
- Frequency as system-wide control signal
- Low losses (direct current)
- No limitations in length (Cables can be used over long distances as there is no reactive power consumption)

Limitations

- Base costs for converter stations economically interesting only at longer distances
- Point-to-point connection (multi-terminal possible with VSC - HVDC)

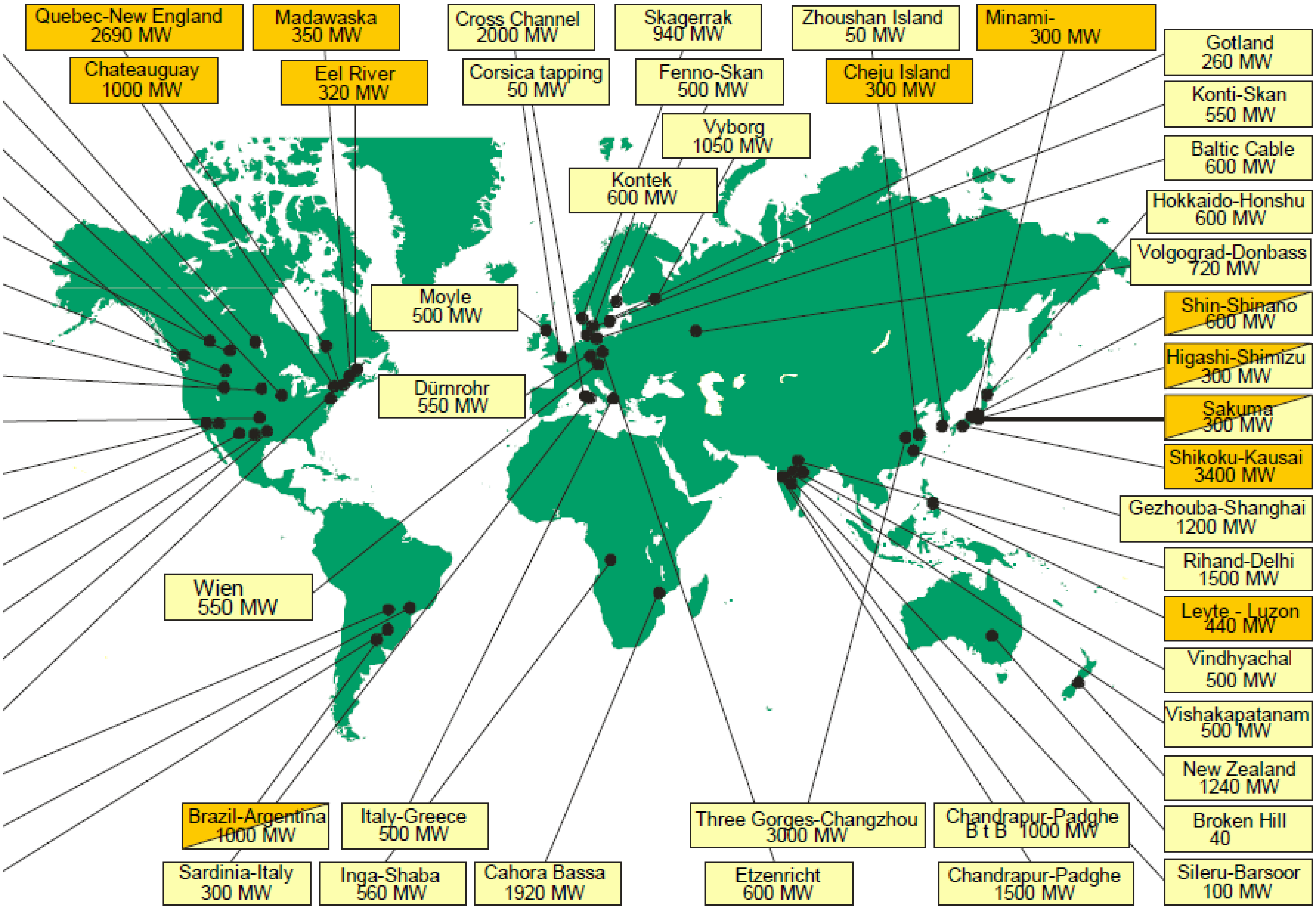
HVDC INSTALLATIONS
EAST- SOUTH INTERCONNECTION IN INDIA

Suspended converter valves of a complete pole at Talcher

- DC harmonic filters of pole 1, Talcher

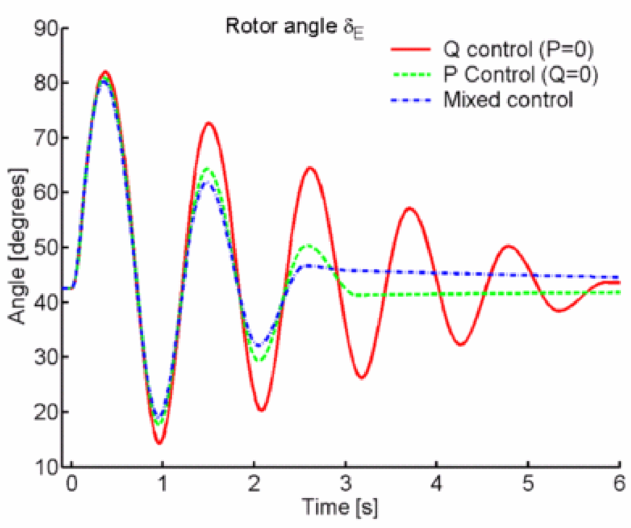
Source: http://www.ptd.siemens.de/artikel0506.html

HVDC WORLD WIDE INSTALLATIONS



CONCLUSION - HVDC

- The power system can be stabilized and the transmission limitations on the AC line can be increased by using HVDC .
- A HVDC transmission line costs less than an AC line for the same transmission capacity.
- However, the terminal stations are more expensive in the HVDC case due to the fact that they must perform the conversion from AC to DC and vice versa.
- **The "break-even distance" for long overhead lines is > 700 km**

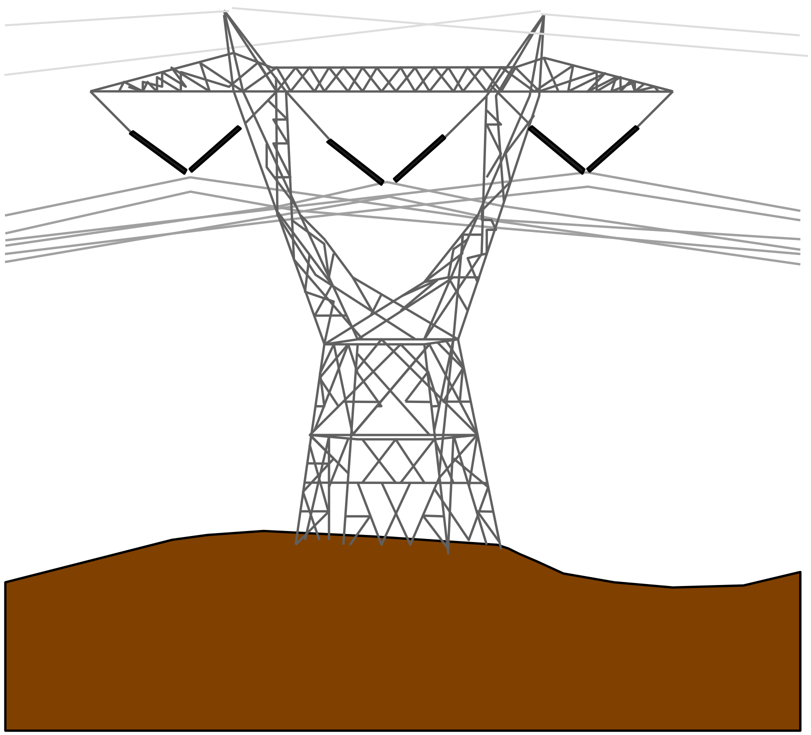


- HVDC can **control/ transmit contracted amounts of power** and alleviate unwanted loop flows.
- An HVDC link can alternatively be controlled to **minimize total network losses**
- An HVDC link can never be overloaded
- The **HVDC damping controller** is a standard feature in many HVDC projects in operation. It normally takes its input from the phase angle difference in the two converter stations. (see fig.)

FLEXIBLE AC TRANSMISSION SYSTEMS (FACTS)

Flexible AC Transmission System

Alternating current transmission systems incorporating power electronics-based and other static controllers to **enhance controllability and increase power transfer capability**



- Transmission system limitations:
  - **System Stability**
    - Transient stability
    - Voltage stability
    - Dynamic Stability
    - Steady state stability
    - Frequency collapse
    - Sub-synchronous resonance
  - **Loop flows**
  - **Voltage limits**
  - **Thermal limits of lines**
  - **High short-circuit limits**

Sub-synchronous resonance

- Resonant frequencies below the fundamental.
- Occurs due to interaction between series capacitors and nearby turbine-generators

FLEXIBLE AC TRANSMISSION SYSTEM (FACTS)

Role of FACTS

- Dynamic:
  - Transient and dynamic stability
  - Sub synchronous oscillations
  - Dynamic overvoltage and under voltages
  - Voltage collapse
  - Frequency collapse

- Steady-State:
  - Uneven power flow
  - Excess reactive power flows
  - Voltage capability
  - Thermal capability

Benefits of FACTS

Control of power flow

- Contractual Power Flow
- **Increase the loading capability of lines** to their thermal capabilities.
- Increase the **system security** through raising the transient stability limit, limiting short-circuit currents and overloads, managing cascading blackouts and damping electromechanical oscillations of power systems and machines.

Provide secure tie line connections to neighboring utilities and regions thereby **decreasing overall generation reserve** requirements on both sides.

- Provide greater flexibility in new generation.
- Reduce reactive power flows, thus allowing the lines to carry more active power.

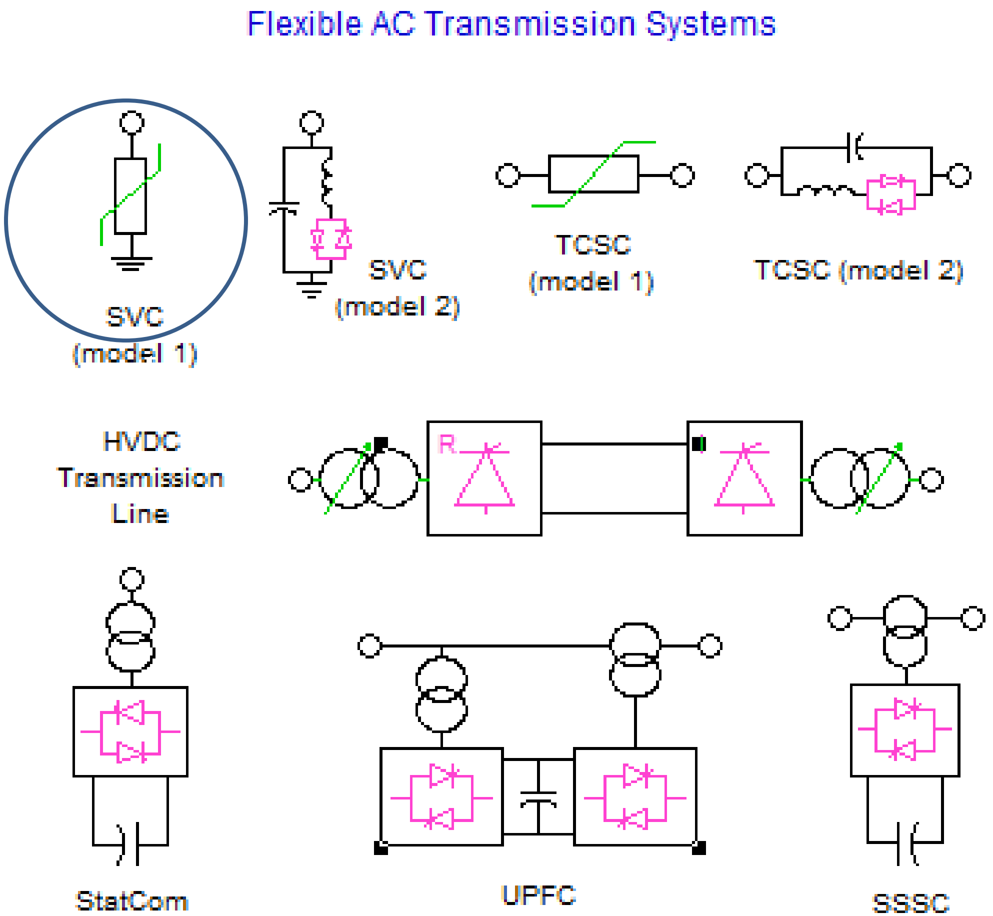
FACTS Devices

- **Static VAR Compensator - SVC**
- **Thyristor Controlled Series Compensator - TCSC**
- Thyristor Controlled Phase Angle Regulator - TCPAR
- **Static Synchronous Compensator - StatCom**
- Solid State Series Compensator - SSSC
- **Unified Power Flow Controller - UPFC**

FLEXIBLE AC TRANSMISSION SYSTEM

FACTS devices are solid-state converter that have the capability of control of various electrical parameters in transmission circuit

- Thyristor Controlled Series Compensator (TCSC)
- Static VAR Compensator (SVC)
- Unified Power Flow Controller (UPFC)
- Static Compensator (STATCOM)
- Static Synchronous Series Compensator (SSSC), etc



Custom Power & FACTS

- Similar to FACTS for the transmission systems, the term custom power (CP) means the use of **power electronic controllers for transmission and distribution systems**.
- Custom power devices enhances the **quality and reliability of power that are delivered to customers.**
- There is also a concept called "**Custom Power Park**" that can serve customers who demand a high quality of power and ready to pay a premium price for the service.
- Custom power assures the pre-specified quality/ specifications:
  - Reduce the Frequency of rare **power interruptions**.
  - **Magnitude and duration of over and under voltages** within specified limits.
  - **Low harmonic distortion** in the supply voltage.
  - **Low phase unbalance**.
  - **Low flicker in the supply voltage.**
  - **Frequency of specified voltage** with specified limits

Custom Power Devices

- Customer power devices can be classified in to two main types.
  - Reconfiguring type
  - Compensating type

- **Reconfiguring type** - Changes the network topology or re-configure the next work by altering the network.
  - Solid State Current Limiter (SSCL)
  - Solid State Circuit Breaker (SSCB)
  - Solid State Transfer Switch (SSTS)

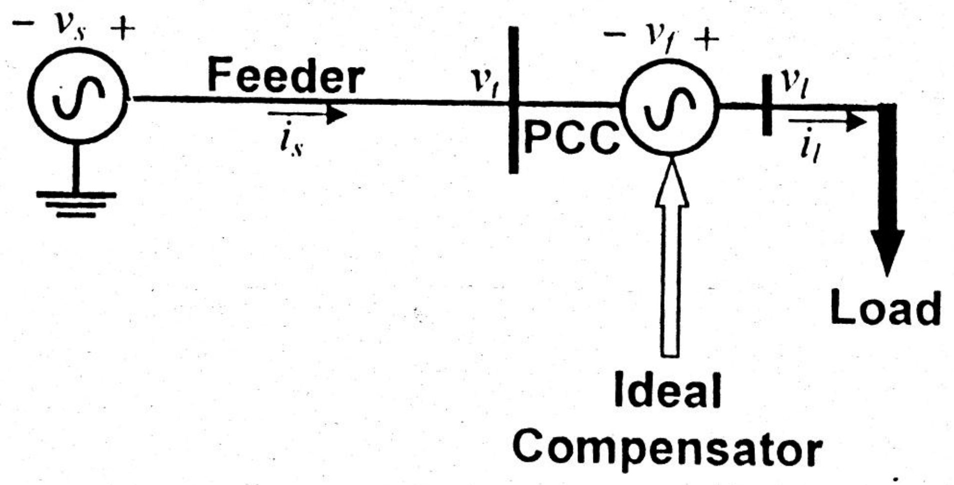
- **Compensating devices** - Compensate a load, by correcting power factor, balancing an unbalanced load or improve the quality of the supply voltage
  - Distribution STATCOM (D-STATCOM)
  - Dynamic Voltage Restorer (DVR)
  - Unified Power Quality Conditioner (UPQC)

(D-STATCOM is a shunt device used for load compensation, dynamic and static voltage control. DVR is a series connected device used for voltage compensation. UPQC is a combination of D-STATCOM and DVR.)

Compensating Custom Device - DSTATCOM

- **Distribution Static Compensator** (DSTATCOM) is basically the same as STATCOM used in the transmission system, except the switches used here are high speed medium power.

Load compensating DSTATCOM

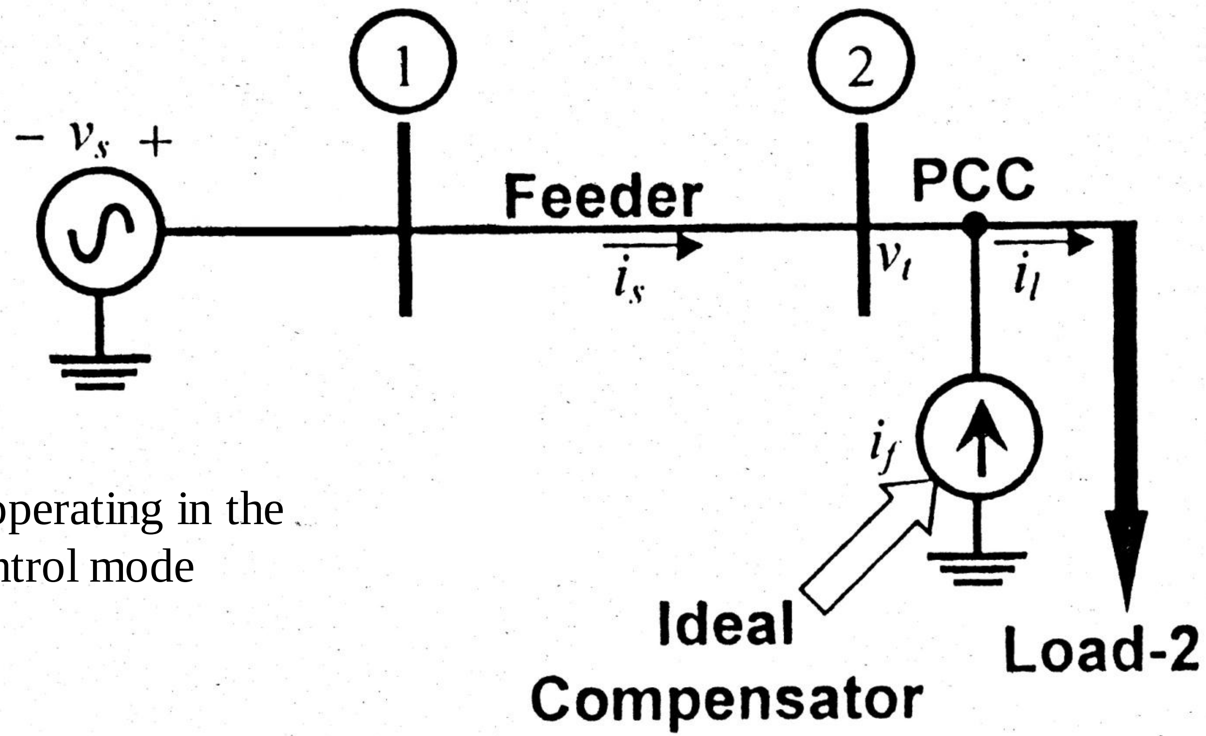


DSTATCOM

- Distribution STATCOM (DSTATCOM) exhibits **high speed control of reactive power** to provide voltage stabilization, flicker suppression, and other types of system control.
- The compensator must **inject current** such that I_s becomes fundamental and positive sequence.
- In addition to those the compensator can also make the **current I_s to be in phase with bus voltage at Bus-2**.
- **DSTATCOM is compensating load current**.
- As far as the utility is concerned Load along with the DSTACOM is drawing a **unity power factor and balanced current** at fundamental frequency.
- The desired performance of the DSATCOM is that it **generates a current I_f such that it cancels the reactive, harmonic components and balanced the load current.**

DSTATCOM - Analysis

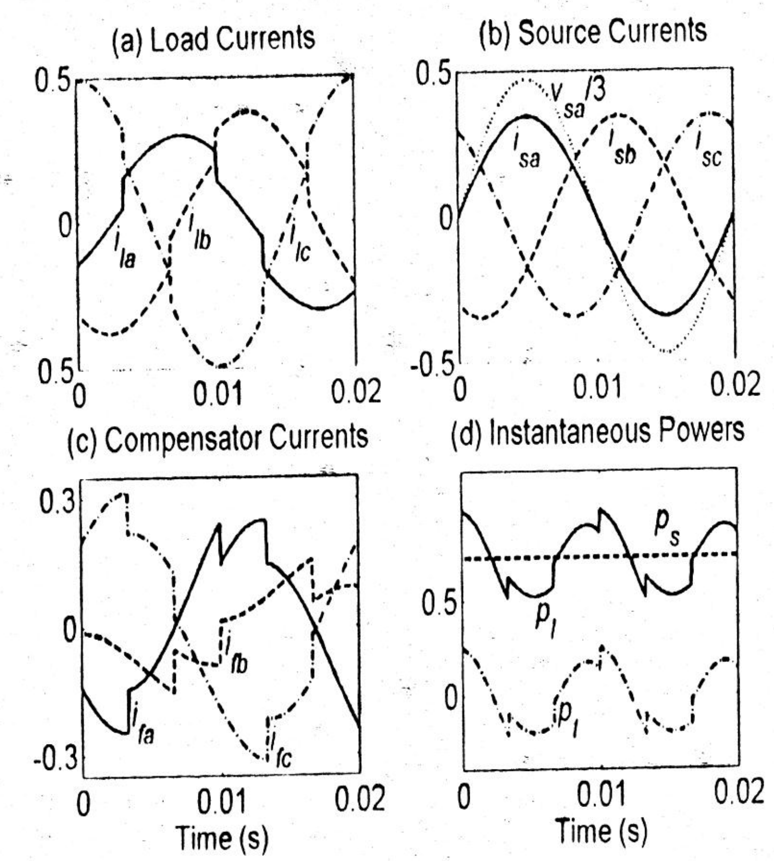
Example: Consider the following circuit in which the voltage sources is considered to be stiff.



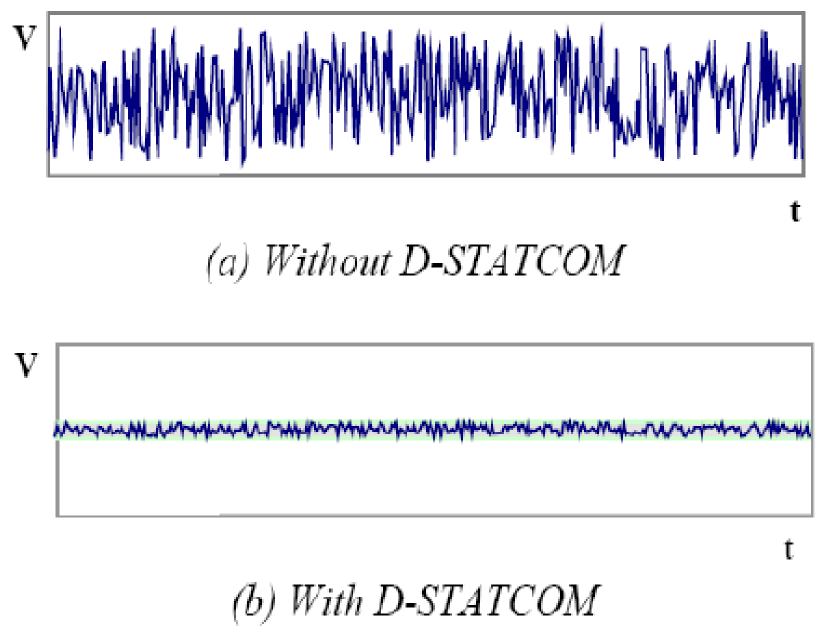
DSTATCOM operating in the current control mode

DSTATCOM

- The DSTACOM **injects currents that cancel harmonics** from load current and also balance the load.
- It also forces the **current draws from the source to be in phase with the voltage at PCC**, i.e. draws current at unity power factor (only real current).
- P**ower supplied by the sources is constant**, the power supplied by the DSTATCOM has zero mean.
- DSTATCOM neither absorbs or injects real power to the load.



- The flicker caused by the arc furnace operation was measured by use of a flicker meter.

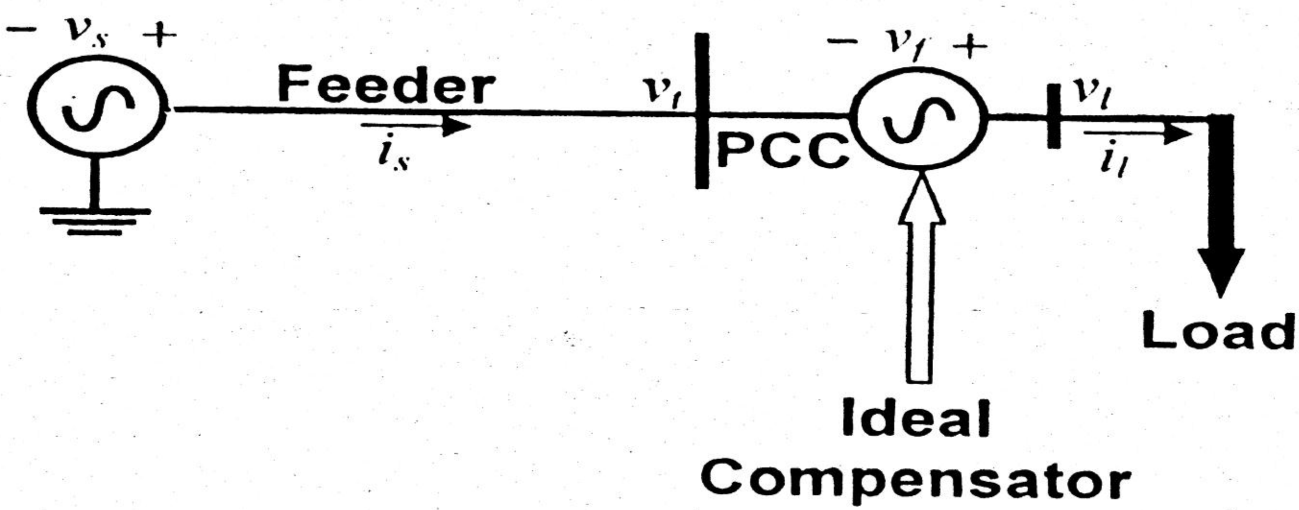


Voltage flicker without (top) and with (bottom) a DSTATCOM on the same voltage scale

In this application, the flicker suppression realized was 58% on average with utilization of the **DSTATCOM.**

http://www.donsion.org

Dynamic Voltage Regulator (DVR)

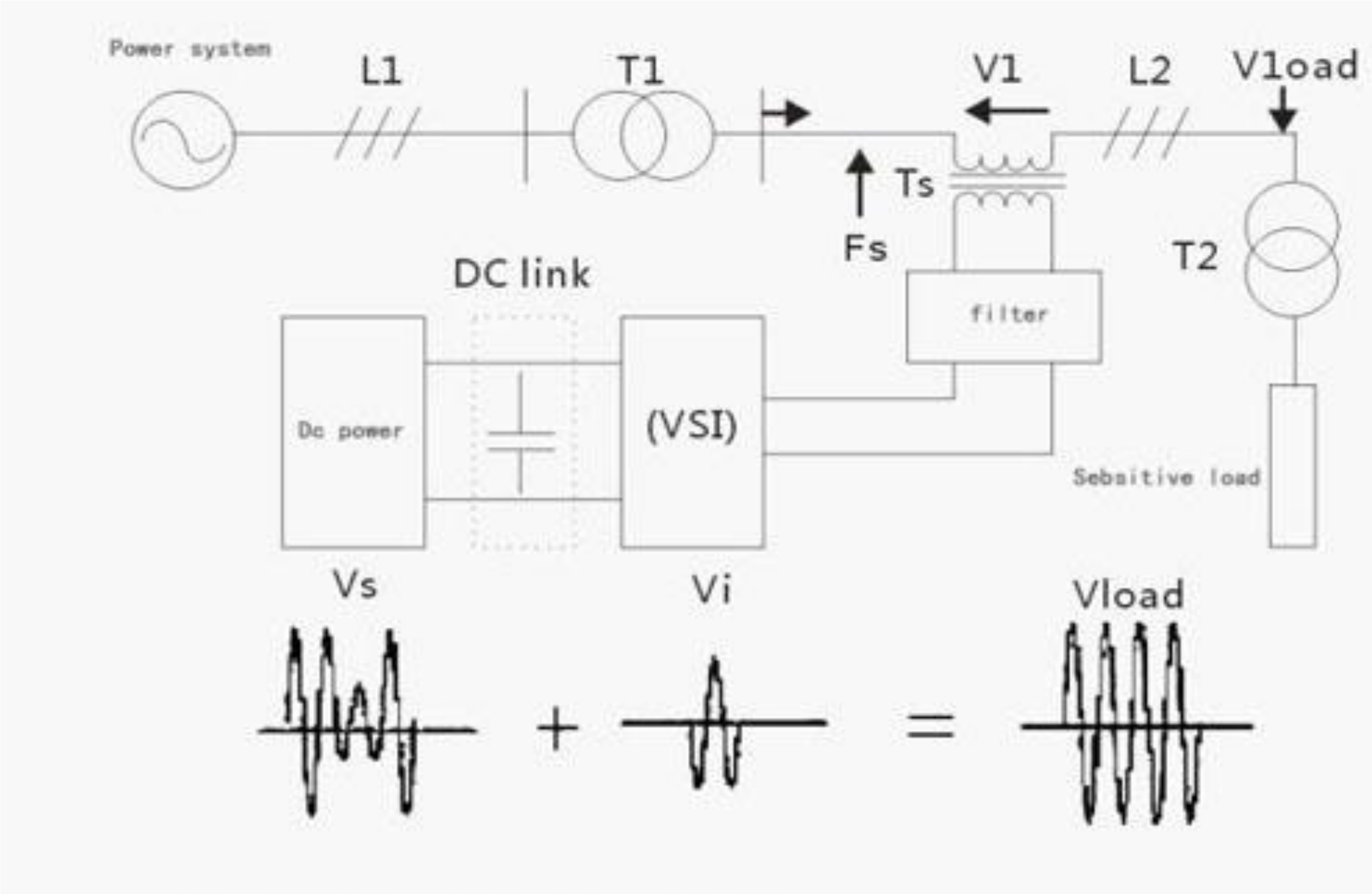


- A Dynamic Voltage Regulator is used to protect sensitive loads from sag/swell or disturbances in the supply voltage.

$$V_l = V_t + V_f$$

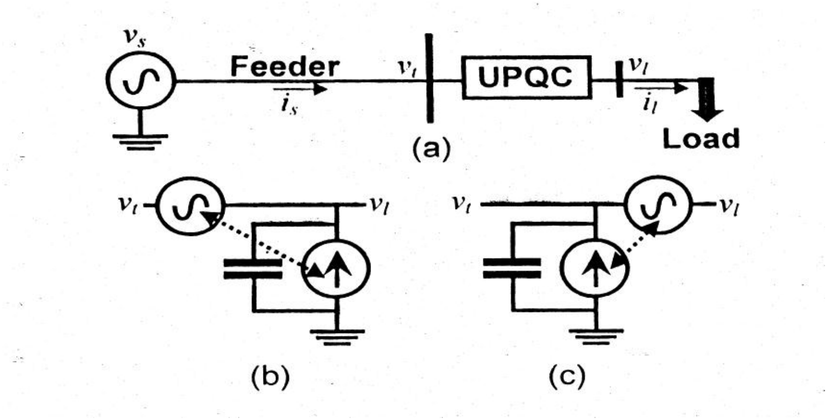
- Where V_l is the load bus voltage, V_t is the terminal voltage and V_f is the DVR voltage.
- DVR can regulate the bus voltage to any arbitrary value by measuring terminal voltage and supplying the balance voltage V_f.

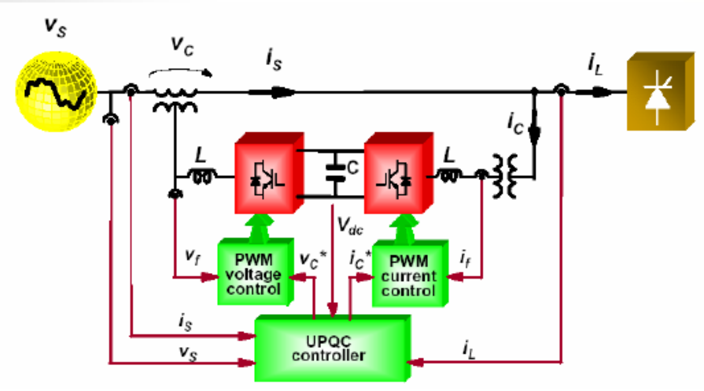
Dynamic Voltage Regulator (DVR)



Picture 3 DVR Dynamic Voltage Restorer Principle

Unified Power Quality Conditioner (UPQC)





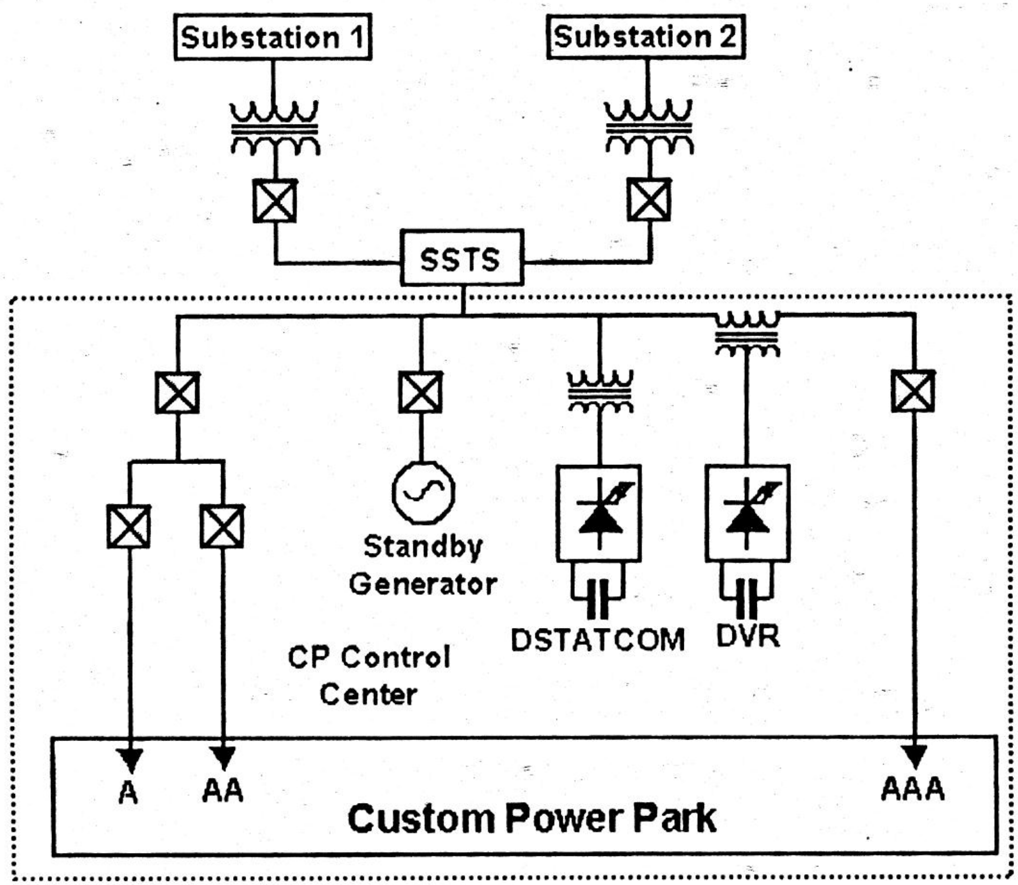
General configuration of the Unified Power Quality Conditioner — UPQC.

- A device that is similar in construction to a Unified Power flow Conditioner (UPFC).
- The UPQC, just as in a UPFC, employs two voltage source inverters (VSIs) that are connected to a d.c. energy storage capacitor.
- One of these two VSIs is connected in series with a.c. line while the other is connected in shunt with the a.c. system.
- A **UPQC** that combines the operations of a Distribution Static Compensator **(DSTATCOM)** and Dynamic Voltage Regulator **(DVR)** together

Unified Power Quality Conditioner (UPQC)

- One of the serious problems in electrical systems is the increasing number of electronic components that injects harmonics in the distribution system.
- The device that can be used for this purpose is **unified power quality conditioner (UPQC)**
- If the source voltage is unbalanced and distorted, the terminal voltage will also be unbalanced and distorted and all the customers connected to the feeder will be affected.
- All the loads connected to the feeder, including unbalanced and nonlinear loads, will have a balanced sinusoidal voltage.
- It will not be possible to correct the unbalance and distortion produced by source using this device.
- There are two ways of connecting a UPQC.
  - The series device is placed before the shunt
  - The shunt device is placed before the series device.
- Usually, the inverter realizing the series device is supplied with a dc capacitor. Similarly, the shunt inverter is also supplied with a capacitor.
- In UPQC, these inverters are supplied by a common capacitor

Custom Power Park (CPP)



Custom Power Park (CPP)

- A custom power park control center is fully loaded with a DSTACOM, a DVR and a stand by generator.
- The **DSATCOM eliminates harmonics and/or unbalance, while the DVR eliminates any sag or distortion.**
- Here the electrical power to the park is supplied through two feeders that are joined together via a SSTS.
- The SSTS ensures that the feeder with higher voltage selected in less than half a cycle in the case of a voltage dip or (sag).
- The SSTS can also be used to protect the loads in the park from dynamic over voltage.
- DSTACOM when operated in voltage control mode and can provide reactive power support to the park and maintain voltage.
- There are three different grades of power can be supplied to the park's customers.
  - Grade A
  - Grade AA
  - Grade AAA

Custom Power Park (CPP)

- **Grade A:** The basic quality power in the park.
  - Since the SSTS protect the incoming feeders, the quality of power is usually better than the one from normal utility supply.
  - In addition this grade has the benefit of low harmonic power due to the presence of DSTATCOM.
- **Grade AA:** This includes all the features of Grade A +
  - It also receives the benefits of standby generator which can be brought into service with in 10-20 seconds (e.g. serious emergency such as power failure in both feeders).
- **Grade AAA:** This includes all the features of Grade AA+

  It enjoys the benefits of receiving distortion and dip free voltage due to the presence of DVR.
  - Semiconductor plant AAA
  - Hospital both AA and AAA
  - Shopping malls and office buildings AA

Regards,

Dr. Sasidharan Sreedharan

YBL Systems and Solutions

(Electrical Power System Research Consultants)

www.sasidharan.webs.com