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Energy Management | Energy Automation

IEC 61850 – Communications

Overview of Topics

- IEC 61850
- Communications
- Advanced Applications
  - Load Shedding
  - Automatic Generation Control

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Communications Protocols

DNP3

Modbus®

PROFIBUS®

Meet the standard IEC 61850

OPC™

PROFINET®

IEC 60870

DeviceNet™

IEC 61850 Applications

- Power Management Systems – Fast Power Based Load Shedding
- Automatic Transfer Schemes
- Inter-tripping / Interlocking Schemes
- Zone Selective Interlocking (ZSI)
- Breaker Failure Schemes
- Data Concentrator
- Direct IED to HMI Connection
- Digital Substations

The IEC 61850 Standard in Brief

- **IEC 61850** provides a **framework** to describe all automation and protection functions of a substation or electrical system:

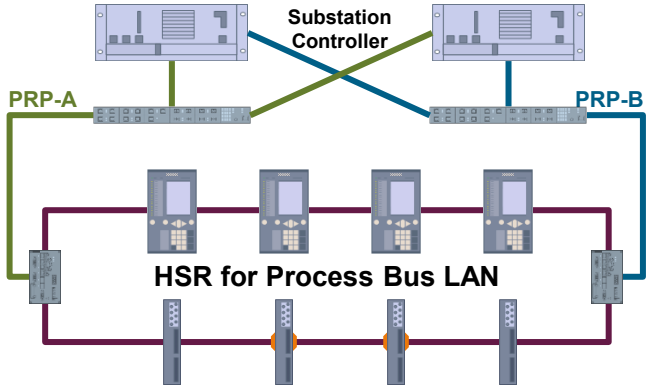
- **Standardized language** categorized with extensive naming convention based off the electrical system

- **Standardized Engineering** based on vendor-independent function descriptions
  - Use devices from different vendors
  - Re-use engineering in the future

- **Ethernet-based** communications

- **Interoperability** between different vendors

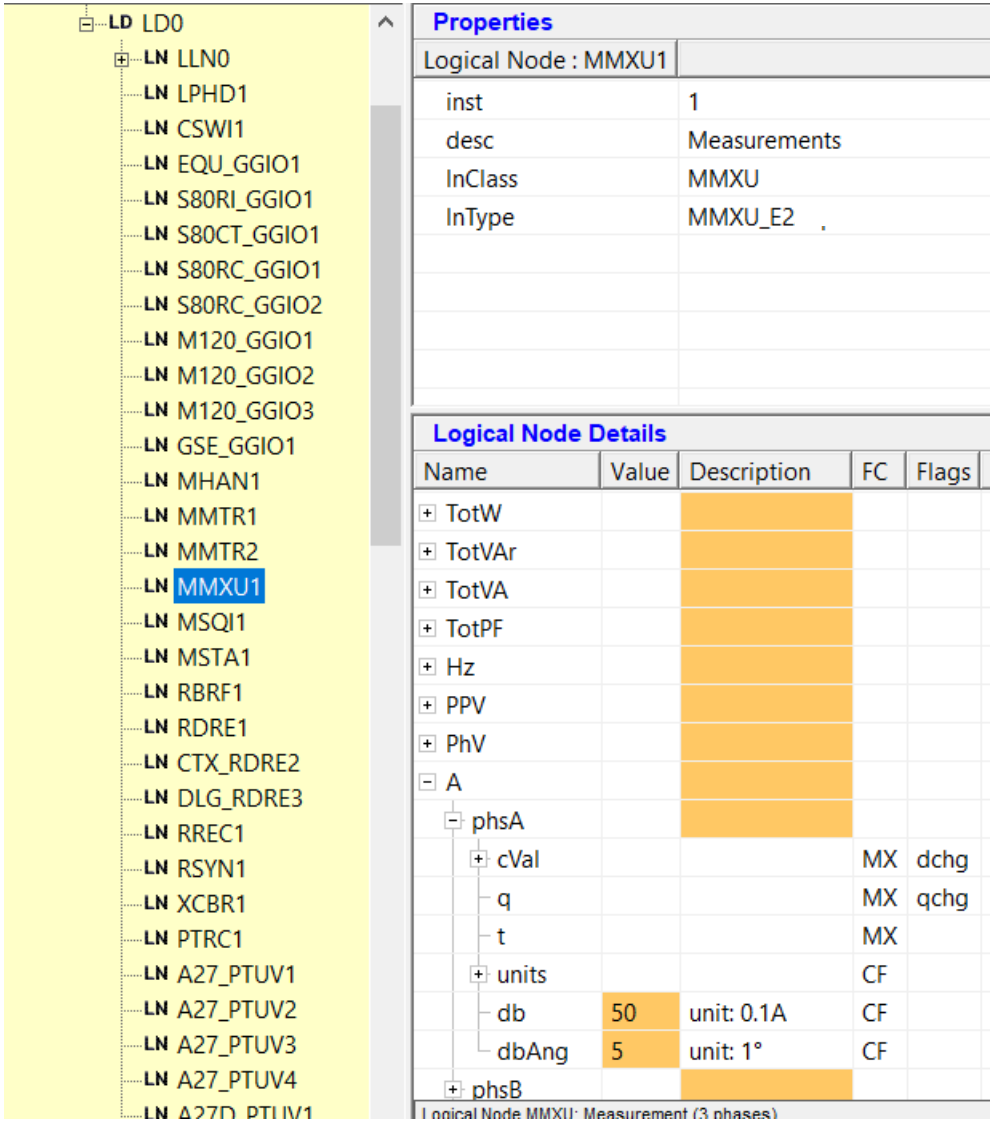
- **Non-hardwired** inter-device communication providing protection functions & coordination



What Is IEC 61850?

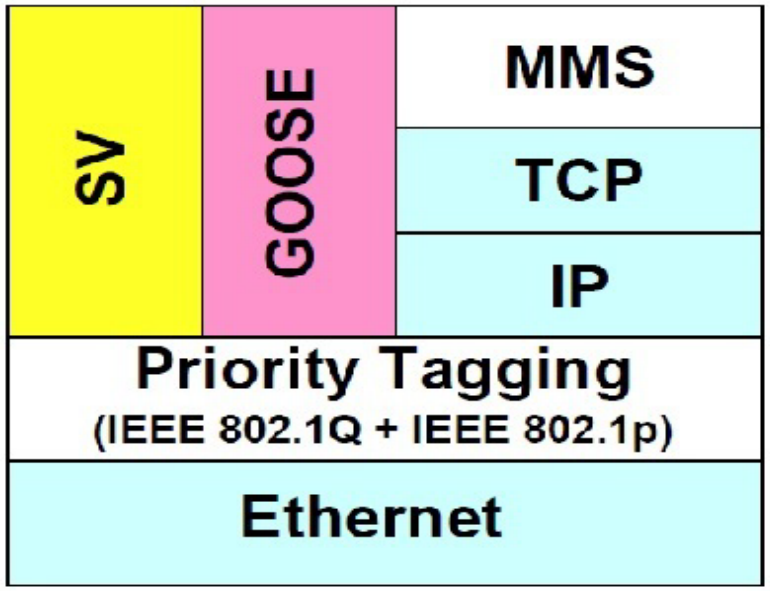
The core idea is a description language, that completely describes the data structure and functionality of a substation information system in a standardized manner.

Three Communications Protocols are based on this standard.



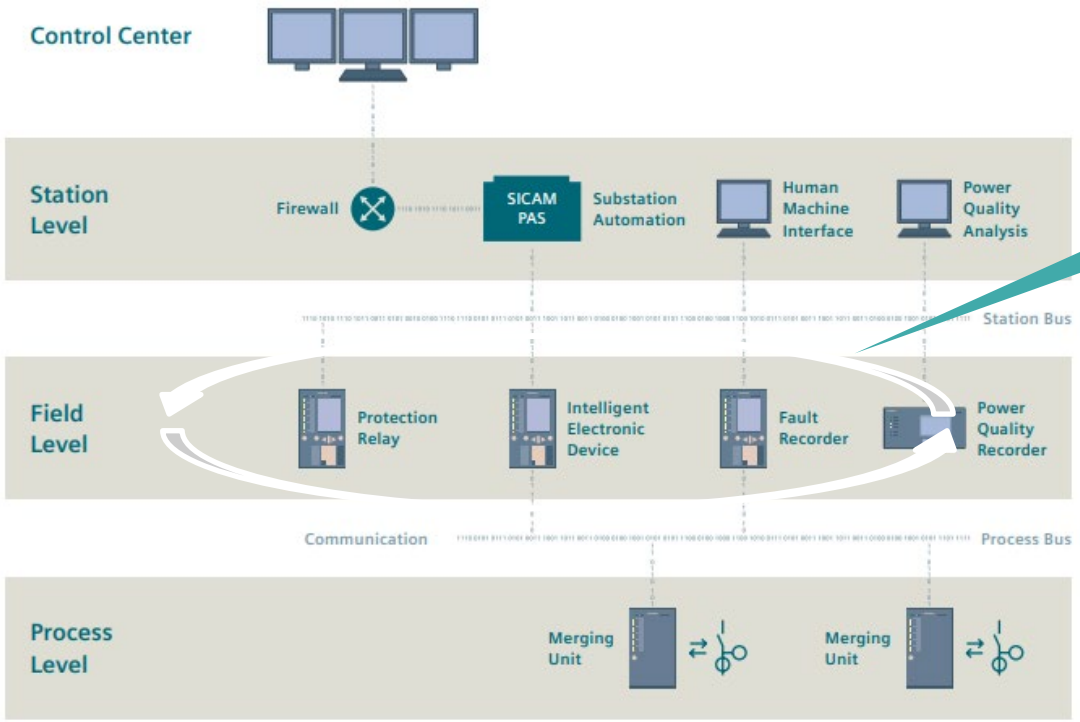
IEC61850 Protocols

- Three IEC61850 Protocols
  - MMS (Manufacturing Message Specification)
  - GOOSE (Generic Object oriented Substation Event)
  - SV (Sampled Values)



IEC-61850 Communication Stack

IEC 61850 Messages



GOOSE
Message exchanged between IEDs
- Fast messages <10 ms

MMS
Message sent from Bay to Substation Level
- Most common usage

SMV
Message sent from Process to Bay Level
- Avoiding copper cables

GOOSE mechanism

GOOSE repetition mechanism

Does GOOSE arrive?

Non deterministic service, backed up by:

- Constant repetition or updating
- Redundancy in LAN and relaying architecture
- Monitoring and alarming by subscriber IEDs that fail to receive publisher's message stream.

GOOSE is like a virtual wire but…

…wires cannot monitor themselves like GOOSE.

…faster implementation of additional signals.

GOOSE - Arc Flash Reduction – Virtual main

Table 1: Arc Flash Hazard Analysis Results, No Virtual Main Relays

Location	Arcing Fault Current, kA	Arc Duration, seconds	Arc Flash Incident Energy, Cal/cm²	Hazard Level, NFPA 70E Category
LV SUB 1	8.68	2	36	4
LV SUB 2	14.25	2	62	>4
LV SUB 3	19.77	2	88	>4

Table 5: Arc Flash Hazard Analysis Results with Virtual Main Relays

Location	Arcing Fault Current, kA	Arc Duration, seconds	Arc Flash Incident Energy, Cal/cm²	Hazard Level, NFPA 70E Category
LV SUB 1	8.68	0.183	3.3	1
LV SUB 2	14.25	0.183	5.7	2
LV SUB 3	19.77	0.183	8.1	3

Texas Power Plant worker

The operator, in addition to wearing a full-body flash suit while racking the breaker, did everything that National Fire Protection Association (NFPA) and Occupational Safety and Health Administration (OSHA) regulations required. Although the suit provided some protection, it did not save the operator's life. The moral of this story: If the arc flash burn doesn't get you, the high-energy blast effects will. Entergy learned the lesson quickly;

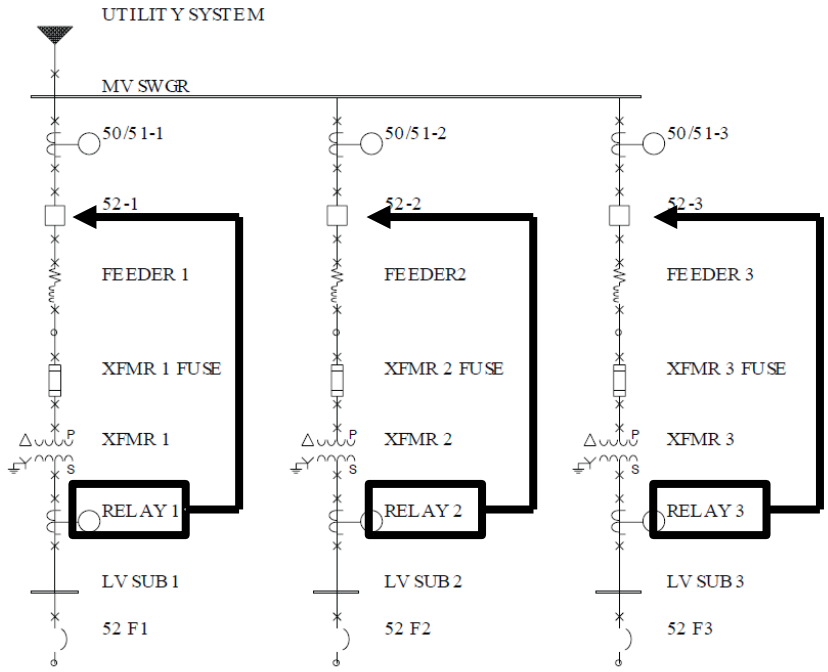


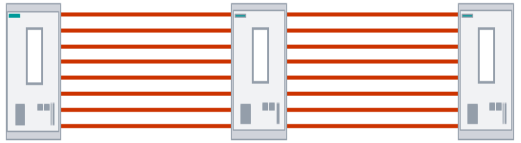
Figure 5: Test system for arc flash hazard calculations

Benefits of IEC61850

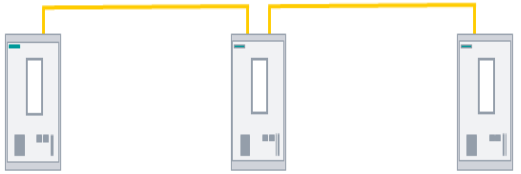
Benefits:

- Reduction of wiring and hardware
- Eliminates need for protocol converters
- Full communications redundancy with fewer switches
- Process bus
- System file exchange

Conventional Wiring



Wiring with IEC 61850



IEC 61850 enables up to 70% reduction in wires

Overview of Topics

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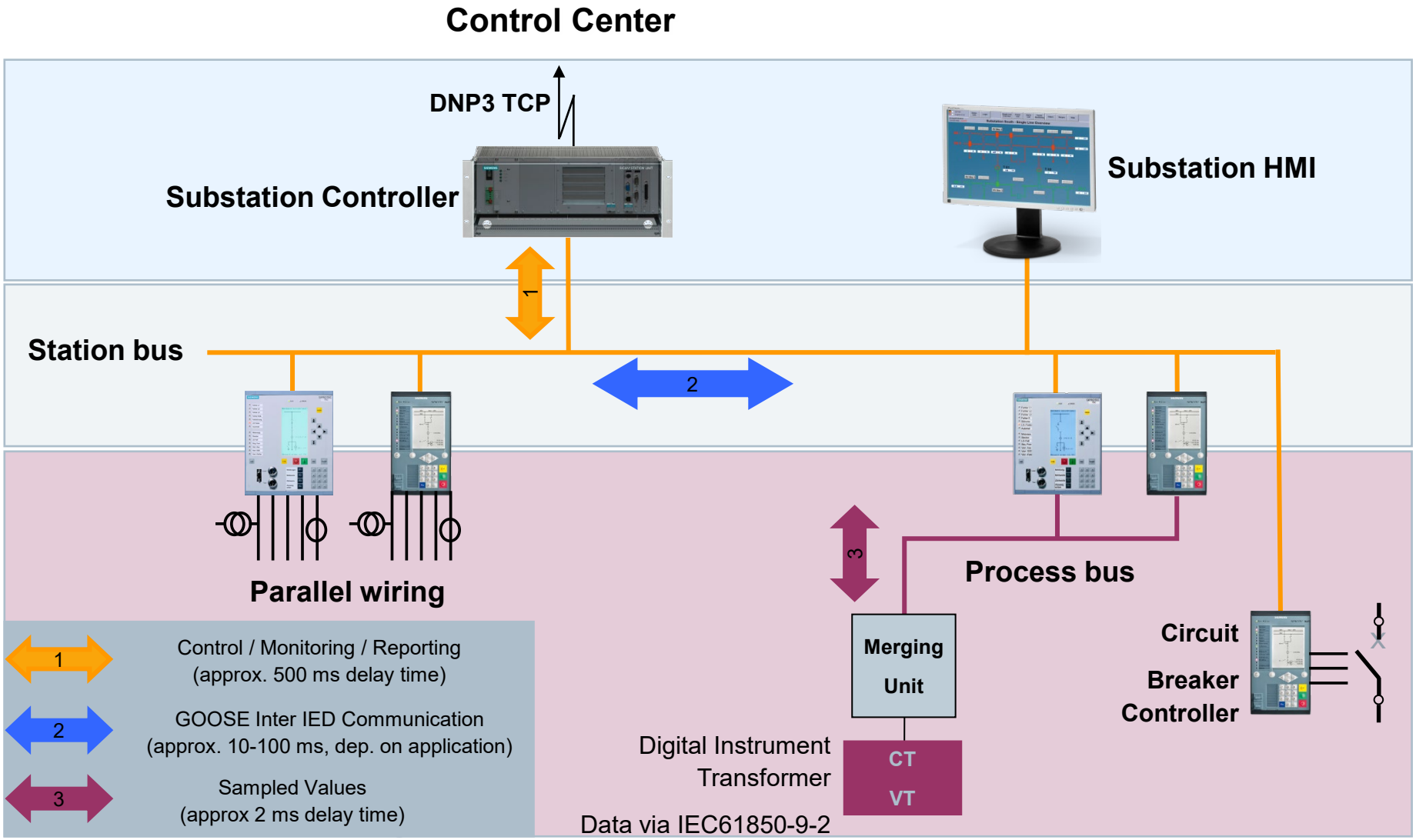
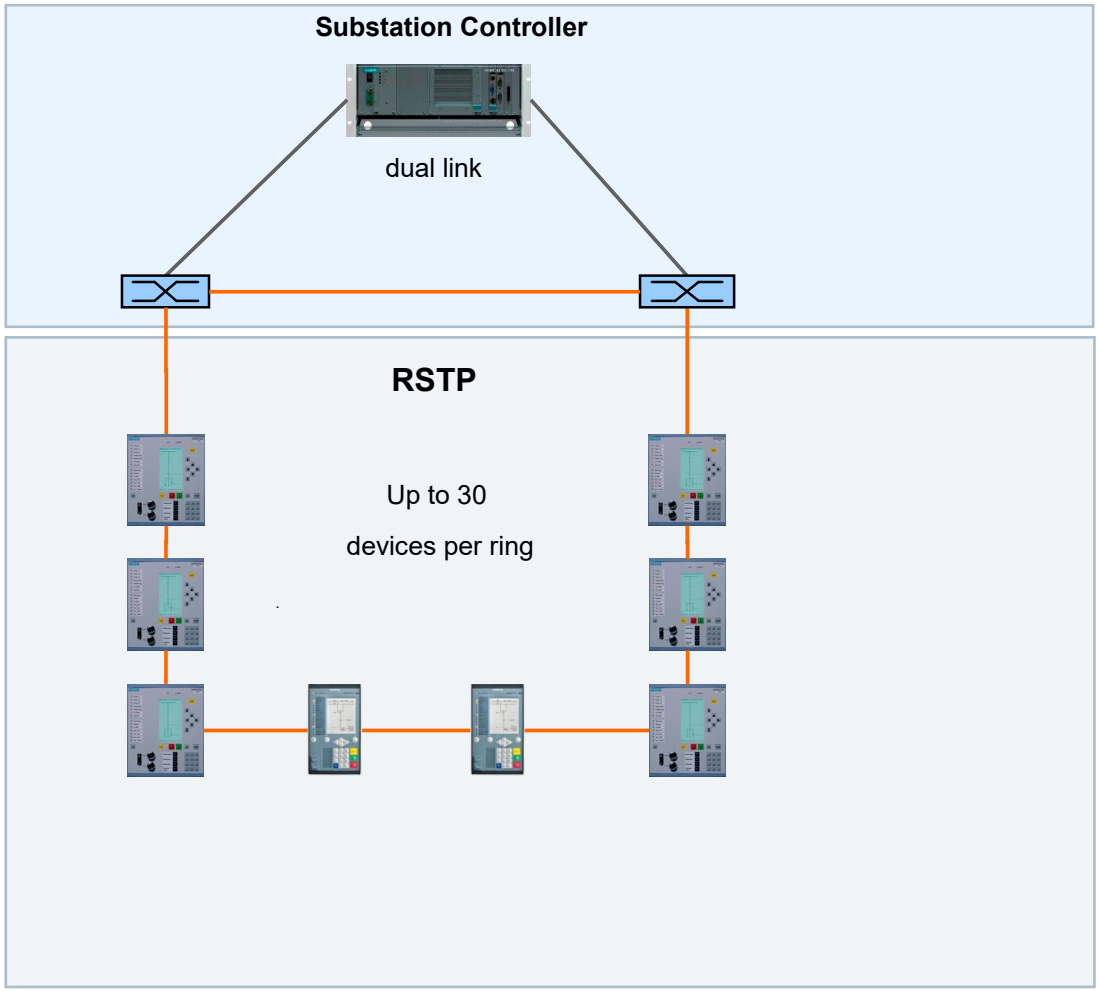
IEC 61850 communication



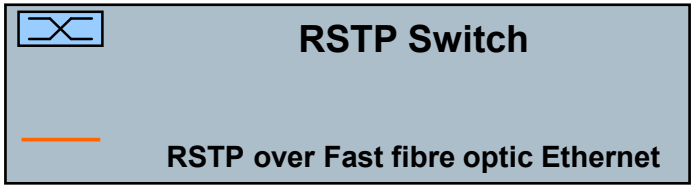
Principle of RSTP- IEEE 802.1D-2004



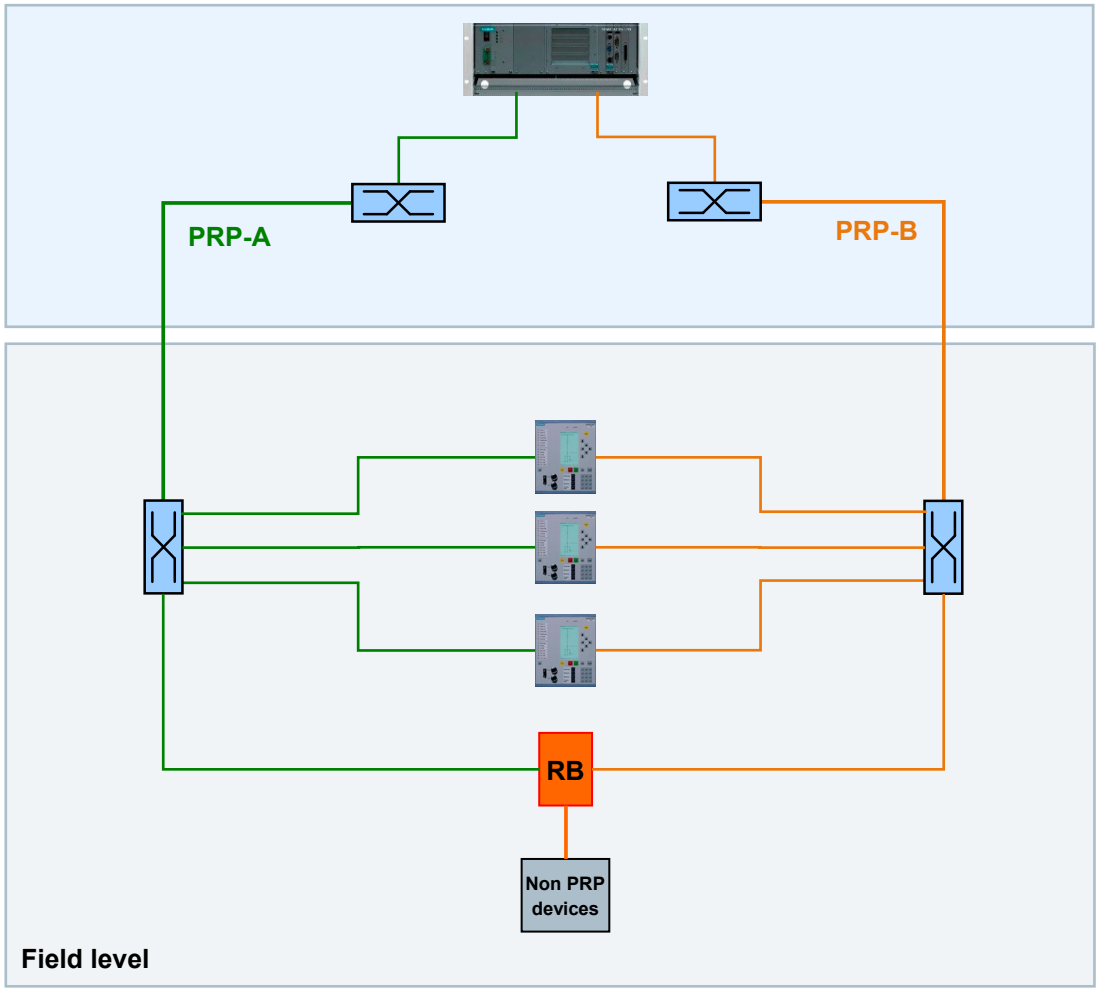
- 2 external RSTP-Switches
- Devices with integrated RSTP switch
- Rings with up to 30 devices
- Several rings can be connected to external switches
- Setting of RSTP parameters necessary

→ Well established technology (> 250.000 devices)

→ Field proven interoperability

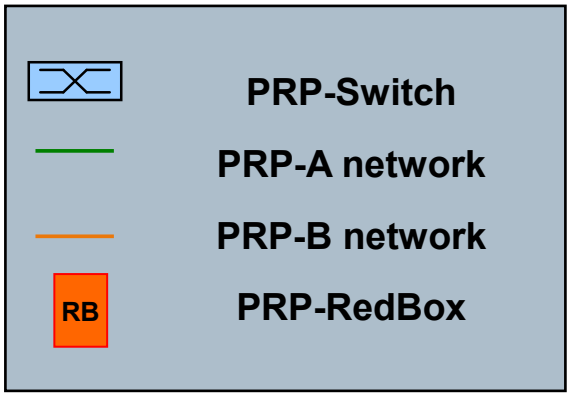


Principle of PRP - IEC 62439-3.4

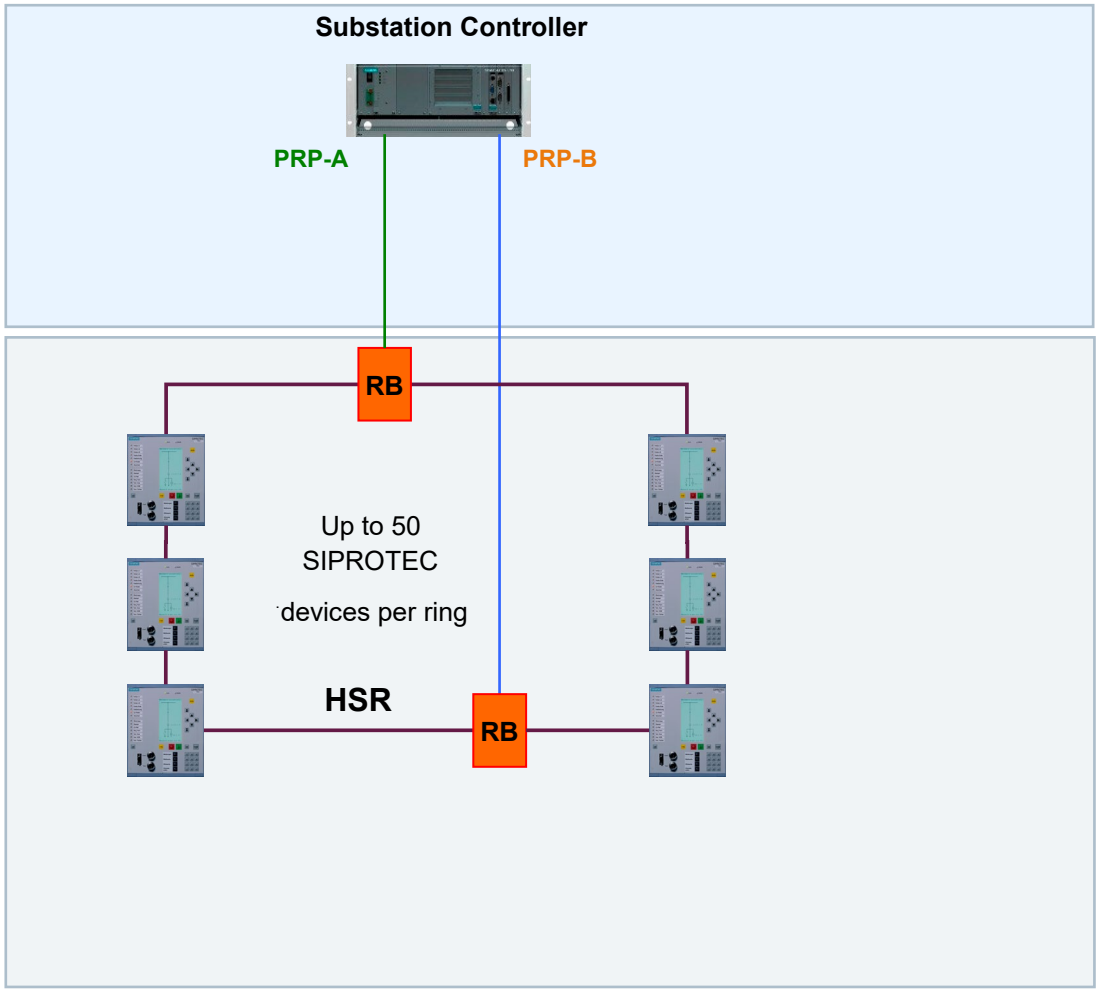


- Two parallel networks
- Device are connected to network PRP-A and PRP-B
- Devices send and receive via both active links
- RedBox for connection of non PRP devices
- Seamless

→ Interoperability tests done

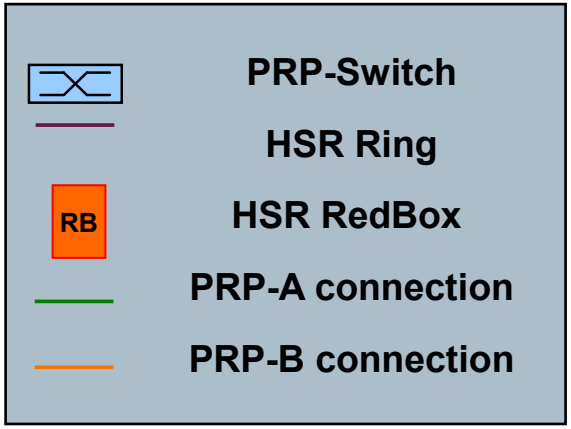


Principle of HSR - IEC 62439-3.5



- 2 Redboxes
- Devices with integrated HSR switch
- Rings with up to 50 devices
- Redboxes distributed in the ring
- Seamless

→ Interoperability tests done



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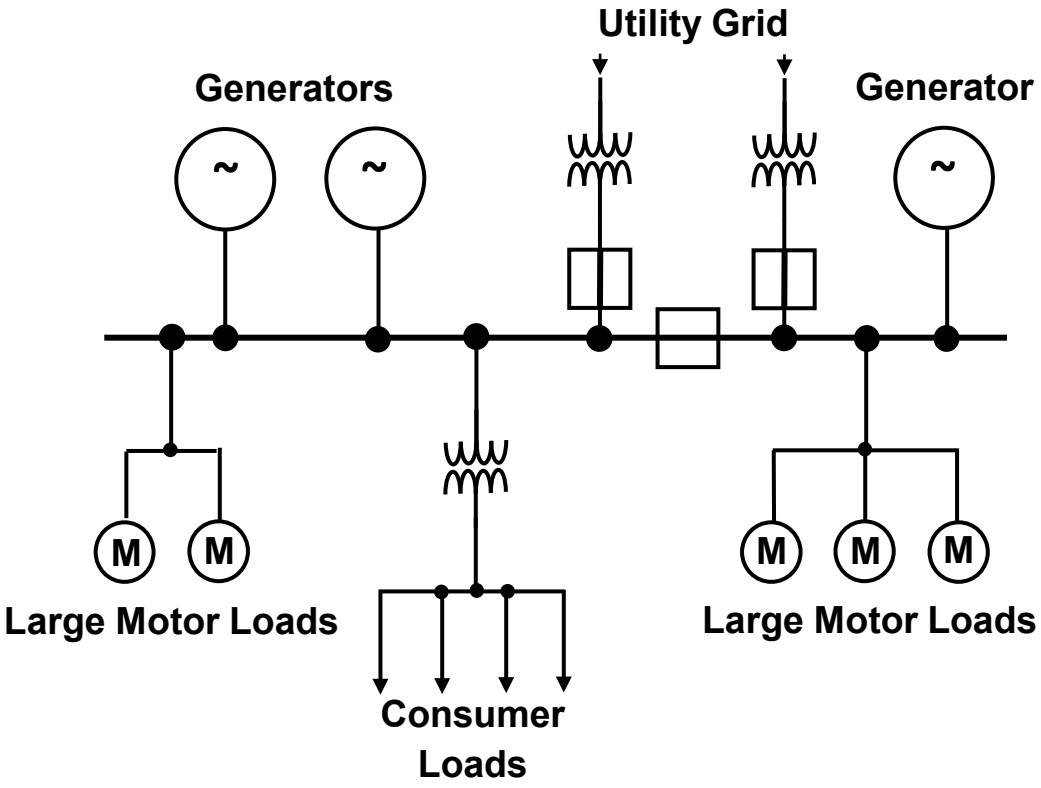
Power Management Systems in Industrial Applications

Operating modes

Interconnected mode



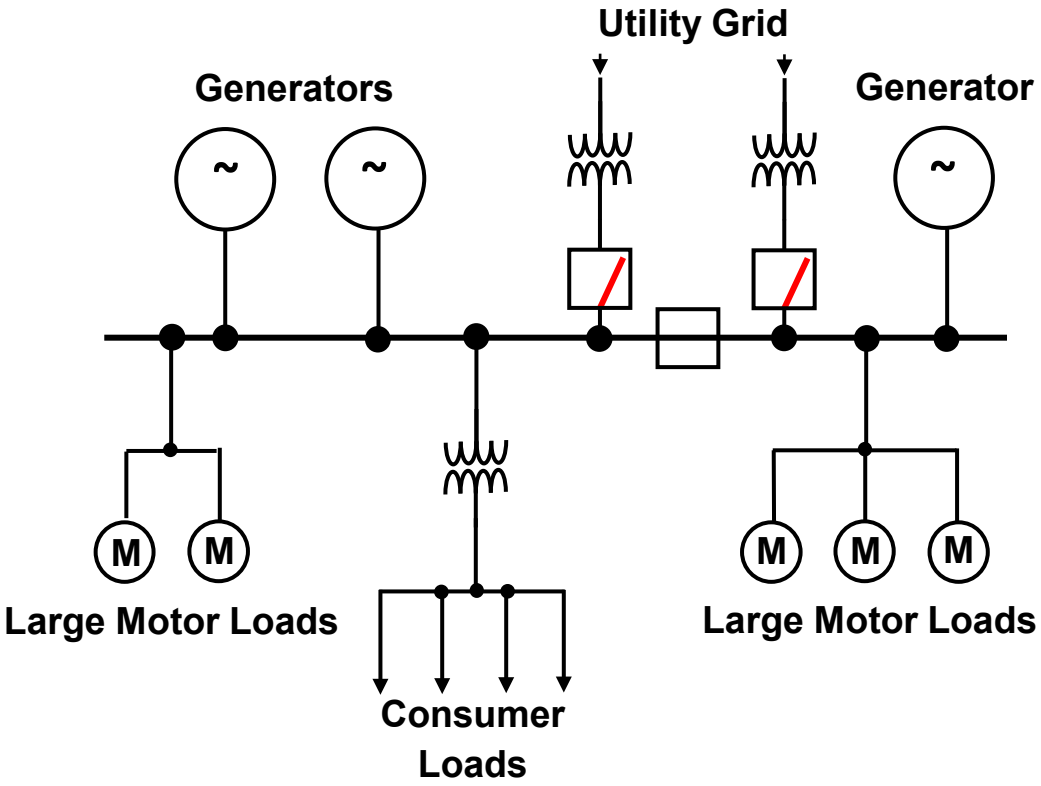
- Most frequently used operation mode
- The industrial power grid is connected to Utility
- The utility grid is leading the frequency
- Load Frequency Control (LFC) not necessary
- Energy import or export
- Contracts between Customer & Utility

Tasks of Power Management System:

- Regulation of import/export power
- Regulation of power factor
- Regulation of bus voltage
- Load sharing
- Load shedding

Operating modes

Island mode



- Islanding in emergency situation
- Intentional Islanding
- The industrial power grid is disconnected from Utility
- Frequency, Voltage & Power must be regulated
- Recognition of different areas = topology adaption

Tasks of Power Management System:

- Automatic island detection
- Load-Frequency regulation (LFC)
- Regulation of bus voltage
- Load sharing
- Load shedding

Overview of Topics

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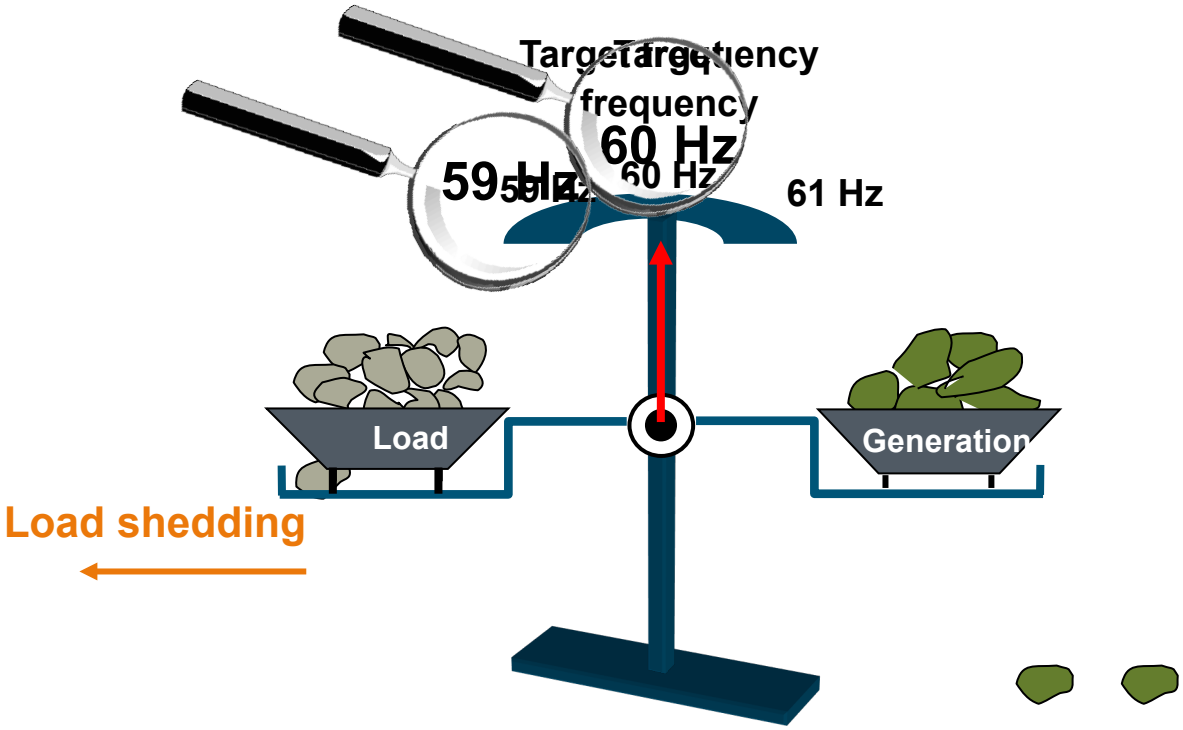
What is Load shedding?

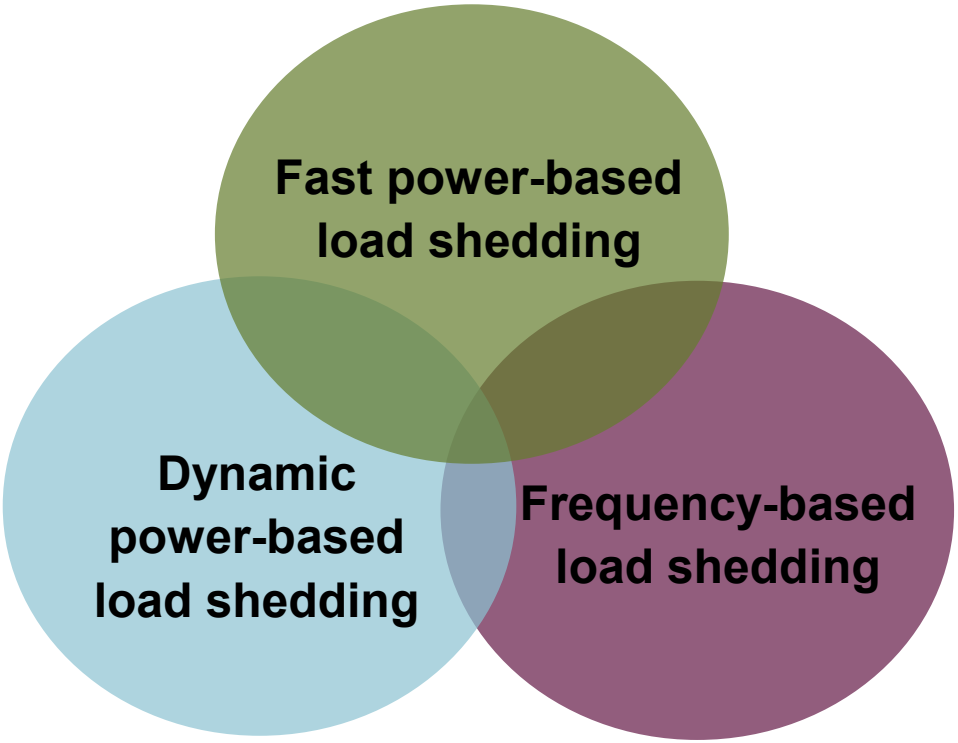
Definition

Load shedding defines automatic trip of selected consumer loads, to ensure stability of a defined grid in situations of insufficient energy supply.



A Comprehensive Load Shedding Solution

Best performance and availability by combining all principles



A Comprehensive Load Shedding Solution

Fast power-based load shedding:

Calculates continuously balance of

- **Generated power**
- **Consumed power**

For each critical event a shedding scenario is precalculated, e.g.:

1. **„If generator 2 would trip now, how much power is to be shed?“**
2. **„which bays to shed?“ according to priority and power.**
3. **Adaption of shedding–matrix in the bay units.**

A Comprehensive Load Shedding Solution

Fast power-based load shedding:

Principle

How much power is missing?
(if contingency occurs)

How much power to be shedded?
(Subtract remaining spinning reserve)

Which feeders to shed?
(start with lowest prio, summarize consumed power up to required value)

Adapt shedding matrix

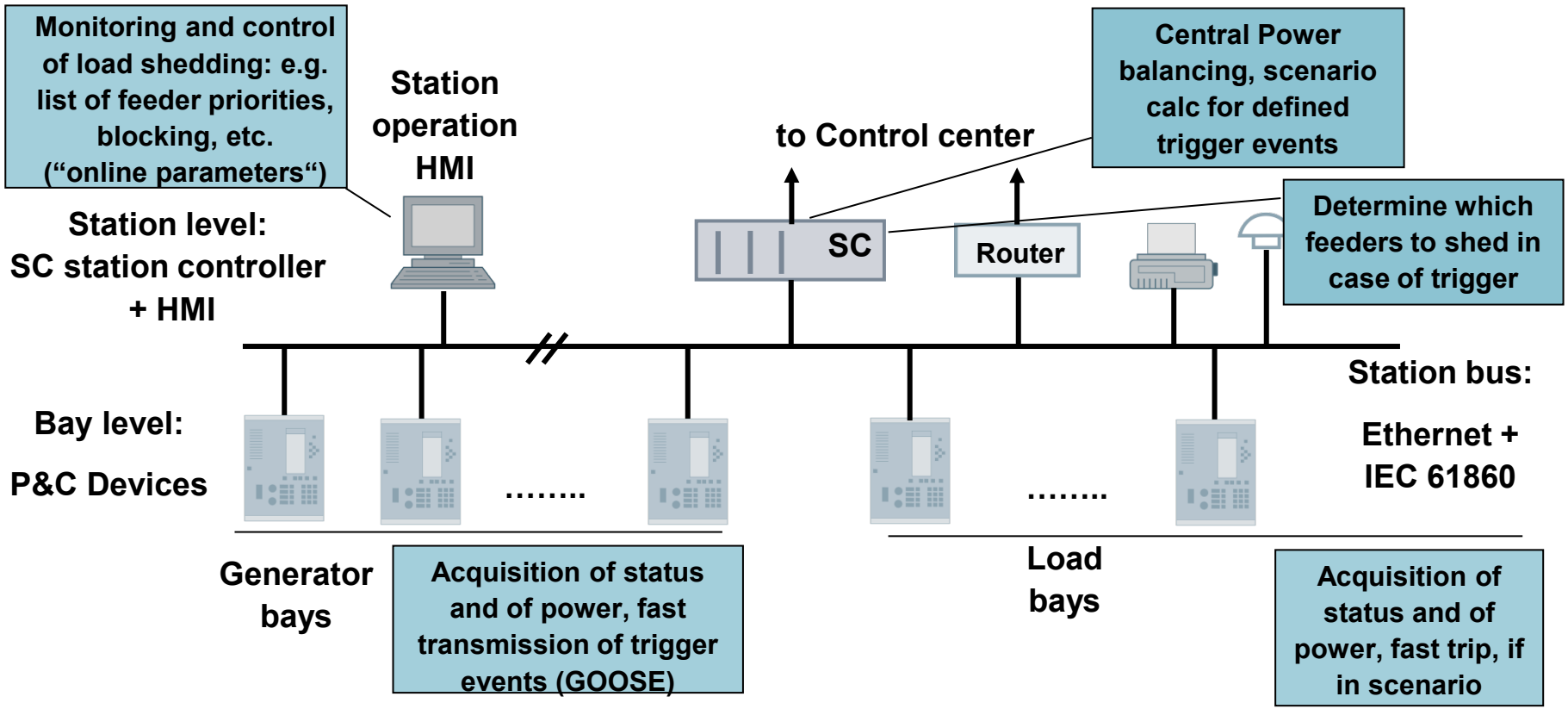
Cyclic calculation

(~2s)

	Bays to be shed						
Trigger	1	2	3	4	5	…	m
1	x		x	x			
2		x		x			
3		x		x	x		
4	x	x	x		x		x
5		x	x	x		x	
..							
n		x		x			x

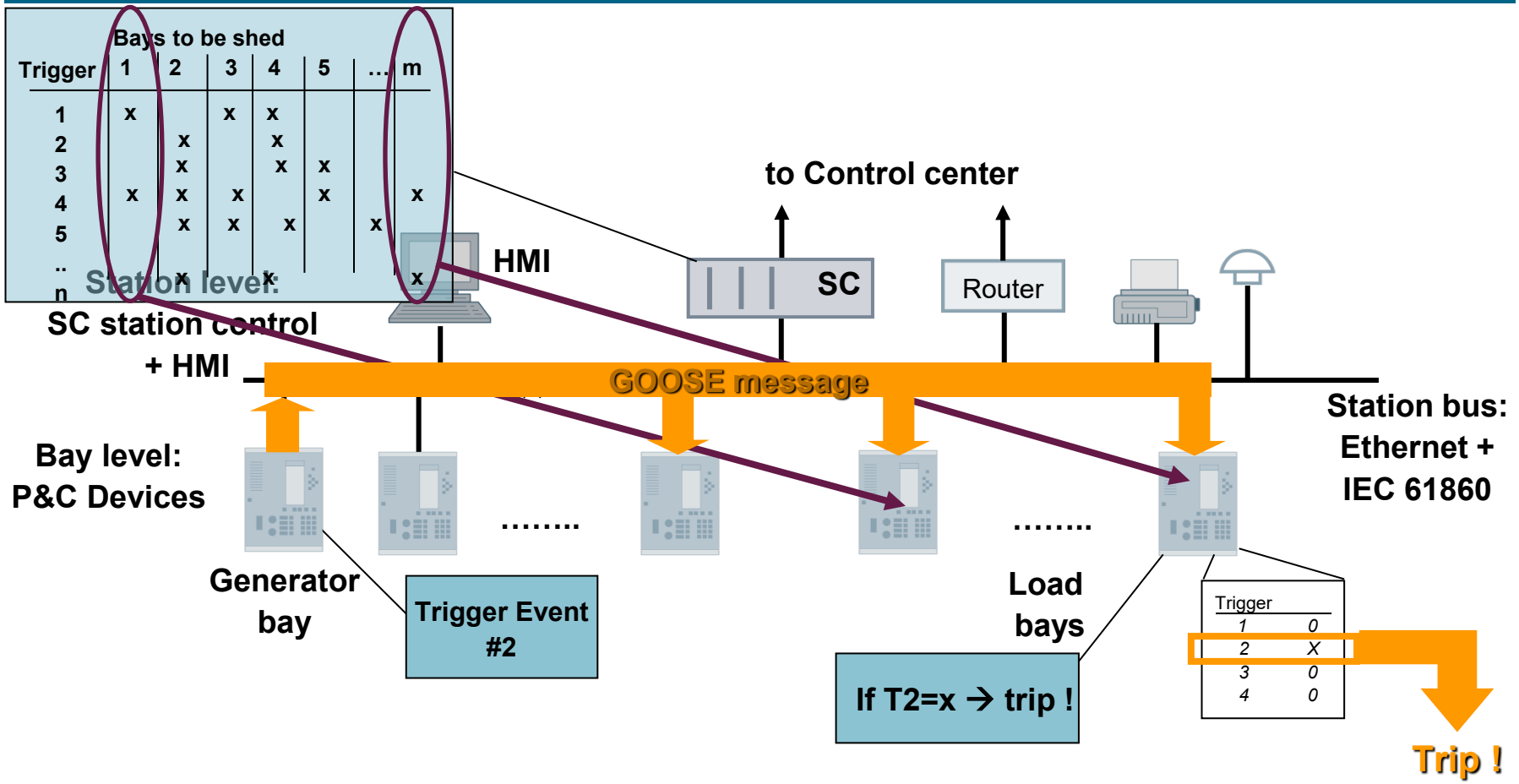
A Comprehensive Load Shedding Solution

Fast Power-based load shedding



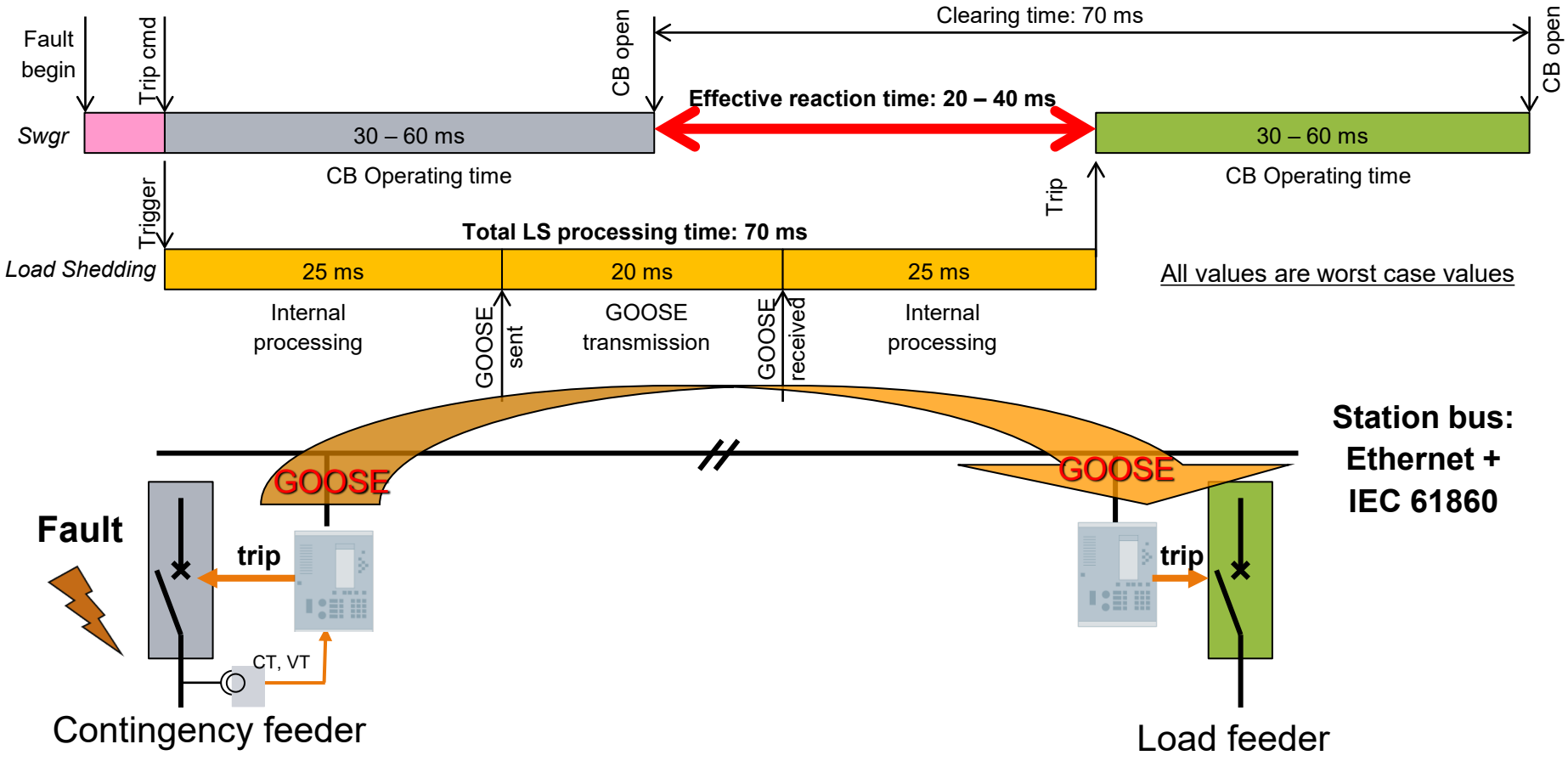
A Comprehensive Load Shedding Solution

Fast Power-based load shedding



A Comprehensive Load Shedding Solution

Power-based LS reacts fast and proactively

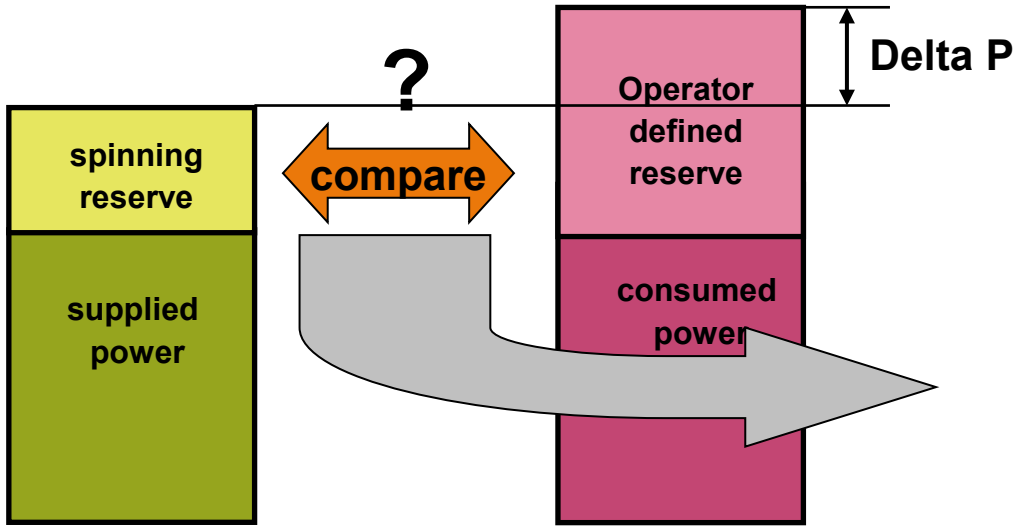


A Comprehensive Load Shedding Solution

Dynamic power-based Load Shedding

Goal: Maintain balance of power during stable island operation:

Supervision of Spinning Reserve
i.e. difference between current generated Power and max. possible Power to be generated.



Delta P can also be reduced by load inhibition

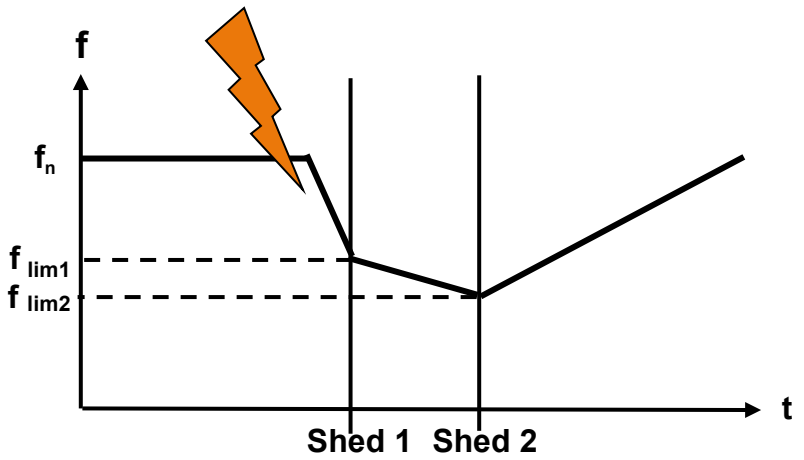
Shed loads acc. to priority list, until Delta P = 0

A Comprehensive Load Shedding Solution

Frequency-based Load-Shedding

uses predefined table, with loads to shed:

- **in case of $f < f_{lim1}$**
- **in case of $f < f_{lim2}$**
- **in case of $f < f_{lim3}$**
- **in case of $f < f_{lim4}$**



Load-table is based on grid-constant for ΔP/ Δf, and the calculated P, which is the equivalent of f_{lim}

The load – tables can easily be monitored and/or adapted on the HMI of the control and protection system.

Summary

Features

- Use of IEC 61860
- Fast GOOSE comm.
- Integration in SAS
- Decentral configuration
- Combined LS-functions: Fast / Dynamic / f-based
- Predictive fast LS
- One joint HMI

Advantages

- Use of bay units -> reduction of devices
- Reduction of wiring
- Self supervised comms
- Graphic definition of topology

Benefits

- P-based LS sheds very accurate
- Very fast LS
- Autom. calc of topology
- Future-proof by IEC61860
- Economic solution: integration in SAS
- Very high availability: redundant controller + backup LS

Improve reliability of energy supply

Overview of Topics

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Generation Control in industry grids

Automatic Generation Control is designed for:

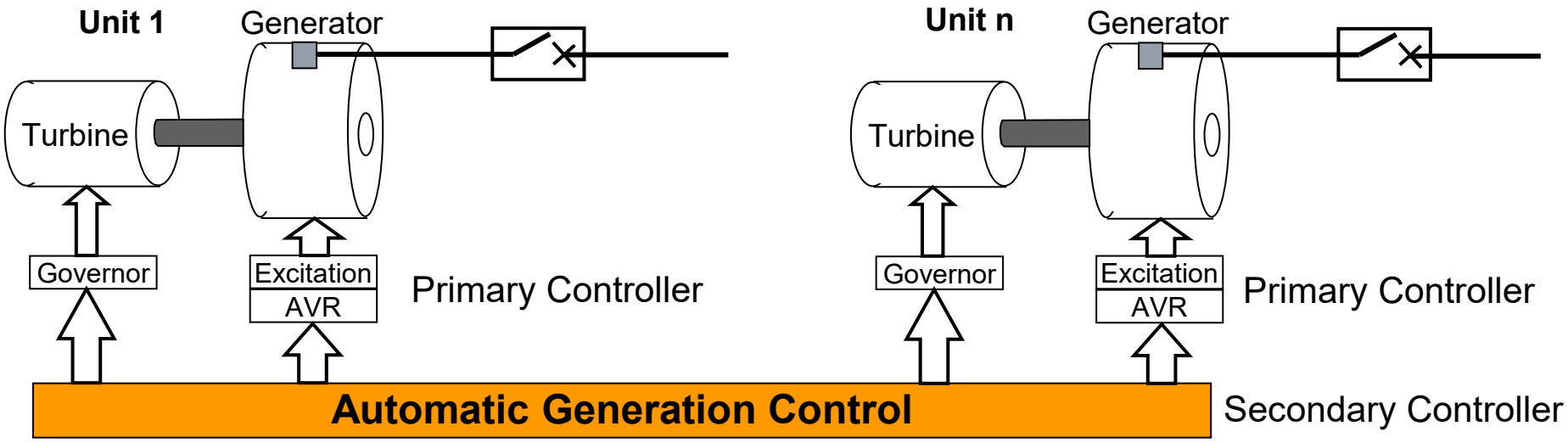
- electric power grids in industry with own generation
- multiple generator units in one grid
- for steam- / gas- / diesel turbines
- industry grids with several areas / islands
- usually combined with load shedding function

Generation Control in industry grids

Generator sets are equipped with primary controllers for:

- frequency/active power control
- voltage/reactive power control

Multiple generator sets need coordination



Generation Control in industry grids

Automatic Generation Control is necessary to:

- keep system frequency and voltage in a specified range
- maintain intended value of interchange at Utility Connection
- share total generated power between assigned generators

Generation Control in industry grids
HMI Screens

Overview for one grid area:

Main cockpit for area
f, V, $P_{interchange}$, $PF_{interchange}$

Status of LFC

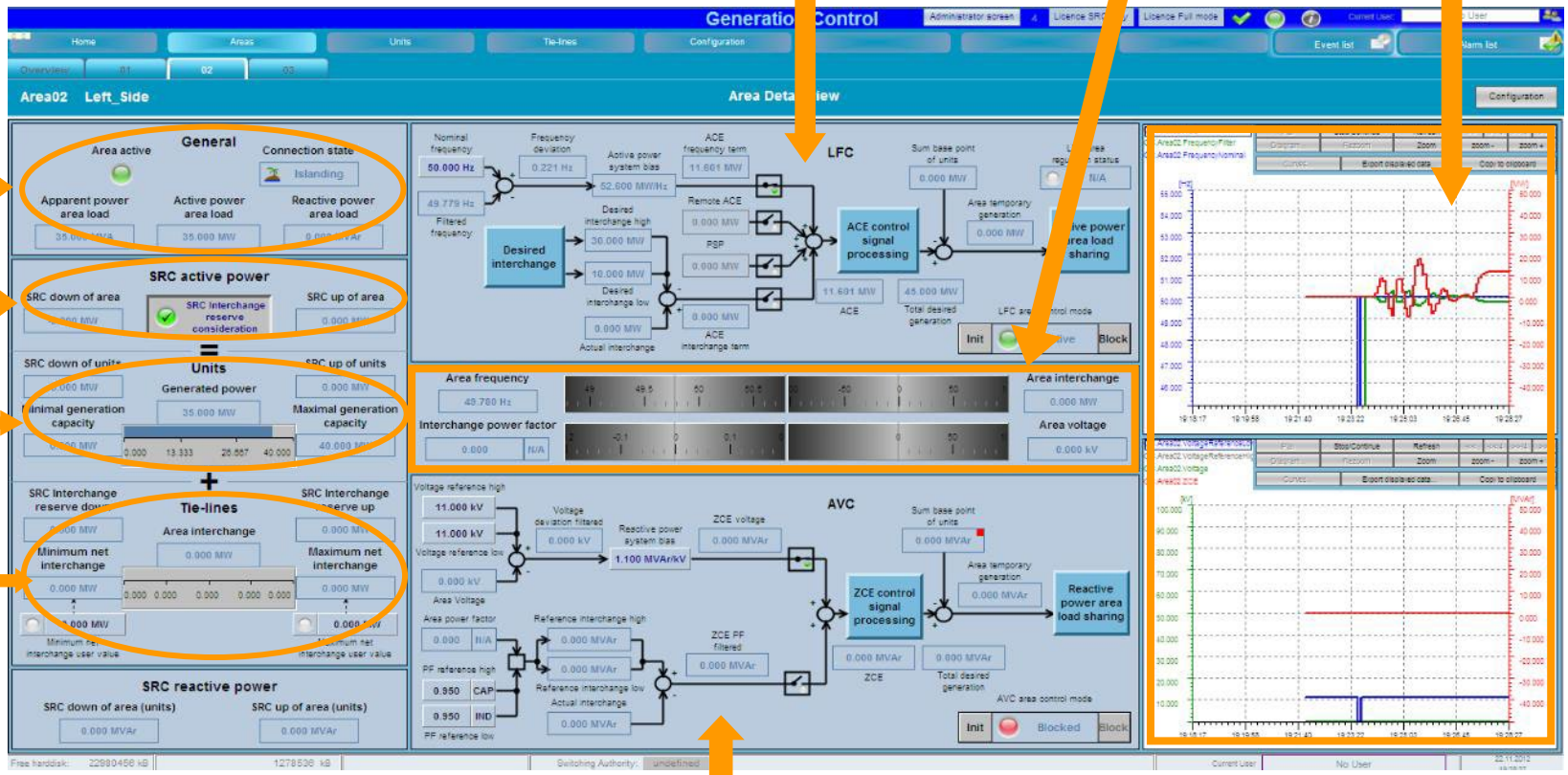
History of main values

Total load of area

Total reserve for area

SRC of all units in area

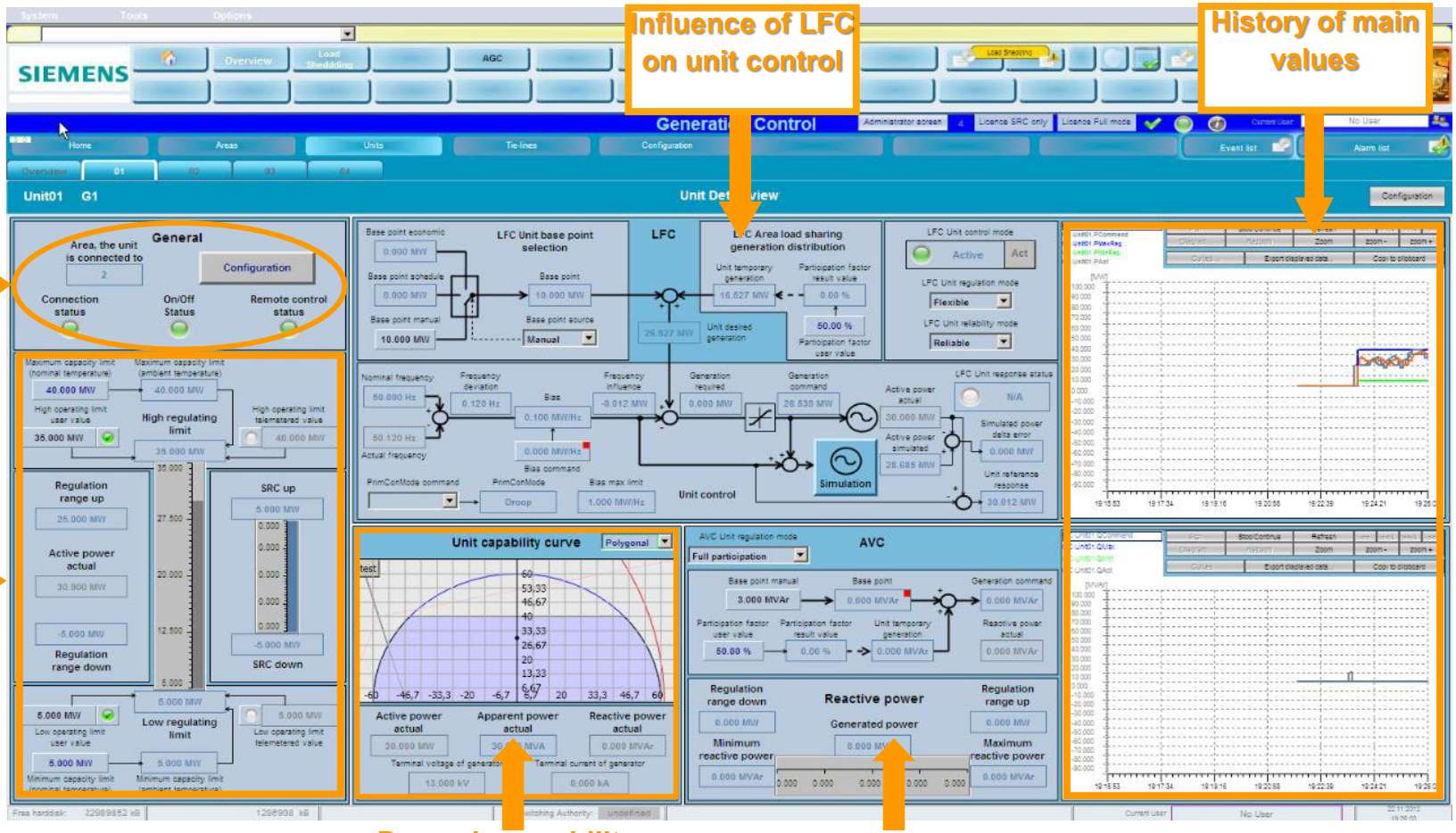
Reserve of tie-lines



Status of AVC

Generation Control in industry grids
HMI Screens

Overview for one unit:



Generation Control in industry grids
HMI Screens

Detail from Unit View:

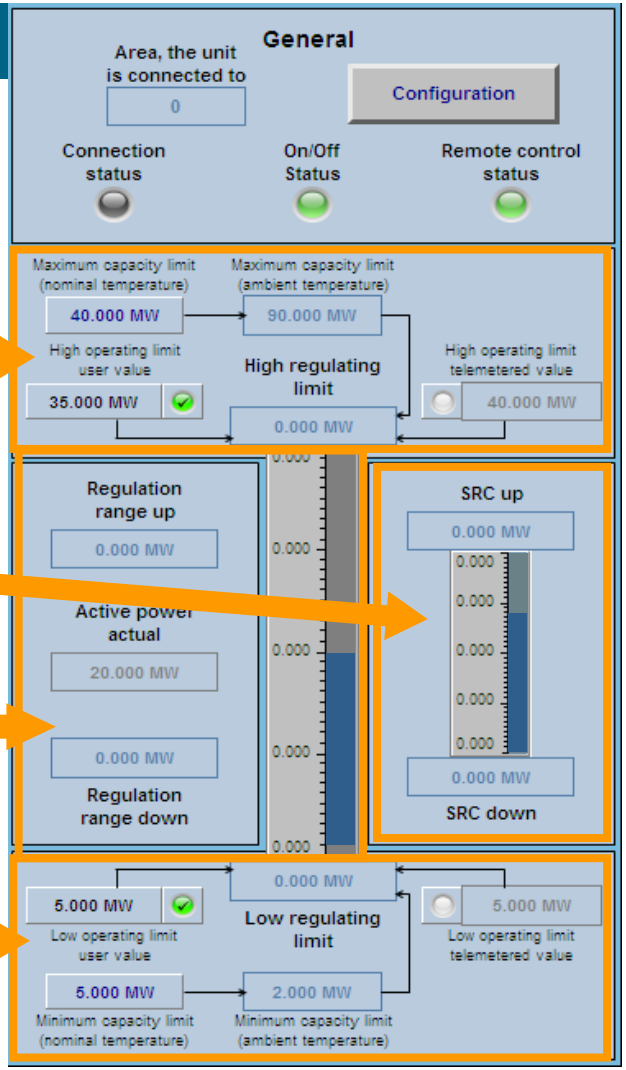
Spinning reserve monitoring (SRC)

Selection of high regulating limit

SR = difference of P_{actual} and regulating limits
(bargraph and values)

“Regulation range“ is limited by short term power gradient of unit

Selection of Low regulating limit



Generation Control in industry grids
HMI Screens

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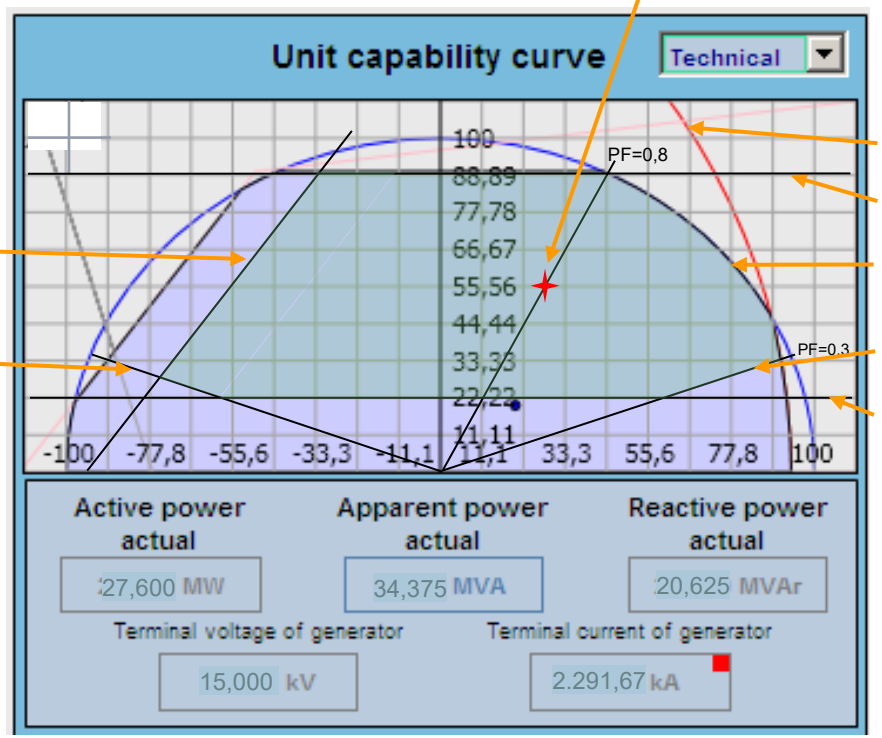
Detail from Unit View:

Dynamic capability curve



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Thank You!

Load Shedding System
HMI Screens

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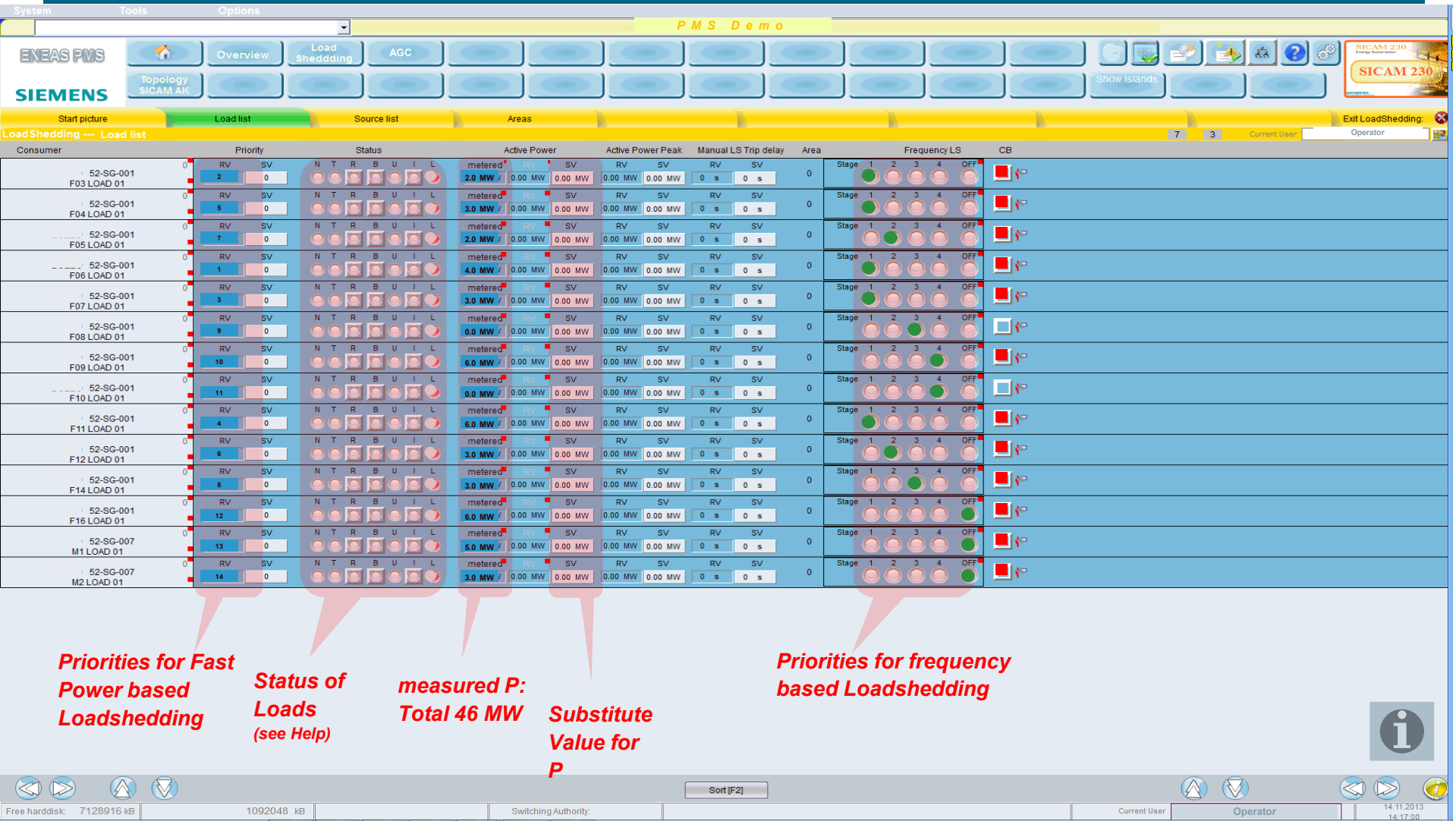
Load List – Priority Setting, etc.



Priorities for Fast Power based Loadshedding

Status of Loads (see Help)

measured P: Total 46 MW

Substitute Value for P

Priorities for frequency based Loadshedding

Load Shedding System
HMI Screens

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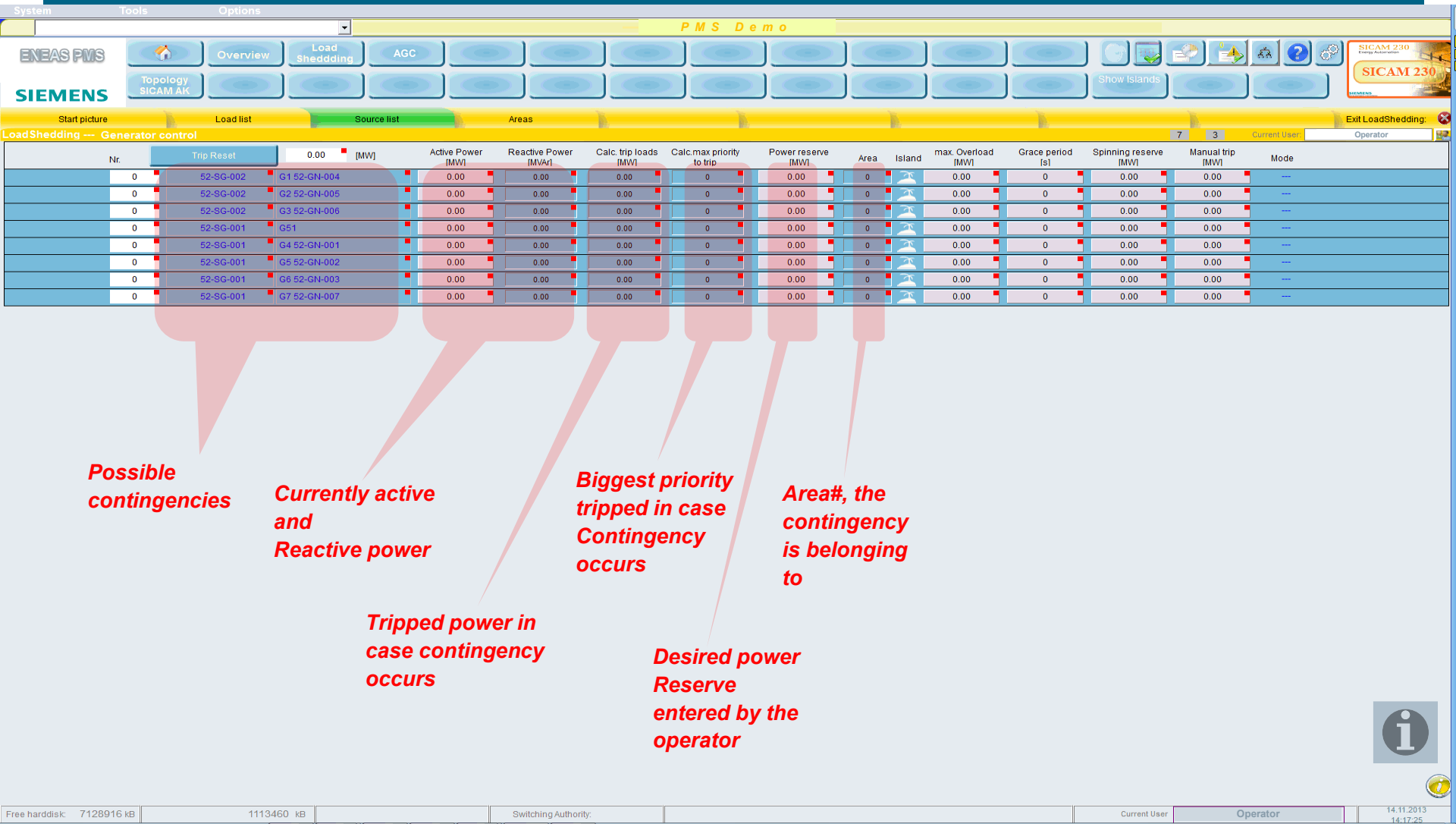
Source List



Possible contingencies

Currently active and Reactive power

Tripped power in case contingency occurs

Biggest priority tripped in case Contingency occurs

Desired power Reserve entered by the operator

Area#, the contingency is belonging to

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https://ewh.ieee.org/r3/nashville

(Address is also in the WebEx Link Email)