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New Sensing Technology To Address Medium Voltage Power Quality Issues

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TRADE SHOW EDUCATION

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- Attend 90% of this presentation
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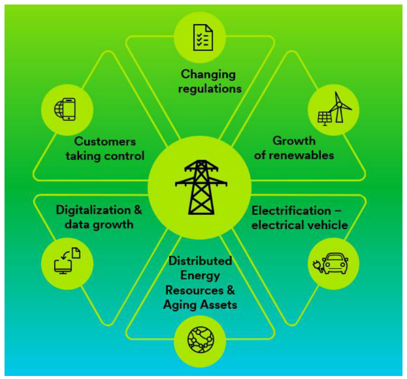
Agenda

- Energy Transition; Industry Challenges and Emerging Applications
- Changes in Grid Connections
- Monitoring & Trends in Sensing Solutions
- Use Cases – State Estimation; Power Quality; Protection & Faulted Segment Location
- Case Study – Network design/upgrade to improve reliability and DER Hosting Capacity

Energy Transition



- Network Reliability **to** maintain Quality of Energy supply
- Resilience network for climate change adaptation
- Optimize Assets life management and preventive maintenance
- Grid Flexibility Power-Flow bidirectional
- Saturations of substations
- Active Management and Monitoring of the distribution grid

Smart, Efficient & Reliable Grid

Industry Challenges

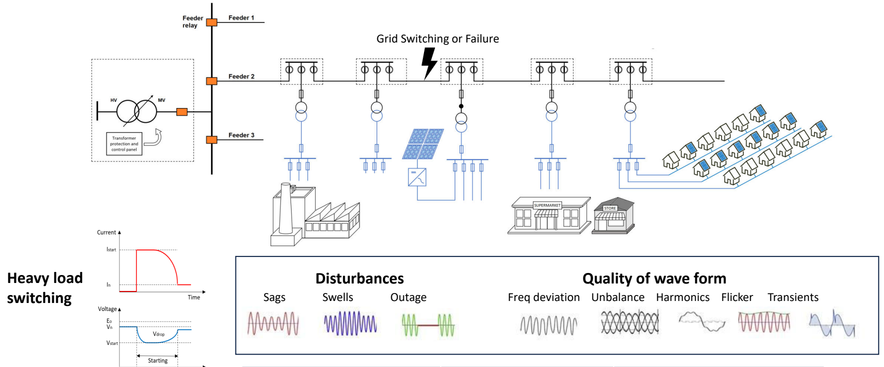
Undergrounding of distribution, renewable penetration, and *need for efficient* infrastructure maintenance have created challenges

- High cost of locating & repairing underground faults
- Reverse power flow issues due to distributed generation
- Inability to determine power quality to commercial and industrial customers
- Safety risks and high cost of hazmat (EHS) inspections
- Inability to assess "true health" of underground grid assets

Emerging Applications

4. Asset Health — Enable **predictive maintenance** and **risk-based asset management** for the electric grids
3. Power Quality, Load Planning & Balancing — Connect to a **variety of platforms**, communications devices, and remote terminal units
2. Fault Detection & Location — Improve **fault location detection and location precision**, enabling timely & accurate response
1. Monitoring — **Reliability and Situational Awareness** of the grid/network

Changing Grid Connections Requiring Broad-based Measurements



PU Power grid	POC Connection point	Customer Installation/Grid
Owned by Power Utility	Utility/Customer	Owned by Customer
Reliable Grid	Safety & Least probabilty of islanding	Maximum uptime and Load below Max levels
Voltage supply within limits	Voltage within limits	Current within Limits
Voltage Quality acc. (EN 50160)	Local Standard or Contract	IEC 61000-3-2 or -12

Monitoring/Co-witnessing Voltage and Current

- Conventionally, the grid monitoring was implemented to detect faults.
- Distributed Generation and high density loads (EV charger clusters) provides different issues:
  - Over Voltage
  - Contributes to increased current and short circuits
  - Alters the power flow direction
- To Manage the Power flow direction and power quality, it is required to monitor Voltage and Current accurately, enabling phasor measurements and zero sequence calculations.
- Such monitoring includes parameters voltage (**V**), current (**I**), load flow direction (**B↓** or **A↑**), power factor (**cos ϕ**), power (**P**, **Q**, **S**), energy (**E**) and frequency (**f**).

Trends In Sensing Solutions

Conventional Voltage Transformers

- Mature technology
- Ferromagnetic core *(can get saturated and lose accuracy at high currents)*
- Bulky, heavy, require calibration and generally periodic maintenance
- Transfer power from primary to secondary
  - Power Source vs Safety

Low Energy Signal Sensors

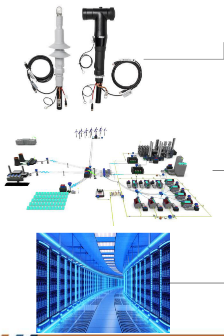
- Evolving technology
- Solid state components with little/no ferromagnetic material → low energy output & high accuracy over broad ranges
- Safer & easier to interface with electronics
- Resistive or Capacitive voltage sensor (Active sensor has to be powered by other means)
- Emerging application for Power Quality, fault localization, fault-isolation and Asset Health

State Estimation – Grid Monitoring and Operations

- **Objective**: Obtain the most probable state of the power system (or of a part of it) based upon measurements and the grid model.
- **Grid State**: Minimum set of variables through which all the other values of interest can be calculated. Typically, V and θ at each node.

Technical	Operations	Business
Provide grid observability	Improves operations	Better decision making
Manage errors in the measurements	Optimizes crew dispatch	Better performance indexes (SAIDI / CAIDI)
Improve data accuracy	Better expansion planning	Improves overall efficiency
Facilitate contingency analysis	Improves efficiency	CAPEX investments deferral
Equipment malfunction identificaiton	Optimizes power flow	

State Estimation – Relies on Measurements Widespread in the Distribution Grid



Measurements

Non-linearity

Grid parameters + Data

State Estimation

Estimated States of the grid

State Estimation: key function to obtain the real-time operation model of the grid, because from the state estimated, the real and current operational conditions will be achieved.

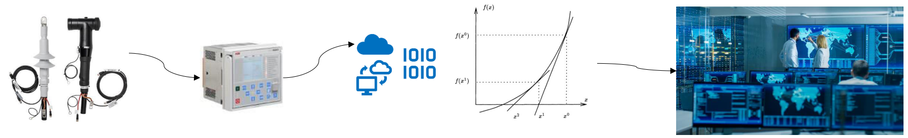
Power system state estimation is critical for on-line security analysis for an electric power network.

State Estimation – Grid Monitoring and Operations

- As the SE algorithm is based on numerical methods, the quality of the measurements influence the SE convergence, a precise input will facilitate the convergence of the system.
- Real-time measurements are much more accurate than pseudo-measurements used to make the system observable and are assigned high weights (i.e. low error variances).

Accuracy of V & I measurements

Facilitate numerical methods convergence



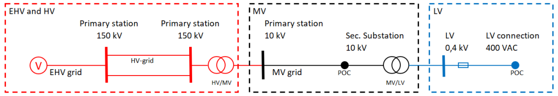
PQ, Load and Standards

The quality of grid Voltage is determined by the deviation versus the ideal sinusoidal wave, amplitude, 3-phase symmetry and frequency.

The deviation from the ideal Voltage is caused by:

- Changes in load
- Failure caused by equipment
- Short circuits

Therefor Power Quality requirements are measured at Point of Connection.



Requirements for Power quality are in International and harmonized standards like IEC 50160 (EU).

Producers, Grid operator (PQ monitoring system), Consumers and the Governmental regulator.

Power Quality aspects described in local electricity contracts.

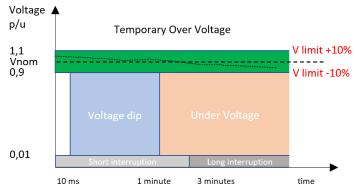
Fast Voltage Variations

Voltage variations are quantified by:

- depth of the Voltage dip ΔU. In % or per unit.
- residual Voltage in % or per unit.

Short Voltage drops (< 1 min, < 10%) are dips and flicker.

- In practical life Dips are in the range of seconds
- Flicker is a repeating Voltage variation that causes light to flicker. Especially light bulbs and halogen lighting suffer from Flicker. Flicker is caused by repeated starting of electric motors



Harmonics

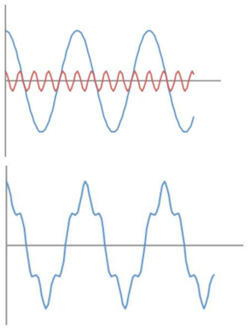
Harmonic distortion is caused by Non-linear loads.
Noticeable in the customers grid as well as Power grid
Harmonic distortion of the 5th harmonic at 20% of the Voltage
Largest source of Harmonic Distortion is Power electronics

- Like rectifiers (computers) or electrical motors (freq. controlled)
- Inverters of PV systems
- Switch-mode circuits in EV chargers

Harmonics currents and Voltages lead to:

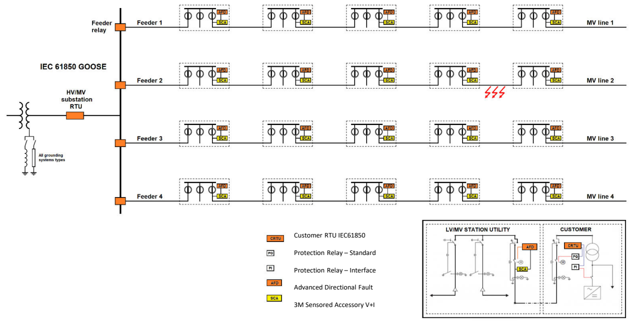
- Overload in Neutral conductors, transformers and capacitors
- Overheating in asynchronous electric motor, unexpected shutdown of protection

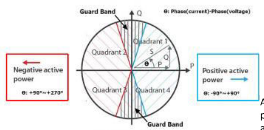
Passive filters for specific frequencies OR active filters can be used for filtering



Protection and Fault Segment Location

- Accurate Real-time measurement Voltage, Current, Phase angle provide power flow direction.
- Self healing and Outage managemen
- Fault detection, isolation and reconfig
- Zero-sequence phasor data from MV Cable Accessories and RTU
  - from each node, prevent false trippi of an external fault & automatically sectionalize the affected section.





A "guard band" can be defined by customers to prevent unnecessary power flow direction alarms caused by phase "oscillations".

Case Study – ENEL (Italy) DG Hosting Capacity Using High Accuracy Sensing

Existing distribution network :

- MV distribution system are **passive**, having **unidirectional** power flow
- In practice, MV networks are operated in **"open-ring"**

Changing dynamics :

- Increased distributed generation are making system **active**

Customer objective :

- **New protection relay scheme** for meshed (loop) operation and ,
- Isolation of '**only faulty segment'**

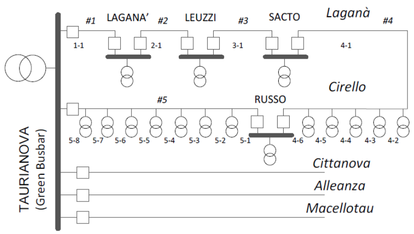


Fig: Structure of selected loop-line.

Source: Ground fault protection in ENEL Distribuzione's experimental MV Loop Line by *A. Capasso *, R. Calone †, R. Lama †, S. Lauria *, A. Santopaolo * *'Sapienza' University of Rome, Italy (stefano.lauria@uniroma1.it), †ENEL Distribuzione, Italy*

Network upgradation

- Installed **Sensored Accessories (Voltage & Current sensors in Accessory)** at every substation for **current flow direction monitoring**
- Replaced load-break switches with **circuit breakers** for enabling **automatic operation**
- Two advanced RGDM 'fault detectors' (fully fledged **digital directional relays**) with **different orientation** at each substation for **generating trip signal**
- An optic fiber-based communication between adjacent channel for **enabling communication between relays** of same segment

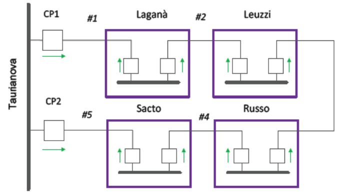


Figure: Upgraded MV looped network with circuit breakers, Sensored termination. Violet square shows automated MV substation, green arrow represents tripping direction of directional relay

- **MV line can be individually switched and protected**
- **Tripping only happens when both terminal agrees in determining an in-line fault**

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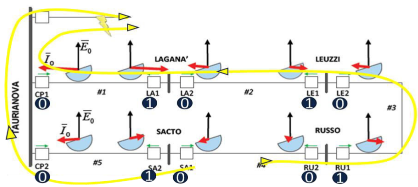
Faulted Segment Isolation

- Case 1 : External Fault

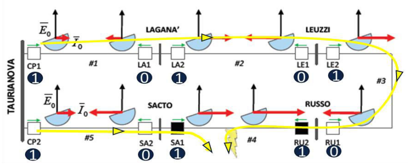


- Loop network stayed operational.

- Case 2 : Internal Fault

⓿ No-trip signal
❶ Trip signal

Case 2 : Internal Fault



- Only faulted segment between SA3 and RU2(#4) gets isolated. Remaining circuit is operational.

- No false tripping occurred in case of external or internal fault. Only faulted segment is effectively isolated.

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Outcomes

- ✓ **Reduced power losses** and operation security
- ✓ Increased **distributed generation hosting capacity**.
- ✓ **Selection of faulted branches** with minimal impact on consumer , i.e. continuity of supply;
- ✓ increase in short-circuit power :reduction of voltage drop and **improved voltage profile**

Distribution Grid Sensing: Traditional vs. Emerging Methods

Features	Traditional Methods (eg. VT/CT)	Emerging Methods (LEA Sensors)
Signal output (RMS)	Typical: 110-240V; 1-5A	Typical: 2V-10V; 10-225mV
Secondary cables	External; Additional installation	Included
Accuracy & dynamic range	Saturation due to Reactance ($2\pi f l$)	VS has no windings => No saturation CS => Rogowski => high accuracy
Linearity	Limited range due to Reactance ($2\pi f l$)	Yes (harmonic accuracy)
Ferro-resonance	Yes (VT)	No
Temperature coefficient	No	Yes (included in accuracy)
Short-circuited secondary	Generally, no inherent current limiting mechanism (VT)	Limited current due to low energy outputs
Footprint & Weight	Typically: 40-60 Kg (PT+CT)	Typically: 1-20 Kg (combined V & I)
Environmental	Large form factor utilizing large raw materials	Small form factor utilizing significantly less raw materials
Knowledge base	Mature and widely adopted	Evolving over last decade
Standardization	Many variations	IEC 61869 family of Standards

Things To Consider For Distributed Sensing

- Safety
- Parameters for range of applications/use cases
- Future use cases
- Accuracy
- Integration to SCADA
- Installation and Maintenance Effort

Thank You!

Discussion

Complete the Online Evaluation