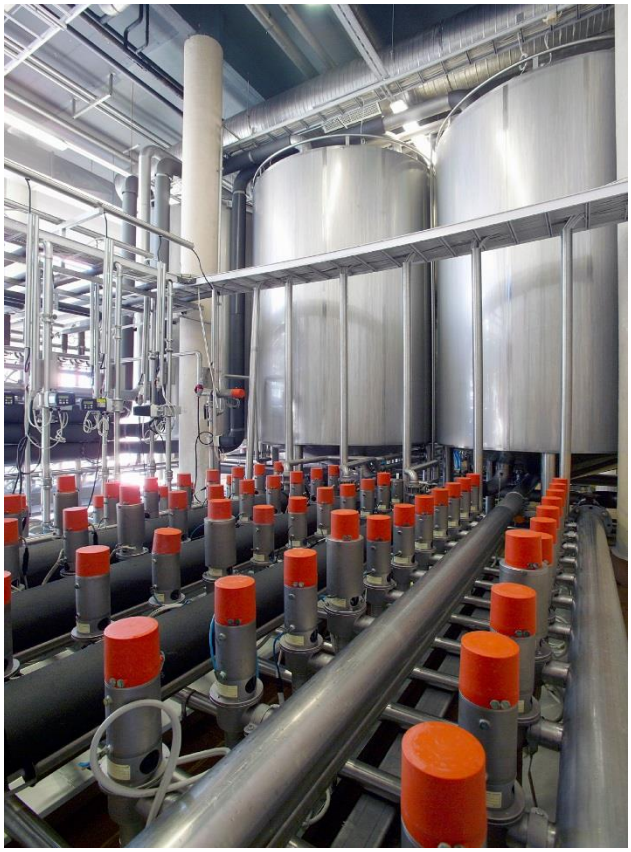
ELECTRIFICATION SOLUTIONS GUIDE

Enabling Food and Beverages Industry to deliver and thrive



ABB's power distribution products and solutions ensure a safer, more reliable and smarter F&B process

Electrification Products | Distribution Solutions | Digital Team

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Table of content

Table of figures

I. Introduction

The food and beverages (F&B) manufacturing and associated ancillary industry is easily the largest one on the planet (1.2 million of F&B production plants worldwide). This industry directly or indirectly impacts the everyday lives of a majority of human beings and some domesticated pets in both urban and rural areas of the world.

Globalization and cultural mix of people has only added to the degree of difficulty and expectations faced by the industry. Such a 'global' consumer base means a multitude of challenges, which are classified as below:

Market related

- Increasingly shorter product cycles with great variation due to ever changing consumer tastes
- Maintaining nutritional benefits, hygiene and traceability
- Increasingly stringent food safety regulations towards food quality
- Rising health consciousness
- Adaptation to local cultural sensitivities
- High cost-consciousness amongst consumers

Business related

- Intense competition and minimal margins
- Pursuit of new markets, innovating and developing market-specific products, deeper market penetration, faster time-to-market etc.
- Business consolidation and M&As for wider market reach

Process related

- Relentless quality execution
- Ensuring safety of personnel
- Ensuring optimal supply and delivery chain in an era of global climate change
- Improving efficiencies in production process chain

Sustainability related

- Managing food wastage
- Reduction of carbon foot print and emissions => energy and system level efficiencies
- And so on…

And this translates into an enormous responsibility on the part of the F&B industry and to deliver to these extraordinary expectations.

It is also quite obvious that contemporary deployed methodologies and technologies in the activities from the ‘farm to the factory to the field’ may be inadequate to tackle some of the above challenges by both global players and also mid-range/regional or local market players. Therefore, a renewed approach in terms of technologies involving man and machinery may be the order of the day for the F&B players to survive, sustain and prosper in the immediate future.

It is essential that the deployed technologies are safe, reliable, eco-efficient, smart and futuristic.

These are indeed the hallmarks of ABB's electrification solutions that are widely deployed for power distribution in utility, industry and infrastructure installations across the globe.

This guide describes some electrification solutions that could significantly contribute towards alleviating some of the above mentioned challenges, faced by the F&B sector and ensure a more reliable, safer and smarter process.

II. Industry trends and customer needs

The seven outstanding trends that are driving the F&B industry necessitated by the challenges, mentioned earlier. [1]

1. Reduced labor and human interface for high safety
2. Increased prevalence of 'smart-enabled' and self-learning equipment
3. More demand for skilled technical experts
4. Shift towards energy-efficient solutions
5. Cost pressure driven by emerging market countries
6. Reduction of total cost of ownership (TCO)
7. Overall Equipment Effectiveness (OEE) improvements

Energy efficiency is an important aspect for the industry. It is one of the major cost drivers in the factory/production process and therefore the focus of this guide is on electrification solutions.

Some of customer needs across different F&B industries such as soft-drinks, dairy, beer and ingredients have been categorized under different focus areas: [1]

1. **End product and consumer market related**
    a. High quality, healthy products
    b. Finished products that can 'live' their shelf lives even in harsh climates
    c. Food safety
    d. Products that allow for microbial management i.e. mould and yeast prevention
    e. Proximity in emerging market locations – local presence
    f. Competitive price – minimal cost and maximum value proposition
2. **Environment and electrical power related**
    a. Energy efficient solutions that reduce energy and water consumption
    b. Minimal input waste
    c. Consistency in energy quality
3. **Equipment (products/solutions/technology) related**
    a. Increasing need for predictive maintenance
    b. Increase need of automation
    c. Machinery that comply with regulatory requirements and hygiene standards
    d. Electrification products that consistently maintain process conditions and do not compromise product quality
    e. Solutions that reduce product reprocessing and mitigate contamination risks
    f. Innovative approaches to manage short product lifecycles; active collaboration with solution provider
    g. Solutions that can be harmonized with existing systems

4. **Investment related**
    a. Best solution from a TCO (total cost of ownership) perspective
    b. Short pay-back of investments
    c. Corporate volume pricing on individual purchases
5. **Operation/process related**
    a. Ensure plant safety and reliability
    b. Need to reduce electricity consumption
    c. People safety
    d. Production sustainability
    e. Service continuity
    f. Correct pressurisation for the bottling process
    g. Easy-to-use machinery for manual process
    h. Fine-tuned technical equipment for automated process
6. **Supplier related**
    a. To do business easily with the suppliers.
    b. Get a reliable partner for specific needs
    c. Supplier as solution partner - bundled engineering solutions
    d. Agility and localized service to facilitate easy access to replacement/spare parts in shortest time.
    e. Linked supply chain, from supplier to customer
    f. Good onsite technical assistance (supplier embedded engineer) and access to experts to solve problems quickly

Electrification products and solution providers directly or indirectly influence the F&B factory value chain process needs in a significant manner.

III. Key Performance Indicators (KPI)

The F&B industry needs from the previous section are broadly mapped into KPIs in this section. Three KPIs and their associated requirements are discussed here: [1]

1. Safety
    a. Food safety during production, storage and shipment ensures that the final products are safe for consumption.
    b. People safety is ensured when the machines, processes and factories are safe for operation by employees.
2. Cost
    a. Optimizing TCO (Total Cost of Ownership) of an asset including its direct costs and also indirect costs required to operate/use the asset.
    b. Increased Asset Utilization
        i. By managing the network in a smart way, reduce outages, reduce the need of backup resources and physical redundancy.
        ii. Adopt predictive maintenance that optimizes network management and guides customers to take good care of their equipment.
    c. Continuous operation
        i. The operation of a production facility around the clock, every day of the week, or during seasonal production cycles.
3. Quality
    a. Manufactured product quality
        i. Every product, every batch, every day is produced to the same quality.
    b. Power quality
        i. Power quality solutions ensure that a factory's power supply is clean and reliable, preventing unplanned downtime and lost production.
    c. Ambient insensitivity
        i. Technologies inspected for suitability in any type of ambient condition (pollution, explosive, high altitude, high humidity….)
    d. Trusted partner
        i. Quality in long term partnership, solution oriented, on-site support

A generic flow diagram of the F&B process is represented below. While some of the bigger plants may have all of the sub-processes in a single location, many others may have these sub-processes in a split manner reflecting their roles in the supply chain.

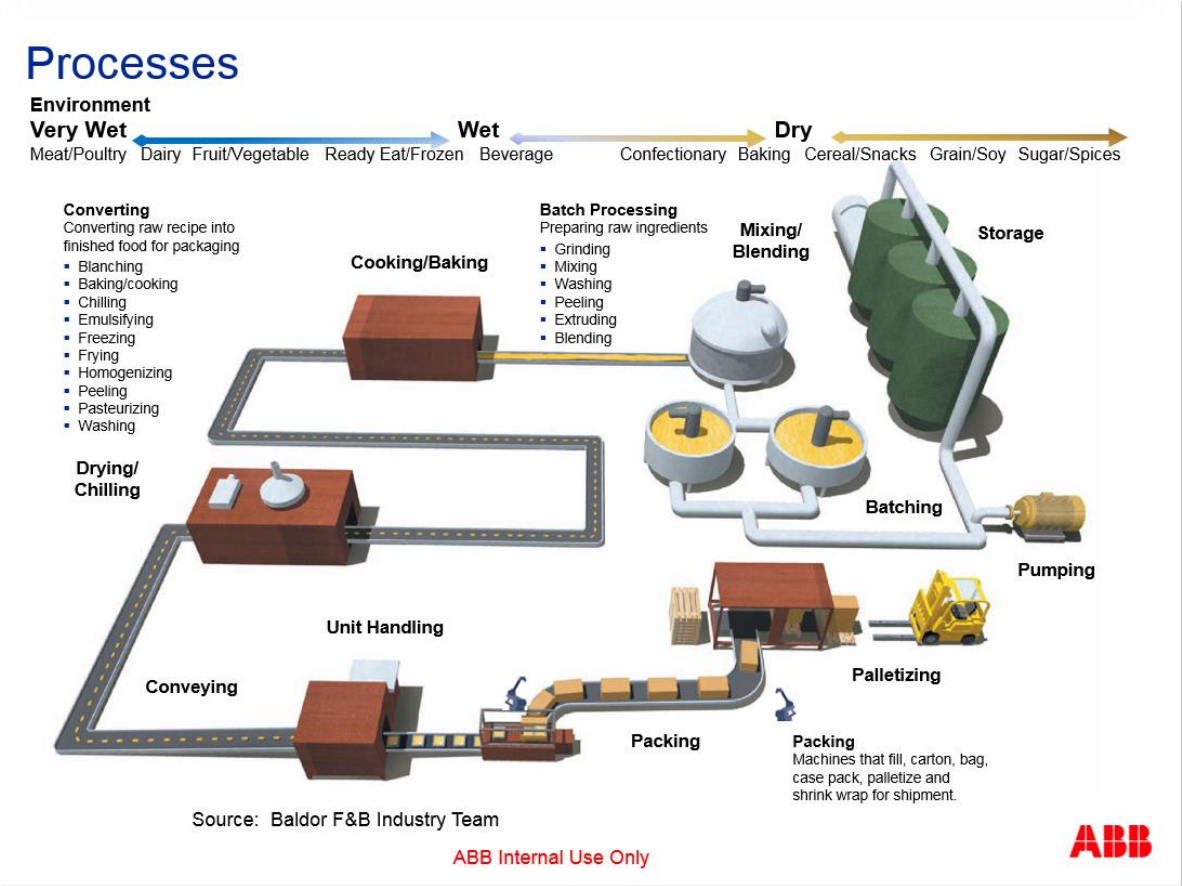


Figure 1: F&B plant overview and process flow

Many of the represented sub-processes themselves are likely to have dedicated power distribution equipment and systems. It is anticipated that ABB's contemporary and upcoming product and solutions in the power distribution realm would help make a substantial difference to the operational aspects of the F&B industry production chain.

IV. Use case for F&B plant electrical systems

This section covers the solutions to address the process requirements [1] related to the identified KPIs in the previous section. Let us consider a generic example of electrification single line diagram (SLD) in an F&B plant. The diagrams are represented in two separate figures, SLD -1 to depict a mainstream process plant and SLD -2 to represent a supplementary process plant with remote outstation units such as a water/effluent treatment plant.

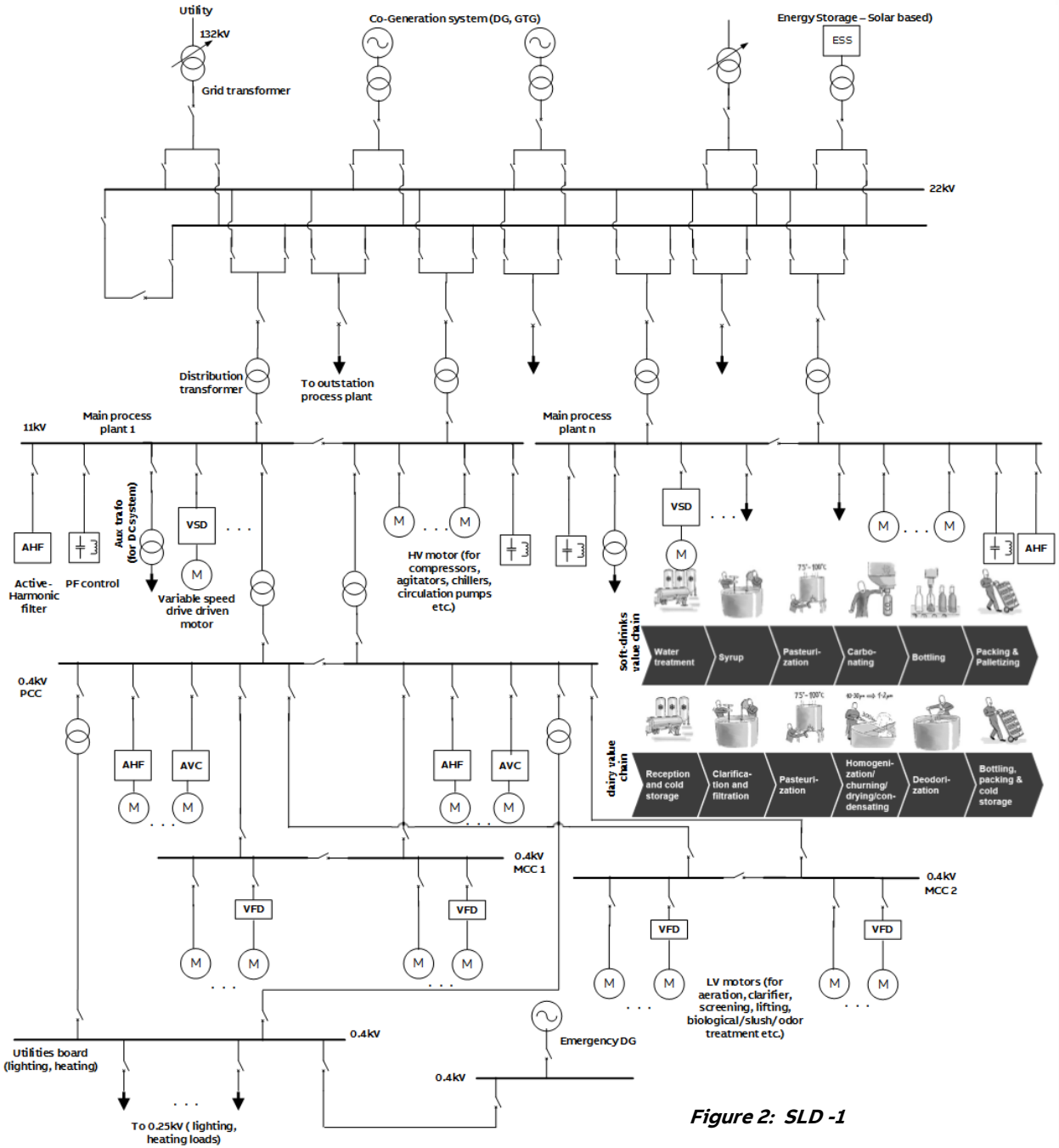


Figure 2: SLD -1

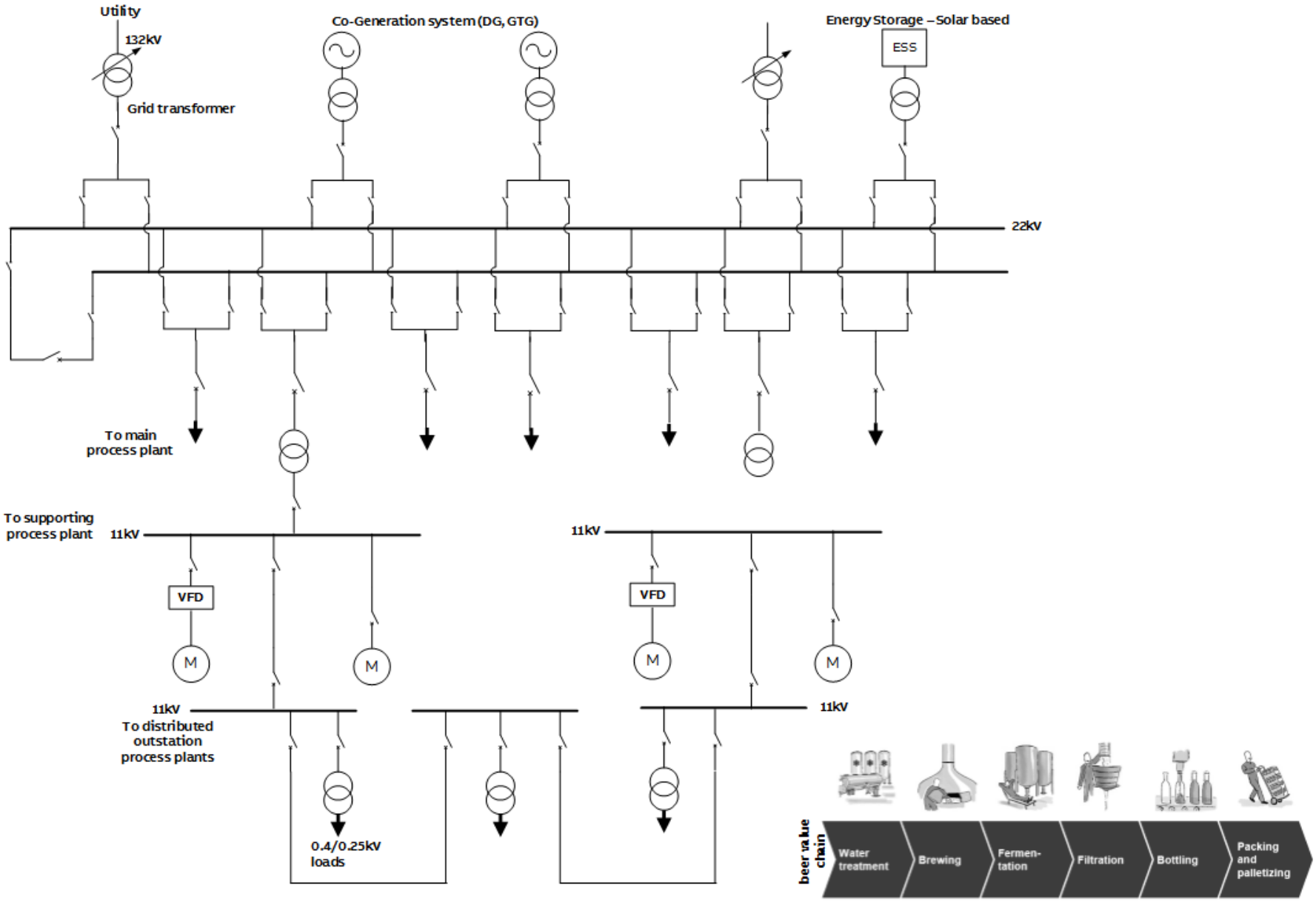


Figure 3: SLD - 2

The following elements can be ascertained from the above representation:

1. Power utility connections through one or more grid transformers (say 132/22kV), with associated equipment in an outdoor switchyard.
2. Co-generation or in plant power generation based on steam or gas or diesel. In the contemporary times, power contribution renewables such as solar plants also are considered. This is represented by an Energy Storage System (ESS), based on storage batteries.
3. Double bus-bar based system for better availability at 22kV. Other bus bar schemes are applicable, depending on overall system reliability requirements at the main power evacuation voltage level in the industrial plant.
4. The power is evacuated from 22kV and distributed to different process plants through distribution transformers. The receiving process plant voltage level(s) could be at 11kV (and 6.6 or 3.3kV) and 0.4kV/0.25kV (low voltage).
    a. Bulk and heavy duty loads are driven by HV motors at 11kV (or 6.6 or 3.3kV) voltage level. These motors cater to loads such as compressors, agitators, mixers, chillers, grinders, conveyers, circulation pumps etc., and requiring very high running efficiencies.
    b. LV motors to cater to similar applications as MV motors in mainstream plants but also in water/effluent treatment plants such as for slush/odor/biological treatments, aeration, clarifier, lifting and screening applications.
    c. Distribution transformers to transform voltage to 0.4kV level in the same process plant to cater to LV motor loads, lighting loads and thereafter to derive single phase voltages at 240V.
    d. Variable speed drives (VSD) and associated HV motors
    e. Power factor controllers (PFC) for reactive power (VAr) compensation and power factor control
    f. Active Harmonic Filters (AHF) to compensate for the harmonic current or voltage drawn by loads such as VSDs and other non-linear loads.

Note: *Voltage levels mentioned are purely to explain the use case. The voltage levels corresponding to high, medium and low voltage levels could vary from region to region and country to country. Also there could be more voltage levels in a plant than mentioned in this example.*

The process plants are depicted according to the various F&B industry value chains such as dairy, soft-drinks and beer. These process plants are often arranged 'in series' according to the chain from handling of production inputs (in the form of discrete ingredients or raw animal products like milk etc.) to finished end products.

The common processes include:

- 1st stage: Water treatment or cold storage
- 2nd stage: Syrup mixing or filtration or brewing or sieving
- 3rd stage: Pasteurization or Fermentation
- 4th stage: Carbonating or churning-drying-condensation or filtration
- 5th stage: Bottling or deodorization
- 6th stage: Packing-palletizing or packing-cold storage

Some of the requirements associated with the above are elucidated below:

Water treatment requires:

- Recovery of maximum amount of water from ingredient water systems
- Recovery of valuable by products such as sugar, protein and starch
- Clean waste water for discharge or reuse to minimize environmental impact
- Requires constant attention necessitating remote monitoring and diagnostics

Cold storage requires [2]:

- Requires maintaining different temperature levels to suit different ingredients (say, -28˚C for vegetables, fruit etc., up to +2 ˚C to -7 ˚C for salads, cut vegetables/fruits, meals etc. , 18 ˚C for dry foods)
- Optimized energy costs irrespective of type of regional climate conditions, power availability, connectivity conditions etc.
- Optimal utilization of storage volume in refrigerated areas.
- Automated solutions to minimize manual labor operations

Sugar syrup preparation requires [3]:

- Heating sugar to liquid form (dissolution) -> agitation process
- High amount of energy to heating water to aid syrup formation and subsequent cooling process
- Preventing crystallization
- Preventing sedimentation or even blocking of vessel outlets
- Further mixing for flavoring, acidity regulation, preservatives, stabilizers, anti-oxidants, coloring etc.

Pasteurization process requires [4]:

- Essentially heat treatment based on different temperature levels and times for different types of food ingredients.
- Bulk liquid: Milk => 63 ˚C for 30 min.
- Short time: Milk (safety) => 72 ˚C for 15 sec.
- Blanching: Vegetables (softening) => 75 ˚C for 5 min
- In-bottle (beer shelf-life extension) => 60 ˚C for 10 min

Packing process requires [5]:

- Robotized for bulk and massive product throughputs
- Seamless and clean transition with minimal human contact from process and picking to primary packaging
- Primary packed product to secondary packaging in cases, trays, crates or shelf-ready packaging

From the electrification perspective, all the above processes require the following, in order to address the identified KPIs/associated requirements [1]:

1. **Safety**
   - High degree of automated processes with minimal human intervention, requiring high safety standards
2. **Cost**

- High process equipment availability
- High-intensive investment (CAPEX) on process and advanced/sophisticated factory automation equipment
- Additional or parallel or redundant equipment operation (e.g. grid transformers, generators, motors etc.) to ensure more availability and to mitigate effects due to planned or unscheduled outages.
- Heavy duty rotating equipment
- Zero or minimal process outage; 24 x 7 operation and system availability

3. **Quality**
    - Reliable, uninterrupted, high quality power
    - Close loop control system for temperature, pressure monitoring and control
    - Great focus on process data monitoring, collection and analytics to help in bettering overall efficiency and production throughputs.

The above process and electrification requirements further translate into to the following requirements on the plant power system and its components, used for evacuation and distribution of power to the various process areas of the plant:

1. Transformers
    a. Grid transformer: 22kV side voltage control
    b. Monitoring of all transformers (winding, oil temperatures etc.)
2. Co-generation: power control, load-sharing, peak shaving etc., when working in parallel or isolation with utility power supply.
3. While the 22kV switchgear can be based on gas insulation (GIS), 11kV switchgear in process plants can be based on air insulation (AIS).
    a. Both AIS and GIS are installed in a substation building. A GIS's physical footprint is about 35% less than an AIS.
    b. The remote 11kV SWG in remote substations can be AIS for indoor installations, while it can be based on GIS for Ring Main Units (RMUs) for outdoor deployment.
4. The 0.4kV switchgear can be based on AIS at PCC, MCC and emergency/utility distribution boards.
5. Using VSDs, the following advantages are achieved:
    a. Accurate ingredient dosage
    b. Enhanced product quality
    c. Minimized energy consumption
    d. Reduced wear and tear of machinery
    e. Lower maintenance costs
    f. Maximized process uptime
6. Power factor controllers in order to minimize penalty payments to the Utility and also to improve in-plant power system voltage/frequency profile.
7. Harmonic filters, inverter bridges, energy storage or active rectifiers etc. to negate the power quality effects of VSDs.
8. High degree of power automation as well as data collection and analytics, in correlation to process data.
9. Customer oriented and flexible service offerings for maintenance and upkeep of equipment and system

V. Operational considerations

Before we focus on the possible electrification related solutions, some aspects related to power system equipment and monitoring in F&B industry are considered, which point to some important aspects of plant operation. These are compiled from real-life experiences of experts in the field. [6]

Equipment aging

A plant's electrical system is often 'forgotten' until something goes wrong and reaches a catastrophic consequence. Some of the behaviors are:

- 'Taken for granted' attitude until time to upgrade or replacement.
- 'Out of sight, out of mind'
- Not accessible by people; rooms relatively clean, 'so what can go wrong'?
- Many plant decision makers keep deferring upgrades even after 25-30 years.

This attitude results in:

- Due to age of equipment, reliability problems occur
- Issues in finding replacement parts
- Most equipment face obsolescence issues after 10-15-20 years;
    - primary equipment ~ 20 years
    - secondary equipment ~ 10-15 years
- Huge compromises on personnel safety
- High cost of overhauls and system installations, coupled with forced outages
- Non-compliance to facility location's and municipal electrical codes
    - Generally, total compliance is mandatory in contemporary times, failing which licenses to operate could be annulled.
    - Therefore, system modification is expected to meet new codes.
- Process side expansions push the electrical system operations near boundaries.

This can be avoided or mitigated by:

- Sensible maintenance and planning for growth and expansion
- Concurrent upgrade of electrical systems together with process equipment/systems
- Conducting energy audits by analyzing power bills => load factor consideration for power consumption, spare capacity provisions when new processes are being added.
- New smart and networked equipment can let one know when and where a problem lies with the plant's electrical system.
- Careful and planned existing system augmentations, instead of full-fledged replacements (case-by-case basis)
- Upgrade of older equipment to meet new code requirements.

- Improve data gathering/reporting
- Reduction of risks such as arc flash hazard levels.
- Deployment of a preventive maintenance program assures well maintained equipment.

Extending equipment life through maintenance

- Regular maintenance essential for upkeep and longevity of any system
- Established processes for maintenance
- Ensuring that staff is fully trained and experienced with equipment
- Updated documentation in digitized format with easy access and modification/distribution processes clearly defined.
- Ensuring that electrical equipment is located in segregated areas to process and not proximal (to avoid problems of failure due to dust accumulation or due to wet areas etc.)
    - For example: location of a switchgear in a room with ventilation near product silos.
        - Failures of circuit breakers could result in process outages.
    - Dust explosion is also a possibility that can compromise destruction of plant and people's safety/well-being.

Avoiding maintenance mistakes

- Personnel safety has utmost focus and is quite sacrosanct. And therefore a huge focus is also laid out in the area of power distribution, where industrial workers operate switchboards, handle power equipment etc. One of the most dangerous and lethal electrical incident that is the arc flash (also called flashover or arc fault), which is an electrical explosion that results from a low-impedance connection through air to ground or another voltage phase in an electrical system. In most cases, exposure is deeply injurious and fatal too.
- Poor maintenance increases likelihood of unplanned downtime and risk of catastrophic failure due to arc flash.
    - Sometime protection relays may not work.
    - Circuit breakers can get stuck
    - Resulting short circuit can result in infrastructure damage and extended downtime.
    - Lack of discipline in following processes and procedures when working on or near switching circuits inside hazard areas can create extreme danger for personnel and equipment.
    - Bypassing interlocks or inadequate overcurrent protection
    - Inadequate component sizing when more process capacity is added; example transformer or circuit breaker capacity getting exceeded.

Update or upgrade wisely to create safer and efficient systems

- Intelligent devices integrated into control and application systems can add levels of protection from electrical incidences such as arc flash.
- Simple reconfiguration of the system design can lower the amount of arc energy at given points within a power distribution system.
- Requirements and technology needs of every plant site to be closely reviewed to fit within the site's existing protection and control strategy.
- Newer devices and systems are programmable, have networking capabilities and facilitate continuous online monitoring.

- Users can be notified of any changes of steady state or imminent failure detection, permitting more logical and controlled process shutdowns
- Segregation of loads into different lighting, process, HVAC, refrigeration, etc. => enables operators and management personnel to review different building loads at any time and determine the largest energy users.
- Upgrading electromechanical relays to contemporary numerical protection relays, fuse based protection to circuit breakers, older circuit breakers with 'intelligent' circuit breakers.
- Zone-select interlocking, circuit breaker coordination and maintain high levels of system reliability.

Intelligent maintenance

- Smart systems facilitate a shift from preventive to predictive maintenance
    - Maintenance cycles can be based on actual circuit conditions instead of specific time intervals.
- Contemporary systems facilitate monitoring and operation away from live equipment and local HMI to reduce search and repair time when circuit breaker is tripped on a fault.
- Embedded intelligence in circuit breakers allow operators to know exact topical situation and facilitates predictive maintenance.
- Pre-alarming provides insight on the health of the contact wear, electrical circuits etc. and energy consumption can be measured through the circuit breaker for precise usage and optimization.
- Protection devices, operating in a well-coordinated manner for a safe power system operation.

Process visualization

- It needs to be ensured that the information from the system components such as protection relays, centralized protection device etc. are presented in an easy-to-understand, unambiguous manner to the system operator in the substation or process control room.
- This is to ensure that the right and precise process control actions are initiated by the system operator and thereby ensure **operational safety** at all times.
- Also the substation information needs to be made available to the corporate network systems from where analysts and decision makers can interpret and take adequate steps for process improvements and/or corrective actions.

Monitor energy smartly

- Internet allows a client in a remote location to actively view the load readings on a plant site practically anywhere, such as corporate headquarters, engineering office etc.
- Plant maintenance team can monitor the electrical performance or consumption over time
- Users can review their overall process requirements. They can use energy and process management tools in combination with the energy feedback data from intelligent networked control and protection devices.
- Correlating energy use versus process efficiencies can highlight areas within the process flow where optimization may reduce process idle or bottlenecked points.
- Facilitates analysis and control of a facility's real-time energy usage in the plant site through a web browser or a mobile device.

- Displays real-time power and demand data from intelligent devices and facility-wide infrastructure systems
- Executes energy management strategies by automating load-shedding schemes; captures disturbances on the electrical network (harmonic distortion and transients)
    - Determines where power is consumed and generates reports.

Protection systems

- Contemporary substation protection and control philosophies are implemented through dedicated protection relays for every feeder in distribution substations, such as in F&B industry.
- This is irrespective of the criticality of the process load that the feeder supplies power to. Back-up protection is available only in the incomer feeder that has to cover for any failure of an outgoing feeder relay unit.
- When back-up protection operates to clear a downstream fault, the entire substation loses power feed. Therefore, the level of discrimination of feeder protection is quite low mainly due to lack of functional and/or physical redundancies at bay level.

Straighten the sags and kill the spikes (Power Quality, PQ)

This is caused due to the non-linearity of customer loads and concerns all stakeholders in the power supply to consumption chain. While it is the responsibility of the power utility to deliver reliable power it cannot certainly guarantee PQ. It is the power consumer who is responsible for protecting sensitive equipment at own expenses. Harmonics, voltage sags and swells distort the waveform shape of voltage and current and increase the current levels, resulting in large disturbances. Despite this, these PQ events are largely untracked, leading to high indirect costs. One example of PQ events impacting downtime and revenues is that of the milk industry. A PQ event impacts the milk sterilization process. On occurrence of a PQ event, the process needs to be reinitiated, causing disruption across several production lines, causing at least a day of production time and consequent losses.

Some of the relevant consequences to the F&B sector are:

- Outages of power equipment such as motors; causing process outage and production losses
- Bigger the drives/motors, slower are replacement possibilities and larger the consequent financial losses.
- Loss of work, additional labor, missed shipment dates etc.
- Even computing equipment, PLCs are susceptible (improper shutdowns leading to data corruption, incorrect interpretation of logical 1 and 0 levels leading to false control actions etc.)
- Dependency on a consistent supply of quality, reliable energy has never been higher.
- Most new equipment designs are more fault tolerant in regard to power quality. Sometimes, additional support equipment, such as industrial uninterruptible power supplies (UPSs) may be required that can be retrofitted to existing control products.
- When a system-wide approach is necessary, a voltage sag protection system may need to be employed to protect against voltage sags.

Dealing with multiple power sources

- Some plants may have more than one public utility feed and may also have multiple power sources onsite.
- In such a situation, it necessitates several additional functionality such as synchronization of the plant system to the grid, synchronization of the individual generators and the bus tie circuit breaker.
- It may also necessitate control of power at the grid coupling point to maintain a certain power flow (or even floating).
- If power export is considered and agreed with the public grid (especially with excess generation from in-plant renewable sources or gas based generators, then the control system needs to be capable to drive the power outputs of the in plant generator systems.
- While the investments in an in-plant generation could be substantial, they are generally quite well balanced with the returns they deliver on production and profitability. However, a single production outage, caused in the power network, can cause substantial operational costs. A complete recovery and return to normalcy could take several hours or days.

Collaboration with solution providers/vendors

- To accomplish all the above objectives, it is quite obvious that the products manufacturer and solution provider has a dedicated team of operational experts to offer both onsite, remote services and consulting.

VI. Constructing the solution

In this section, we derive the necessary solutions for the identified F&B plant power system and its components (Section IV), in order to satisfy the process and electrification requirements. The F&B plant SLD, represented across two figures in Section 4, is considered as the basis for constructing the solutions.

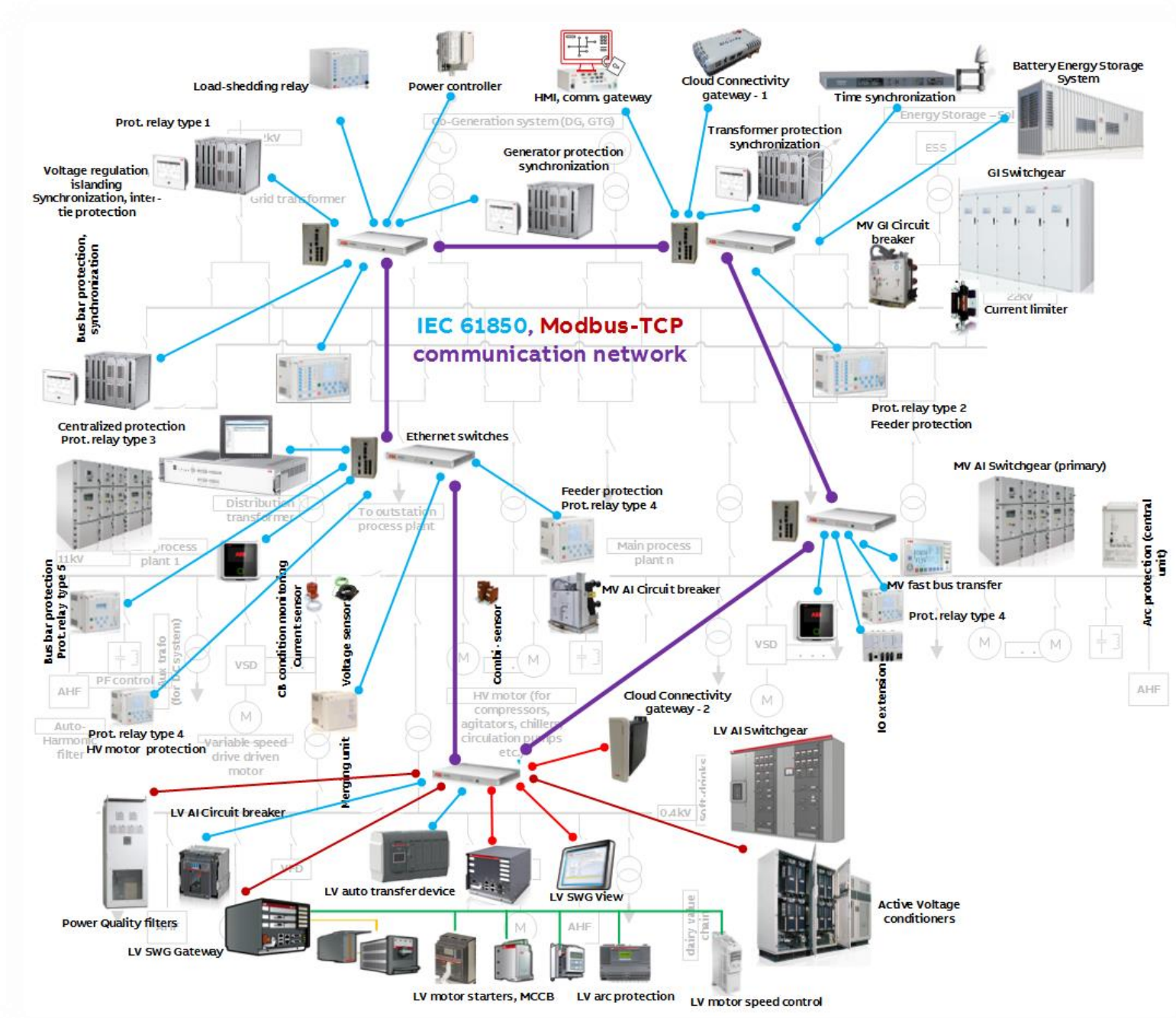


Figure 4: System overview - 1

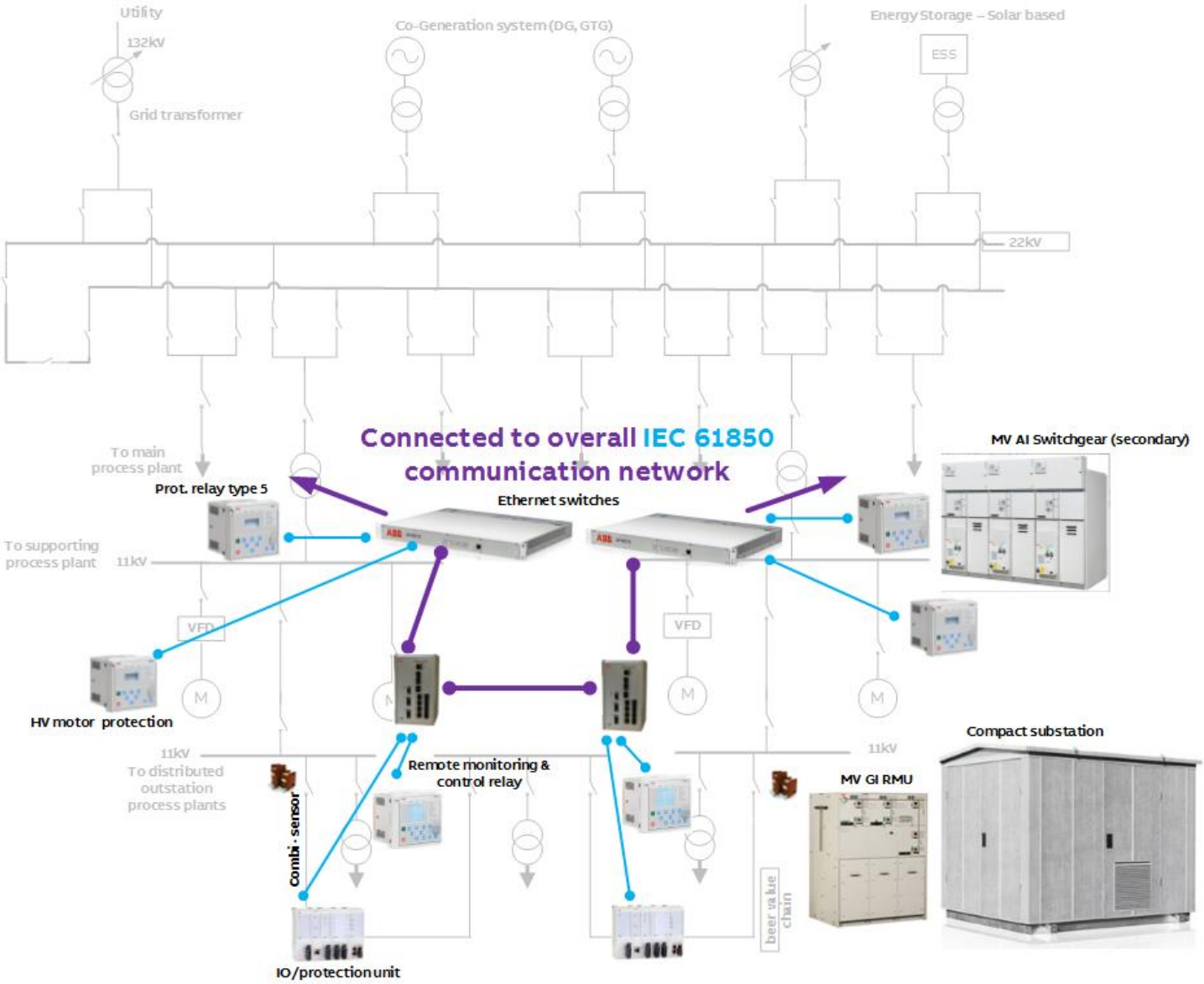


Figure 5: System overview - 2

A list of networked or standalone equipment represented in the system overviews is represented below.

S No.	Equipment		Voltage level	Physically hosted in	Product name
	Classification	Generic name			
1	**Switchgear**				
1.1	Gas Insulated	MV GIS - primary	22kV	Main power evacuation center substation	ZX0.2
1.2	Air Insulated	MV AIS - primary	11kV	Main process plant substation	Unigear ZS1 Digital
1.3	Gas Insulated	MV GIS- secondary/RMU	11kV	Outstation/remote supporting process plant	SafeRing/Safeplus
1.4	Air Insulated	MV AIS- secondary	11kV	Outstation/remote supporting process plant	UniSec/LeanGear
1.5	Air Insulated	LV AIS type 1	0.4kV	Main process plant substation, (MCC#1)	MNS iS
1.6	Air Insulated	LV AIS type 2	0.4kV	Main process plant substation, (PCC, MCC#2, Emergency and Utilities DB)	MNS Digital
1.7	Air Insulated	LV AIS type 3	0.4kV	not suggested in this use case	MNS UP
2	**Substation**				
2.1		Compact secondary substation	11kV, 0.4kV	Outstation/remote supporting process plant	Rigel/Mercury compact secondary substation
3	**Primary equipment**				
3.1	**Sensors**	Sensors (Current, voltage, current + voltage)	22kV, 11kV	MV GIS - primary, MV AIS - primary, MV GIS - secondary/RMU	KECA, KEVA, KEVC
3.2	**Instrument transformers**	Current, voltage	22kV, 11kV	MV GIS - primary, MV AIS - primary, MV AIS - secondary	TJC (voltage), KOKS, BB, BBO, TTR (current)
3.2	**Circuit breakers**				
3.2.1	Gas Insulated	MV circuit breaker type 1	11kV	MV AIS - primary	HD4
3.2.2	Vacuum Insulated	MV circuit breaker type 2	22kV, 11kV	MV GIS - primary, MV AIS - primary, MV AIS - secondary, MV GIS - secondary	VD4
3.2.3	Vacuum Insulated	MV circuit breaker type 3	11kV	MV AIS - primary	VM1
3.2.4	Air Insulated	LV circuit breaker type 1	0.4kV	LV AIS type 1 and type 2	Emax 2 (air insulated) with Ekip unit for integrated protection and communication
3.2.5	Air Insulated	LV circuit breaker type 2	0.4kV	LV AIS type 2	Tmax XT (moulded case) with integrated protection and trip units

S No.	Equipment		Voltage level	Physically hosted in	Product name
	Classification	Generic name			
4	Secondary equipment				
4.1	**Digital substation merging unit**	Merging unit	11kV	MV AIS - primary	Relion SMU615
4.2	**Numerical relays**				
4.2.1		Protection relay type 1	22kV	MV GIS - primary	Relion REX640 *(to be released)*
4.2.2		Protection relay type 2	22kV	MV GIS - primary	Relion 620 series
4.2.3		Protection relay type 3	11kV	MV AIS - primary	SSC600, Smart substation control and protection *(available for pilots, to be released)*
4.2.4		Protection relay type 4, remote monitoring & control relay	11kV	MV GIS - secondary, MV AIS - primary	Relion 615 series
4.2.5		Protection relay type 5	11kV, 0.4kV	MV AIS - secondary, LV AIS type 2 (PCC)	Relion 611 series
4.2.6		IO extension and fault passage indicator	11kV	MV GIS - secondary	RIO600
4.3	**Motor controller**				
4.3.1		LV Motor controller type 1	0.4kV	LV AIS type 1 (MCC#1)	MStart – Mcontrol pair (direct on line) with integrated circuit breaker unit
4.3.2		LV Motor controller type 2	0.4kV	LV AIS type 1 (MCC#1)	MSpeed (with drive ACS 850 for speed control) with integrated circuit breaker unit
4.3.3		LV Motor controller type 3	0.4kV	LV AIS type 1 (MCC#2)	UMC100
4.3.4		LV Motor controller type 4	0.4kV	LV AIS type 1 (MCC#2)	M10x-M
4.3.5		LV Motor controller type 5	0.4kV	LV AIS type 1 (MCC#2)	ACS850 (discrete variable speed drive)
4.4	**Visualization/data handling**				
4.4.1		Plant electrification visualization, supervision and control	22kV, 11kV, 0.4kV	Dedicated panel at Main power evacuation center substation (control room)	COM600/SYS600-MicroSCADA Pro/800xA
4.4.2		LV AIS view	0.4kV	LV AIS type 1, LV AIS type 2	MView
4.4.3		MV communication gateway	22kV, 11kV	Dedicated panel at Main power evacuation center substation	COM600
4.4.4		LV SWG gateway type 1	0.4kV	LV AIS type 1 (MCC#1)	Mlink
4.4.5		LV SWG gateway type 2	0.4kV	LV AIS type 1 (MCC#2)	MNS Digital gateway

S No.	Equipment		Voltage level	Physically hosted in	Product name
	Classification	Generic name			
4.5	**In-plant network communication handling**				
4.5.1	Time synchronization	GPS equipment, receiver	22kV, 11kV, 0.4 kV	Dedicated panel at Main power evacuation center substation (control room)	3rd party (Meinberg, Hirschmann) according to SNTP, IEC 61588 PTP
4.5.2	Ethernet switch	Industrial grade Ethernet switch	22kV, 11kV, 0.4 kV	Switchgear or dedicated panels	AFS660, AFS670
5	**Special applications and equipment**				
5.1	**Condition monitoring**				
5.1.1		MV CB cond. Monitoring	22kV, 11kV	MV GIS - primary, MV AIS - primary, MV AIS - secondary	MySiteCare
5.1.2		LV On-site condition monitoring type 1	0.4 kV	LV AIS type 1 (MCC#1)	MService
5.1.3		LV On-site condition monitoring type 2	0.4 kV	LV AIS type 2 (MCC#2)	ABB Ability Condition Monitoring for electrical systems, MNS Digital Edge gateway *(to be released)*
5.2	**Power Management**				
5.2.1		Load-shedding relay	22kV, 11kV, 0.4 kV	Dedicated panel at Main power evacuation center substation	Relion PML630
5.2.2		Load-shedding controller	22kV, 11kV, 0.4 kV	not suggested in this use case	AC800M
5.2.3		Power controller	22kV	Dedicated panel at Main power evacuation center substation	AC800M
5.2.4		Applications: Islanding, load-shedding, Power Control, Autosynchronization, Voltage control	22kV, 11kV, 0.4 kV	Load-shedding relay/controller, Power Controller, protection relays	Integrated Compact Power Management
5.3	**Arc Protection**				
5.3.1		MV Arc protection type 1	22kV, 11kV	MV GIS - primary, MV AIS - primary, MV AIS - secondary	REA10x + REX640 + Relion 620 series
5.3.2		MV Arc protection type 2	11kV	MV AIS - primary	SSC600 + SMU615
5.3.3		LV Arc protection type 1	0.4 kV	LV AIS type 1, LV AIS type 2	Emax 2 with Ekip 2K
5.3.4		LV Arc protection type 2	0.4 kV	LV AIS type 1, LV AIS type 2	TVOC-2 (Emax 2 with Ekip 2K)
5.3.5		MV/LV Arc protection	11kV, 0.4kV	not suggested in this use case	UFES

S No.	Equipment		Voltage level	Physically hosted in	Product name
	Classification	Generic name			
5.4	**Bus transfer**				
5.4.1		High speed bus transfer (HSBT)	11kV	MV AIS - primary (or even special panel)	SUE3000
5.4.2		Auto transfer (HSBT) type 1	0.4 kV	LV AIS type 1, LV AIS type 2	Emax 2 with ATS feature
5.4.3		Auto transfer (HSBT) type 2	0.4 kV	LV AIS type 2 (Emergency and Utilities DB)	TruOne (mini-ATS)
5.5	**Cloud connectivity**				
5.5.1		Cloud gateway type 1	22kV, 11kV	Dedicated panel at Main power evacuation center substation	Ability Edge gateway *(not released, available for technology pilot projects)*
5.5.2		Cloud gateway type 2	0.4 kV	LV AIS type 2 (PCC)	MNS Digital Edge gateway *(not released, available for technology pilot projects)*
5.6	**Special software/applications**				
5.6.1		Industrial energy management software	22kV, 11kV, 0.4 kV	HMI	ABB Energy Manager (CPMplus Energy Manager)
5.6.2		Product lifecycle management (for protection relays)	22kV, 11kV	Cloud	Clionet Data Care
5.6.3		CB remote analytics suite	22kV, 11kV, 0.4 kV	Cloud	MyRemoteCare, Asset Health Center for MV and LV systems
5.6.4		Cloud based monitoring, optimization and control of electrical system	0.4 kV	Cloud	ABB Ability™ Electrical Distribution Control System
6	**Special equipment**				
6.1		**Short circuit current limiter, SCC limiter**	22kV	MV GIS - primary	Is limiter
6.2		**Battery based Energy Storage Systems, Power Conversion System – (BESS-PCS)**	22kV	Special enclosure at Main power evacuation center substation	ESSPro PCS - Containerized system, EPIC control system
6.3		**Active Harmonic filters**	0.4 kV	Special enclosure at Main process plant substation	PQF series
6.4		**Active Voltage conditioner**	0.4 kV	Special enclosure at Main process plant substation	PCS100 AVC -40
6.5		**Uninterrupted Power Supply**	0.4 kV	LV AIS type 3	Conceptpower DPA 500

Note: In this section, generic names of the equipment are used in the solution context. There could be more equipment that may not be listed in this section. However, all possible solution components can be found in Section VII (Appendix 1).

Also, it might be so that only some of the total feature/functionality set of the above products could be used in the context of the solutions described in this section. This should not be misconstrued or misinterpreted as a constraint or limitation in any manner.

Some product combinations in the below solutions may not be applicable in actual practice (eg. LV Motor controller types 5 and 6) and therefore should be considered conceptual in the context of this solution guidebook.

The functionality that would be needed to form a comprehensive solution for the electrification system, represented in the 'System Overview' diagram, are listed below.

1. IEC 61850 based power automation system
2. Islanding and fast load-shedding
3. In plant power generation
4. Power generation control and voltage regulation
5. Automatic synchronization
6. Gas insulated, air insulated switchgear and equipment layout
7. Power automation system delivering dedicated/advanced protection (to secure each part of the network) and energy efficiency solution
8. Busbar protection
9. Fast acting and coordinated arc protection system
10. Short circuit current limiters facilitating system augmentation
11. High-speed bus transfer / Automatic transfer switching
12. Power Quality monitoring and corrective control
13. Communication system redundancy
14. Intelligent substation asset analytics aiding predictive maintenance
15. Interface to Distributed Control System

In order to ensure a compact substation at the 22kV main power evacuation center substation, a Gas Insulated Switchgear (GIS) panel line up is suggested. Depending on the process requirements, investment/operational/maintenance costs involved, space availability etc., a single or double busbar based arrangement needs to be selected.

A double busbar is necessary when:

- There is a need to operate incoming circuit breakers from non-synchronized systems.
- There is a higher need of system flexibility and availability, during inspection or maintenance procedures without load interruption.
- Extensions need to be done without switchgear shutdown

For the present use case, a double busbar based system is opted for at the 22kV main power evacuation center substation.

The downstream process plant substations are based on an Air Insulated Switchgear (AIS) with a single bus bar with sectionalizer/bus coupler.

The fault levels at the GIS and AIS are expected to be in accordance to the power feeds and loads connected to the 22kV, 11kV and 0.4kV levels and the associated equipment selection (circuit breakers, disconnectors, bus bars etc.) is done accordingly.

More details on some of the solution components and their solutions can be found in the Appendixes 1 and 2 respectively.

1. IEC 61850 based power automation system

All protection relays, merging units and dedicated functionality devices shall be based on IEC 61850 standard for communication networks in substations in order to make the best use of advantages offered:

a. Saving in copper wiring and therefore environmental friendly
b. Reduces space requirements in switchgear and substation due to reduction of hardware associated with wiring like transducers, input/output boards etc.
c. Increased safety
d. Supervised communication
e. Ensures interoperability across vendor equipment
f. Offers maximum reliability and availability
g. Guaranteed real-time performance
h. Is future proof
i. Reduces cost of ownership

Time synchronization according to IEC 61588 precision time protocol (PTP) ensures a very accurate time synchronization of the protection relays and merging unit clocks to a microsecond accuracy level, required for IEC 61850-9-2 LE communication.

The protection relay types 1, 2, 4 and merging unit, connected to conventional instrument transformers or sensors are capable of generating current and voltage samples at 4kHz sampling frequencies, according to IEC 61850-9-2 LE messaging format.

Besides protection relay type 3, protection relay types 1, 2 and 4 are also capable of subscribing to these current and voltage samples, sent by other bay/feeder's protection relays or merging units, in order to execute protection functions/applications.

The alternative arrangement to getting current and voltage samples would be to directly connect the conventional instrument transformers to the protection relay types 1, 2 and 4 and generate the current and voltage samples within the protection relay and to 'feed' them to its own protection functions/applications..

These protection functions/applications are identical to both use cases and are oblivious to the 'source' of these current and voltage samples. This implies that when sourced using IEC 61850-9-2LE, these samples need have extreme accuracy and precision in the sub-microsecond range.

SNTP (Simple Network Time Protocol) is required to time synchronize devices to a millisecond accuracy level. This is needed for devices needing to communicate on IEC 61850 MMS such as protection relay type 5, IO extension unit, load-shedding relay, power controller, HMI-communication gateway unit. Also SNTP based time synchronization is required for LV switchgear system data handling in the LV on-site condition monitoring type 1 and type 2 units. The 1 millisecond accuracy and resolution is necessary and sufficient to get a proper chronology of system/process alarms and events in the HMI.

Generally, the same GPS clock receiver can broadcast time messages in both formats. In the subsequent solution descriptions, the time synchronization aspect is not repeated and is considered as an implicit item.

2. Islanding and fast load-shedding

The F&B plant power system would generally work in parallel with the utility grid connection(s) in the following situations:

a. When the in-plant power generation sources' capacity (in particular conditions) is insufficient to meet the overall plant load
b. Even when in-plant power generation sources' capacity is sufficient, the grid connection is maintained in a 'floating' as a 'backup' for any eventuality (due to generation power source loss or increase in plant load etc. e.g. during heavy production cycles).
c. Sometimes it may be economical to also export power to the grid, when the in-plant generation is more than connected load and thereby benefiting in tariff related arrangements with the utility company.

In such situations, a fail-safe mechanism needs to be in place to safeguard the plant power network from getting 'sucked into' an external fault in the power grid.

This is prevented by a fast acting islanding action that trips the grid transformer's 132kV circuit breaker. And the inter-trip action also opens the 22kV side circuit breaker.

Grid disturbances or faults are characterized by conditions like:

- Under or overvoltage
- Over or under frequency
- Rapid fall of frequency (df/dt)
- Reverse power flow (reactive power)

The high-end protection relay (**protection relay type 1**) detects the above conditions along with voltage vector shift (VVS) feature to trip the 132kV circuit breaker and thereby avoiding a plant power system collapse.

(LOM = Loss of Mains)

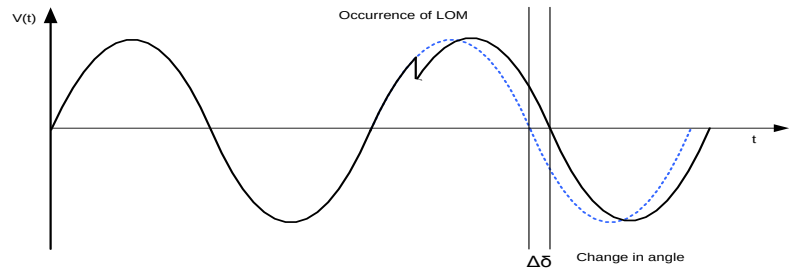


Figure 6: Voltage vector shift

This solution prevents power network blackouts by isolating the industrial power network from the utility grid and shedding loads within tens of milliseconds.

The protection relay type 1 also acts as a dedicated transformer protection relay.

The immediate aspect to be taken care of after an islanding action is to ensure that in-plant generation capacity is sufficient to cater to all the connected plant load.

Depending on the nature of power exchange conditions mentioned above, there may be a necessity of performing an extremely fast load-shedding action within tens of milliseconds. The

load throw off should be ideally equal to or slightly more than the power deficit caused due to the loss of utility connection.

Alternatively, when the plant network is already islanded and working based on in-plant generation capacity, a load-shedding solution is needed to prevent a power black-out. When one of the sources develops a fault (related to turbine or excitation), fast acting load-shedding is needed to prevent a cascade tripping of other generating units.

The dedicated **load-shedding relay** protects the plant network by dropping less critical plant loads ones in an extremely fast, accurate and selective manner and in doing so ensures availability of power supply for critical process loads.

As a result, the duration and frequency of production downtime in the plant and power outages in the plant power network is minimized. Also potential damage to electrical and process equipment, material loss/wastage are also avoided.

The load-shedding (LS) relay uses the IEC 61850 communication network to get the necessary inputs such as active power from all power sources, loads and tie feeders at 22kV, 11kV, 0.4kV voltage levels of the plant, protection operation status of in-plant generation sources, grid transformer connectivity, process load connectivity, critical process alarms etc. Protection relay types 1, 2 and 3 interface with the LS relay in the overall scheme. **Protection relay type 3** (centralized protection device) performs the entire protection, measurement, monitoring and control for the downstream process plant.* All information exchange between the protection relays and the load-shedding relay is accomplished using IEC 61850 analog and binary GOOSE.

It continuously performs power balance calculations and initiates a load-shed once a deficit is detected in a particular power network. Besides, power balance the load-shedding function also monitors the power network to detect disintegration or reconnection. The shed commands are issued from the load-shedding relay to the respective load's (type 2)/loads' protection relay (type 3).

The load-shedding action at 11kV level is completed by extension of the trip commands to the merging units.

However, load-shedding is only envisaged at 11kV process plant outgoing feeder level as only this strategy will ensure a distributed shedding action (granular) and not render a complete process plant outage. However, load-shedding at 22kV is also a possibility, if required.

Further granularity can be achieved at the 0.4kV level (PCC outgoing) by directly extending the shed commands from the LS relay to the respective outgoing feeders' circuit breaker units that are directly capable of receiving binary GOOSE command information.

While issuing trip commands an outgoing feeder (non-motor) that feeds a lower level (where loads are not shed individually), the same command is also extended to inhibit the auto-transfer/change over (HSBT/ATS) scheme or system.

The total time taken to detect an event within protection relay type 1, 2 or 3 to the issue of circuit breaker trip command is generally within 40-60 milliseconds.

** Protection aspects for downstream process plants are covered later in this section.*

The LS relay also supports other load-shed modes such as:

- Slow (overload or maximum demand violation-based) load-shedding: In this mode, the LS relay performs **peak-shaving** during excessive plant load conditions and resorts to shedding this excess load demand and thereby ensuring that load demand is within statutory limits as agreed in the power purchase agreement with the utility. In the process, it also prevents the overloading of the utility grid transformer.

  Overload monitoring of all power sources (generators and utility grid transformers) is also possible individually and a 'localized' corrective (load-shed) action in the affected part of the network is taken.

- Manual load-shedding based on operator action
- Under-frequency load-shedding as a backup to fast and slow load-shedding

Flexible priorities from 1 to 19 can be assigned to each process load connected to a bus bar. Up to 8 power sources (grid transformers, generators) and 60 load feeders can be considered in the

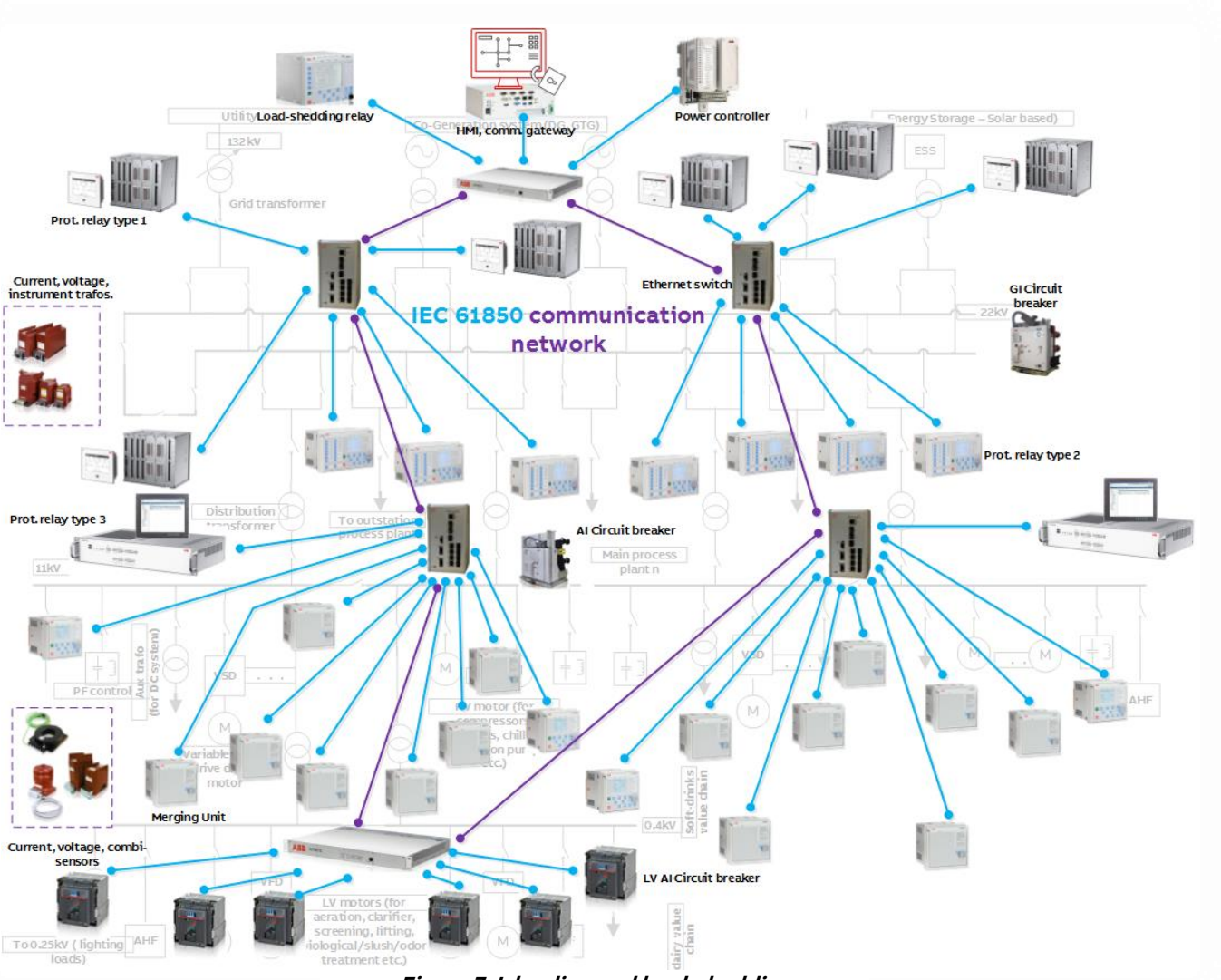


Figure 7: Islanding and load-shedding

load-shedding scheme. Up to 3 units of load-shedding relays can be connected in tandem in a distributed load-shedding scheme. See diagram ‘Islanding and load-shedding’.

Further, protection relay types 2 and 3 also are capable of performing frequency based load-shedding (df/dt and underfrequency) of their individual feeders.

Dedicated process displays, operator dialogs are realized in the process visualization unit (HMI).

The power controller sends topical/dynamic capability of the generator capacity depending on the ambient conditions (temperature) to the load-shedding relay.

Thus a combined islanding and load-shedding solution ensures an uninterrupted, reliable supply of power with an assured quality (perfect sinusoidal voltage with constant frequency), ensuring food safety at every stage in the process chain such as production and storage. This is paramount also to ensure continuity of operations without shutdowns due to unexpected power network disturbances.

3. In-plant power generation

When the total connected plant load is unable to be met by the utility grid company (capacity reasons) or if it is desired to have a 100% redundancy approach related to utility power availability, it is necessary to go in for in-plant power generation. The capacity can vary depending on the utility grid connection strategy (parallel or islanded operation).

Based on the operation economics, diesel based or gas based (or even steam based) generation can be opted for. While diesel or gas based generation can quickly respond to load changes, steam based generation can be used to supply constant load. In case if the F&B plant has sufficient space for accommodating solar panels to harness solar power, then a solar based battery energy storage system (BESS) can be deployed, thus utilizing 'clean' and 'green' power/energy.

Using BESS-PCS, the customer can:

- Compensate any intermittency of renewable energy (solar in this case)
- Store energy during off-peak time periods that can be used during peak time periods in order to cut down demand from the utility grid.
- Save energy costs

In this manner, BESS-PCS also contributes to **peak-shaving**.

Using the BESS-PCS the following energy storage applications could be realized.

- **Capacity firming**: Smoothening of power output to eliminate rapid voltage and power swing on the 22kV side.
- **Frequency regulation**: Absorbing and injecting power in order to keep system frequency within pre-set limits (see power regulation)
- **Load leveling**: Storing power during low-load periods and delivering it during periods of high demands in order to ensure economic power production from regular in-plant generation (GTG, DG etc.)
- **Peak shaving**: Reducing power consumption during periods of high demand which would reduce peak demand charges from the utility
- **Power quality**: Will be explained later.
- **Spinning reserve:** Making available power supply to quickly respond to instant loss of in-plant power generation.

4. Power generation control and voltage regulation

When utility power supply and in-plant generation need to work in tandem, then the combined power needs to be controlled in accordance with the individual capacities of the power sources and the limits imposed by power utility, as per the power purchase agreement. The power control solution would also ensure efficient operation, utilization of reserve capacity and power factor optimization. While the power control is realized in the **Power controller**. See figure 'Power-voltage control-Autosync'.

The control of active and reactive power from a single generator is performed by adjusting the governor (GOV) and automatic-voltage regulator (AVR) modes respectively and ensuring that the power outputs is within the generator's capability limits. It also involves a real time calculation of the generator's spinning reserve, also required for load-shedding.

The selection of the GOV and AVR modes is done from the HMI. When in manual mode (e.g. generator power can be controlled from HMI). In automatic mode, generator power output is controlled by the power control function.

A mode coordination/supervision function ensures that the selected GOV and AVR modes are permitted according to the 22kV network configuration.

The power control function helps in maintaining a stable plant operation (system frequency and voltage) by a coordinated control of the generators and BESS, when islanded.

When connected to the utility grid, the power control function manages to maintain the set power factor at the utility grid connection point by controlling the active and reactive power output of generators. Also import and export limits for power can be defined and maintained.

The active and reactive power demand is shared amongst the participating generators/BESS (not in isochronous mode, when islanded or put in droop mode due to system limitations) and utility power connection(s) to allow the working points of the controllable generators to operate within their operational margins to the maximum extent possible. This also enables some robustness in the plant power system to withstand disturbances (internal such as a HV motor start or externally as seen from the utility grid perspective) as possible, ensuring that the plant can withstand bigger disturbances.

Power control function ensures that there is a stable plant power system irrespective of when the plant is working in parallel or in isolation from the utility grid. By sharing the power demand across the generators, it also ensures fuel savings (non-renewables).

When connected with the grid, the power control function too contributes to **peak-shaving** by ensuring a higher power capacity factor from the in-plant generation assets and improving efficiency of electrical energy utilization.

For the BESS source, the power control function in the Power controller issues active and reactive power set points to (BESS-PCS controller) in accordance to the overall power generation requirement, when connected with the grid or in islanded operation.

The Power controller receives real-time active, reactive power, circuit breaker status etc. information from protection relay type 1 units associated with the grid transformer and the generator units using IEC 61850 analog and binary GOOSE signals.

The Power controller issues the control actions, that is, the speed and voltage raise/lower commands or setpoint actions using IEC 61850 analog/binary GOOSE the protection relays associated with the generator/BESS-PCS units.

The voltage control function is run in the **protection relay type 1** associated with the grid transformers (1 or 2 or 1 & 2) to control their tap positions (motor driven on-line tap changers) and

thereby to manually or automatically regulate or control the load-side voltage, when the plant system is connected with the utility power supply.

This function can be run independently or coordinated (if required) with the power control function, depending on the objective at the tie line. Voltage control is either performed by grid transformer protection relays or by power control function.

The load-side voltage to be maintained is made as a setting in the protection relay type 1 associated with the grid transformer 1, which can be considered as the master (say).

When operating both grid transformers in parallel, the following principles are taken care of:

1. Master (grid transformer 1) /follower (grid transformer 2)
2. Negative reactance
3. Minimizing circulating current

IEC 61850 analog and binary GOOSE messaging is used to exchange tap change position, tap raise/lower command from master to follower and tap change confirmation between the protection relay type 1 units associated with grid transformers.

Maintaining designated voltage in an electrical power system is important for proper operation for electrical power equipment to prevent damage such as overheating of generators and motors and to maintain the ability of the system to withstand and prevent voltage collapse, due to a sudden increase in connected load.

5. Automatic Synchronization

After an islanding event and eventual confirmation of the grid fault normalization, it will be necessary for the grid transformer 1 or 2 to be synchronized.

When the plant network needs be integrated as a single power network, the 22kV GIS bus section circuit breaker needs to be closed. This process also calls for synchronization of the two power networks (say ‘left side’ and ‘right side’)

Similarly, when a generator or BESS needs to be brought ‘on-line’ and connected to the 22kV bus (step-up transformer side), then the HV side (22kV) circuit breaker needs to be synchronized (assuming there is no generator/source side circuit breaker).

The **protection relay type 1** associated with the grid transformers 1 and 2, generators and 22kV bus sectionalizer circuit breaker host the auto-synchronization functionality.

First we consider the 22kV incoming generator circuit breaker. The generator circuit breaker ‘object’ is selected from the HMI. Once selected, the generator is disabled from being controlled from the generator/power control function.

Once the circuit breaker is selected, the generator auto synchronization function checks the conditions (frequency, voltage and phase angle) across the circuit breaker from generator transformer HV side and 22kV bus side and issues the (raise/lower) pulse commands to the generator AVR and GOV for matching the voltage and frequency conditions respectively.

Once the synchronization check and synchronizing conditions (~ zero slip, ~zero voltage difference & ~ zero phase difference) are fulfilled across both sides of the circuit breaker, the function gives the permission to close the circuit breaker. The synchronization includes the functionality of energizing check, synchronization check and voltage and frequency matching.

The function supports manual, semi-automatic and fully automatic modes of operation.

In the manual mode, the raise/lower commands are issued manually from the protection relay type 1's front panel and circuit breaker too is closed manually. In the semi-automatic mode, the raise/lower commands are issued automatically by the function and circuit breaker too is closed manually. And in the fully automatic mode, both raise/lower commands and circuit breaker closing are executed by the function automatically.

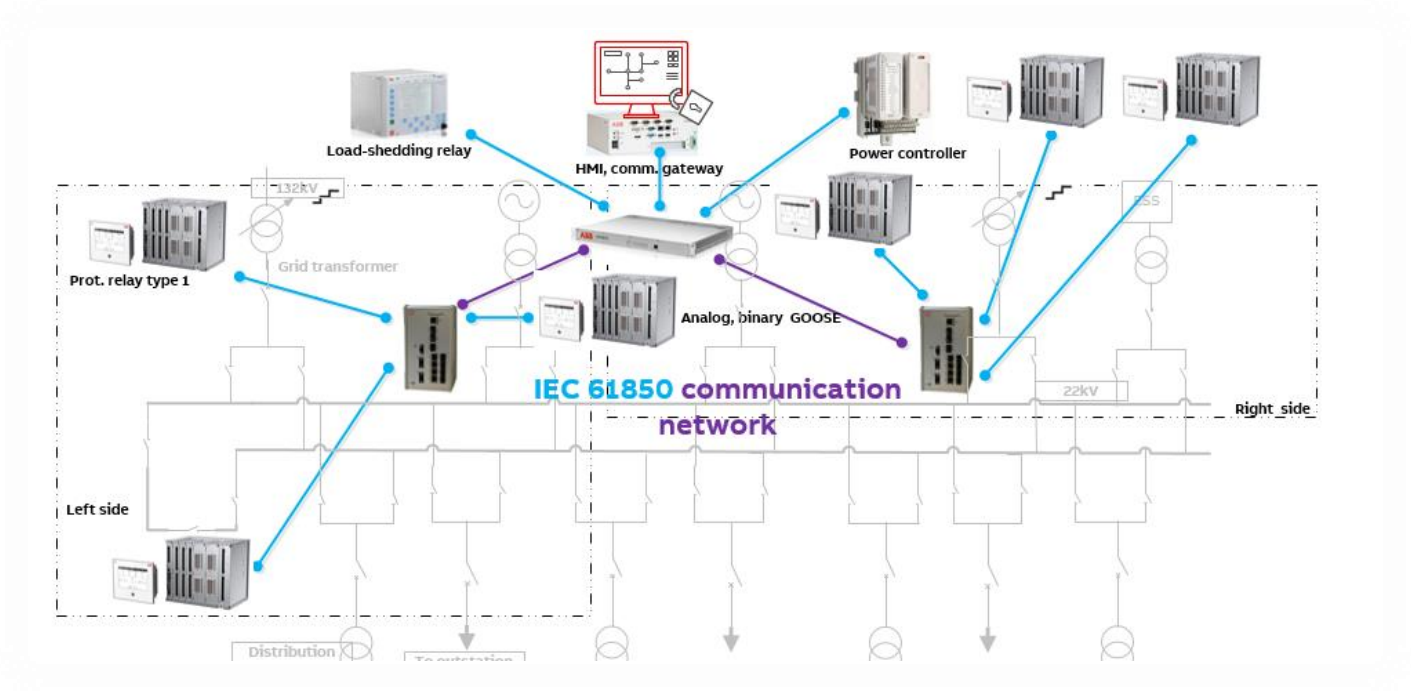


Figure 8: Power-voltage control - Autosync

Next, we consider the 22kV grid transformer 1 circuit breaker to be synchronized after an islanding event. The transformer LV side 22kV circuit breaker 'object' is selected from the HMI. The user needs to also select the 'available' generator(s) to 'participate' in the synchronization process. *In the current use case, only 2 generators and a BESS unit are shown. In reality, there could be several units.* Once selected, the participating generator(s) is/are disabled from being controlled from the generator/power control function.

Once the circuit breaker is selected, the tie feeder auto-synchronization function checks for the power system conditions between the utility and plant sides across the circuit breaker, which would be asynchronous. While the grid-transformer 22kV side voltage transformer (VT) can be directly connected to the associated protection relay type 1, the 22kV bus side voltage can be extended from the bus sectionalizer/bus coupler protection relay type 1 using IEC 61850 sampled measured values (SMV).

Accordingly, the function calculates the slip and voltage difference and distributes to the protection relay type 1 units associated with the participating generators using IEC 61850 analog GOOSE. Network topology is ascertained by the function before the matching commands are extended.

(Note: In case a BESS unit needs to participate in the utility grid incomer circuit breaker synchronization, then the slip and voltage difference values need to be converted into active and reactive power set-point information in its protection relay 1. Also the response times to a set-point change may need to be ensured to be coordinated with the overall synchronization process).

The generator protection relays 'translate' the dynamic slip and voltage information into matching commands towards their respective GOV and AVR systems.

Once synchronizing conditions are achieved across the circuit breaker, the circuit breaker close command can be issued manually or automatically.

The procedure to synchronize the 22kV bus sectionalizer circuit breaker is very similar to the grid transformer circuit breaker, except that the reference side would be the one that is grid connected. If both sides are isolated from the grid, the user can select the 'reference' and 'variable sides'. Then only those generator(s) on the variable side can be controlled by the auto-synchronization function.

Only one circuit breaker can be synchronized at any point of time.

The advantage of such a distributed auto-synchronization function eliminates the need of dedicated voltage selection scheme with associated panel, hardware and wiring that comes with its own complexity.

This function also ensures complete safety of the switchgear equipment and generators and therefore safeguarding customer investment. Having a single protection relay type 1 for islanding, power control, voltage control and auto-synchronizer provides a great advantage to the customer.

6. GIS, AIS switchgear and equipment layout

Before describing the protection system, we will cover the arrangement of the various devices in the switchgear and dedicated panels in the various substations.

The air insulated or gas insulated switchgear, where the protection relays and circuit breakers are deployed, should ensure personnel safety based on reduced wiring.

See figure 'Switchgear/panel and devices' layout'

22kV GIS indoor switchgear line up at the main power evacuation center substation, comprising of the following equipment types:

1. Protection relay type 1 (generator feeders)
2. Protection relay type 1 (grid transformer feeders)
3. Protection relay type 1 (bus sectionalizer/bus coupler feeder and bus bar protection)
4. Protection relay type 2 (outgoing feeders)

5. All relays are 'fed' current and voltage signals (as applicable), based on conventional current and voltage transformers.
6. MV circuit breaker type 2
7. Dedicated arc protection (MV arc protection type 1).
8. Dedicated industrial grade Ethernet switches for IEC 61850 (GOOSE, SMV, MMS) connectivity between mentioned protection relay types and rest of the plant network.

11kV primary indoor AIS switchgear line up at the main process plant substations, comprising of the following equipment types:

1. Protection relay type 3 (centralized protection device for entire switchgear line up, not exceeding 20 feeders). For further protection system availability, a redundant protection relay type 3 can also be considered.
2. Merging units (all motor, VSD and LV feeders)
3. Protection relay type 4 (incomer and capacitor bank feeders)
4. Protection relay type 5 (bus section, bar protection)
5. Dedicated high speed bus transfer (HSBT relay)
6. All relays are 'fed' current and voltage signals (as applicable), based on current, voltage sensors or combined sensors or by conventional current and voltage transformers. Adaptation to sensor technology, enhances safety levels, wherein the operators need to handle secondary signals only amounting to a few volts.
7. MV circuit breaker type 1 or MV circuit breaker type 2 or MV circuit breaker type 3
8. Dedicated industrial grade Ethernet switches for IEC 61850 (GOOSE, SMV, MMS) connectivity between mentioned protection relay types, merging units and rest of the plant network.

11kV secondary indoor AIS switchgear line up at the outstation/remote supporting process plant substations, comprising of the following equipment types:

1. Protection relay type 5 (dedicated feeder and motor protection)
2. All relays are 'fed' current and voltage signals (as applicable), based on conventional current and voltage transformers.
3. MV circuit breaker type 2
4. Dedicated industrial grade Ethernet switch for IEC 61850 (GOOSE, MMS) connectivity between mentioned protection relay types and rest of the plant network.

11kV gas insulated ring main unit (RMU) housed with low-voltage (LV) transformer housed in an outdoor compact substation, typically in remote 'corners' of the F&B plant (like water or effluent treatment plants) [8], comprising of the following equipment types:

1. Protection relay type 4 (remote monitoring, protection and control relay)
2. I/O + fault passage indicator (FPI) unit
3. Above units are 'fed' current and voltage signals (as applicable), based on current, voltage sensors or combined sensors. Adaptation to sensor technology, enhances safety levels, wherein the operators need to handle secondary signals only amounting to a few volts.
4. MV circuit breaker type 2

5. Dedicated industrial grade Ethernet switch for IEC 61850 (GOOSE, MMS) connectivity between remote monitoring & control units and I/O + FPI units types and rest of the plant network.

A dedicated panel, at the main power evacuation center substation, comprises of the following equipment types:

1. Load-shedding relay
2. Power controller
3. HMI and communication gateway
4. Cloud connectivity gateway type 1 for 22kV, 11kV (6.6kV or 3.3kV) systems
5. Industrial Ethernet switch for IEC 61850 (GOOSE and MMS) communication between mentioned devices and rest of the plant network
6. GPS time receiver with antenna for time synchronization according to IEC 61588 PTP and SNTP time protocols.

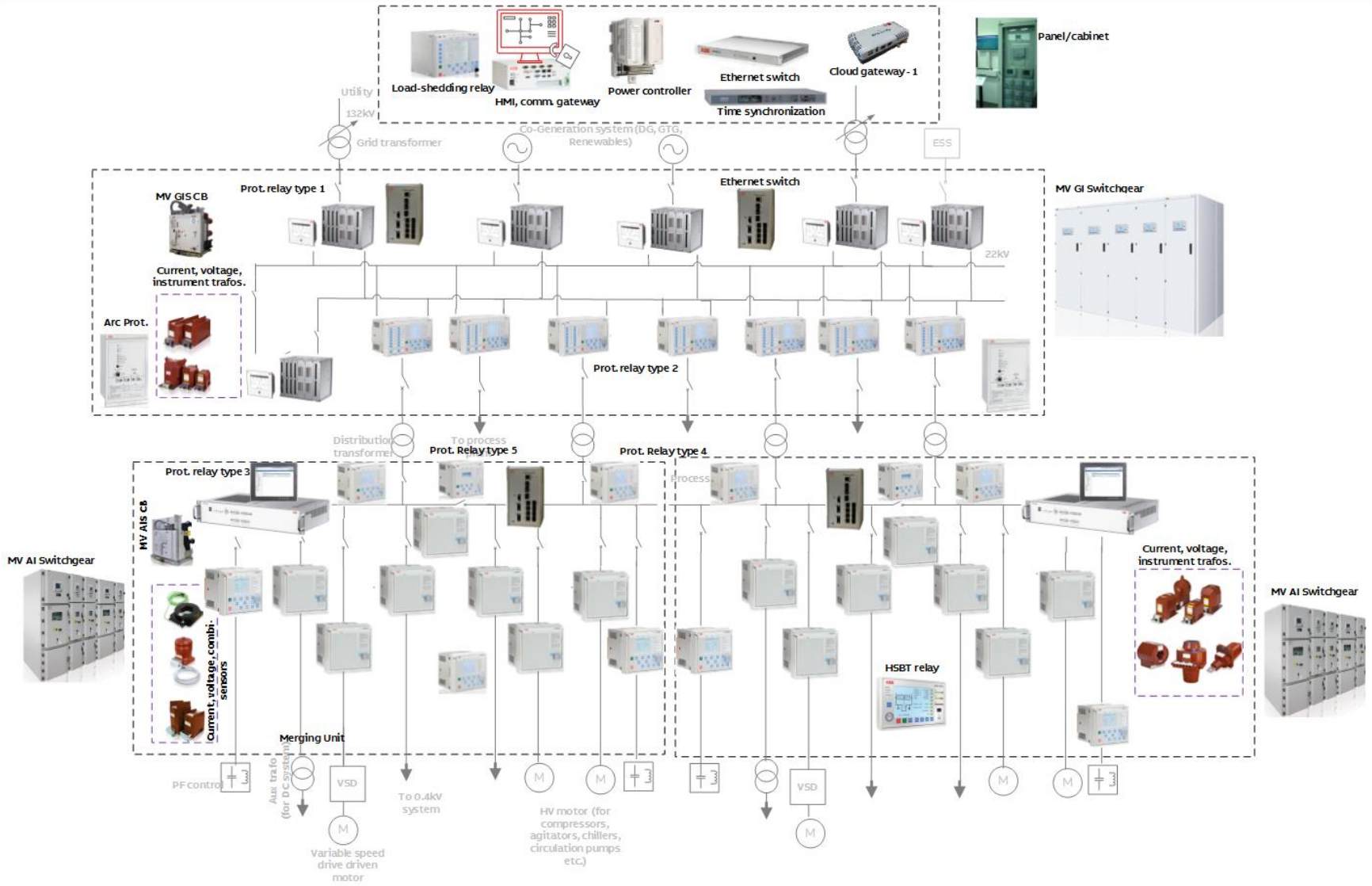


Figure 9: 22/11kV primary switchgear/panel and devices' layout

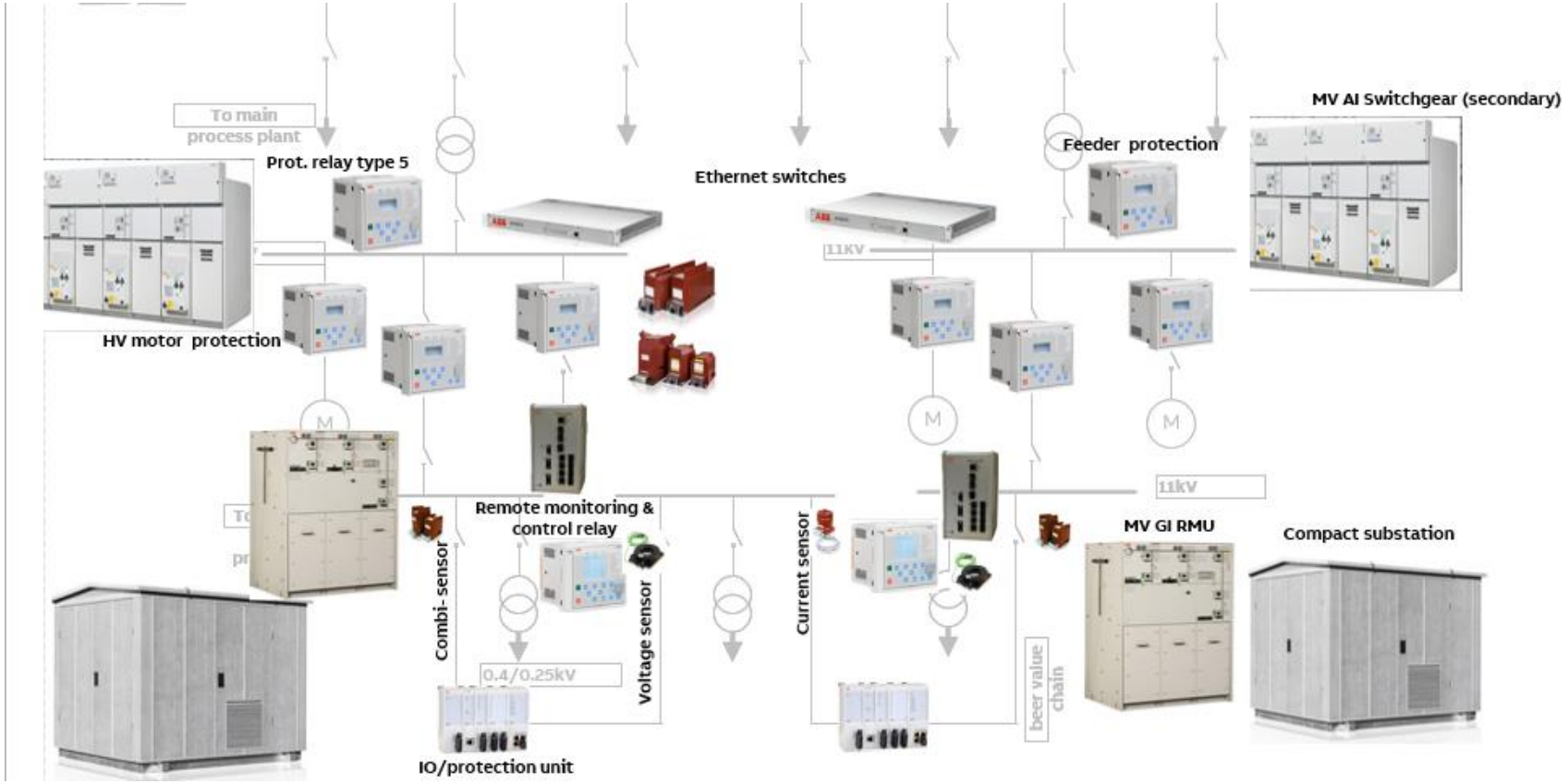


Figure 10: MV switchgear/panel, devices' layout and compact substation at outstation/supporting process plant area

0.4kV indoor AIS switchgear, also referred as LV AI switchgear type 2, (Power Control Center, PCC) line up at the downstream end of the main process plant substations, comprising of the following equipment types:

1. Protection relay type 5 at incomer feeders (feeder protection)
2. LV circuit breaker type 1 integrated with protection, measurement and control unit for all feeders
3. LV circuit breaker type 1 with dedicated auto-transfer switch (ATS) for bus coupler
4. Above units are 'fed' current and voltage signals (as applicable), based on conventional current and voltage transformer or sensors.
5. Arc protection based on LV circuit breaker type 1 or dedicated set up based on LV arc protection type 2 system.
6. LV SWG gateway type 2 to collect all feeder information gathered from circuit breaker units based on Modbus TCP.
7. Local visualization of switchgear information (measurements like currents, voltages, power factor, frequency, motor control status, alarms and events etc.)
8. Cloud connectivity gateway type 2 for 0.4kV systems
9. LV on-site condition monitoring type 2 for switchgear monitoring and diagnostic (M&D) using Cloud connectivity gateway type 2.
10. Dedicated industrial grade Ethernet switch for IEC 61850 (GOOSE, MMS), Modbus-TCP connectivity between mentioned protection relays, integrated circuit breaker units, switchgear gateway unit, local visualization unit, other Ethernet switches in the same process plant and rest of the plant network.

0.4kV indoor AIS switchgear (Motor Control Center MCC#1), also referred as LV AI switchgear type 1, line up at the downstream end of the main process plant substations, comprising of the following equipment types:

1. LV circuit breaker type 1 integrated with protection, measurement and control unit at the incomers.
2. LV circuit breaker type 1 with dedicated auto-transfer switch (ATS) at MCC#1 and MCC#2 in the bus coupler feeder.
3. Above units are 'fed' current and voltage signals (as applicable), based on conventional current and voltage transformer or sensors.
4. LV Motor controller types 1 and 2 and trip units in the outgoing motor feeders, 'fed' with current and voltage signals (as applicable), based on dedicated sensor units
5. Arc protection based on LV circuit breaker type 1 or dedicated set up based on LV arc protection type 2 system.
6. LV SWG gateway type 1 to collect all feeder information gathered from:
    a. LV circuit breaker-type 1 units based on Modbus RTU
    b. LV Motor controller types 1 and 2 based on a proprietary protocol
7. Local visualization of switchgear information (measurements like currents, voltages, power factor, frequency, motor control status, alarms and events etc.)
8. LV on-site condition monitoring type 1 for switchgear monitoring and diagnostic (M&D)
9. Dedicated industrial grade Ethernet switch for IEC 61850 (GOOSE, MMS) connectivity between mentioned integrated circuit breaker units, other Ethernet switches in the same process plant and rest of the plant network

0.4kV indoor AIS switchgear (MCC#2, Utility/emergency distribution board),), also referred as LV AI switchgear type 2) line up at the downstream end of the main process plant substations, comprising of the following equipment types:

1. LV circuit breaker-type 1 integrated with protection, measurement and control unit at the incomers.
2. LV circuit breaker-type 1 with dedicated auto-transfer switch (ATS) in the bus coupler feeder.
3. Above units are 'fed' current and voltage signals (as applicable), based on conventional current and voltage transformer or sensors.
4. Arc protection based on LV circuit breaker type 1 or dedicated set up based on LV arc protection type 2 system
5. LV Motor controller types 3 and 4 in MCC#2 board outgoing motor feeders, 'fed' with current and voltage signals (as applicable), based on dedicated sensor units
6. LV Motor controller type 5 for motor feeders requiring speed control.
7. LV circuit breaker-type 2 MCCBs integrated with protection and trip unit at the utilities board for outgoing feeders
8. Dedicated ATS unit at the DG incomer feeder in the utility distribution board.
9. Switchgear gateway unit to collect all feeder information gathered from:
    a. LV circuit breaker-type 1 units based on Modbus RTU
    b. LV Motor controller type 3 based on a Modbus-TCP protocol
    c. LV Motor controller type 4 based on a Modbus-RTU protocol
    d. LV circuit breaker-type 2 based on a Modbus-RTU protocol
10. Local visualization of switchgear information (measurements like currents, voltages, power factor, frequency, motor control status, alarms and events etc.)
11. Dedicated industrial grade Ethernet switch for IEC 61850 (GOOSE, MMS) connectivity between mentioned integrated circuit breaker units, other Ethernet switches in the same process plant and rest of the plant network

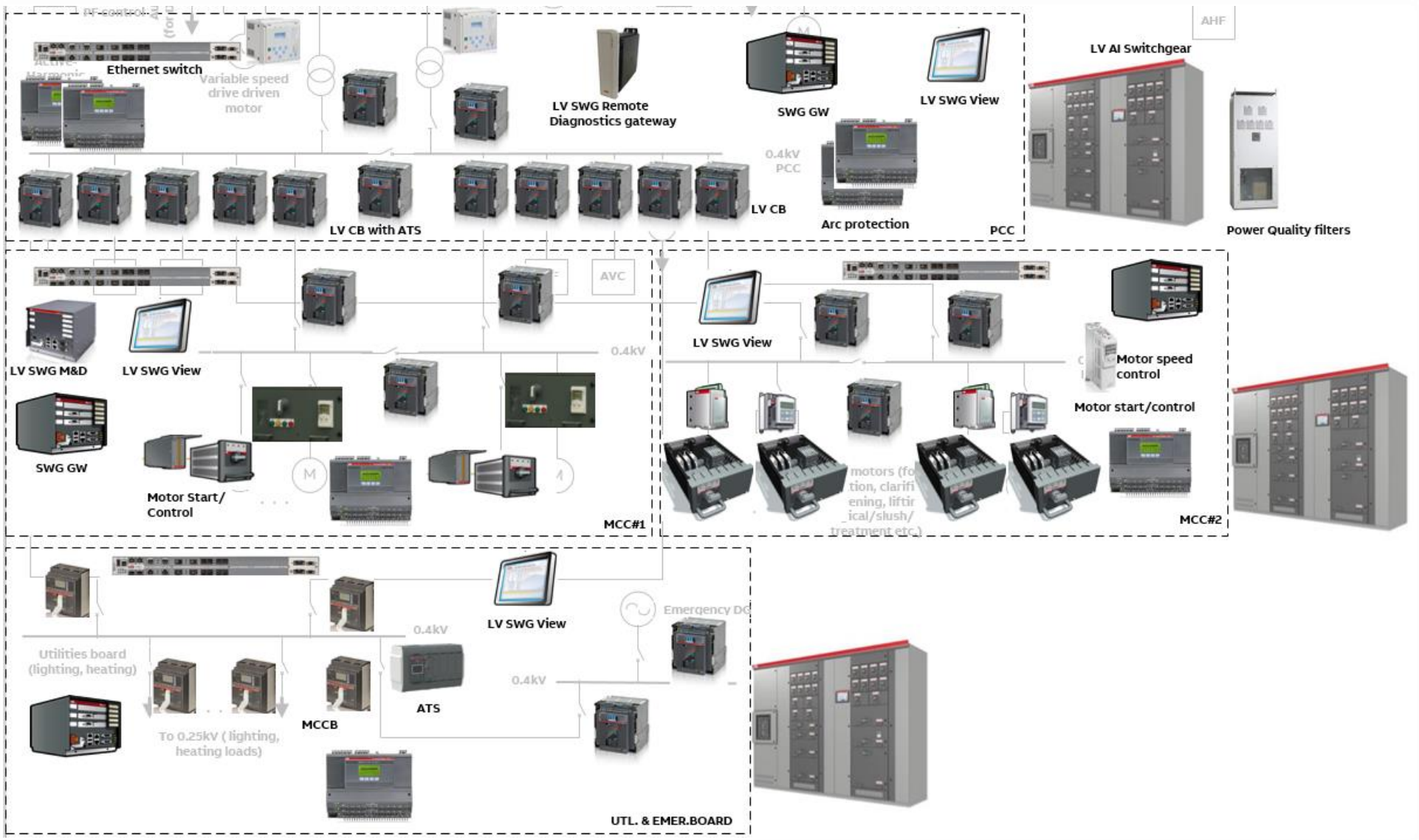


Figure 11: 0.4kV switchgear/panel and devices' layout (main process plant area)

7. Power automation system delivering dedicated/advanced protection and energy efficiency solution

Before considering the protection aspects for the entire system at 22kV, 11kV and 0.4kV levels, the common power/substation automation functionality aspects for the entire setup are touched upon.

All measurement, monitoring information are reported to the HMI from the protection relays and the 0.4kV intelligent circuit breaker units using IEC 61850 MMS. Using its communication gateway functionality, the HMI sends required information to an upper level system such as a DCS (not represented as a part of the solution) over well accepted industrial communication protocols such as Modbus or OPC.

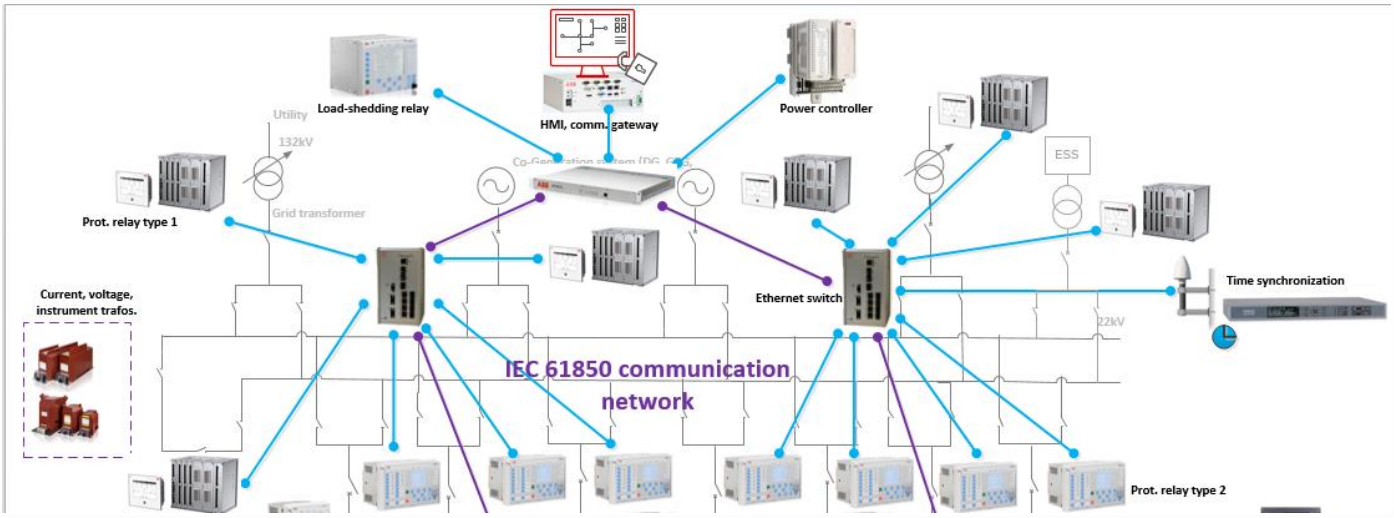


Figure 12: 22kV protection system

Switching operations to control substation equipment such as circuit breaker, disconnectors or to initiate transformer tap position change or general operator actions are done using HMI process displays over IEC 61850 MMS. When higher level systems such as a DCS is involved, then HMI's gateway function is used to route the received commands (using Modbus or OPC) towards the protection relays, in which the object control application resides.

Disturbance and fault records can be retrieved as COMTRADE files from the protection relays using IEC 61850 MMS file transfer services.

The HMI incorporates process displays, trends, reports. Also non-time critical process control applications like temperature control could be executed with this device together with protection relays or extension IO units. See Appendix 2, Step 5. In some cases, the PLC functionality offered by the protection relays and Power Controller too could be utilized.

Besides dedicated protection, the involved protection relay and integrated protection + circuit breaker units in any of the voltage levels also can be configured to perform cross-bay functions like process or system-wide interlocking using IEC 61850 GOOSE.

A different approach has been considered for protection philosophy at 22kV, 11kV and 0.4kV levels. At the 22kV level a dedicated protection relay unit is considered for each of the feeder types as mentioned earlier. Refer figure below '22kV protection system'. As mentioned earlier, protection relay type 1 are considered for their role in multiple solutions.

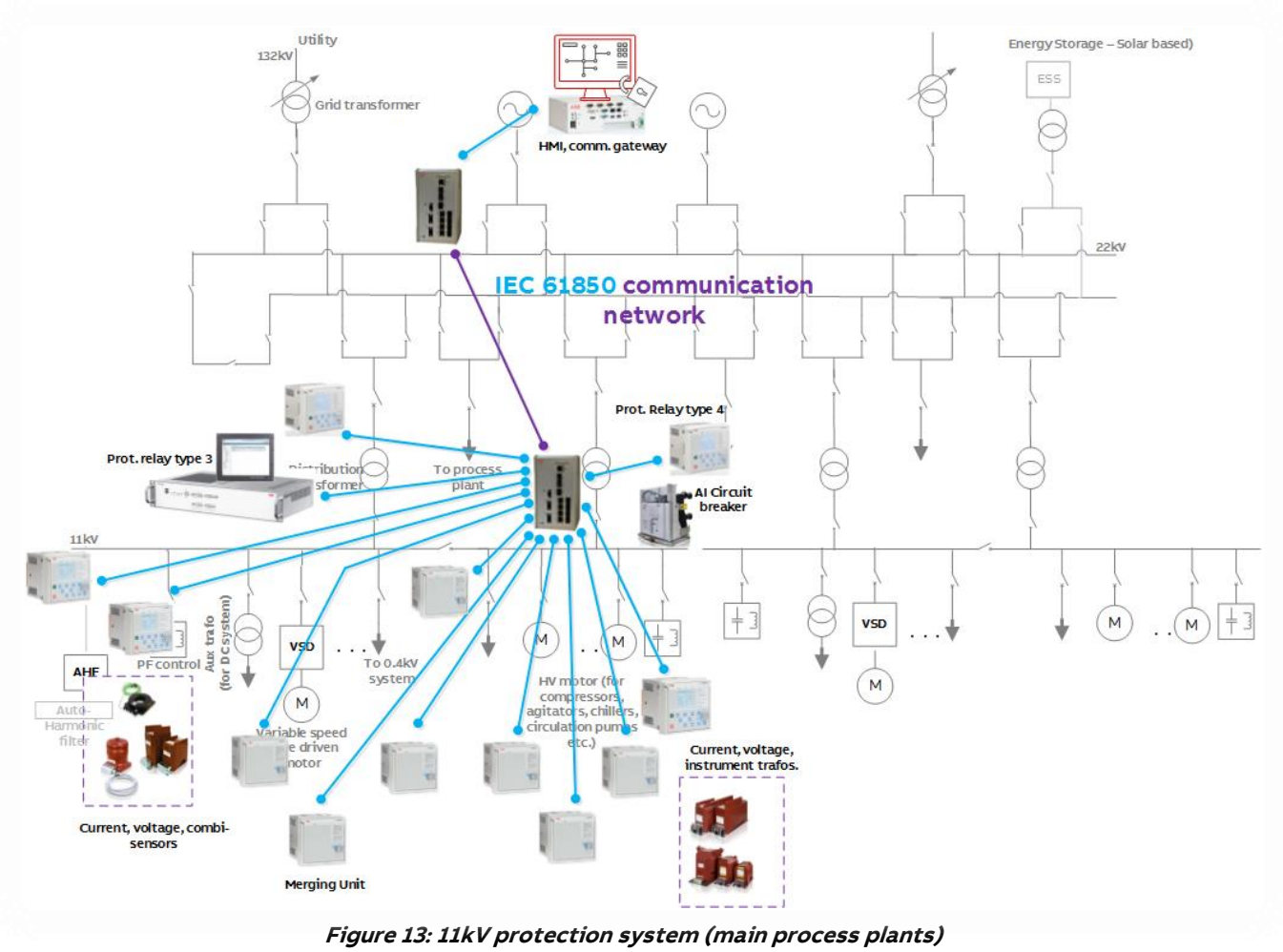


Figure 13: 11kV protection system (main process plants)

At the 11kV level in the main process substations, a centralized protection system is comprised as shown in the figure below '11kV protection system' is considered.

The voltage and current signals obtained from the sensors or conventional instrument transformers are converted into sampled measured values (SAV) by the merging units of all outgoing feeders and the protection relay type 4 at the incomer, according to IEC 61850-9-2 (LE) at 4kHz sampling frequency.

The centralized protection device subscribes to these samples sent simultaneously and runs protection, measurement and monitoring functions for all the feeders in the 11kV level of the process plant. It also can run advanced single or multiple feeders/substation-wide applications, as required.

The protection relay type 4 at the incomer feeders acts a backup unit to the centralized protection unit. Dedicated protection for the capacitor bank feeder and active harmonic filters are taken care by their own dedicated relays.

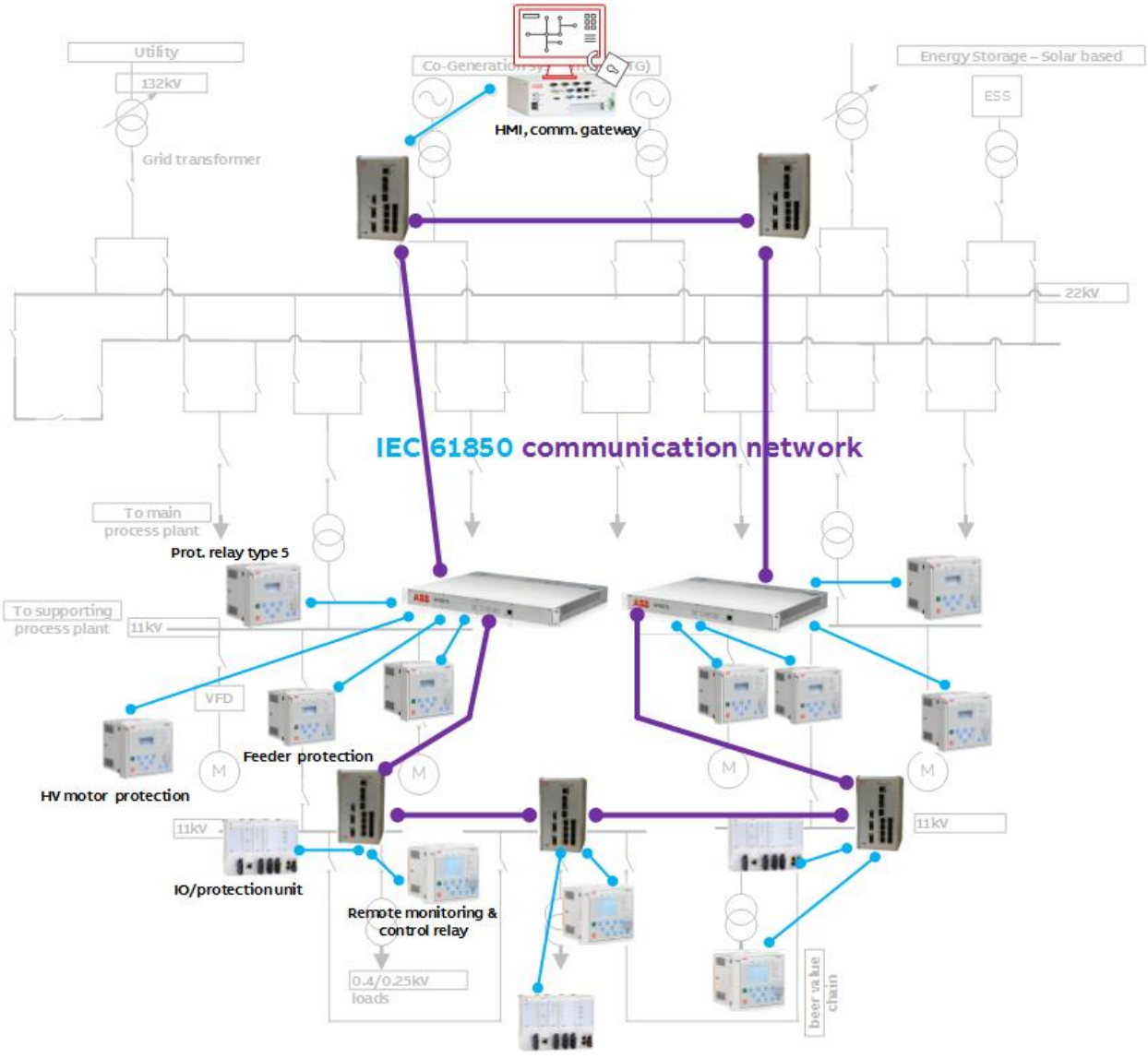


Figure 14: 11kV protection system (outstation/remote supporting process plants)

System-wide interlocking is realized in the centralized protection device. IEC 61850 MMS reporting to HMI is similar to the protection relays in the 22kV level or protection relay type 4. Switching commands are issued from the HMI or the centralized protection device's panel are extended to the respective merging units and protection relay type 4 using IEC 61850 GOOSE.

The centralized protection device plays the role of a main protection relay in the 11kV process plant substation. Depending on the criticality of a feeder, functional and physical redundancies can be defined.

Depending on priority of the feeders a selective approach can be taken. For example, a high priority feeder can be protected with a dedicated protection relay and the centralized protection device acts as a functional back up protection unit. So a tailored redundancy approach (functional and physical) is feasible to suit customer's situational needs at 22kV level also.

The 11kV protection system at outstation/ remote supporting process plant areas comprises is as shown below. In the indoor substations (secondary substations), dedicated protection relay type 5 are considered for feeder and motor protection. It is anticipated that such remote substations are characterized by HV motors for heavy duty pump applications.

The protection system in the RMU (2 or 3 feeders) in the remote areas are typically characterized by a protection relay type 4 that doubles up as an RMU automation controller + protection unit for the transformer feeder and the IO unit that doubles up as a fault detection unit for protection of switch fuse unit (SFU) based feeders.

The 0.4kV protection system in the main process plants is accomplished in the following manner for every individual feeder:

1. The PCC incomer feeders that typically need more protection functions (than what is possible with LV circuit breaker type 1), are protected by IEC 61850 compliant protection relay type 5.
2. The PCC, MCC#1, MCC#2, Emergency distribution boards' incomer and bus coupler feeders are protected by LV circuit breaker type 1.
    a. Data reporting to HMI/communication gateway is done based on IEC 61850 MMS like other protection relays.
    b. Also reporting is done to the switchgear local switchgear HMI (LV SWG View) and switchgear gateway (SWG GW) over Modbus RTU, Modbus-TCP combination.
3. Motor controller types 1 and 2 (MCC#1) incorporate integrated protection functionality and trip units. They communicate their data to the switchgear gateway over a proprietary switchgear fieldbus.
    a. The switchgear gateway then sends data to the switchgear HMI over Modbus-TCP.
4. Motor controller types 3 and 4 (MCC#2) also incorporate integrated protection functionality together with LV circuit breaker type 2.
    a. Motor controller types 3 and 4 communicate their data to the switchgear gateway over a Modbus-RTU.
    b. The switchgear gateway then sends data to the switchgear HMI over Modbus-TCP.
5. The incoming and outgoing feeders in the utilities board are protected by the LV circuit breaker type 2, which also incorporates protection functionality and communicates its data to the switchgear gateway over Modbus-RTU.

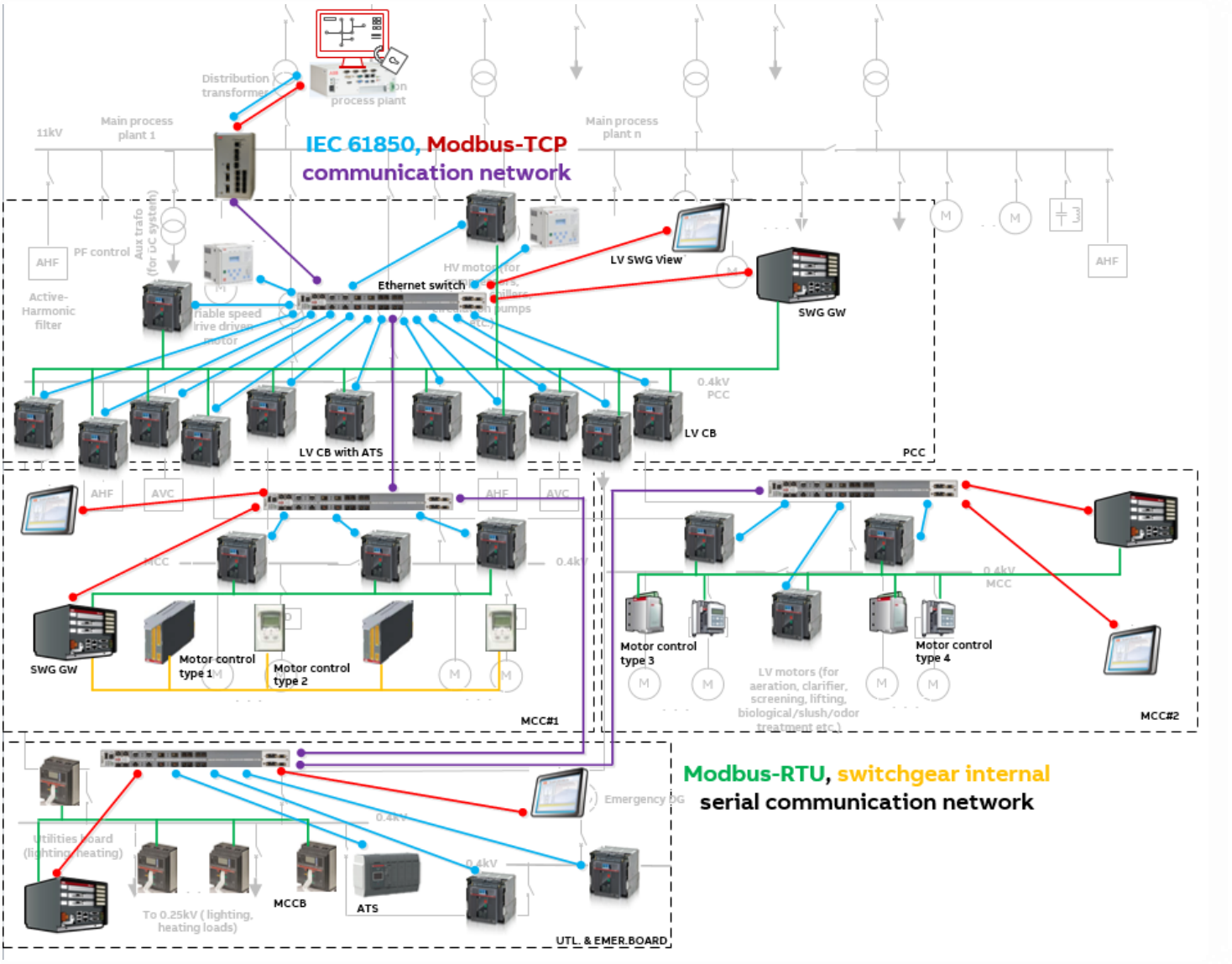


Figure 15: 0.4kV protection system

An energy optimization software package integrated with the HMI (within the same physical device or a separate computer), ensures addressing the need for real-time energy monitoring and reporting. Such a software would need to be scalable and modular to provide complete load balancing and optimization of energy use and supply of the entire facility of the F&B customer. For a corporate, multi-site F&B customer installations, multiple facilities can be integrated to provide a company-wide solution and to allow highly visual comparisons, benchmarking and the sharing of best practices between the production facilities.

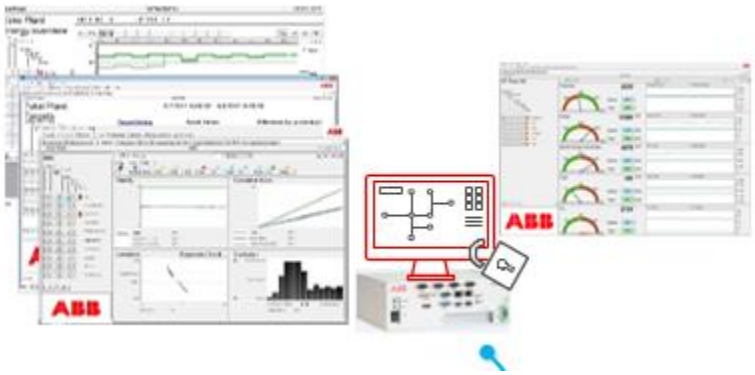


Figure 16: Energy efficiency software integrated with HMI

8. Busbar protection

See figure 'Bus bar protection' below. Protection relay types 1 and 5 provide standalone high-impedance busbar differential protection at 22kV and 11kV respectively. Alternatively, the centralized protection system at 11kV too has a provision to provide Bus bar protection solution based on low-impedance principle.

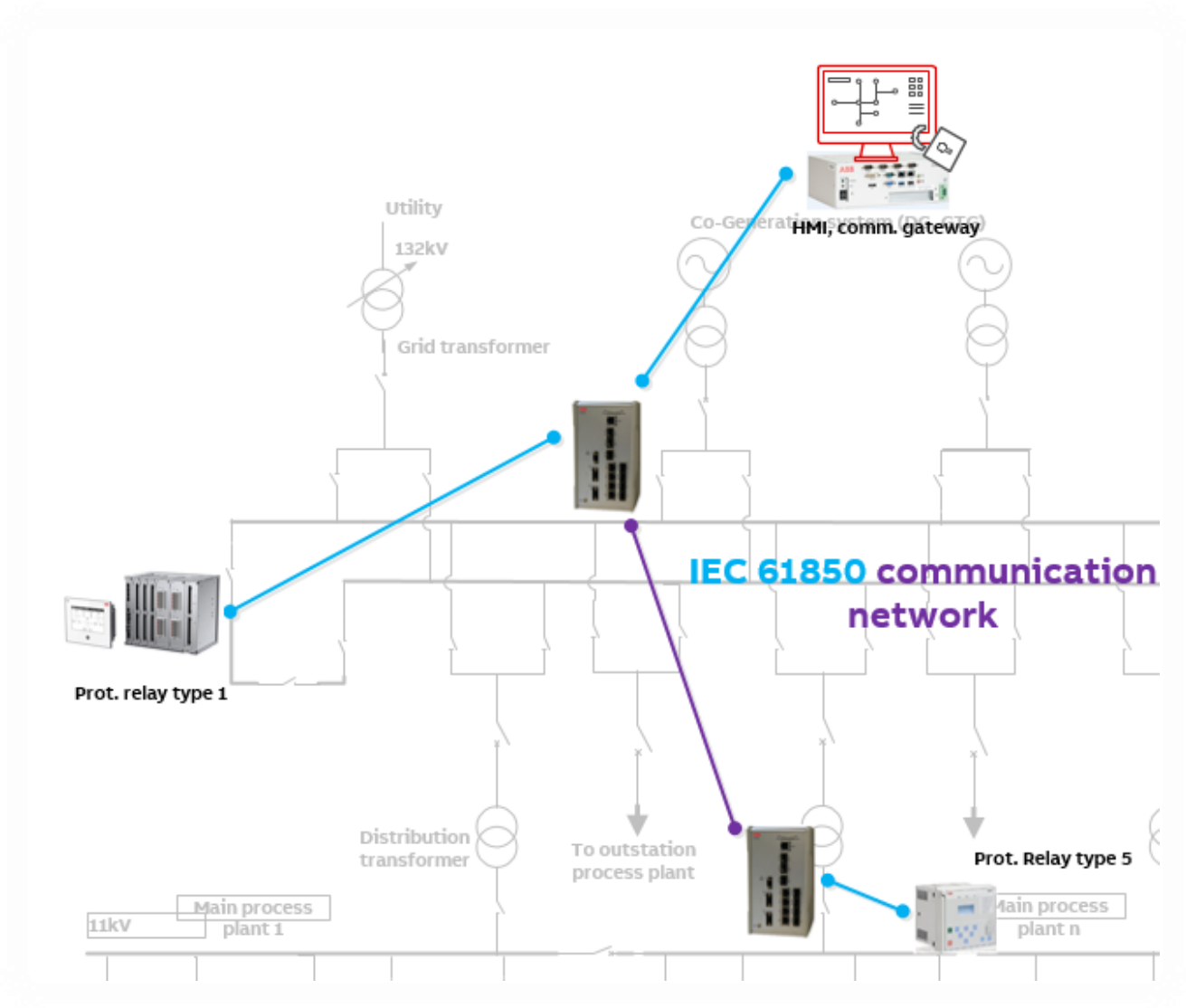


Figure 17: Busbar protection

Fast acting busbar protection can save the entire switchgear lineup from severe faults such as flashovers, thus ensuring **personnel safety** and saving of customer investment.

9. Fast acting and coordinated arc protection system

A comprehensive arc protection is achieved using dedicated arc protection devices and protection relays as shown in the figure 'Arc protection'.

The unit provides protection based on light only or simultaneous light and phase overcurrent/earth fault current measurement. It detects the arc flash in the 22kV side using it loop type or radial type light sensors (-35degC - +80degC).

The two units of the 'Arc flash protection relays' ensure secure tripping in the grid incomer feeders. They coordinate with each other using a dedicated optical fiber connection to exchange overcurrent fault condition. The two high speed outputs from each unit can operate within 2.5ms to trip both HV and LV sides of the grid transformer.

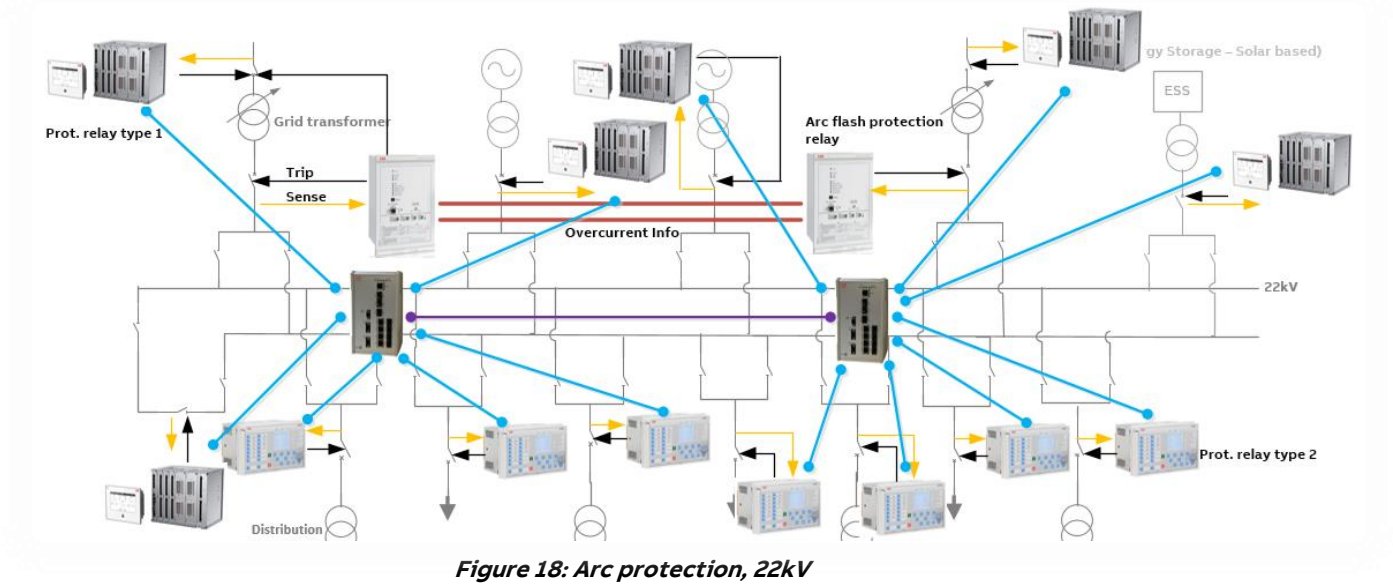


Figure 18: Arc protection, 22kV

Protection device types 1 and 2 at the other 22kV feeders are capable of detecting arc flash and enabling fast and selective arc protection. Using their light sensor inputs and fault current measurements, they initiate high speed trip output. The trip can be based on light detection (10ms) or a combination of light and current detection (12ms).

The trip output detected by one relay can be sent out to other feeders' relays using IEC 61850 GOOSE and ensure a near simultaneous tripping of all feeders in the 22kV switchgear.

On the 11kV side (main process plants), all merging units and protection relay type 4 are equipped with arc /light sensor inputs. On detection of an arc flash, one of more merging units and/or protection relay send the information to the centralized protection device over IEC 61850 GOOSE the centralized protection device. Based on either light or light and overcurrent/earth fault measurement detection, the centralized protection device would issue trip commands to the feeder circuit breakers through their respective merging units/protection relay type 4's high speed outputs.

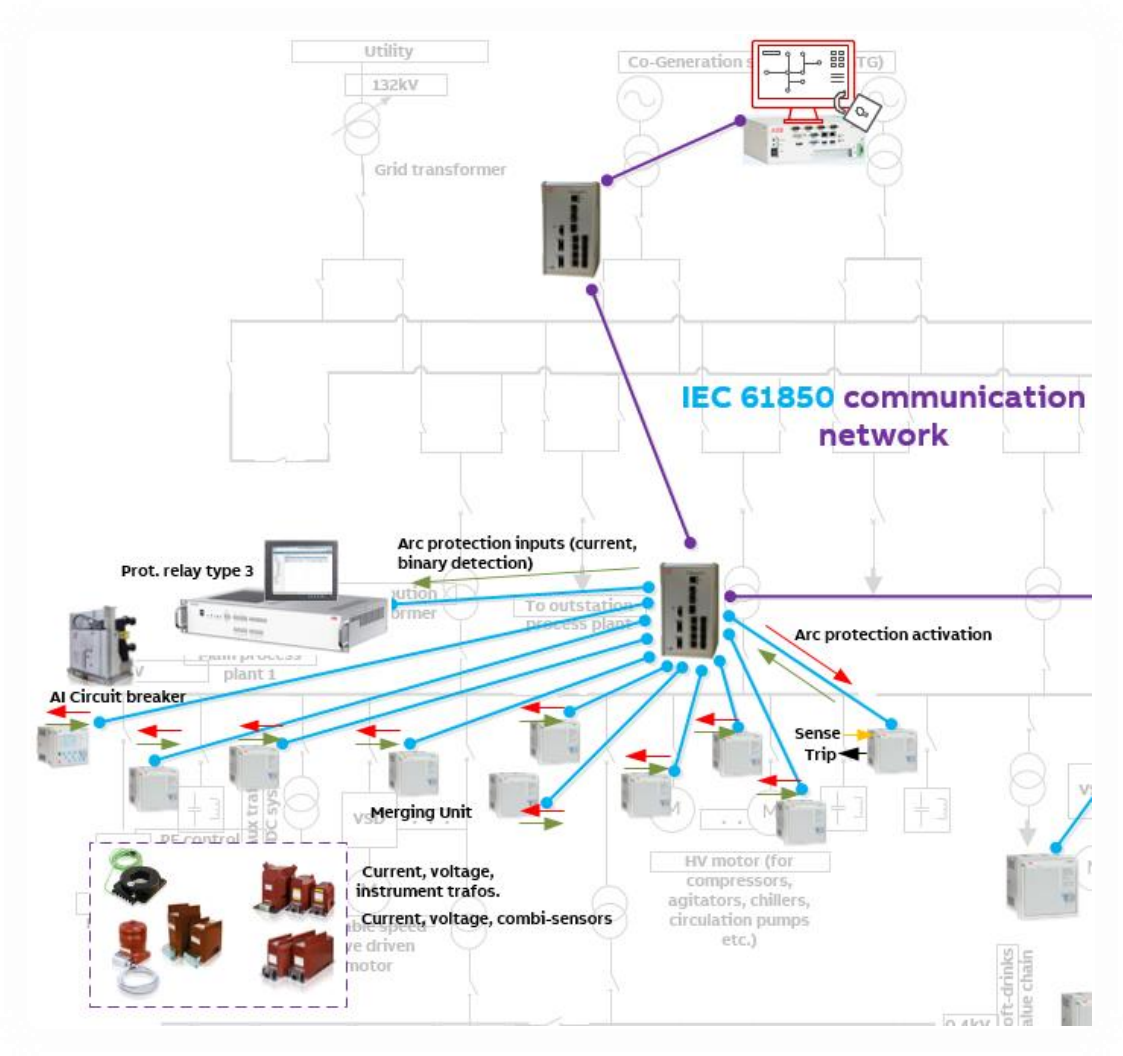


Figure 19: Arc protection, 11kV

The 0.4kV LV circuit breaker type 1 with integrated protection itself takes care of arc flash detection, protection activation and isolation in LV AI switchgear type 2 (PCC).

Using a combination of parameters of (minimum) time delays based on instantaneous ground fault, directional overcurrent and over-temperature detection, sufficient selectivity is maintained between downstream and upstream devices. Also individual actions by the device is possible, independent of instantaneous protection functions, when the circuit breaker is being taken in maintenance (when energy level is lower than when during operation).

Using a combination of a dedicated LV arc protection device type 2 and LV circuit breaker type 1 (dedicated LV arc protection device type 1), a comprehensive arc protection system can be realized that can trip up to 3 circuit breakers in the LV switchgear. For handling more circuit breakers, additional dedicated LV arc protection device type 2 units will be required.

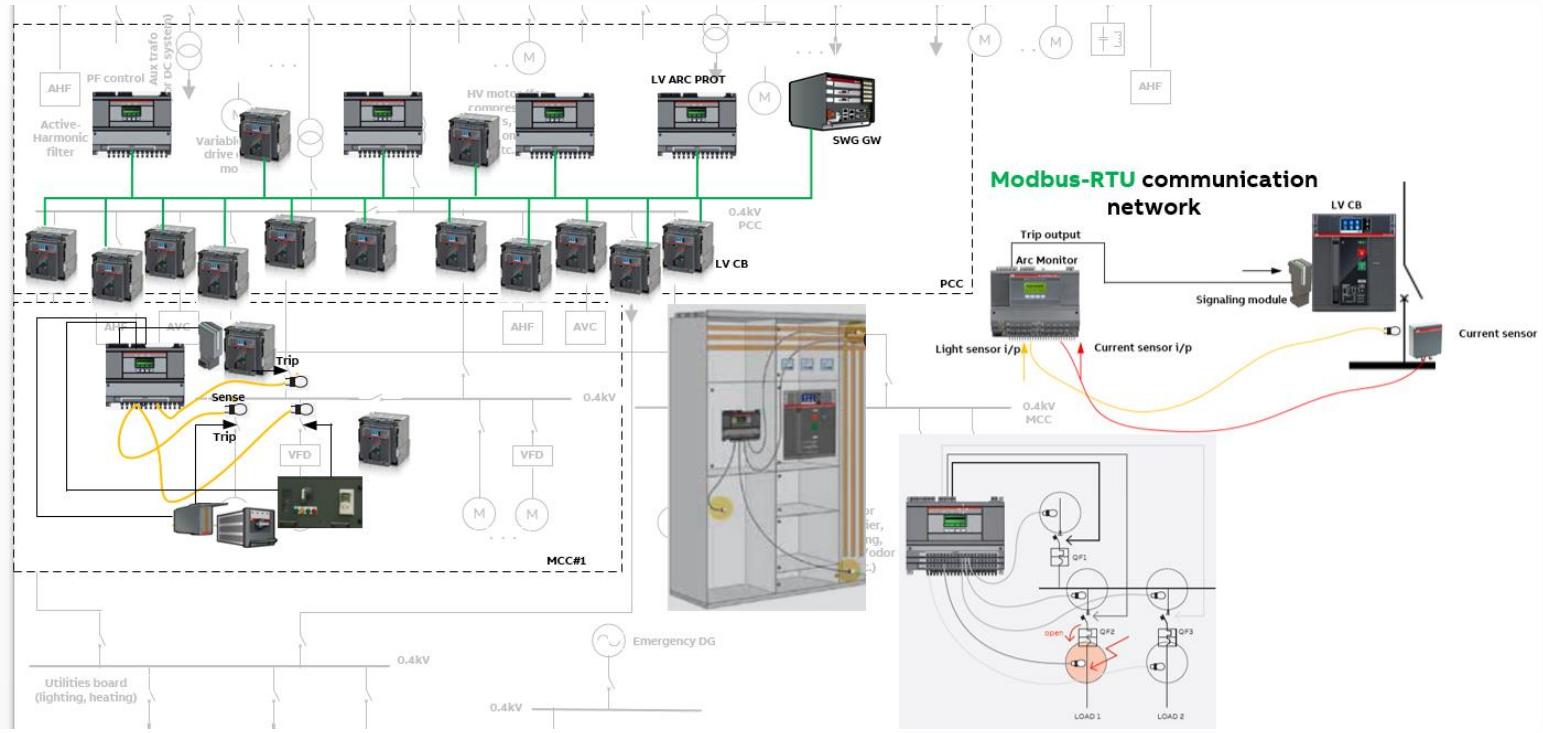


Figure 20: Arc protection, 0.4kV

10. Short circuit current (SCC) limiters facilitating system augmentation

When manufacturing capacity need to be increased, it mostly implies that power distribution arrangement also needs to be augmented. New load feeders need to be added at the 22kV level (additional panels in the 22kV switchgear line up) to cater to the new process plant(s). And if the existing power source arrangement is inadequate to cater to the additional load, then additional power source(s) may also be needed.

The introduction of new power sources would add to the fault levels at the 22kV level. In such a case, short-circuit current (SCC) limiters are added in each phase of the busbar (like a fuse) between the existing and new part of the 22kV switchgear.

For short circuit faults that are above system permissible capacity, the SCC will isolate the two systems by tripping the bus coupler between the two sections and limit the short circuit current within 0.6 ms after detection. The fault level is brought to the levels that existed before the system augmentation. This ensures an easy system extension and also that the customer need not invest in replacement of bus bars and circuit breaker equipment etc. for the new fault ratings. Therefore, the 22kV switchgear downtime and production losses are also prevented.

See figure ‘System expansion’ below where a typical expansion of the 22kV switchgear by two more panels is shown. Also see Appendix – 2 (Step 13)

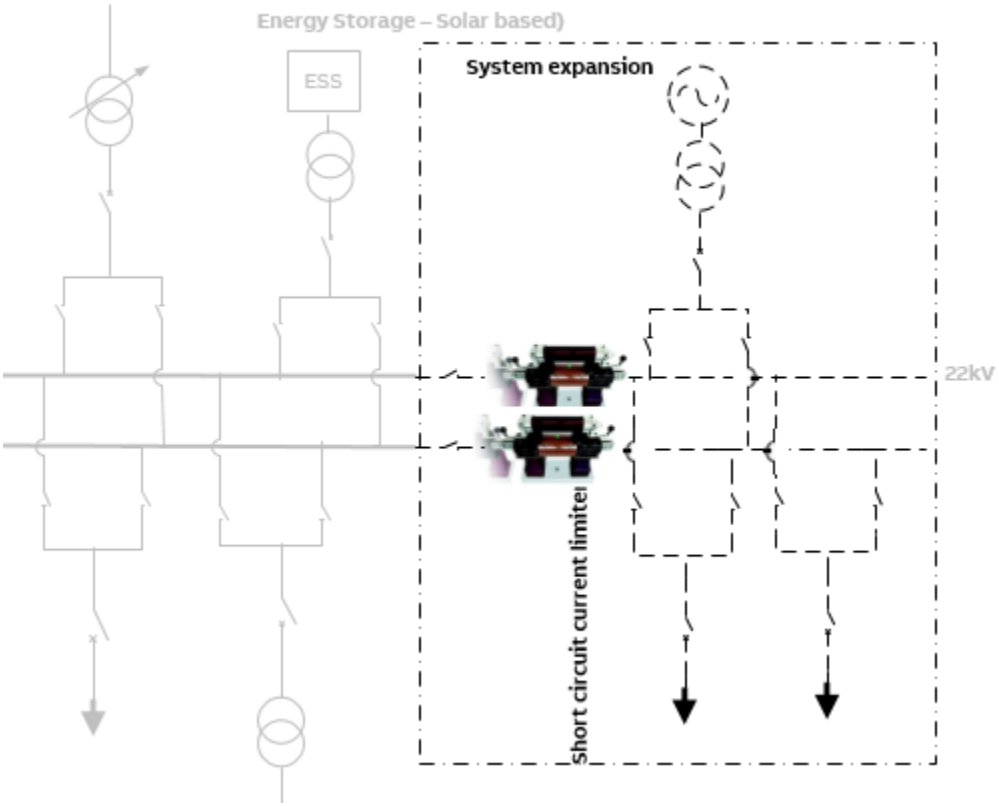


Figure 21: System expansion

11. <u>High-speed bus transfer (HSBT) and Auto-transfer switching (ATS) system</u>

It is paramount to ensure power supply to essential electrical equipment by changing over from one source of power to the stand-by feeder as fast as possible. This is essential to ensure:

- Zero loss of productivity and finished goods' deliveries to the supply chain
- Safety of equipment and personnel
- Zero environmental impact

As per customer strategy and philosophy, the HSBT or ATS solution can be deployed in the main (and support) process plants at 11kV and 0.4kV voltage levels respectively.

It is generally expected that the bulk load in these areas would be HV motors driving heavy duty pumps, fans, conveyors, compressors etc. Such critical loads need to be ensured with continuity of power supply (a requirement also for load-shedding). In a two incomer and one busbar tie configuration (as represented in the figure 'HSBT-ATS'), the two incomers are closed and the busbar tie or bus-coupler is open. In case one of the two incoming feeder trips (due to transformer failure or cable/line fault etc.), it is essential that a fast and automatic transfer of the loads (in the affected busbar section) is ensured by closing the bus-coupler circuit breaker (and thereby connecting the affected busbar section to the available incomer feeder).

The HSBT and ATS solutions, though identical in operation, mainly differ in the speed of operation and the devices/equipment involved.

Please see figure below (HSBT-ATS).

The 11kV main process plant HSBT solution would comprise of the following:

- Dedicated HSBT relay
- Protection relay type 4 at incomers with high-speed binary output contacts
- Interface between the HSBT relay and incomer relays is based on dedicated hardwiring.

The protection relay type 4 at the 11kV incomers detect fault conditions on the incomer feeder like undervoltage or underfrequency or any desired fault condition detection etc. and send this protection activation signals to the HSBT relay using high speed outputs*. Also the incomer circuit breaker status is sent.

The HSBT relay considers voltages of the bus sections and the incomers and the signal information from the incomer relays, before activating the close command to the bus coupler circuit breaker. Considering the closing time of the proposed MV AIS circuit breaker (~60 milliseconds), the total transfer time could be about 75 milliseconds. Using a special circuit breaker with ~16 milliseconds closing time, the overall transfer time could be faster (~30 milliseconds).

Depending on the type of the load on the busbar (static or rotating), the philosophy can be decided (type of hardware IOs, detection/activation, circuit breaker type etc.). Typically, with rotating equipment and therefore the associated inertia, the time for transfer can be higher (as voltage does not collapse), say around 100 milliseconds than with static loads, where the switch over needs to be ensured within 30-40 milliseconds (before the undervoltage detection + operation happens).

The results of the action are reported by the HSBT relay to the HMI/gateway using IEC 61850 MMS.

On the other hand, the ATS at 0.4kV level of the main process plant (PCC, MCC#1 and MCC#2) would comprise of the following:

- 0.4kV AIS circuit breakers at the incomers and bus coupler, integrated with protection and control (see section 9 in this chapter) PLUS ATS application (Auto transfer (HSBT) unit type 1)
- Above equipment are integrated using IEC 61850 GOOSE.

The incomer fault detection and circuit breaker opening is mainly based on undervoltage condition (or other). After a preset time setting, bus bar dead condition, other incomer healthy status and ensuring ready to close status of the bus coupler, the ATS application residing in the bus coupler AIS circuit breaker equipment issues a close command to itself. IEC 61850 GOOSE communication ensures a fast availability of incomer feeder data in the bus coupler circuit breaker. The overall transfer time of the ATS system is about 120 -150 milliseconds.

Results of the operation are reported by the bus coupler AIS circuit breaker using IEC 61850 MMS.

The dedicated Auto transfer (HSBT) unit type 2 at the 0.4kV utility distribution board/DG incomer level with a current capacity (up to 1200A), ensures an automatic switch of supply from mains to DG or vice versa with substantial flexibility.

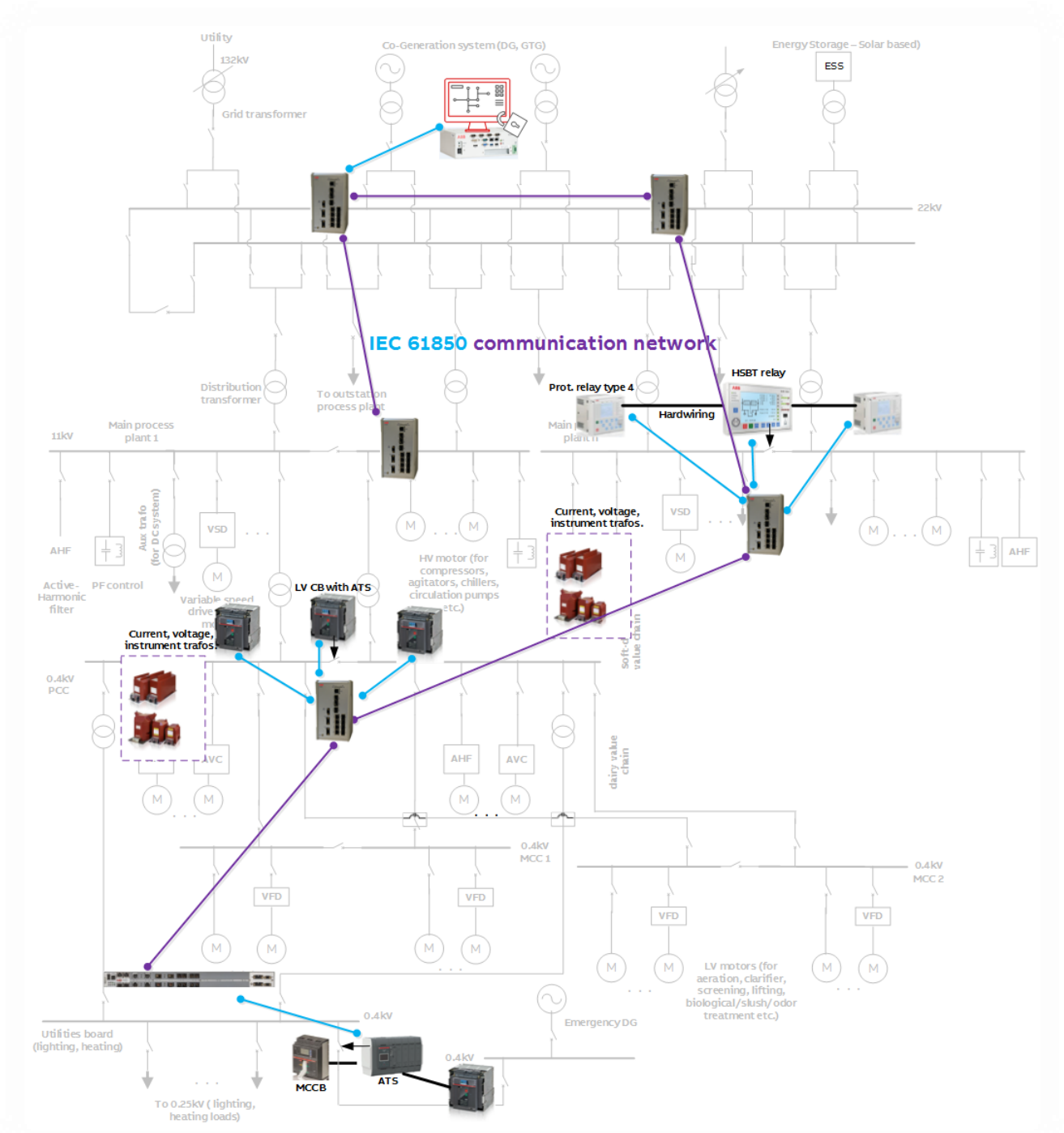


Figure 22: HSBT – ATS

12. Power Quality monitoring and corrective control

All mentioned protection relay types 1, 2, 3 and 4 at 22kV and 11kV voltage levels, as mentioned in section 9 of this chapter, further deliver value by detecting power quality (PQ) conditions and generate alarms. If required, the protection relays can be configured to take necessary corrective actions using these alarms to safeguard against network or equipment failure.

BESS-PCS contributes to power quality at 22kV level by supplying reactive power, when system voltage profile needs a boost.

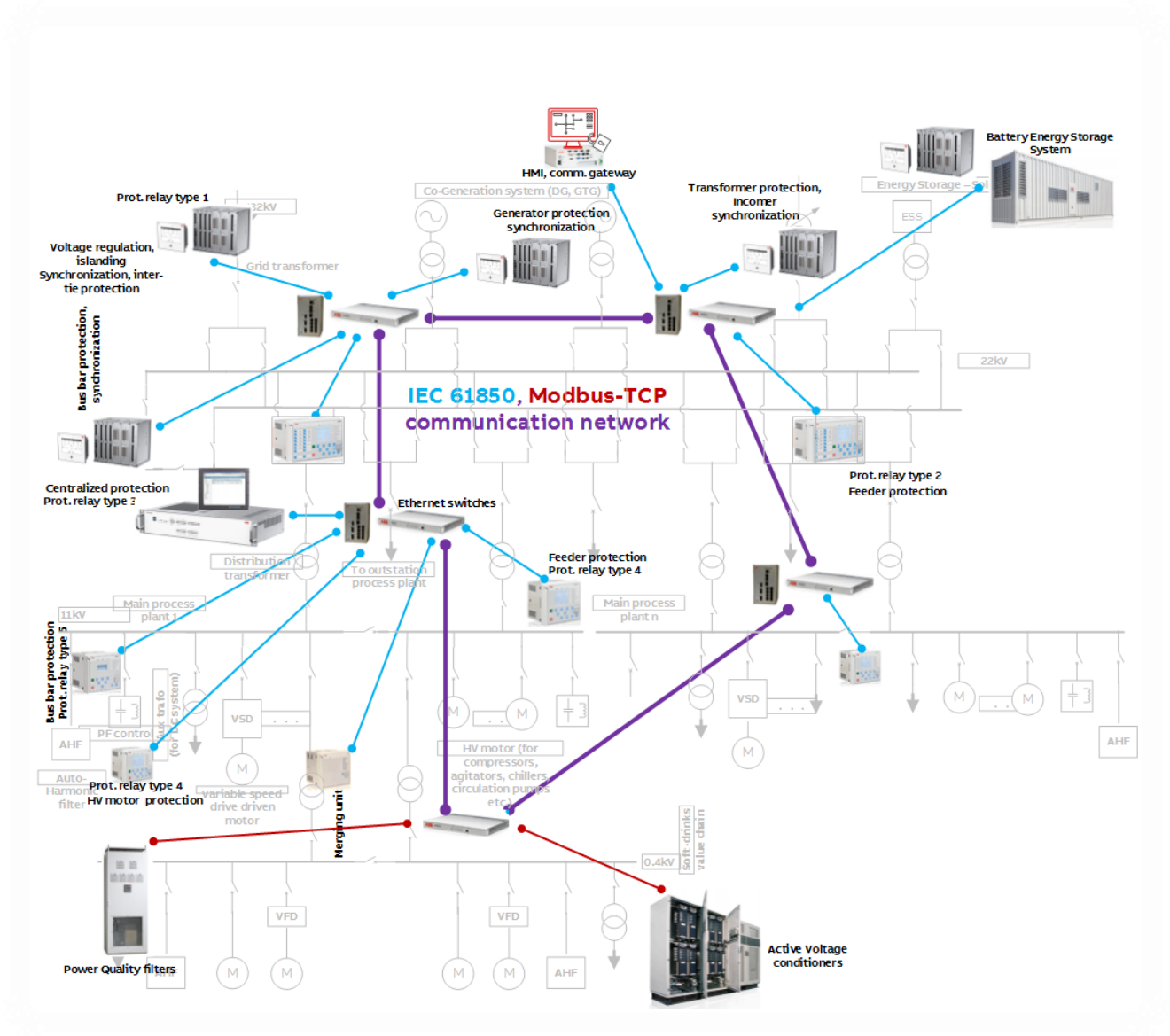


Figure 23: Power quality

Dedicated systems such as Active voltage conditioner (AVC) ensure an instant response to power quality events such as voltage sags and swells (surges) by providing a continuous regulation of voltage and thereby ensuring maximum productivity. The AVC is proposed at 0.4kV level where predominantly motor loads are connected that are either at constant speed (continuous operation) or driven by variable speed drives (VSDs). Voltage variations can adversely impact VSDs by affecting the voltage level of the VSD's DC bus, potentially causing it to exceed its overvoltage trip point.

At the 0.4kV and 11kV levels exist a substantial motor loads with variable speed drive units (VSD) that contribute to power quality problems such as harmonics. An active power quality filter or harmonic filter (AHC) is proposed to be installed directly connected to the bus sections with VSD based motors, which would monitor the line current for each harmonic (and reactive power component). Accordingly, it can then compare this value with the set target by the customer. It then generates for each harmonic frequency, a compensation current in perfect phase opposition to the 'polluting' current. Thus the deviations are automatically eliminated.

All PQ related measurement and actionable data are recorded in the protection relays, BESS-PCS, AFC and AHC and reported to the HMI/gateway using IEC 61850 MMS and Modbus-TCP.

13. Communication system redundancy

Data communication network reliability and availability are a standard pre-requisite. Besides, any new devices added to the network due to system augmentation should be easily accommodated without additional investment.

The IEC 61850 communication network can be duplicated, based on IEC 62349-3 Parallel Redundancy Protocol (PRP), for additional reliability and availability of the overall system as shown in figure 'Communication redundancy'.

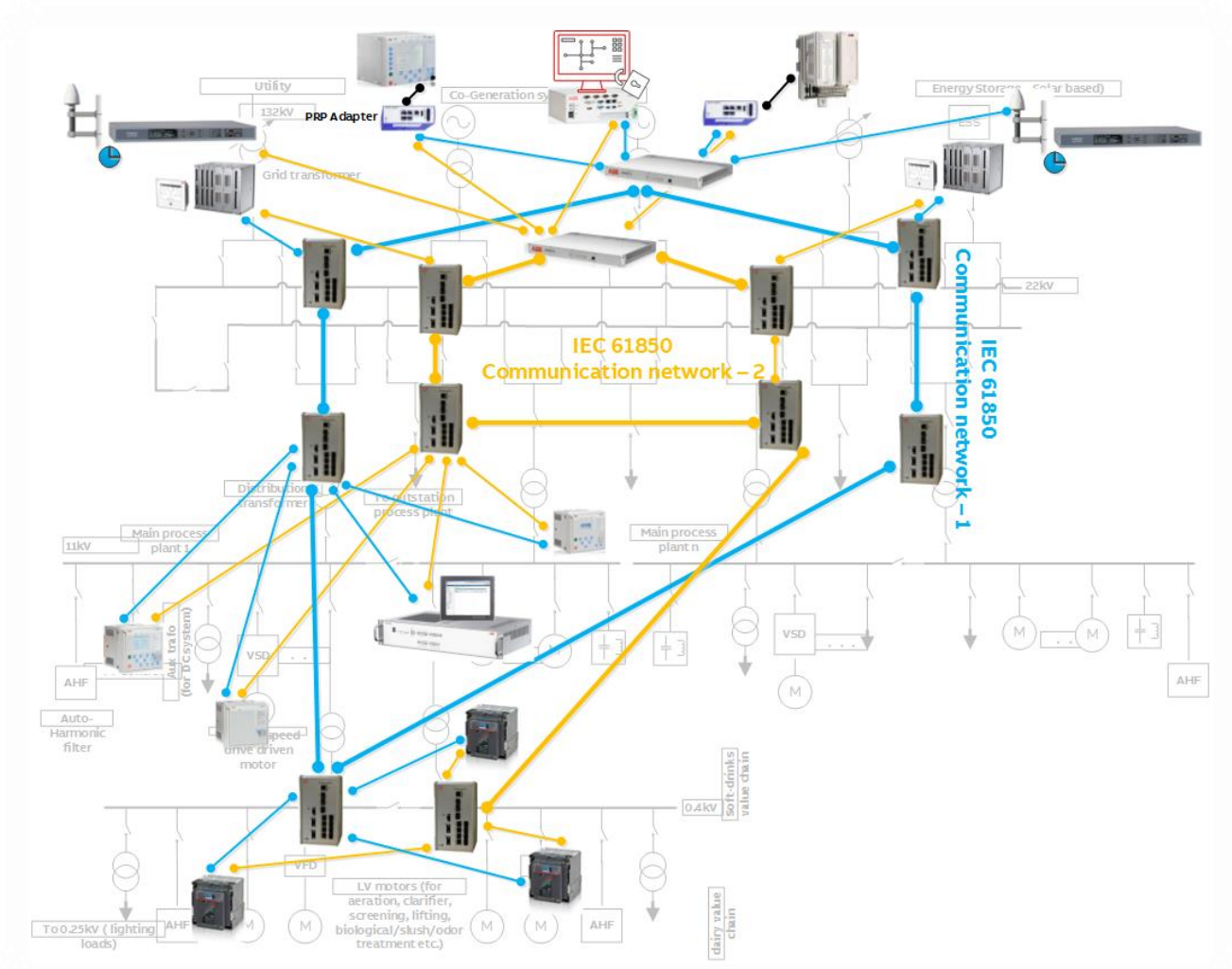


Figure 24: Communication redundancy (MV, PCC)

Each IEC 61850 compliant device or unit is connected to communication networks 1 and 2 that have their own addressing ranges. Devices that do not have dual ports to address redundancy need to be deployed with a PRP adapter. The time server device can be duplicated and connected to the respective networks.

Similar to the above, system redundancy can also be established at the MCC#1 and MCC#2 levels, especially when there are important motor feeders to be accessed/controlled without loss of availability. The relevant switchgear gateway level and the associated fieldbus as shown below.

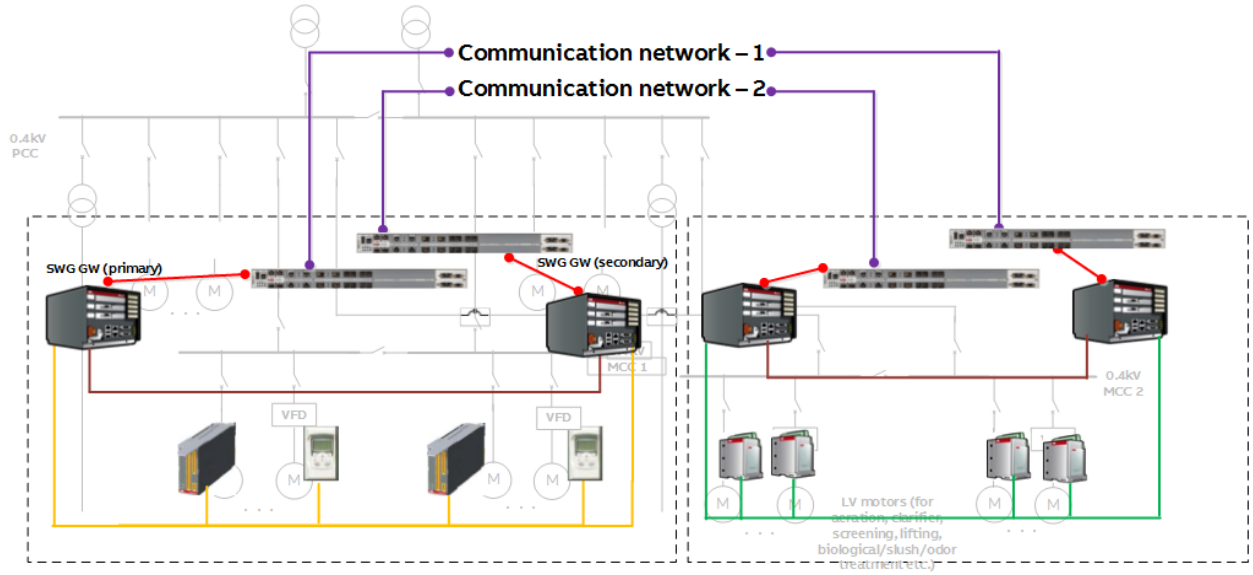


Figure 25: Node and communication redundancy (motor control)

Motor controllers types 1, 2, 4 get connected to primary and secondary switchgear gateways and report data to both units. The primary unit is 'hot' and the secondary is the 'standby'. Both units get updated with data from the motor controllers. However only the 'hot' unit sends data to the upstream system.

In the MCC#2, motor controller type 3 units are replaced by motor controller type 4 units, as they support dual RS485 communication ports (different to the earlier solutions, which covered motor controller types 3 and 3 also).

This arrangement provides:

1. Primary and secondary switchgear gateway units, connected to two separate communication networks.
2. Capability of the upper level system to read information simultaneously from primary and secondary switchgear gateway units.
3. Increased process availability
4. An inbuilt functionality controlling switching commands permissions

14. Intelligent substation asset analytics aiding predictive maintenance

Significant capital investments are made in procurement and deployment of electrical equipment like transformers, switchgear, circuit breakers and motors. These assets need to be maintained proactively to ensure longevity of service, reduce or eliminate outages and running operation with

minimal equipment inventory. Thus, **protection of capital investments** and **optimal asset utilization** can be realized, leading to better **operational efficiency**.

Conventional instrument transformers and sensors collect process voltage, current and position information from substation assets and switchgear equipment such as bus bars, transformers, circuit breakers, feeder cable cores, capacitor banks etc. This physical information is transformed into several digital signals by merging units, protection relays, energy meters, substation process controllers etc. using dedicated software in the form of protection, measurement/metering and monitoring functions or applications.

The generated digital data can be analyzed within the substation or remotely and lets the customers "know more" by providing insights about asset conditions, trends and alerts on their infrastructure.

Using control applications, the substation devices convert the processed digital data back into physical action like controlling position of circuit breakers, tap changers, frequency or voltage regulation etc. This helps customer to "close the loop".

The next step would be to optimize and improve the situation further like reducing energy consumption, reduction of faults, improving cyber security etc. For instance, the plant data can be remotely analyzed in a dedicated cloud environment and can be subject to digital simulations of substation equipment to produce customized maintenance reports. The generated reports can be used to assess the substation asset condition, associated risk levels, cost impacts and schedule preventive maintenance activity that would enable maximize asset life, while minimizing maintenance costs. This enables the customers to "do (things) better".

Optimization within a single plant may often require improvements, requiring them to collaborate with partners in the supply chain. For example, in order to optimize operating energy costs, it may be at times be better to import power from the network than operating in-plant generation, especially if it is based on non-renewable sources. The cost of importing power plus the customer side grid transformer losses may be lesser than operating captive generation (gas, steam or diesel). In such situations, having live power trade market place data would enable purchasing power and enabling the customer to do things "together".

Refer to the figure 'Remote analytics' aspects for the 11kV and 0.4kV process plant AIS lineup.

In the below example, every 11kV MV AI switchgear panel's circuit breaker is mounted with sensors detecting temperature information the circuit breaker's lower and upper arms (all 3 phases) and partial discharge information. This data is sent to the HMI/gateway unit. Also feeder current values from the centralized protection device (protection relay type 3) and protection relay type 4 units associated with the 11kV incomer are also sent.

The intent is to calculate temperature using the current information. Using the temperature and current values, the temperature rise can be calculated.

Similarly, 0.4kV circuit breaker, together with other equipment in the LV switchgear such as circuit breakers, motor controllers etc. provide energy data, equipment data for energy management, condition monitoring and predictive maintenance to their respective switchgear gateway units.

The downstream devices at voltage levels (from 22kV to 0.4kV) can be modelled according to well accepted methods such as JSON or OPC-UA for Cloud connectivity. IEC 61850 or Modbus-TCP data from downstream devices need to be mapped to data and event services of JSON or OPC-UA, in a device called 'Edge gateway'. Data reported from the downstream devices to the HMI/gateway unit and data generated by applications run in the HMI/gateway unit can be used to 'populate' these instantiated object models in the Edge gateway.

Two levels of Edge gateways are proposed, one for MV (22kV, 11kV levels, called Cloud gateway type 1) and the other one at the LV - 0.4kV level (Cloud gateway type 2) respectively.

Cloud gateway type 1 is gets data directly from downstream protection relays on IEC 61850 or Modbus-TCP, while type 2 gets data from the LV switchgear gateway units.

Advanced analytics can be carried out in a remote cloud computing environment and results presented, using which preventive maintenance can be scheduled.

Besides advanced analytics, the same infrastructure can also be used to perform life cycle and fleet management of substation relays and devices.

With connectivity from the plant substation communication network to external systems, it is extremely essential that adequate **cyber-security** aspects are also in place to safeguard the plant power automation and control equipment against cyber-attacks. Robust, safe, highly available substation communication networks are a necessity.

Adequate and necessary cyber security features are incorporated in the Edge gateway, HMI/gateway and in downstream relays and devices in the plant network

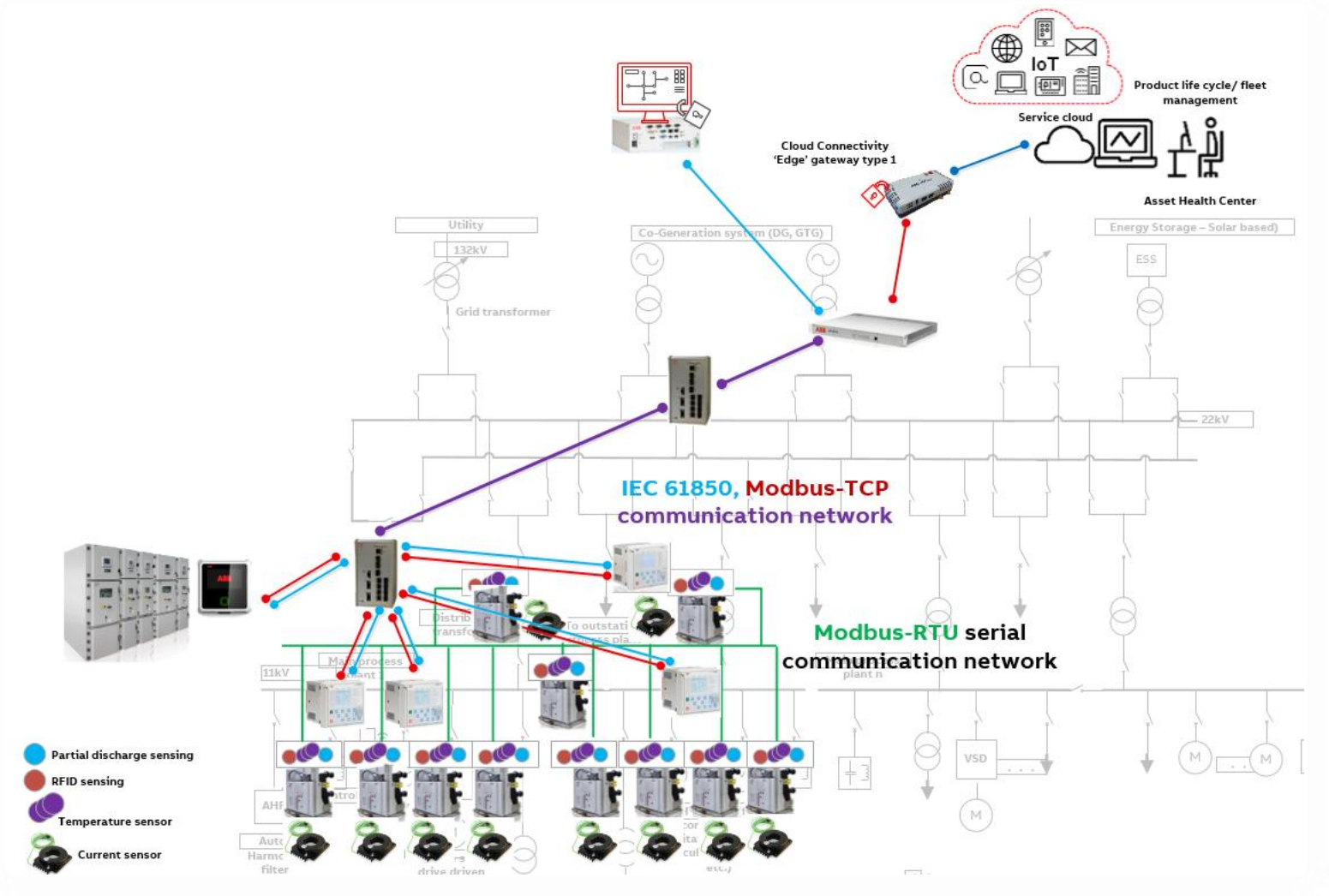


Figure 26: Remote analytics – 22kV, 11kV

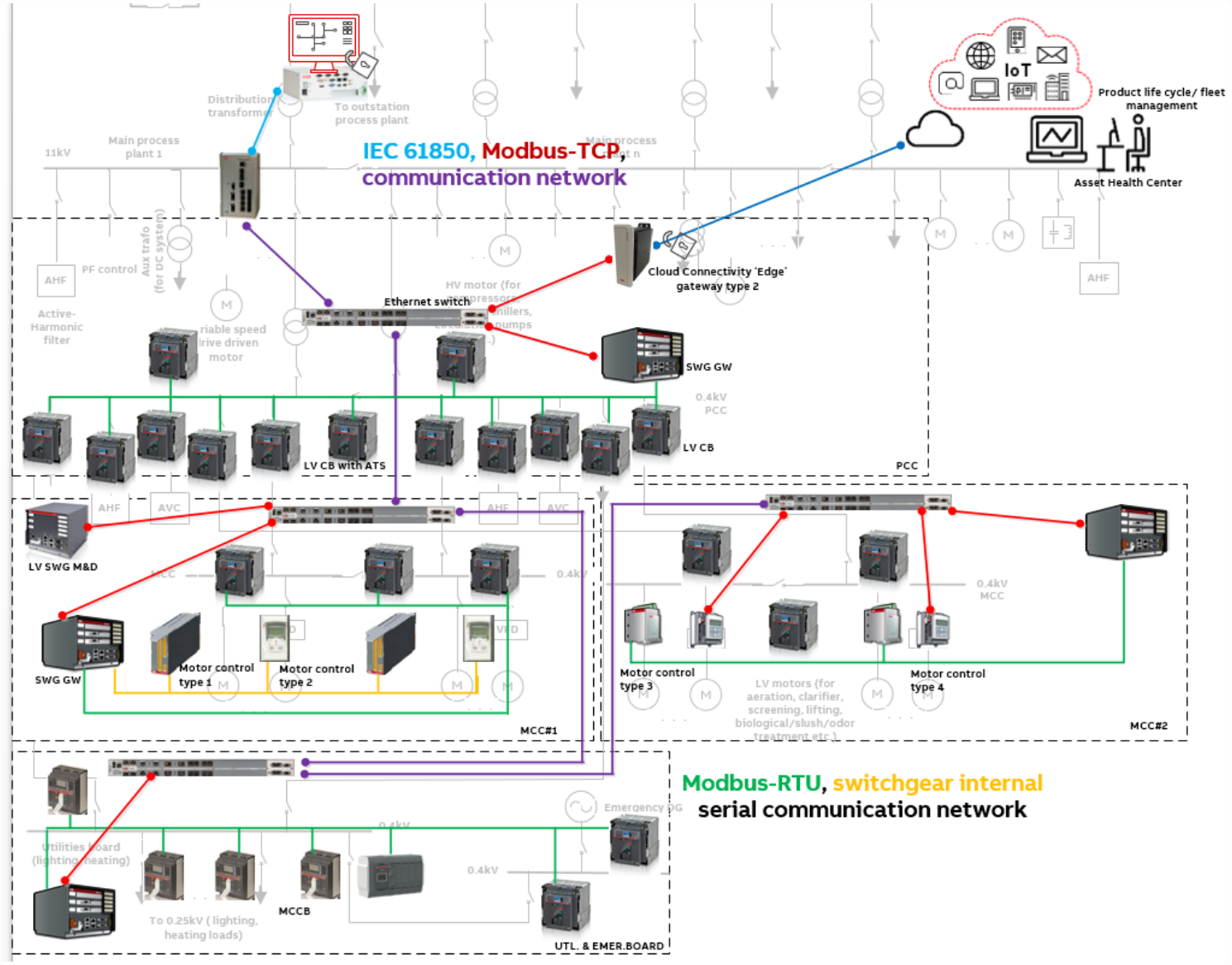


Figure 27: Remote analytics – 0.4kV

15. Interface to Distributed Control System (DCS)

The electrification automation system should be integrated with the process DCS in order to have an integrated approach to the plant monitoring and operations thereby improving overall operational efficiency.

The interface of the electrification automation system with the DCS is envisaged for sending electrification process information (measurements, process alarms/events, substation auxiliary system information etc.), to facilitate control of equipment such as circuit breaker operation for

motor on/off operations and also to run applications that may use both manufacturing process and electrification data and initiate automated actions.

The envisaged modes of communication between the electrification or power automation system and DCS are as follows:

1. IEC 61850 MMS, GOOSE
2. Modbus-TCP, serial
3. OPC DA
4. Profibus-DP

The DCS interface is envisaged at the following levels:

1. Between protection relays type 1 to 5, IO interface and DCS controller (IEC 61850 GOOSE, Modbus-TCP/serial, or Profibus-DP)
2. Between load-shedding relay, power controller and DCS controller (IEC 61850 GOOSE, Modbus-TCP or OPC DA)
3. Between protection relays type 1 to 5, load-shedding relay and DCS operator workplace (IEC 61850 MMS, Modbus-TCP)
4. Between power controller and DCS operator workplace or controller (IEC 61850 GOOSE or OPC DA)
5. Between HMI/communication gateway and DCS controller (OPC DA, Modbus-TCP)
6. Between HMI/communication gateway and DCS operator workplace (OPC DA, Modbus-TCP)

Note: The HMI/communication gateway can be used as a protocol converter between protection relays/load-shedding relay and power controller and the DCS controller, in case the latter cannot support IEC 61850 GOOSE, that is, conversion of OPC/Modbus-TCP to IEC 61850 GOOSE.

The above protocols could be available from the DCS operator interface (through its front-end communication servers) or the DCS process controllers.

Not all communication protocols could be supported by a single device. Only possibilities are indicated.

Depending on point of control or control hierarchy, the HMI/communication gateway unit passes on the supervisory control authority to the DCS (operator station) when remote control is desired. Similarly, it can also take away control authority from the DCS, when control is desired from the power automation system HMI (already discussed in chapter 7 of this section). This is only applicable when the DCS is present as a higher-level automation system.

In other cases, when the HMI in the power automation system is not present or when a unified visualization system is preferred for both process and power automation systems, then the DCS process visualization assumes this role.

The following data is envisaged for data exchange between the two systems:

1. Substation or electrification measurements, circuit breaker/disconnector status, feeder alarms etc. from protection relays (types 1 to 5).
2. Common substation alarms, events (HVAC, battery charger, UPS etc.) from IO extension units

3. Special application status and information from load-shedding relay and power controller
4. Generator process side data such as ambient temperature, spinning reserve etc. from DCS controller for power management functionality such as load-shedding and power generation control.
5. Control actions (manually or automated) from DCS operator workplace / process controller

A few scenarios are presented here for control of downstream circuit breakers on 11/6.6kV and 0.4kV levels.

Solution 1 for motor feeder and non-motor feeder control at 11kV or 6.6kV at main or remote outstation process plants

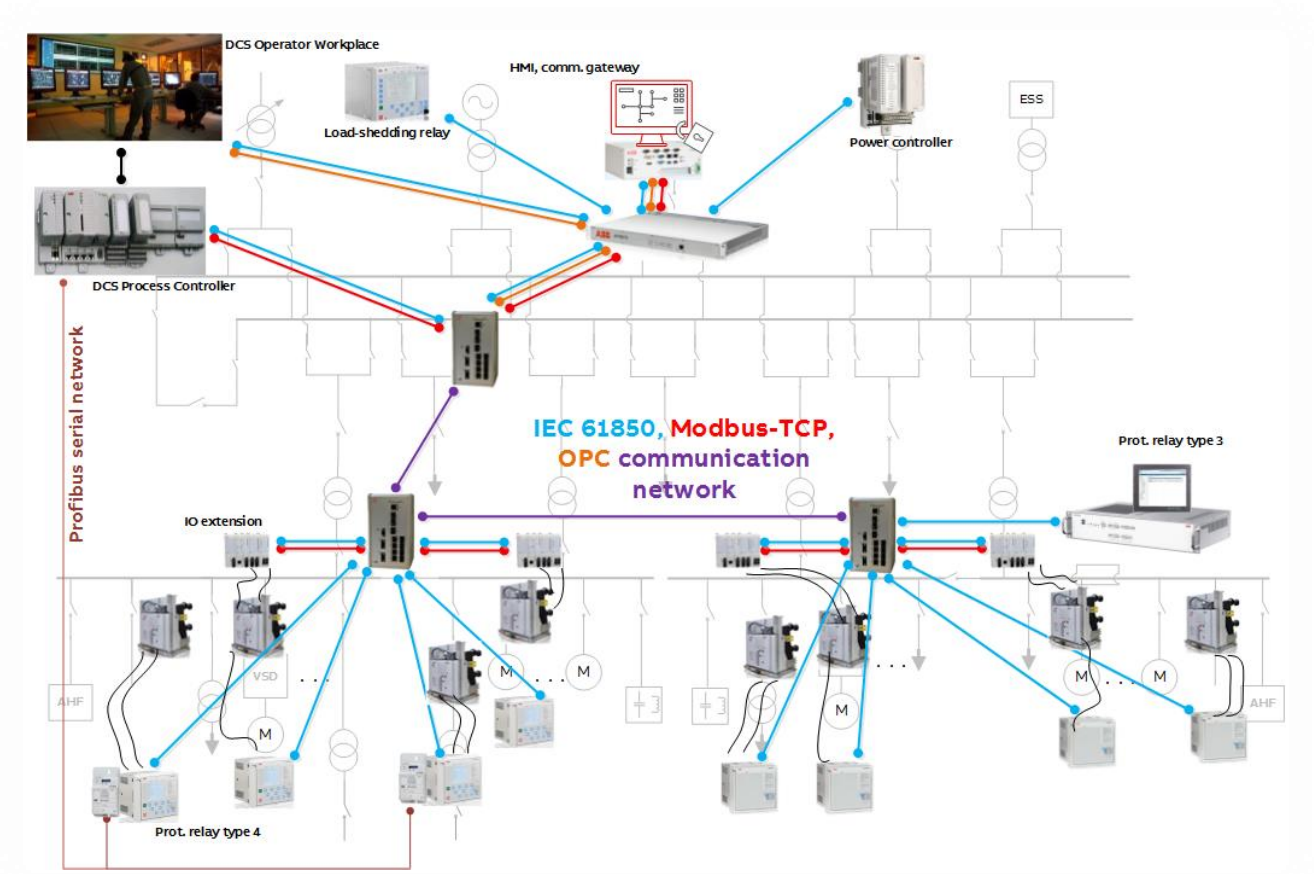


Figure 28: DCS interface with 11kV part of network

In the above figure, it is considered that the main process area (left side) is based on dedicated motor or feeder protection (relay type 4), while the right hand side process area is based on a centralized feeder protection and control (protection relay type 3) and merging units.

IO extension devices communicating on IEC 61850 GOOSE or Modbus-TCP are also connected to the respective process areas' Ethernet switches.

For process area (left side)…

1. Motor start and stop commands are issued from the DCS operator workplace executed through the DCS controller.

2. Commands are directed to the IO extension units over IEC 61850 GOOSE or Modbus-TCP
3. From the IO units, the start and stop commands are directly wired into the close and trip coils of the 11kV AI circuit breaker.
4. The corresponding motor protection relay only issues trip command, based on protection functionality.
5. For non-motor feeders, start and stop commands are issued from the DCS operator workplace to respective protection relays (type 4) using IEC 61850 MMS, which then operates the circuit breaker to open or close it.
6. In case, the customer has a preference of using Profibus-DP as the communication protocol with the DCS, then the DCS controller acts as a Profibus-DP master to the Profibus slave devices (protection relay type 4 with Profibus-DP adapters).

For process area (right side)…

1. Motor start and stop commands are handled and directed to IO extension units over IEC 61850 GOOSE or Modbus-TCP, similar to the 'left side'.
2. The protection relay type 3 (centralized protection and control device) executes its protection trip through its corresponding merging unit, which then extends the tripping signal to the circuit breaker.
3. Similarly for non-motor feeders, the start and stop commands are issued from the DCS operator workplace to the centralized protection and control device that are executed by the respective feeder's dedicated merging units.
4. Profibus-DP based alternative communication is not possible in this case.

In both situations mentioned above, OPC-DA communication can also be used between DCS operator workplace and HMI/communication gateway to execute the close/open operations of the 11kV and 6.6kV circuit breakers.

Solution 2 for motor feeder and non-motor feeder control at 0.4kV at main or remote outstation process plants

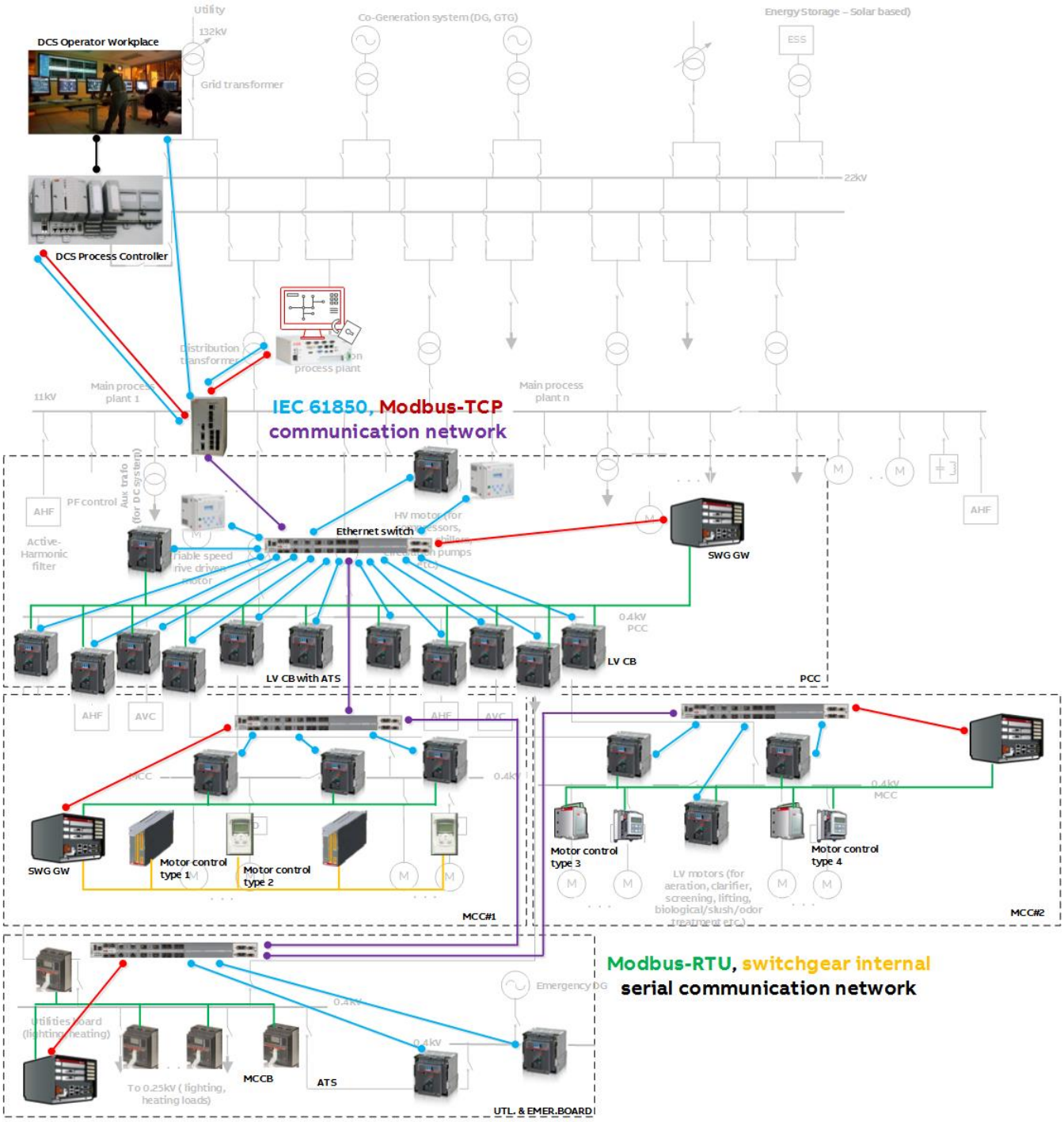


Figure 29: DCS interface with 0.4kV part of network (1)

The 0.4kV system's motor and non-motor feeder control from DCS have the following possibilities.

1. Control of integrated circuit breakers using IEC 61850 and Modbus-TCP
    a. The PCC feeders can be directly controlled for close and open operations from the DCS operator workplace over IEC 61850 MMS.
    b. The MCC#1, MCC#2 incomer and bus coupler feeders and Emergency board feeders can be operated using Modbus-TCP.
2. Control of outgoing motor and non-motor feeders using Modbus-TCP/Modbus-serial
    a. MCC#1 outgoing motor feeders are controlled via the switchgear gateway (Modbus-TCP). The commands to the motor controller units from the switchgear gateway would be over a proprietary protocol. MCC#2 outgoing motor feeders are also controlled via the switchgear gateway (Modbus-TCP). However, the eventual control commands are converted to Modbus-serial (Modbus-RTU) using a converter, which is not represented.
    b. The incomer and outgoing feeder MCCBs in the utilities board are controlled remotely operated using Modbus-serial interface.

An alternative for the PCC, MCC and utility/emergency board motor/non-motor feeder control from the DCS is using Profibus-DP through LV switchgear gateway type 1 or 2, as shown below.

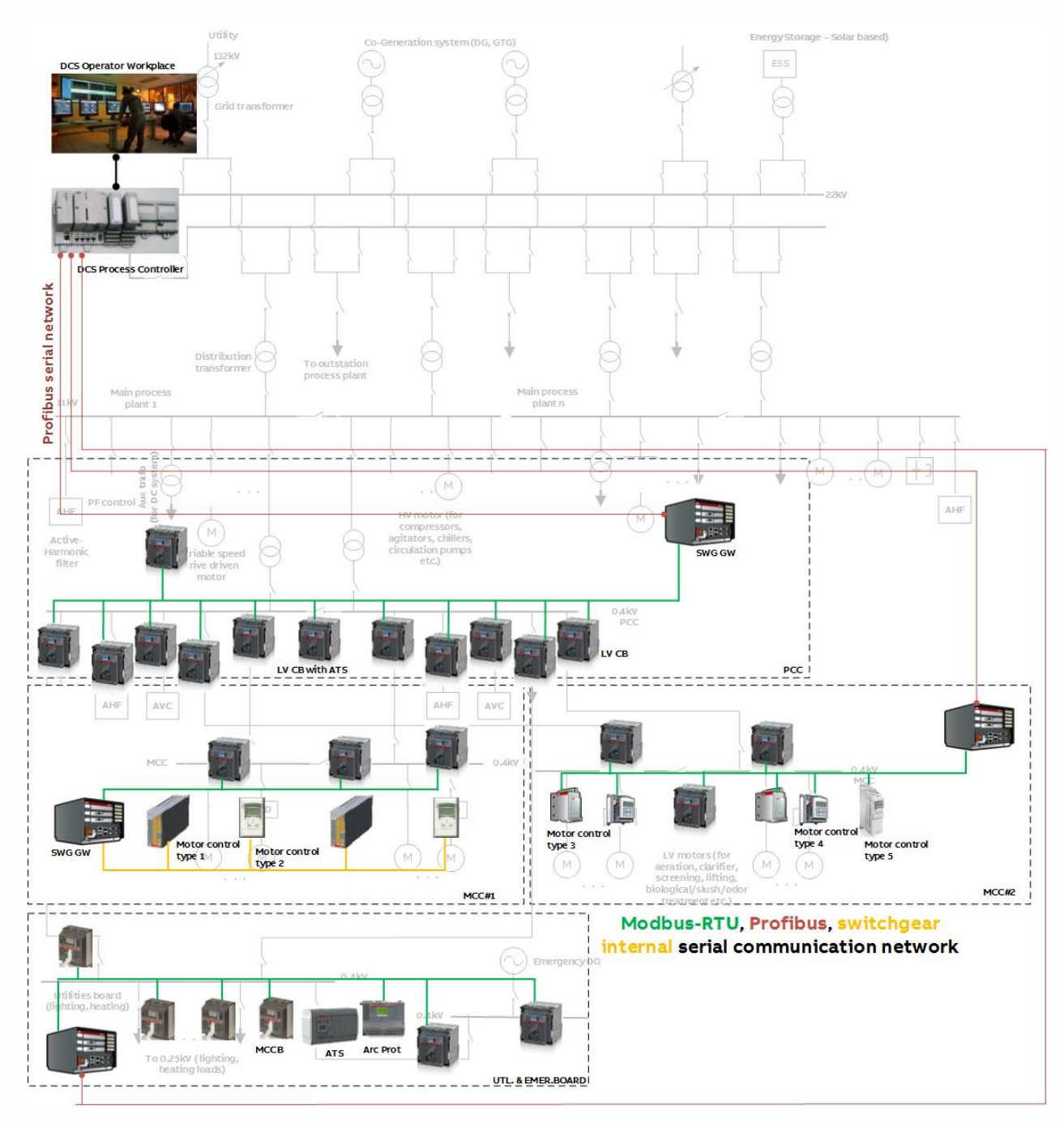


Figure 30: DCS interface with 0.4kV part of network (2)

VII. Appendix – 1 (Solution components)

Having described the challenges, nature of possible solutions and the example from the use case, we map the proposed products (solution components) from ABB's power distribution equipment portfolio to the KPIs.

We start with the components nearest to the process and work layer by layer towards the top. We briefly describe each component and its contribution towards the KPIs.

Note: While most of the products, enlisted in this section have been mentioned by their generic names and their roles in the different solutions have been covered in Section VI, there could be some products that could be standalone with no coverage at all in Section VI.

KPI addressed	ABB solution component and role	Values
• People safety • Operators need to handle secondary signals only amounting to a few volts	 **Sensors** • Voltage sensor – **KEVA series** (sensing primary side voltage) • Current sensor – **KECA series** (sensing primary side current) • Combined sensors – **KEVCD series** (sensing primary voltage and current)	• High accuracy (class 0.5/3P) • High linearity • Large dynamic range (up to 4000A; 50kA; 36kV) • No saturation • No Ferro-resonance • Small dimensions, light weight • Compatibility with Relion protection relays, air insulated and gas insulated switchgear
	 **Indoor instrument transformers** • Voltage transformer – TJC • Current transformer – KOKS, BB, BBO, TTR	• A broad selection of instrument transformers ranging up to 40.5 kV. • Can be installed in any position within a cubicle-type or cellular-type MV switchboard • Transformers can be equipped with fuse, introduced in the primary winding, or without fuse. • Providing cost savings through innovative technology
• People safety • Optimizing total cost of ownership • Safeguards investment	 **Is-limiter** (reduce high short circuit currents, advanced fault current limiter in existing or new installed networks)	• Immediate fault current interruption before the first current peak • Optimized protection concept • Selective tripping in predefined areas • Selective fault current limitation • Very high adjustability and flexibility • Up to 40.5kV, 5000A and 210kA breaking capability • Highest stability with regard to unnecessary tripping

KPI addressed	ABB solution component and role	Values
• People safety • Optimizing total cost of ownership • Safeguards investment	 **Surge Arrestor (MWD)** • Shed-less surge arrestor for indoor medium voltage/distribution systems up to 52kV. • Secure protection against overvoltages from atmospheric discharge and switching conditions.	• Proven safe short-circuit current design • Excellent protection level with low residual voltage • Maintenance free • Nominal discharge current 10kA$_{peak}$ • Thermal energy rating 5.0kJ
• People safety • Continuous operation • Safeguards investment	  **VD4 vacuum circuit breaker** (1.5 – 3 cycles of closing or opening time) **VM1 vacuum circuit breaker** (0.5 – 0.8 cycles of closing or opening time)	• Sealed-for-life poles • Operation under different climatic conditions • Stored energy operating mechanism with anti-pumping device supplied as standard • Fixed and withdrawable versions with front operating mechanism • Circuit-breaker racking-in and racking-out with the door closed • 12-46kV, 630-4000A, 16-50kA • Optional intelligent unit for integrated protection and control based on IEC 61850 available. • Medium voltage circuit breakers with magnetic actuator for primary distribution up to 24 kV, 3150 A (4000*), 50 kA. • Maintenance-free solution, ideal for highly demanding applications • Ideal for applications requiring frequent switching

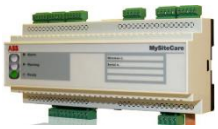
		• Special version available for fast transfer switch application • Electronic board performs diagnostics on circuit-breaker conditions • Suitable for a wide range of auxiliary supply voltages
	 • **HD4 SF6 circuit breaker** (1.5 – 3.5 cycles of closing or opening times)	• Medium voltage gas breaker with mechanical actuator (spring mechanism) for primary distribution up to 40.5 kV, 3600 A, 50 kA. • Unique ABB quenching technique (without arc chopping and without generation of overvoltage) to ensure smooth switching operations • Ensures ling electrical life of circuit breaker and limited dynamic, dielectric and thermal stresses on the installation • Ideal circuit breaker for revamping and retrofitting in aging plants in which insulating materials have been stressed since for a long time • Only one common actuator for up to 40.5 kV with a wide range of accessories, safety locks and interlocks

	 • [Emax 2 all-in-one circuit breaker] (3-4 cycles of closing or opening times)	• Compact dimensions and high performance. Up to a 25% cost savings in both footprint and copper. • Ease of use and safety • Productivity is increased while all stages, from design to daily operations, are simplified. • Up to 15% time savings for terminal connection installation. Unique alarm tracking and network analyzer for the best continuity of service. • Up to 6300A, 200kA (IEC) • Up to 5000A, 100kA (ANSI)
KPI addressed	**ABB solution component and role**	**Values**
• Contributes towards KPIs addressed by SSC600 (multi-feeder protection and control device) • Ambient insensitivity	 **Relion SMU615 substation merging unit** • Substation merging unit to interface with sensors or traditional instrument transformers and circuit breaker interface unit.	• Based on ABB Relion series. • Generates voltage and current samples at 4 kHz frequency according to IEC 61850-9-2LE standard. • Generates data according to IEC 61850-8-1 GOOSE and MMS. • Takes in circuit breaker, disconnector, arc sensor inputs • Closes and opens circuit breaker, disconnector • Runs logic for measurement, monitoring, control and feeder interlock handling. • Combines with UniGear Digital and ZX Digital switchgear with sensors • Operating temperature -25 to 55 deg C • Relative humidity < 93%

KPI addressed	ABB solution component and role	Values
• People safety • Increased asset utilization	 **UFES (Ultra-Fast Earthing Switch)** • Dedicated arc flash protection system for arc elimination < 4ms	• Avoidance of the severe effects of arc faults • Greatly increased switchgear operator safety • Drastic reduction in downtimes & repair costs • Retrofitting of ABB and non-ABB switchgear
	 **REA10x arc fault protection unit/system (x = 1, 3, 5)** • Dedicated/standalone arc flash protection system for detection and trip initiation < 2.5ms.	• Loop or radial type fiber sensor, or lens-type sensor for light detection • Two high-speed IGBT outputs for direct CB trip • Relay output for circuit-breaker failure protection or as an alarm output • Selective tripping schemes by additional REA 105 extension modules
	 **Arc Guard TVOC-2** • An optical detection system that together with an external breaker can limit the damage done to personnel and equipment in case of an arc accident happening. • From light detection to trip initiation < 1-10ms	• Increased safety to personnel and equipment • Minimizes downtime after arc accident has happened • Easy-to-read interface makes reading status information quick and easy • Simple start-up menu quickens installation and setup • Can easily be expanded with up to 30 sensors to increase cabinet coverage from a single TVOC-2 • No calibration needed ensures reliable function and quick installation.

KPI addressed	ABB solution component and role	Values
• Food safety • People safety • Maintaining consistency in product quality • Fast and reliable fault detection and isolation • Ambient insensitivity • Increased asset utilization	  **Emax 2 circuit breaker integrated with protection trip, measurement and trip unit with communication functions** • Protection: Designed to protect transformers, motors and drives. • Advance functionality such as ATS, adaptive/predictive load-shedding, adaptive protection etc. • Ekip Touch unit with protection and measurement	• Easy integration to medium voltage automation system using IEC 61850 (GOOSE, MMS) and Modbus TCP communication • All-in-one circuit breaker that matches new smart and integrated industrial power automation requirements.
	 **Tmax XT** • Tmax XT moulded case circuit breakers guarantee an extremely high performance level while being progressively smaller in size, simple to install and able to provide increasingly better safety.	• Up to 250A, 150kA breaking capacity • High breaking capacity in compact dimensions • Ease of use and installation flexibility • Customized protection and information availability • Increased safety for operators • Easy integration to automation system using Modbus RTU, Profibus and DeviceNet
• People safety • Increased asset utilization • Ambient insensitivity	 **Relion 611 series protection relays for bay level protection *(secondary distribution in this use case)*** • Busbar protection (designed for phase-segregated short-circuit protection, control, and supervision of single busbars)	• Bus bar and ideal multi-purpose backup protection • Directional or non-directional overcurrent and earth-fault protection for feeders

	• Feeder protection (designed for protection, control, measurement and supervision of cable or line feeders) • Motor protection (designed for protection, protection, control, measurement and supervision of asynchronous motors in manufacturing/process industry)	• Motor protection and control for variety of drives • IEC 61850 HSR and PRP, GOOSE • Powerful and user-friendly web browser-based human machine interface (HMI) • Support for IEC 61850 GOOSE • Operating temperature -25 to 55 deg C • Relative humidity < 93%
KPI addressed	**ABB solution component and role**	**Values**
• Maintaining consistency in product quality • Food safety • People safety • Fast and reliable fault detection and isolation • Ambient insensitivity • Increased asset utilization • Power quality	 **Relion protection relays for bay level protection *(primary distribution in this use case)*** • Relion 615 series, 620 series, REX640 • Feeder, Transformer, Motor, Generator, Voltage, Capacitor bank & Harmonic filter circuits, Grid interconnection, remote monitoring and control application, Arc, Harmonic based protection, control, measurement and monitoring applications • Extensive range of protection and control functionality, either with sensors or conventional instrument transformers • Provision for arc and temperature inputs • PQ monitoring: Voltage variations, imbalance, current and voltage harmonics (Total Harmonic Distortion) detection and operation provision; harmonics earth-fault protection. • Arc protection for detection and trip initiation < 4-10ms. • Special functions like automatic synchronization of one generator or a network circuit breaker with multiple generators and grid connection is also possible. • Remote control, monitoring, protection, power quality analyzing and automation of secondary distribution systems	• Withdrawable plug-in unit design for swift installation and testing • IEC 61850 HSR and PRP, GOOSE and IEC 61850-9-2 LE for less wiring and supervised communication • IEEE 1588 V2 for high-accuracy time synchronization and maximum benefit of substation-level Ethernet communication • Large graphical display (Local HMI) for showing customizable SLDs, accessible either locally or through a web browser-based HMI • Operating temperature -25 to 55 deg C • Relative humidity < 93%

KPI addressed	ABB solution component and role	Values
• Food safety • Ensuring climate detection and control etc. in the food storage. • Ambient insensitivity	 **Remote IO unit RIO600** • Analog, binary IO extension for Relion protection relays • Measurement of temperature inputs (-4 to 200°C) • Analog outputs for regulation • Precise and unique directional fault passage indication (FPI) functionality using ABB sensors.	• Ensures efficiency of the distribution network and operations • User level and operational security to ensure operational reliability • IEC 61850 and Modbus TCP to extend protection and control applications • Fast real-time communication between protection and control relays and physical inputs/outputs • Wide set of different I/O options • Enables power flow and power quality monitoring • Fulfills IEC 61850 GOOSE communication performance requirement • Operating temperature -25 to 70 deg C • Relative humidity < 93% • Monitoring using WebHMI
• Increased asset utilization • Facilitates data analytics for predictive maintenance	 **MySiteCare** • Monitoring and diagnostic unit for circuit breakers • Predictive diagnostic algorithms and provides indications concerning the mechanical, electrical and operating conditions of the circuit-breaker • Switchgear hot-spot detection	• User-friendly interface that displays faults by means of a traffic light • Indication on how serious the fault is and the probability of failure • Impaired reliability and safety of the monitored equipment.
• Increased asset utilization • People safety • Fast and reliable fault detection and isolation • Tailored functional and physical redundancies	 **SSC600 (Smart-substation control and protection)** • Multi-feeder protection and control relay for up to 20 feeders; feeder, transformer, motor protection and control.	• Adaptable according to customer philosophies and requirements • Functional or physical redundancies (protection) can be introduced depending on medium voltage feeders' importance • Effective change management of

• Reduce outages with smarter, faster management of power and substation network operation • Ambient insensitivity	• Advanced applications like arc protection, frequency load-shedding, PQ etc. • In combination with Relion 615 series protection relays and merging unit • Handles IOs based on IEC 61850-9-2LE, IEC 61850-8-1 GOOSE and MMS	protection and control functions • Increased system availability • Facilitates flexibility for different protection philosophies • Web browser based HMI for operator interface • Use of state-of-the-art, future-proof substation automation technologies that also safeguard investment • Operating temperature -25 to 60 deg C • Relative humidity 5 – 95%
KPI addressed	**ABB solution component and role**	**Values**
• Continuous operation • Food safety • People safety • Keeping critical processes running • Avoiding production outages and consequent material loss/wastage • Uninterrupted, availability of reliable and quality power • Increased asset utilization • Reduce outages with smarter, faster management of power and substation network operation	 **Relion PML630 load-shedding controller** • Prevents blackouts and power outages in small to medium-sized industrial power networks. • Fast load-shedding based on network contingencies and power balance • Slow load-shedding based on either overloading of power sources or power demand violation at grid coupling points • Manual load-shedding based on operator-initiated actions • Underfrequency load-shedding as backup to fast load-shedding • Handles IOs based on IEC 61850 GOOSE and MMS information from Relion (or 3rd party) relays	• Handles network with 8 power sources (generators, grid connections), 4 bus bars and 60 loads. • Safeguard and provide value for investments • Ensure high availability of customer process through high performance solution • Seamless integration of protection & control, station automation and power management functionality in switchgear • Increased flexibility and scalability and improved system integration and customization, fulfilling a variety of requirements and needs. • Large graphical display (Local HMI) for showing customizable SLDs, accessible either locally or through a web browser-based HMI • Designed to unleash the full potential of the IEC 61850 standard.

<table>
<tr><td></td><td></td><td>• Ensures frequency profile in the network with fast shedding action.
• Load-shedding operation time within 10-20ms
• Overall load-shedding performance time with Relion protection relays, RIO600 IO units and VD4 vacuum circuit breaker is 60-100ms.
• Operating temperature -25 to 55 deg C
• Relative humidity < 93%</td></tr>
<tr><td>KPI addressed</td><td>ABB solution component and role</td><td>Values</td></tr>
<tr><td rowspan="2">• Continuous operation
• Food safety
• People safety
• Avoiding production outages and consequent material loss/wastage
• Uninterrupted, availability of reliable and quality power
• Increased asset utilization
• Reduce outages with smarter, faster management of power and substation network operation</td><td>  </td><td rowspan="2">• Handles network with 6 power sources (generators, grid connections), 4 bus bars
• Safeguard and provide value for investments
• Ensure high availability of customer process through high performance solution
• Seamless integration of protection & control, station automation and power management functionality in switchgear
• Increased flexibility and scalability and improved system integration and customization, fulfilling a variety of requirements and needs.
• Designed to unleash the full potential of the IEC 61850 standard.
• Max. Operating temperature -25 to 55 deg C
• Relative humidity 5 - 95%</td></tr>
<tr><td>AC 800M controller running generator and tie line control functions
• Full modularity and flexibility for all environments for future expansion of control applications
• Compact Control Builder software offers a wide range of powerful control solutions and reusable libraries for efficient configuration
• Robust design and its components secures maximum availability
• Handles IOs based on IEC 61850 GOOSE based on data from Relion (or 3rd party) relays for running generator power application.
• Automatic adjustments based on mode of generator (governor, AVR operation)
• Manages voltage and frequency when system is islanded
• Manages active, reactive power generation from generators/total plant system and power import/export when grid connected + peak shaving</td></tr>
</table>

KPI addressed	ABB solution component and role	Values
• Optimizing TCO • Lowers operational costs • People safety • Increased asset utilization • Continuous operation • Manufactured product quality	 **Unigear ZS1 (Digital) air insulated switchgear** • Innovative and advanced switchgear solution • Uses sensors (or instrument transformers), protection relays, merging unit and IEC 61850 digital communication	• Increases substation availability • Continuous monitoring and upstream connectivity using IEC 61850 standard • Lowers overall costs • Safe and reliable; increases equipment reliability and increases safety level in substation • Simple and efficient: Minimizes lifetime costs during switchgear operation; saves space switchgear room by reducing switchgear footprint • Provides flexibility towards varying load flows and switchgear operation • Offers possibility of late customizations and changes • Lower environmental impact: Lowers energy consumption due to sensor technology; up to 250 MWh • Up to 17.5 kV, 4000 A, 50 kA
KPI addressed	**ABB solution component and role**	**Values**
• Optimizing TCO • People safety • Increased asset utilization • Continuous operation • Manufactured product quality	 **ZX2 – gas insulated switchgear** • Metal partitioned single or double busbar system applications • Provides a proven solution by incorporating arc-proof cubicles and vacuum circuit breakers in a compact housing, suitable for all requirements.	• Maximum operator safety • Minimum overall costs due to low maintenance requirements • Maximum availability due to impressive MTBF figures • First manufacturer of GIS with over 30 years of experience • Extremely long service life of gas-insulated switchgear is optimally achieved by using SF6.

	• Extremely long service life of gas-insulated switchgear is optimally achieved by the use of the insulating gas sulphur-hexafluoride, an inert gas which not only insulates but also protects all the high voltage components throughout the entire life of the switchgear. • Uses sensors (or instrument transformers), protection relays, IEC 61850 digital communication	• Proven solution by incorporating arc-proof cubicles and vacuum circuit breakers in a compact housing • Up to 40.5kV, 2500A, 100kA
	ZX0.2 – Digital GIS • An enhancement of the existing ZX0.2 gas-insulated switchgear portfolio for primary applications. • Other main pillars are state-of-the art sensor technology for current and voltage measurement and advanced communication technology according to IEC 61850 • Complements Unigear Digital (AIS) offering • For single busbar installations, individual panel design; versatile in application and cover a very broad range of instrument transformer configurations and panel erection methods. • Just one bus system, which carries interlocking information as well as sampled measured values of voltage signals replaces complex wiring schemes of conventional switchgears, based on IEC 61850 9-2 SMV and 8-1 GOOSE. • Continuous supervision of communication on the redundant bus system, ZX0.2 Digital offers superior reliability in comparison to a conventional switchgear.	• Simplified planning of switchgear projects • Shortened delivery time by up to three weeks • Increased flexibility towards changes in projects • Increased safety during operation, commissioning and operation thanks to sensor technology • Lower energy consumption by up to 250 MWH • Up to 36kV, 2500A and 31.5kA, IEC standard
	 **SafePlus – gas insulated compact switchgear** • Compact SF6 insulated switchgear for secondary distribution • Unique flexibility due to extendibility and possible combination of fully modular and semi-modular configurations • Completely sealed system with stainless steel tank containing all live parts and switching functions	• Ensures high reliability, personnel safety and virtually maintenance free system • Up to 40.5kV, 630A • Compact design with small footprint and low physical weight

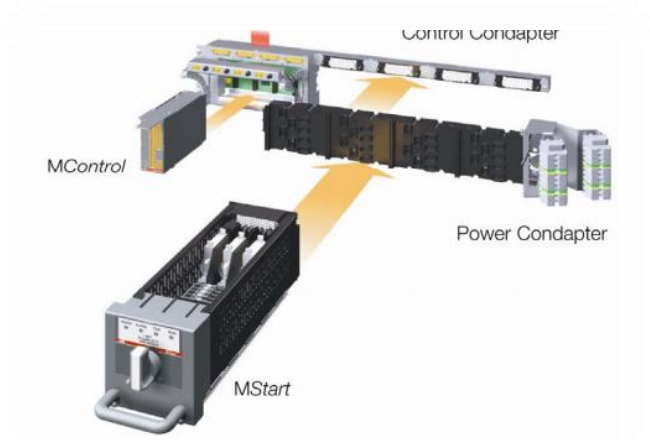
	 **UniSec – air insulated secondary switchgear** • For medium voltage secondary distribution • Modular and flexible design ensures simple and easy installation, use and maintenance • Suitable and certified for installation in the most severe conditions like areas with high seismic hazard, and low temperature environments	• High-level operator safety due to internal arc-proof design and a wide range of mechanical interlocks • Optimized investments as a result of space-efficient design, with compact functional units and reduced footprint • Up to 24kV, 1250A, 25kA
KPI addressed	**ABB solution component and role**	**Values**
• Optimizing TCO • People safety • Increased asset utilization • Continuous operation • Manufactured product quality	 **MNS – low voltage air insulated switchgear** • For low voltage distribution systems • Modular, flexible and compact design • Different design available depending on operating and environmental conditions • **Digital** variant allows access to real time data from operations and cloud connectivity.	• Safe and reliable • Easy to use • Flexible configurations • Easy to maintain • Optimum protection for personnel and plant • Design verified by testing (type-tested) including arc fault containment • High operational reliability and availability • Earthquake-, vibration- and shock-proof designs are available • Maintenance-free busbar and frame construction • Simple retrofitting procedures • Compact, space-saving design • Up to 100kA at 480V and 65kA at 600V • 4000A horizontal bus; 1600A vertical bus available • Arc resistant for 600V 65kA

		• Enables users to save up to 10 percent capital in electrical infrastructure • Requires up to 30 percent less space as compared to traditional architectures • Can be up and running as much as 20 percent faster due to reduced installation and commissioning time
	MNS-Up • Integrates tried and tested innovations to eliminate cabling and bulky bolt-ons that waste space. The system comprises of : ▪ Conceptpower DPA 500 uninterruptible power supply (UPS) ▪ MNS switchgear with Emax 2 circuit breakers	
KPI addressed	**ABB solution component and role**	**Values**
• Optimizing TCO • People safety • Increased asset utilization • Continuous operation • Manufactured product quality		• High level of safety for personnel & equipment due to the highest degree of Internal Arc Classification • Wide range of ratings & capacities as well as layouts in steel, concrete and innovative GRP housing • Type tested solution • Modular product range • Flexible solutions adaptable to specific requirements
	Compact Secondary Substation (CSS) • For energy transformation in secondary distribution from medium voltage to low voltage or vice versa. • Type tested and arc tested assembly • Comprises of medium voltage secondary switchgear, distribution transformers, low voltage switchboards, connections and auxiliary equipment to supply low voltage energy from medium voltage systems. • Typical solutions for 3 panel secondary GIS ▪ Rigel 12W-D (for 1250kVA transformer, 3 panel 12kV or 24kV gas insulated secondary switchgear)	

<table>
<tr><td></td><td>▪ Mercury 3C (for 315kVA transformer, 3 panel 12kV or 24kV gas insulated secondary switchgear)</td><td></td></tr>
<tr><td>KPI addressed</td><td>ABB solution component and role</td><td>Values</td></tr>
<tr><td rowspan="2">• Continuous operation
• Food safety
• People safety
• Keeping critical processes running
• Avoiding production outages and consequent material loss/wastage
• Uninterrupted, availability of reliable and quality power
• Increased asset utilization
• Reduce outages with smarter, faster management of power and substation network operation</td><td> 
SUE3000 High-speed bus transfer (HSBT)

• Ensures uninterrupted power supply to essential processes
• Through automatic transfer from a main incomer to a standby/alternative incomer as fast as possible.
• Subsidiary processes are protected from expensive stoppage times.
• Solution comprises of SUE3000 device + protection relays (ABB or 3rd) + circuit breaker (Special ABB circuit breaker VM1 or VD4 or 3rd party).
• Configuration with two or three circuit-breakers
• Four different configurable motor bus transfer modes
• Permanent supervision of involved incomers, busbars and circuit breakers
• Integrated disturbance recorder and watchdog self-monitoring
• Integrated safety features such as coil supervision function and decoupling function</td><td rowspan="2">• Designed for easy integration into existing and new switchgear installations
• Increased plant availability and prevention of costly production outages
• Independent of voltage levels
• Lower investment and operation costs, easier installation compared with UPS systems
• Minimum space requirements for the mechanical installation
• Only one successful transfer can create a full amortization of the investment
• Communication based on IEC 61850 MMS, Modbus-TCP.
• Dedicated HMI unit detached from the base relay unit
• Operating temperature -10 to 55 deg C
• Relative humidity up to 95%</td></tr>
<tr><td>Same as for SUE3000</td><td>  
Emax 2 based embedded auto-transfer switch (ATS)

• To automatically switch supply from main to an emergency feeder and reducing problems due to faulty conditions to a minimum.</td><td>• Maximizes the service continuity of any process
• Achieves a good compromise amongst reliability, simplicity and cost-effectiveness
• Provides a power supply with high quality voltage if the main network is out of service
• Cost savings on cabling and commissioning of switchboard by 50%</td></tr>
</table>

	• Used in the context of 2 mains and 1 bus coupler, based on close transition (make before break) • Solution based on Emax 2 circuit breakers + Ekip and IEC 61850 GOOSE	• Space saving on MNS switchboard by up to 30% • Provides the maintenance staff and managing system with a power source able to supply the installation or part of it when the transformer is being serviced. • Used for ATS schemes from 250 up to 5000A.
KPI addressed	**ABB solution component and role**	**Values**
• Food safety • People safety • Fast and reliable fault detection and isolation • Increased asset utilization	   **<u>MStart/MControl</u>** • The power module MStart/MFeed comprises of an electrical isolator, short circuit protection device (fuses or circuit breaker), contactor and any electrical control equipment and status indication, sensor module (measuring the electrical values, which are then available to the process via the MControl module). • The integrated motor controller module MControl (located in the control compartment) comprises of the processor performing all the protection, control functions and monitoring functions.	• For AC motor and the operated installations this means: ▪ Reliable protection ▪ Maximum utilization ▪ Continuous supervision ▪ Flexibility

	• It exchanges information with the MStart/MFeed via an internal bus. I/O interface modules providing an interface to external components for control, protection and indication. **Universal Motor Controller UMC100** • It is a motor protection and control device for 3-phase motors. • It provides electronic motor protection with through-the-hole current transformers, 3 relay outputs, one 24V DC output, 6 digital inputs for controlling and an optional LCD panel for parametrization and operation. • Pre-programmed starter functions simplify the engineering process. The UMC100-FBP can be expanded with different IO module **M10x intelligent motor control and protection** • M10x is an intelligent motor control and protection device based on current measurement or current measurement and voltage measurement. • It is a microprocessor-based product providing comprehensive but standard features in one device. • Standard features simplify maintenance and plant expansion. • Each motor starter is equipped with one standard M10x device. With dedicated parameters in each device, M10x provides specific control, monitoring and protection functions, tailored for various motor applications. • It comprises of the main unit (with current converter unit) and Operator panel MD21/MD31	
KPI addressed	**ABB solution component and role**	**Values**
Same as for MStart/MControls		• Single point purchase of MCC & VSDs • Ease of deal and cost saving • Solution for speed and simplicity • Eco-friendly • VSDs in withdrawable technique • Practical and safe • Tested and verified • Inherent safety of MNS iS technology • Complete solution package

	MNS iS with MSpeed • Energy saving low voltage switchgear solution with MNS iS combined with MSpeed. • MSpeed is the innovative integration of MNS iS and ACS850 industrial drive. • Precisely engineered in withdrawable and fixed techniques. • Withdrawable technique inherits the flexibility and features that are present in the MNS iS withdrawable motor starter design.	• Withdrawable technique - up to and includes 45kW for 400V, and 55kW for 500V motors • The fixed technique is designed for motors up to 160kW for 400V, and 200kW for 500V systems.
KPI addressed	**ABB solution component and role**	**Values**
Same as for SUE3000 and Emax2 - ATS	 **TruONE ATS** • To automatically switch supply from main to an emergency feeder and reducing problems due to faulty conditions to a minimum. • Used in context of two mains or main-generator, based on open (delayed) transition. • Connectivity based on IEC 61850 and other protocols such as Modbus-TCP	• Up to 80% faster installation • Up to 60 meters of wire saved per ATS • For 20 connections in older ATS systems, only one connection needed with TruOne. • Used for ATS schemes from 30A up to 1600A
• Continuous operation • Keeping critical processes running • Avoiding production outages and consequent material loss/wastage • Uninterrupted, availability of reliable and quality power • Increased asset utilization • Reduce outages	 **Conceptpower DPA500** UPS • Fulfills power requirements from 100 kW to 3 MW	• Provides maximum availability for processes requiring for zero downtime as well as a low cost of ownership • Delivers power protection from 100 to 500 kW (one to five modules) in a single cabinet (vertical scalability). • Cabinets can operate in a parallel configuration to build a system of up to 3 MW (horizontal scalability) • Provides the highest degree of protection in critical applications where the load must be fed with quality power

• Food safety • Ensuring climate detection and control etc. in the food storage. • People safety • Increased asset utilization • Facilitates data analytics for predictive maintenance • People safety • Ambient insensitivity	 **COM600S Substation Management Unit** • All-in-one user interface, automation platform and gateway designed for IEC 61850-based substation automation communication • Incorporates substation analytic applications such as circuit-breaker condition monitoring • Automation controller for temperature control functionality • Inbuilt firewall, constant operating system update mechanism and anti-virus software ensure cyber-security • Includes Historian module for trending	• Ensures efficiency of the substation network and operations • User level and operational security to ensure operational reliability • Better value for customer investment through substation device integration based on native IEC 61850 or most other commonly used communication standards and legacy protocols • Easy to add substation automation functionality to existing protection and control installations • Facilitates substation analytics and thereby simplifies choice of IEC 61850 relays in the substations • Operating temperature -10 to 55 deg C • Relative humidity 5 to 95%
KPI addressed	**ABB solution component and role**	**Values**
• Energy efficiency	 **Industrial energy monitoring and reporting software** • Analyzes the use of energy and utilities to calculate energy efficiencies • Provides visual tools to support energy efficiency improvement actions ▪ by quickly and accurately indicating actual performance and comparing it with set targets • Initial package – basic energy monitoring and reporting	Delivers performance reports to ascertain: • Consumption and cost of utilities per hour/day/month/year, by individual and aggregated users • Consumption and cost of utilities per end product unit • Analysis of load profile and peak demand • Benchmarking (comparing current performance against the past) • Rating energy performance against targets

	▪ Expandable to provide complete optimization of energy use and supply for the entire facility • Multiple facilities can be integrated to provide a company-wide solution and to allow comparisons, benchmarking and sharing best practices between the production facilities.	• Reduce cost and carbon emissions • Create transparency • Identify weak spots • Reduce carbon emissions • Maximize profitability
KPI addressed	**ABB solution component and role**	**Values**
• Food safety • People safety • Increased asset utilization • People safety	 **MLink** • The system interface MLink is an industrial PC equipped with interface cards and ports required for communication internally to MControl and externally to process control systems. • One MLink can communicate internally with up to 60 MControl. If more than 60 MControl are required, then additional MLinks have to be used. • Supports following communication protocols: ▪ PROFIBUS DP (-V0) and PROFIBUS DP-V1 ▪ MODBUS RTU / TCP ▪ PROFINET IO **MView** • To monitor the MNS iS status and display information for each connected motor/ feeder. • HMI Interface based on touch screen interface (8.4”) • Visualization of all the information coming from MLink • Possibility of access restriction by password	• Ensures efficiency of the substation network and operations • User level and operational security to ensure operational reliability • Better value for customer investment • Versatile communication interfaces to higher level systems • Easy and seamless integration into substation automation solutions
• Increased asset utilization • Facilitates data analytics for predictive maintenance	 **MService** • Switchgear condition monitoring package for ABB intelligent low voltage switchgear systems.	• Helps improve operational efficiency by enabling proactive, needs based maintenance practices • Increased maintenance effectiveness • Higher asset availability • Lower maintenance costs

	• Hardware and software package specifically designed for MNS iS low voltage switchgear. • Embedded industrial PC that offers an electrician-friendly operator interface based on commonly-used web browser technology. • Point-and-click navigation provides near-instant ease of use. • Implements the whole condition monitoring concept from collecting field level real-time data to performing assessment algorithms and keeping users up-to-date on developing maintenance situations. • Collection and storage of data as well as system alarms and events allow detailed analysis of operational performance for both process equipment and MNS iS switchgear. • Packed with features that can help analyze failures and reduce mean time to repair.	
KPI addressed	**ABB solution component and role**	**Values**
• Increased asset utilization • Ambient insensitivity	 **AFS660 and AFS670 substation Ethernet switch** • Facilitates non-redundant or redundant IEC 61850 communication (HSR, PRP) amongst Relion 611, 615, 620 protection relays, Relion SMU615 merging unit, Relion PML630, SSC600 smart substation control and protection, COM600S Substation Management unit	• Up to 11 ports for fiber optic and galvanic Ethernet connections • Uninterrupted data communication • Enhanced security functions to provide all-round protection against network attacks • Precise synchronization to meet stringent real-time requirements of applications • Huge variety of management and redundancy methods • Operating temperature -40 to 70 deg C • Relative humidity 10 to 95%
• Increased asset utilization • Facilitates remote services; cloud based customer support	 **Arctic wireless gateway series**	• Enable intelligent networks • Secure, fast and cost-efficient communication enables accurate information from substation devices towards remote cloud for accurate analytics.

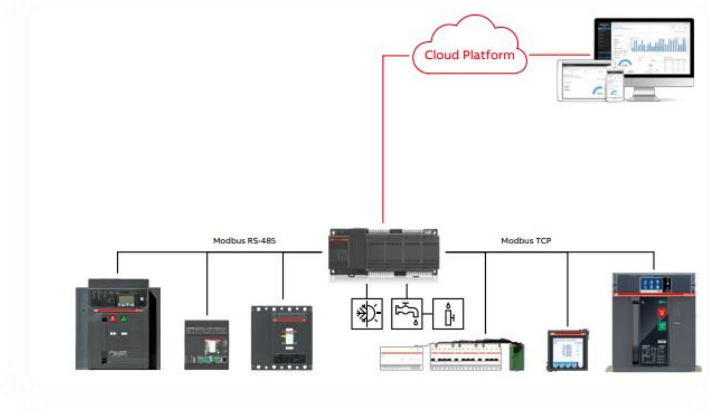
	• **ARx600** wireless gateways provide protocol conversion (**x=G, P, R, C**) at plant substation end. ▪ Integrated firewall, routing capabilities ▪ Secure wireless communication solutions ▪ Use public cellular networks: GPRS, 3G, LTE (2 x SIM cards for redundancy) • Remote end communication server: **ARM600** ▪ Manages VPN tunnel connectivity to Arx600 devices and configurations. Integrated firewall, routing capabilities	• Operating temperature -30 to 70 deg C • Relative humidity 5 to 85%
	  (representational) **Edge gateways (Ability Edge and MNS Digital Edge)** • Resides at the 'edge' of a plant network or system, see Section VI, chapter 14. • Capability to do data-pre-processing and run analytics/applications within plant network or system • Possesses processing and storage capabilities • Connects to devices of the system using IEC 61850 or Modbus-TCP • Serves as a communication endpoint to and from ABB Ability™ cloud via a wide area network (WAN) over standard, well-accepted industrial protocols.	• Scalable and flexible according to customer installed system requirements • Secure, fast and cost-efficient communication enables accurate information from substation devices towards remote cloud for accurate analytics.
KPI addressed	**ABB solution component and role**	**Values**
• Facilitates remote services; cloud based customer support • Customer, situational oriented short and long term support, based on operational expertise. • Trusted partner	 **Remote cloud servers** • **MySiteCondition** ▪ To evaluate the condition and assess the reliability of customer assets in the electrical network in order to mitigate risks, optimize allocation of operational and investment budgets. • **MyRemoteCare** ▪ To monitor plant substation switchgear and circuit breakers for proactive maintenance planning.	• Develop risk profile of asset base • Risk mitigation plan with priorities for action • Execute reliability centered maintenance actions • Perform periodic re-assessments to sustain safe and reliable operation • Optimizes maintenance schedules • Increases uptime and safety

	▪ On-line condition monitoring supporting condition-based maintenance services • **Clionet Data Care** ▪ To maintain configuration backup of protection relays' configuration files, disturbance recordings based on customer access. ▪ Upload and download of configuration files • **MVAM (upcoming)** ▪ Remote view of disturbance records, parameter settings and configurations of SSC600. ▪ Remote upgrades for SSC600 based on purchased functions.	• Reduces operational costs • Safeguards device configuration files and prevents loss of data , secure approach against cyber attacks • View and share protection relay files and data online – anywhere, anytime • Share files easily between customer personnel, ABB specialists etc. • Get individual user rights and accounts for each user, even on substation level
KPI addressed	**ABB solution component and role**	**Values**
• Ambient insensitivity	 **SNTP and IEEE 1588 PTP GPS time server** • Distribution of SNTP time synchronization (millisecond accuracy) messages to Relion 611, 615, 620 relays, PML630, COM600 • Distribution of IEEE 1588 PTP (microsecond accuracy) messages to Relion 615, 620, SMU615, SSC600	• Enables microsecond level time stamping of IEC 61850-9-2LE current and voltage samples, generated from Relion 615 series (protection relay, SMU615), Relion 620 series relays. • Enables SSC600 to execute protection functions (as if receiving signals from instrument transformers). • Enables time tagging of binary information for alarms/events on COM600S. • Enabling time tagging of measurement information for trends on COM600S.

• Continuous operation • Manufactured product quality • Power Quality • Optimizing TCO • Increased asset utilization • Ambient insensitivity • People safety	 **ESSPro energy storage Power Conversion System (PCS)** • Designed to keep the in-plant 'smart grid' stable. • Total containerized solution comprising of: ▪ Power converter racks ▪ LV/MV switchgear (protection relays, circuit breaker etc.) ▪ Control cabinet (with PCS) ▪ Step-up transformer • Advanced application for system optimization (see Section VI, chapter 3) • Connectivity based on IEC 61850. • Ability to connect to different battery types or energy storage mediums	• Seamless system integration and battery control • Utility grade solutions with advanced controls • High performance in any climate • Minimized risk due to proven technology • Battery technology independence • Delivers exceptional returns on investment • Maximizes the use of the energy storage system • Modular design and advanced controls maximize the availability, value and performance of large or small energy storage systems in a variety of applications. • From 500kW to 5,000kW • Operating temperature -20 to 50 deg C
KPI addressed	**ABB solution component and role**	**Values**
• Manufactured product quality • Power Quality • Continuous operation • Optimizing TCO		• Compliance with the strictest power quality regulations thereby avoiding penalties and/or refusal by utilities to connect installations to the electrical grid. • Reduced production downtime and/or

	PQF series Power Quality Filters • Can be applied to small, medium or large applications and are suitable for both industrial and commercial installations in low-voltage networks. • Can also be employed in medium-voltage networks through the use of a coupling transformer. • PQFI, PQFM, PQFS variants • Filter up to 20 harmonics simultaneously • Selection of harmonics up to the 50th harmonic. • Harmonic attenuation factor better than 97%. • Connectivity using Modbus-TCP	commercial installation downtime. • Increased system efficiency and reduction of CO2 emissions. • No detailed network analysis required and rapid and easy implementation of the solution. • Well adapted to low-voltage installations that are typically upgraded frequently • Unprecedented filtering efficiency with unique closed loop control system and individual harmonic selection capability • Step-less reactive power compensation of both inductive and capacitive loads • Load balancing in both 3- and 4-wire systems • Increasing of system reliability to unprecedented levels with full redundancy functionality • Network voltage: 208-480V, 380-415V • Current: 30A-450A • Operating temperature -10 to 40 deg C • Relative humidity 95%
KPI addressed	**ABB solution component and role**	**Values**
• Manufactured product quality • Power Quality • Continuous operation • Optimizing TCO	 **PCS100 AVC-40 Active Voltage Conditioner** • Designed for sag correction in industrial applications.	• Continuous protection from the most common utility voltage problems found in modern power networks • Failsafe worry free operation even in harsh electrical environments • Faster return on investment due to low operation costs

	• Proven and dependable converter platform with sophisticated control software • Industrial design with rugged overload capability • Redundant internal bypass providing fail-safe operation • No battery energy storage required • Connectivity based on Modbus-TCP for notification of power quality events	• Multilingual graphical touch screen interface – Class leading efficiency of more than 98 percent • Modular design providing high reliability and low mean time to repair • Reduced maintenance and long design lifetime • Small footprint with industry leading power density • Available in load capacities from 150 kVA to 3600 kVA
KPI addressed	**ABB solution component and role**	**Values**
• Continuous operation • Manufactured product quality • Food safety		• Helps to achieve better efficiency and reliability without compromising food safety • Reliable performance in extreme conditions • Meeting the efficiency requirements
	Low voltage motors for F&B • IP69K protection -> Withstands extreme washdown conditions • Encapsulated windings -> Long lifetime in extreme humid conditions • H1 food grade grease -> Safe operation in food processing environment • TENV cooling -> Very easy to clean • IE3 efficiency -> Lower operation costs and lower surface temperature	

KPI addressed	ABB solution component and role	Values
• Facilitates remote services; cloud based customer support • Customer, situational oriented short and long term support, based on operational expertise. • Trusted partner	  **ABB Ability EDCS** ABB Ability™ Electrical Distribution Control System assists anytime and anywhere via smartphone, tablet or personal computer so the user can: • Monitor: Discover plant performance, supervise the electrical system and allocate costs. • Optimize: Schedule and analyze automatic reports, improve the use of assets and take the right business decision. • Control: Set up alerts and notify key personnel, and remotely implement an effective power management strategy to achieve energy savings in a simple way	• Enables the collection of relevant information from the ABB devices installed in the low-voltage power distribution system • Truly plug & play architecture • Discover facility performances anytime, anywhere • Implement strategy and reach the goal • Collect data, analyze information and taking decision • Power of understanding at fingertips • Savings up to 30% on operational costs • Connect panel to Cloud in 10 minutes • Plant managers can take action in a matter of couple of minutes from anywhere, anytime • Smart solution to optimize electrical systems performance and ensure continuous improvement increasing the project value by 15%

KPI addressed	ABB solution component and role	Values
• Trusted and reliable partner to do business with. • Agility and localized service to facilitate easy access to replacement/spare parts in shortest time.	Service level agreement ‘packages’ to subscribe different activities to be performed. Typical service activities for secondary system equipment and systems: • System health check (inter-node communication related) • Tool to device connectivity • Incident or special requests • Routine cyber security checks	• Agile and localized service • Easy access to replacement and spares • On-site assistance with dedicated personnel and experts • Tailored service solutions based on customer needs

• Linked supply chain, from supplier to customer • Good onsite technical assistance (supplier embedded engineer) and access to experts to solve problems quickly	• Special support access to product specialists • System software/patch updates • System performance check benchmarking, optimization • New firmware versions and enhancements • License updates for new packages • New functions and applications enabling • Cyber security active updates (patch management) • Configuration backups and software management • Health check of plant power system through secondary system data (remote analytics) • Periodic training, webinar and technology updates • Configuration migrations • Flexi-support on different services • System upkeep services	

VIII. Appendix – 2 (Detailing the solution)

Having described all the solution components, now we try to seamlessly associate some* of them with each other in order to 'construct' the intended solution(s). Alongside, the envisaged combined value contribution is also mentioned. Quite clearly, bundled and interconnected solutions are the norm.

***Note: Not all products listed in sections VI and VII are included in the selected solutions enlisted in this section.**

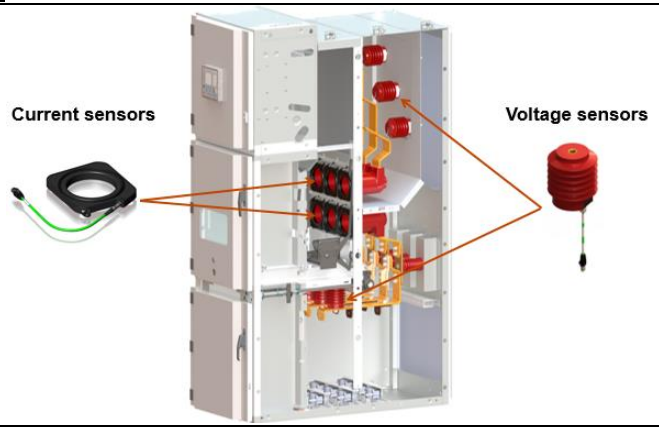
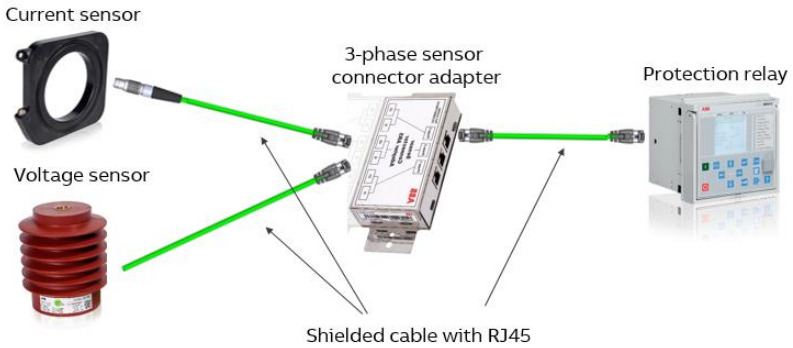
ABB solution	**Illustration**	**Benefits**
Step 1 (single feeder): • Unigear (Digital) switchgear incorporated with KEVA, KECA and KEVC sensors to collect feeder voltage and current signals		• Compact switchgear • Easy to maintain and handle • Enhances safety
Step 2 (single feeder): • Connectivity between KEVA, KECA and KEVC and Relion 615/620 protection relay is established. • Relion protection relay runs all applications in the same manner when connected directly to instrument transformers.		• A mix and match approach for retrofit and new panels/substation is facilitated. • Easy integration of primary and secondary equipment • Enhances safety and maintainability

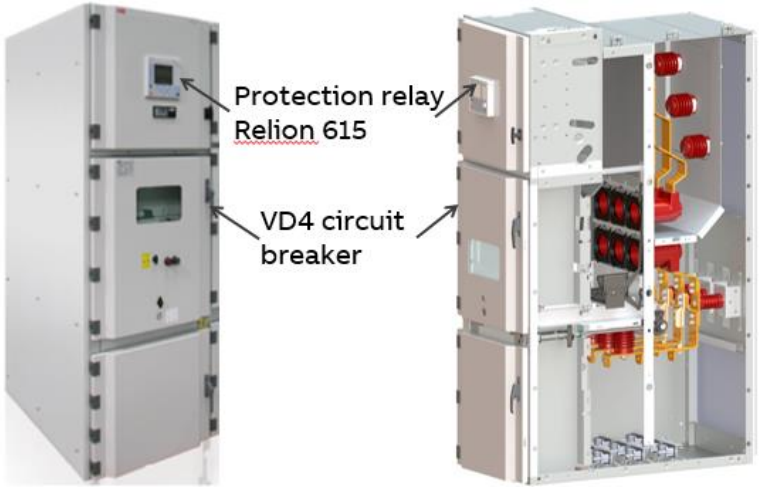
ABB solution	**Illustration**	**Benefits**
Step 3 (single feeder): Including the following components in the Unigear (Digital) switchgear: • VD4 vacuum circuit breaker • Relion 615 series protection relay OR SMU615 merging unit With conventional instrument transformers (CT/VT) incorporated in Unigear switchgear • VD4 vacuum circuit breaker • Relion 611, 615, 620, 630 series protection relay		• As in steps 1 and 2 • Inherent functions towards condition-based monitoring • IEC 61850 enabled switchgear

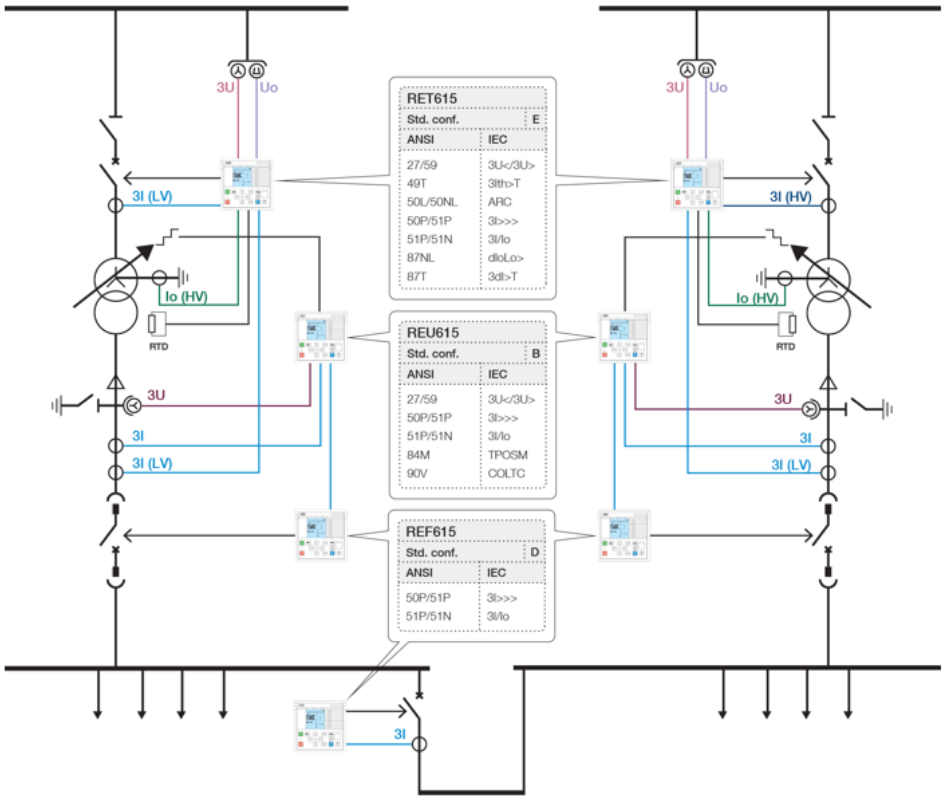
ABB solution	**Illustration**	**Benefits**
Step 4a (single feeder, specific): • Plant incomer power transformer tap change control for regulating voltage on the plant busbar side, called 'Compact Power Management – cPMS voltage control solution'. • Relion REU615 voltage protection and control relay is added to the transformer bay panel in the Unigear (Digital) switchgear. • Other relays like Relion RET615, REF615. REM615 are added as necessary in the Unigear (Digital) switchgear. • Coordination between relay functions and between relays for maximum protection coverage.		• Comprehensive power system and equipment protection and control functionality • Easy cross-bay functionality and interlocking possibilities according to customer requirement due to IEC 61850 GOOSE. • Use of IEC 61850 GOOSE significantly reduces inter-panel wiring. • Consistent ease of use across product and series

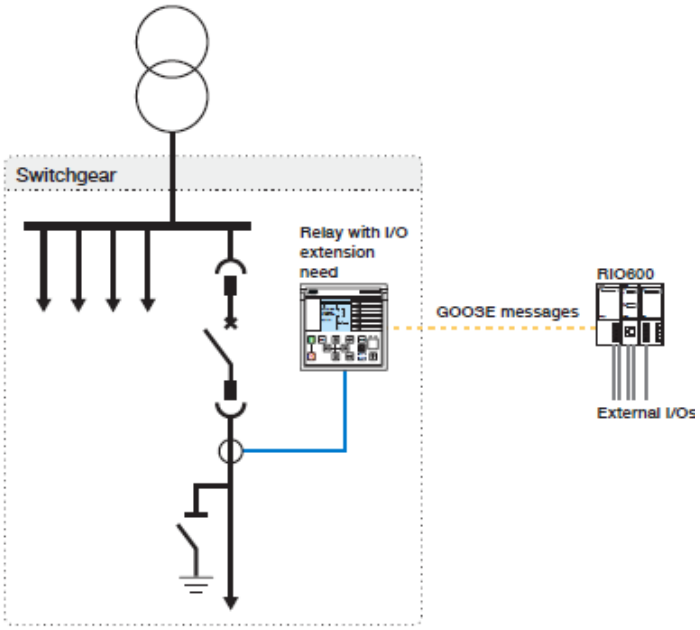
ABB solution	**Illustration**	**Benefits**
Step 4b (single feeder, general): • When the switchgear/process IOs are much more than what the bay protection relay can accommodate …. • A Remote IO RIO600 unit is added to the bay panel in the Unigear (Digital) switchgear. • The RIO600 and Relion 615, 620, 630 protection relays communicate with each other using IEC 61850 GOOSE communication. • The IEC 61850 communication acts like a 'fieldbus. • Relion protection relay's 3rd port is connected to the RIO600.		• System extensions can be easily accommodated • No need to change protection relay for additional IOs • Cost effective • IO wiring from remote equipment all the way to protection relay. • No impact on mainstream IEC 61850 communication from protection relay

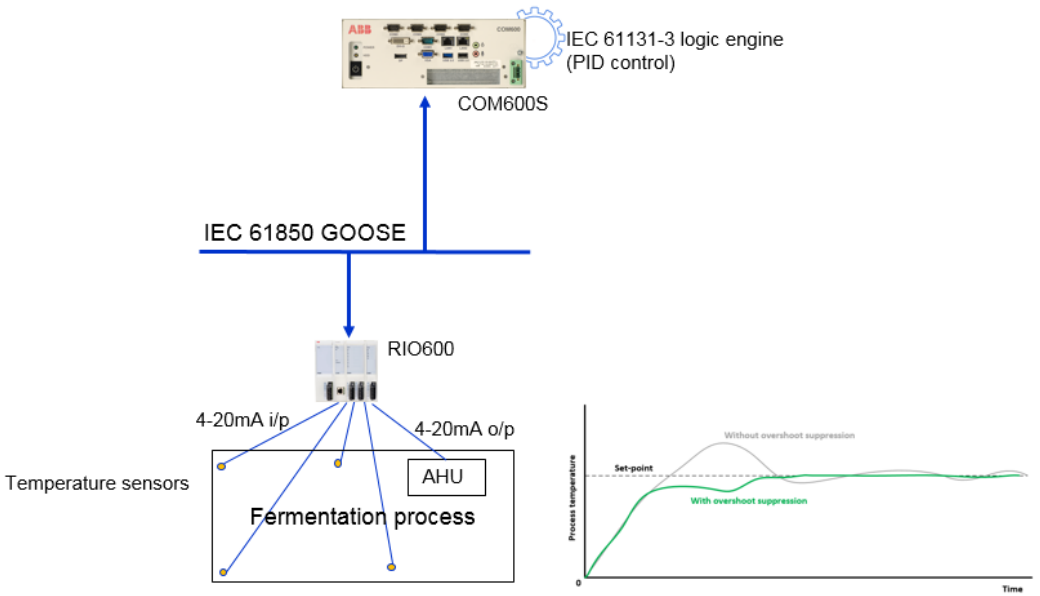
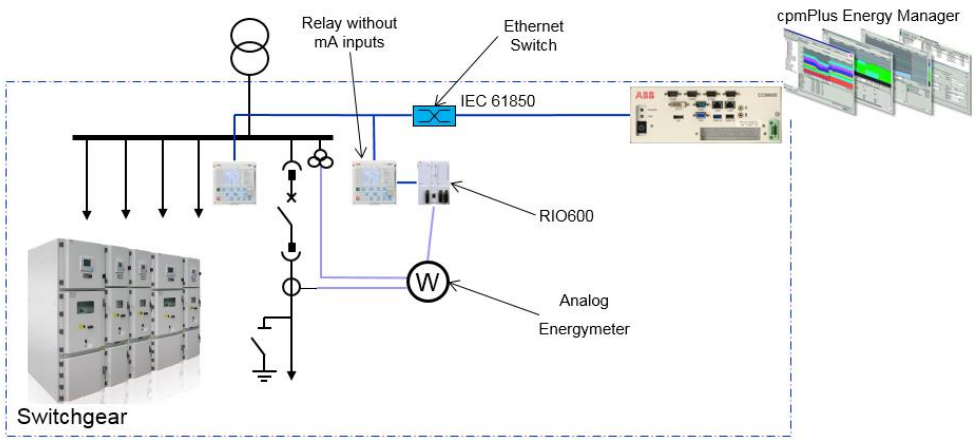
ABB solution	**Illustration**	**Benefits**
Step 5 (process control): • When temperature control needs to be realized with high efficiency without energy wastage… • Temperature regulation realized using Remote IO RIO600 and COM600S Substation Management unit combination. • RIO600 measures temperature of a process (such as fermentation) through sensors and sends control output to a temperature controller in an AHU, for example. • The COM600S substation management unit runs a temperature control logic using a PID controller, thereby preventing overshooting (over-heating) or undershooting (overcooling).		• Comprehensive IO capabilities of RIO600 facilitates process control functionality to be integrated with electrical distribution automation system. • Codesys logic engine, fully compliant with IEC 61131-3 standard for PLC programming (as in other contemporary process controllers) • IEC 61850 GOOSE communication between RIO600 and COM600S reduces latency.

ABB solution	Illustration	Benefits
Step 6 (energy management): • When energy monitoring and reporting functionality is required…. • Relion protection relays for feeder measurements (power energy etc.) • RIO600 for connecting analog power meters with 4-20mA outputs and extending values to Relion protection relays. • The COM600S substation management unit collects all power and energy data and prepares trends and reports using its Historian (cpmPlus). • Using cpmPlus Energy Manager module provides features such as energy monitoring and reporting, energy load planning and energy optimization (future possibilities)		• Seamless integration of protection & control, substation automation, energy management, analytics functionality in medium voltage switchgear • Easy adaptation of existing infrastructure like power meters into the solution mix. • Comprehensive energy efficiency and energy audits to realize relevant KPIs across different process areas in a plant. • Facilitating processed data to higher level systems at the customer control center to facilitate operational/strategic planning.

• Substation data and cpmPlus data can be sent to higher level systems using COM600S's communication gateway function		

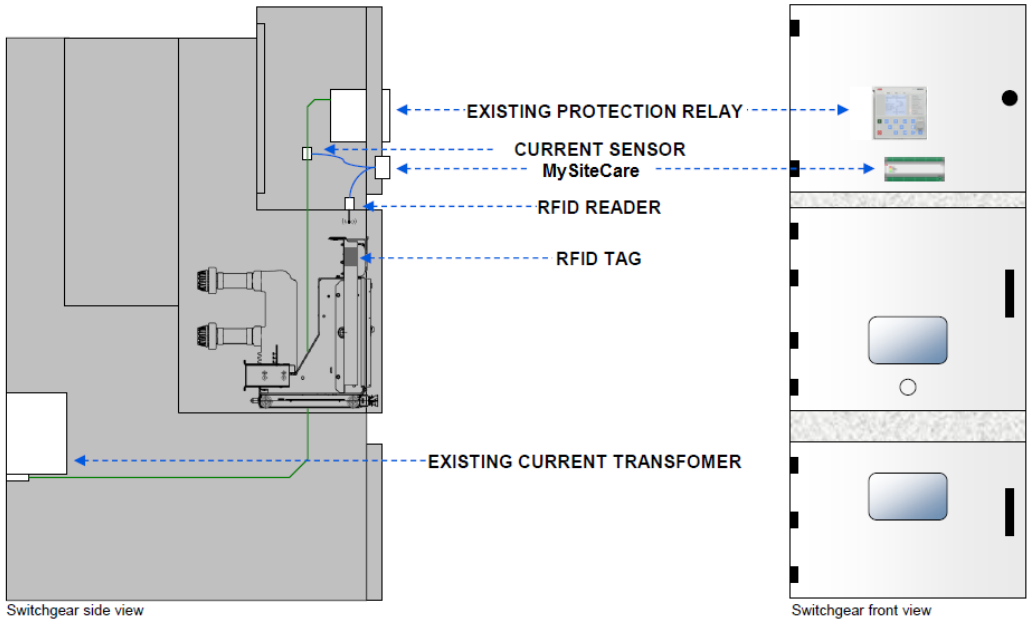
ABB solution	**Illustration**	**Benefits**
Step 7 (single feeder): • In order to perform detailed diagnostics of a circuit breaker associated with a feeder…. • A MySitecare monitoring and diagnostic unit is installed together with associated current sensor, RFID reader etc. in the Unigear switchgear.		• To facilitate predictive maintenance based on live-on site data. • Improves asset utilization

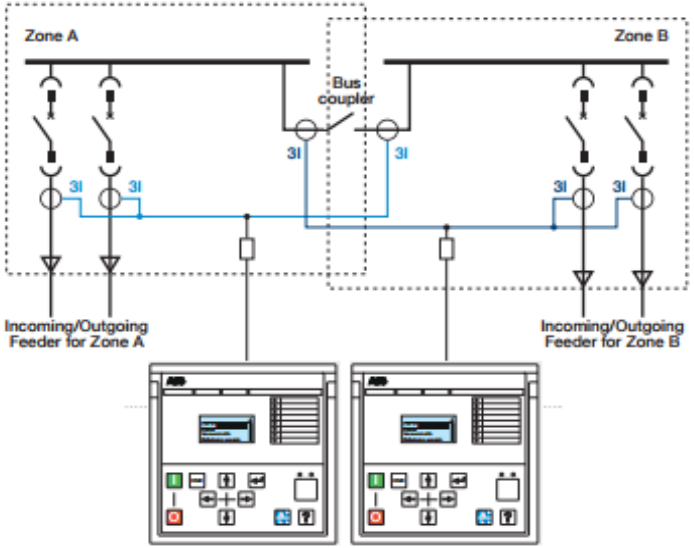
ABB solution	**Illustration**	**Benefits**
Step 8 (switchgear panel line up): • Bus-bar protection for 1 or 2 zones of a single bus bar system in the Unigear (Digital) switchgear incorporated using REB611.		• Switchgear wide protection. • Safety • Protecting capital investment

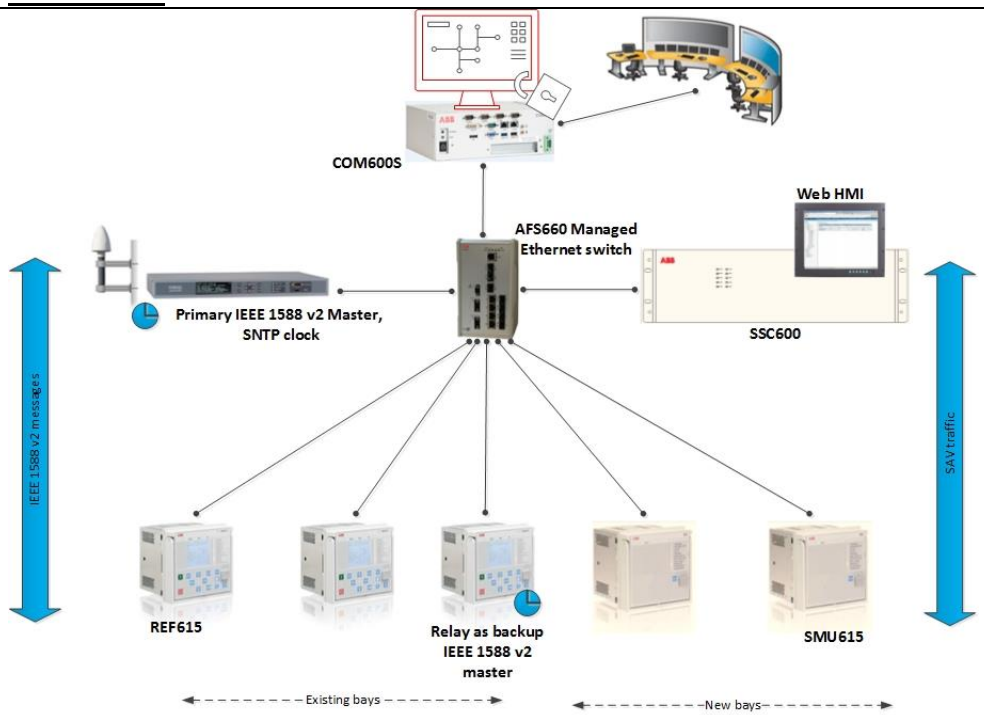
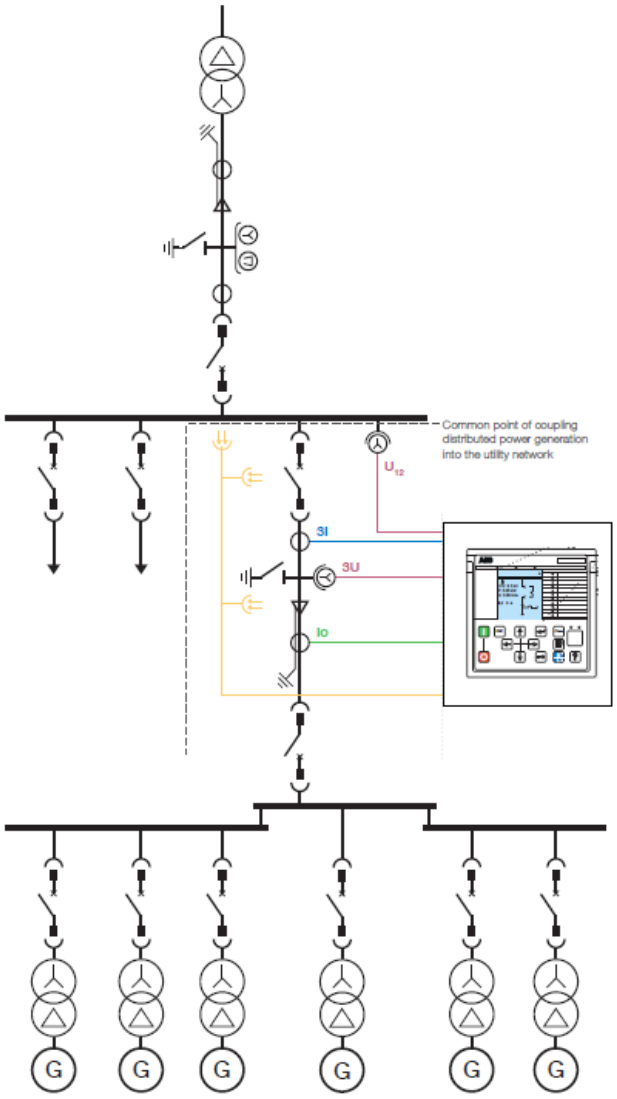
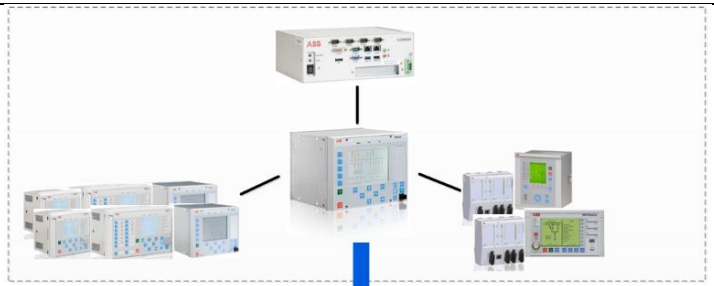
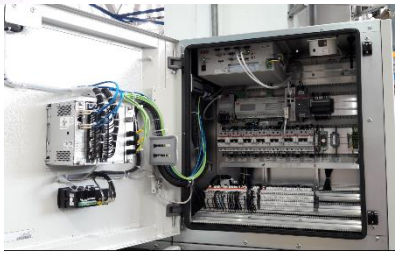
ABB solution	**Illustration**	**Benefits**
Step 9 (multi-feeder or substation wide): • For new or retrofit substations, when single or multi-feeder standard or advanced applications is required…. • A hybrid protection and control solution comprising of SSC600 multi-feeder protection device (computer) is deployed in a solution cluster mode together with: ○ Relion REF615 protection relays ○ Relion SMU615 merging units ○ IEEE 1588 PTP time server ○ COM600S substation management unit ○ AFS600 Ethernet switch ○ GPS time server		• Customizable depending on priority/importance of the feeder or customer philosophy • State-of-the-art and future proof • Easily adaptable for retrofit and new substations • If primary GPS sever fails, one of the configured Relion 615 protection relay or SMU615 merging unit acts as a backup time master.

ABB solution	**Illustration**	**Benefits**
Step 10 (system level): • To safeguard the plant system from external power system disturbances…. • The system can be islanded by Relion 615 or Relion REX640 generator/interconnection protection relay. • Referred as Compact Power Management System – cPMS islanding solution.		• Advanced interconnection protection fulfilling the latest grid codes for higher grid stability and reliability • Ensures plant power system availability

Step 11a (plant/substation wide):

- When a system-wide protection function load-shedding functionality needs to be incorporated in the plant, it can be done so totally in the Unigear (Digital) switchgear ….
- Relion PML630 load-shedding controller is incorporated (typically) in the bus-section's LV compartment of the Unigear (Digital) switchgear in a solution mode along with:
  - Relion REF615, 620, 630, 3rd party, legacy protection relays
  - Remote IO RIO600 units
  - COM600S substation management unit





- Safeguards and provides value for customer investment
- Ensures high availability of customer process
- Avoids costly power blackouts, production outages and consequent environmental damage. Only one successful operation can create a full amortization of the investment.
- Easy system integration using open and well accepted communication technologies
- Seamless integration of protection & control, substation automation, power management, analytics functionality in medium voltage switchgear

- Ethernet switch AFS660 or AFS670
- GPS server

- All the above units are connected to the Ethernet switch; IEC 61850 based load-shedding solution cluster, referred as 'Compact Power Management System – cPMS load-shedding' solution.

- Integrated HMI, automation controller and communication gateway through COM600S

- Total performance time including load circuit breaker opening < 100ms

- External systems too can trigger and execute load-shedding through the COM600S-PML630-Relion protection relays combination.

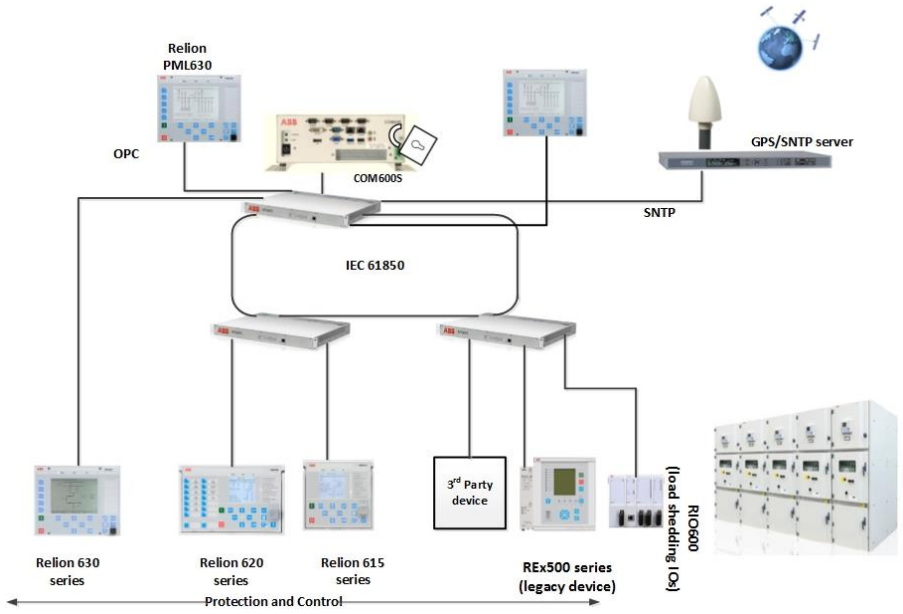
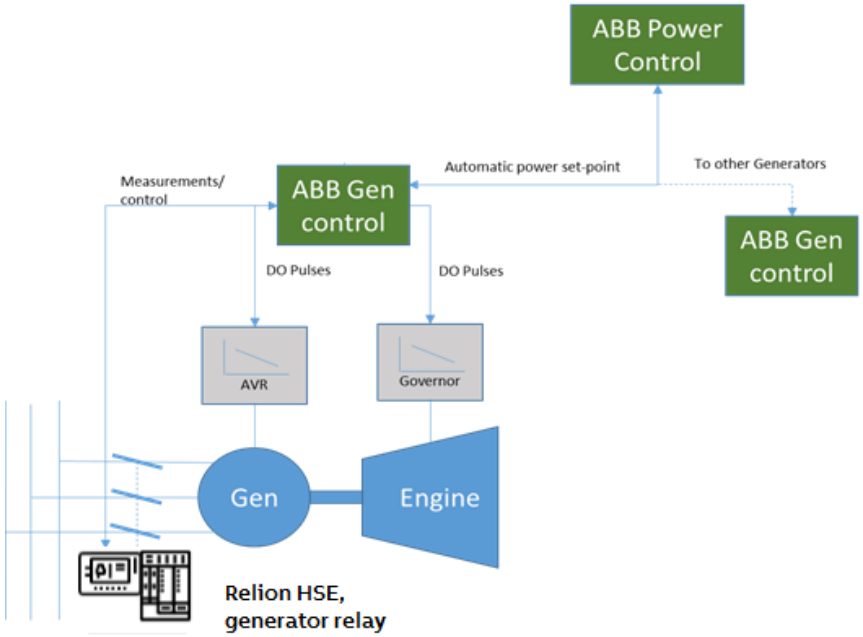


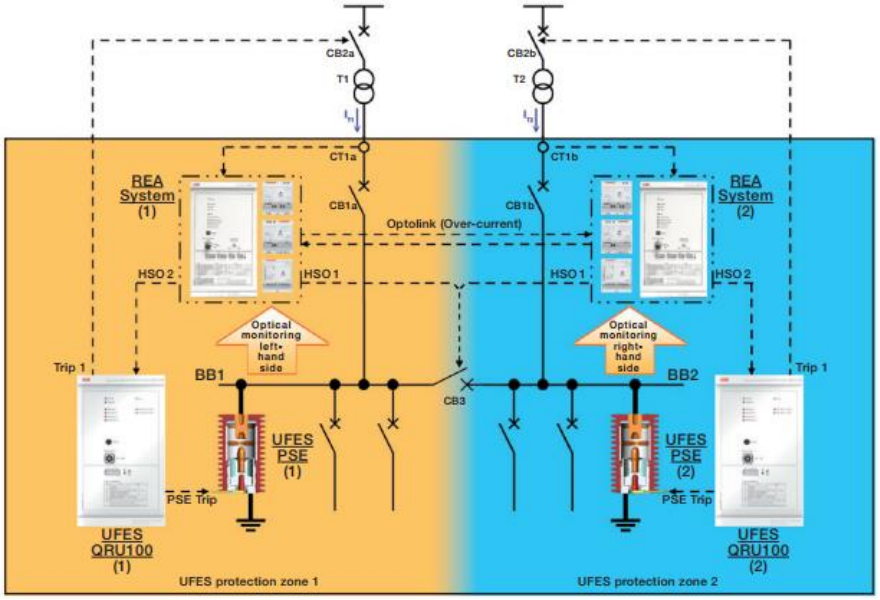
ABB solution	**Illustration**	**Benefits**

Step 11b (plant/substation wide):
 	
• When generation from all plant generators need to be balanced dynamically with respect to the connected load ….
 	
• AC 800M controller, running generator/plant power control application is incorporated (in a solution mode) along with:
  ○ Relion REX640 protection relays,
  ○ Remote IO RIO600 units
  ○ COM600S substation management unit
  ○ 800xA Process Visualization
  ○ Ethernet switch AFS660 or AFS670
  ○ GPS server
		• Safeguards and provides value for customer investment
		
		• Stabilized power production, system voltage and frequency
		
		• Automated, efficient, stable energy distribution to withstand disturbance and load demands
		
		• Automated load sharing amongst prime movers (turbines), leading to fuel savings
		
		• Ensures high availability of customer process
		
		• Easy system integration using open and well accepted communication technologies
		
		• Seamless integration of protection & control, substation automation, power management

• All the above units are connected to the Ethernet switch; IEC 61850 based power control solution cluster, called 'Compact Power Management System – cPMS Power Control solution'. • Refer Fig 8 for autosynchronization solution, based on Relion REX640. This is specifically referred as 'Compact Power Management System – cPMS Autosynchronization solution'. • Integrated HMI, automation controller and communication gateway through COM600S		

Step 12a (substation-wide):

- Having established the protection and control arrangement with the switchgear and circuit breaker, we now incorporate the dedicated arc protection solution…
- The Unigear switchgear is incorporated with the UFES PSE (primary switching elements), when arc flash mitigation is needed < 4ms.
- Integrating a REA101 arc protection and UEFS QRU100 tripping units as a part of overall UFES arc protection system



- Safeguards and provides value for customer investment
- High levels of safety ensured
- Reduction in downtimes and repair costs

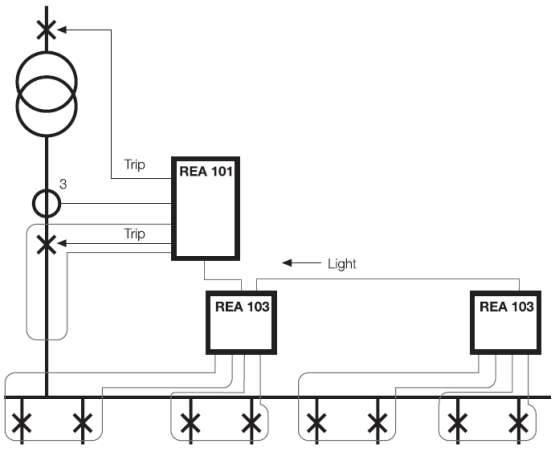
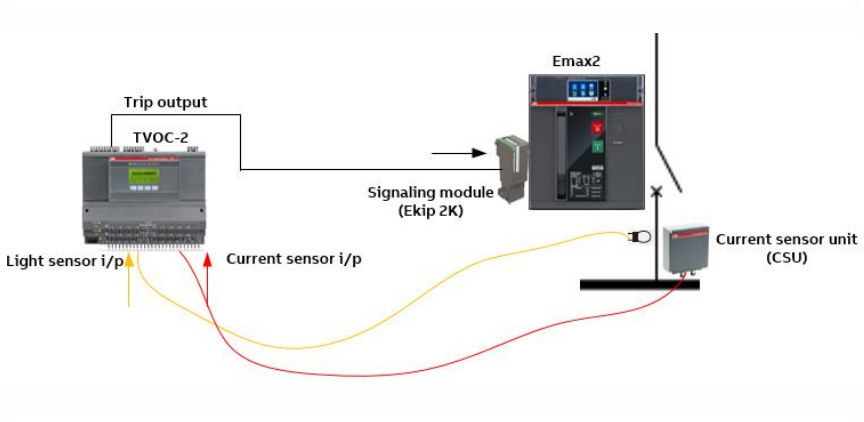
ABB solution	**Illustration**	**Benefits**
Step 12b (substation-wide): • When a lesser stringent arc flash clearing time ~ 45ms, yet a dedicated system is desired… • A dedicated network of REA101 arc protection unit and extension modules REA103 are arranged as illustrated.		• Safeguards and provides value for customer investment • High levels of safety ensured • Ultra-fast protection < 2.5 ms
• A dedicated arc protection system for LV installation with overall clearance time within 50ms.		• Detection between 1-10ms.

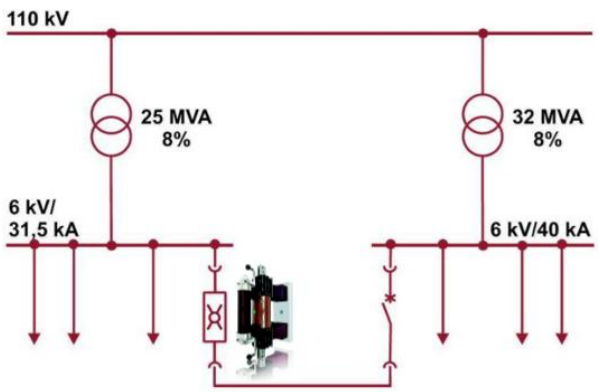
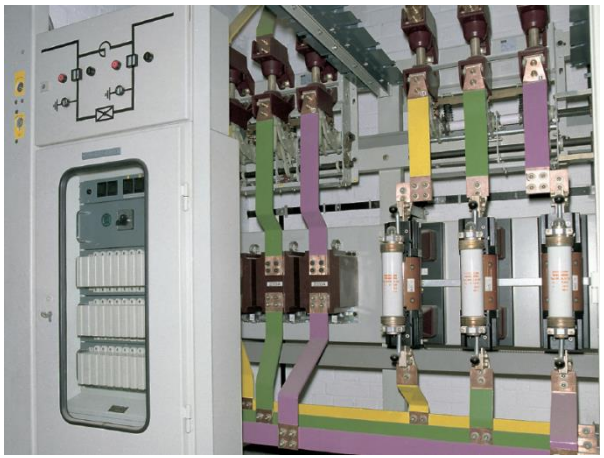
ABB solution	**Illustration**	**Benefits**
Step 13 (substation-wide): • In order to reduce fault levels when two switchboards are being interconnected during system augmentation or expansion…. • Is limiter system (short-circuit current) is installed in a dedicated panel between the two switchgear boards.	 	• Safeguards and provides value for customer investment • Fault current interruption before first peak • Very high adjustability and flexibility to adapt to system changes

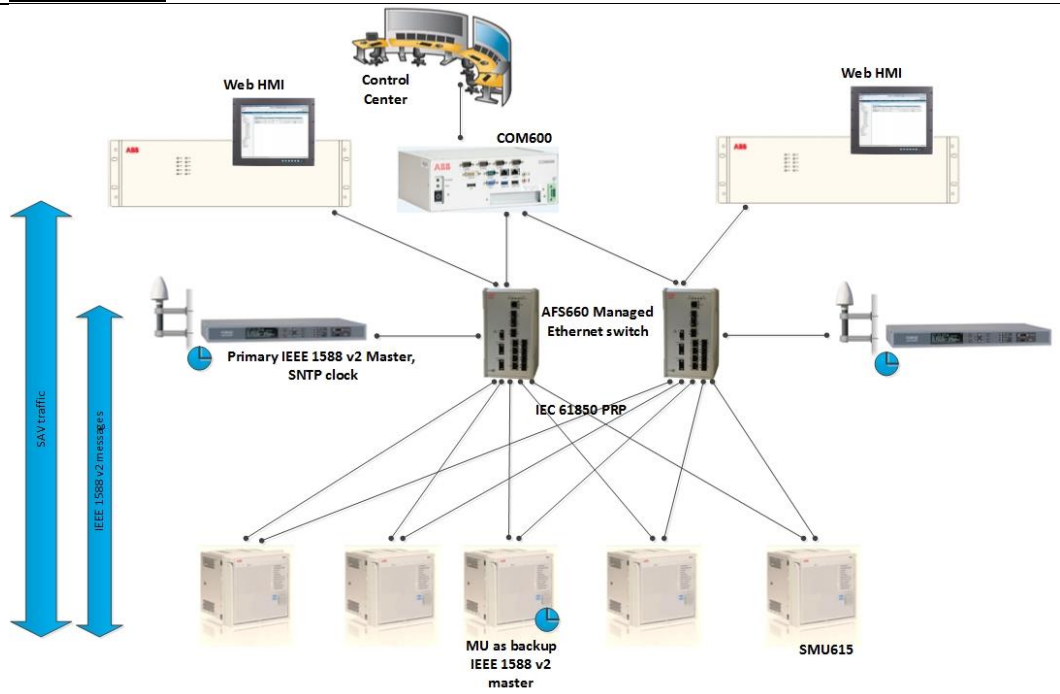
ABB solution	**Illustration**	**Benefits**
Step 14a (substation communication network): • When IEC 61850 communication network to be made more reliable, available etc.…. • Single or redundant devices are connected to two separate networks in accordance with IEC 61850 PRP (Parallel Redundancy Protocol). • This creates communication redundancy.		• Secures critical communication between devices • No interlinks • Failure of a switch causes zero-switchover time

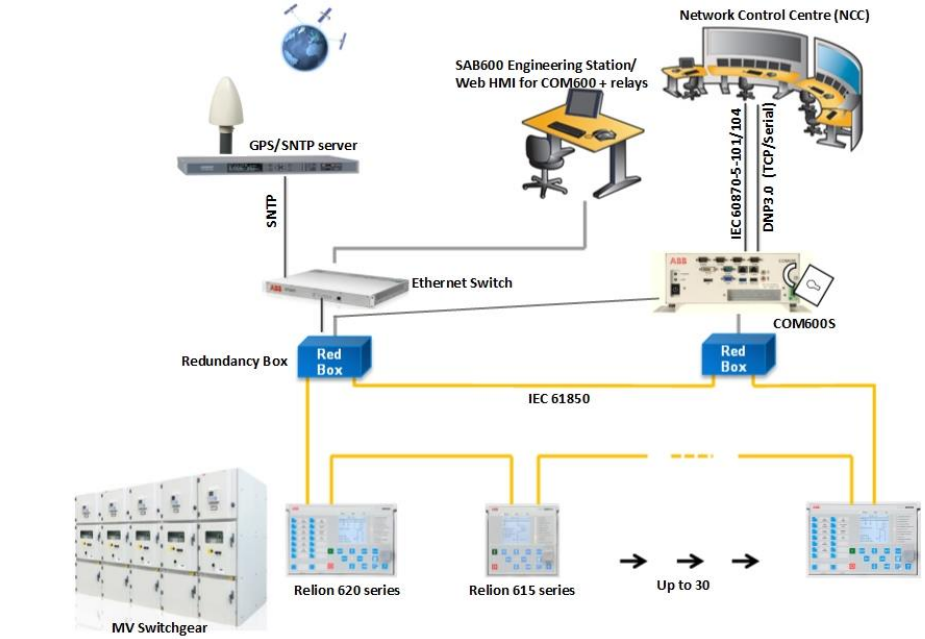
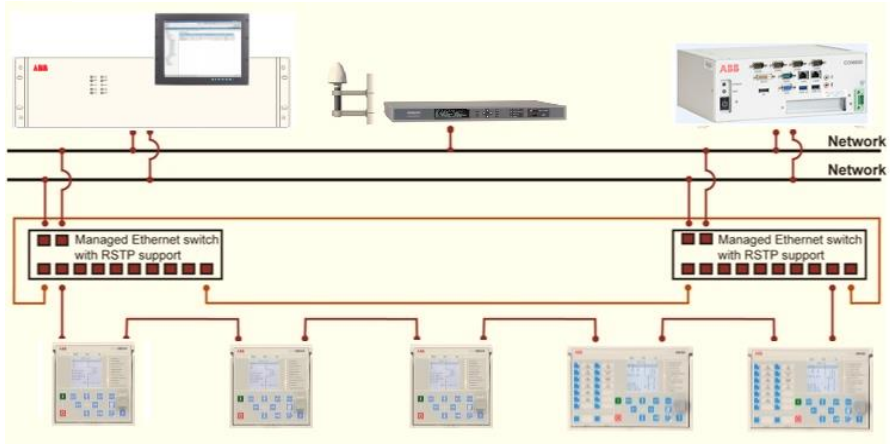
ABB solution	**Illustration**	**Benefits**
Step 14b (substation communication network): • When IEC 61850 communication network more reliable, available etc. at a lesser cost than PRP…. • Devices like protection relays are connected in a loop, without the need of a substation Ethernet switch, accordance with IEC 61850 HSR (High-speed Seamless Ring). • This creates a redundant path for IEC 61850 data between protection relays • Non HSR compliant devices are connected to the ring through an Ethernet switch or in PRP mode through redundancy boxes like COM600S.	 	• Secures critical communication between devices • No interlinks • Failure of a switch causes zero-switchover time • Combinations of HSR with other popular arrangements like RSTP (based on switches) is also possible for maximum reliability.

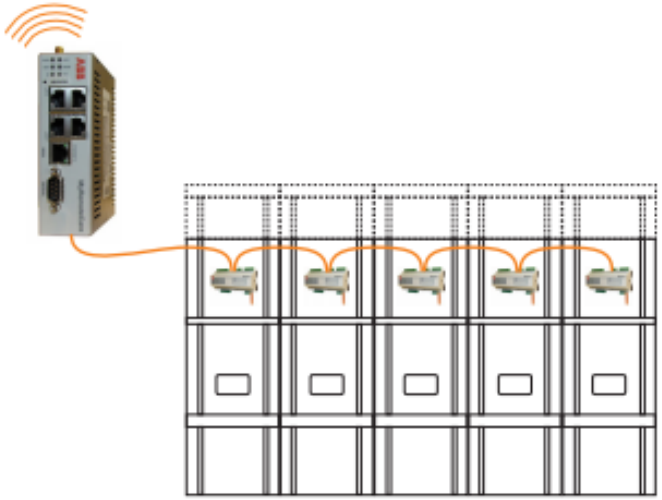
ABB solution	**Illustration**	**Benefits**
Step 15 (multi-feeder): • When remote (cloud-level) diagnostic need to be carried out…. • Multiple MySitecare monitoring and diagnostic units are networked together to be connected to a local gateway such as Arctic wireless gateway		• To facilitate predictive maintenance based on live-on site data for whole switchgear lineup. • Improves asset utilization

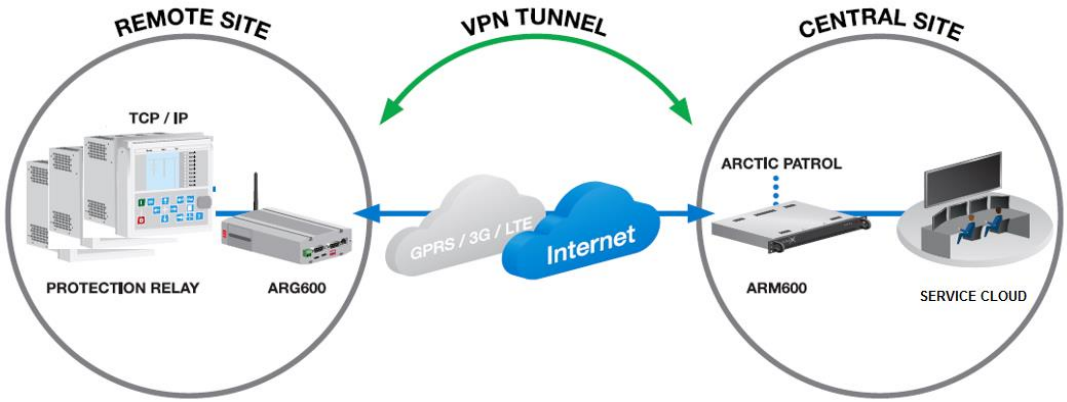
ABB solution	**Illustration**	**Benefits**
Step 16a (plant-wide): • When plant/substation data is to be sent to a secure remote cloud for analytics…. • Multiple Relion protection relays are connected to an Arctic wireless gateway ARx600 connected to a substation switch. • Over a secure VPN tunnel established between ARM600 remote-end communication server and ARx600 in the substation, data from the protection relays is sent to the remote/service site. • Clionet Data Care system ensures download or upload of configuration backups based on customer access.		• Cloud based repository of protection relay configurations and site data. • Cyber-secure solution • Individual user rights and accounts • Uses 4G mobile or wireless networks

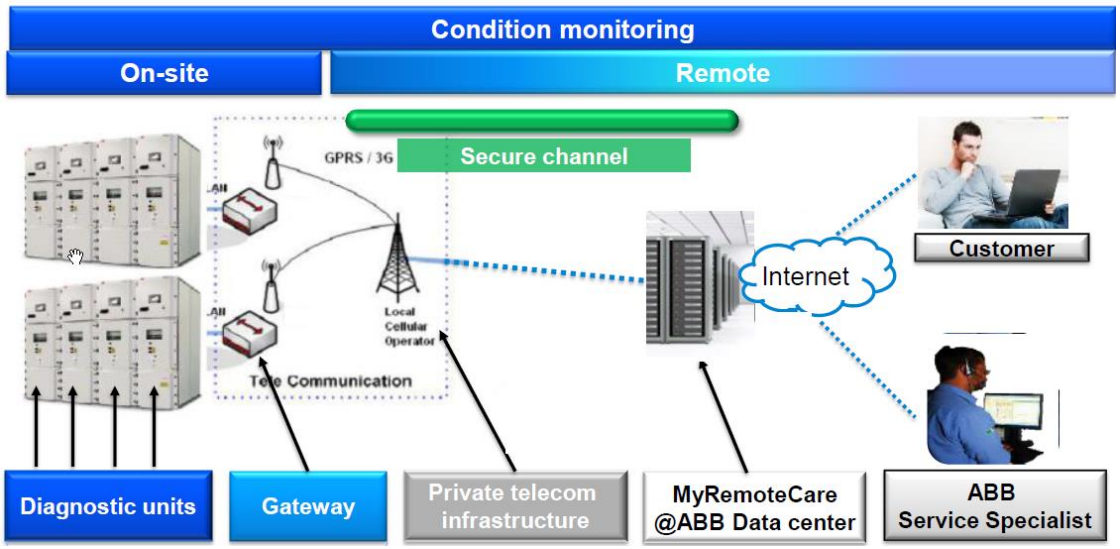
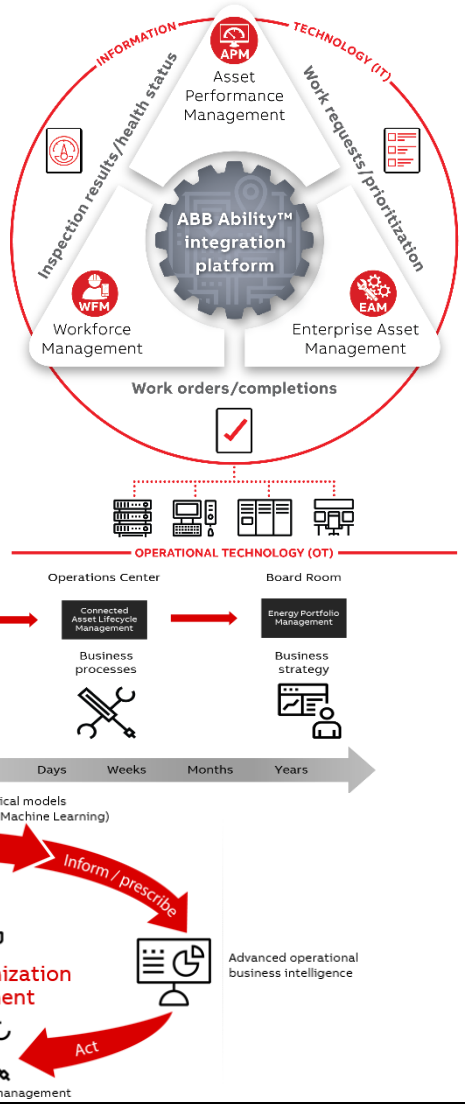
ABB solution	**Illustration**	**Benefits**
Step 16b (plant-wide): • When plant/substation circuit breaker and switchgear data is to be analyzed in a remote cloud by experts and service specialists…. • Associating multiple MyRemoteCare remote cloud server with Arctic wireless gateway ARx600, ARM600 MySitecare monitoring and diagnostic units and Unigear switchgear.	MyRemoteCare system Condition monitoring 	• Reduces unscheduled downtime and operational costs. • Increases asset availability and linked production • Risk-based and predictive maintenance facilitated • Proactive maintenance approach saves investment by preventing breakdown maintenance • Uses 4G mobile or wireless networks

ABB solution	**Illustration**	**Benefits**
Step 16c (single or multi-site): • When the customer has deployed a SSC600 multi-feeder protection device (computer) in a hybrid or centralized protection and control solution…. • The customer has a provision for remote view of disturbance records, parameter settings and configurations OR have a possibility to get remote upgrades from ABB. • An MVAM cloud application is deployed together with Arctic wireless gateway ARx600, ARM600 • Processed information from process plants (COM600S unit(s)) can be used for operational planning, control actions in the field		• Futuristic solution • Remote product lifecycle management • Extending centralized or hybrid protection and control solution by adding analytics based on processed substation data is available • Uses 4G mobile or wireless networks

ABB solution	**Illustration**	**Benefits**

Step 16d (plant-wide):
 	
• When life cycle assessment of power network asset condition is required, together with aim to reduce likelihood of failure, damage and injury….
 	
• MySiteCondition facilitates advanced maintenance methodologies by assessing:
  ○ Importance of equipment
  ○ Actual site-condition
  ○ Critical points in the network
  ○ Available historical data
  ○ Operator and asset safety
  ○ Product life cycle status
 	
• Can be used for MV and LV equipment
	
	MySiteCondition
	Outlook on current and future reliability
	On-site collections and evaluation of data - the foundation of risk mitigation -
	Basic actions
	Preventive actions
	Urgent actions
	A documented and transparent decision making framework
		• Delivers results in the form of reports with required high-priority actions.
		
		• Reports for each asset covered
		
		• Risk mitigation plan with actions to improve condition index.

ABB solution	**Illustration**	**Benefits**
	 	• Condition-based / predictive maintenance leading to high asset utilization • Safeguards customer investment

IX. Appendix – 3 (Mapping KPIs, solutions and products)

Having described the customer needs and derived KPIs in Sections II and III respectively, the solution components and the suggested electrical power network solution steps (in Sections IV, V , VI and VII respectively, it is now necessary to map them in a table in order to have traceability.

KPI	Solution	Components/Products
• Food safety • People Safety • Manufactured product quality • Reduce outages (smart system management) • Continuous operations • Preventing unplanned downtime and lost production • Energy efficiency	• IEC 61850 based power automation system • Islanding and fast load-shedding • In plant power generation • Power generation control and voltage regulation • Automatic synchronization • Power automation system delivering dedicated/advanced protection and energy efficiency solution • Busbar protection • High-speed bus transfer / Automatic transfer switching • Power Quality monitoring and control • Communication system redundancy • Cybersecurity • DCS interface	• AFS660, AFS670 • GPS/time servers • Relion PML630 • Relion 611, 615, 620 series, REX640 • SSC600, Relion SMU615 • Emax, Emax2 + Ekip, MStart+MControl, UMC100, M10x-M, Tmax • AC800M + Small PMS library • COM600S, SYS600, MView, Mlink • ABB Energy Manager software • SUE3000 • TruOne – ATS • Relion 611 series • ESSPro PCS • PQF series • PCS100 AVC -40 • ARx600, ABB Ability Edge gateway, MNS Digital Edge gateway • MNS iS, MNS Digital • MySiteCare, MySiteCondition, MyRemoteCare, MService, ABB Ability Condition Monitoring • Clionet Data Care, MVAM , Asset Health Center, ABB Ability EDCS • Low voltage motors • UPS Conceptpower DPA 500

KPI	• **Solution**	**Components/Products**
• Food safety during storage (maintaining supply voltage, temperature)	• Power generation control and voltage regulation • Power automation system (temperature control)	• Relion REX640, REU615 • AC 800M + Small PMS library • SSC600 • RIO600 • COM600S, MView, Mlink
• People (operational) safety • Protection of capital investment on assets • Preventing unplanned downtime and lost production	• Fast acting and coordinated arc protection system • Gas insulated, air insulated switchgear and equipment layout • Power automation system AND dedicated/advanced protection (to secure each part of the network) • Bus bar protection • Short circuit current limiters facilitating system augmentation • Power automation system (substation HMI)	• KEVA, KECA, KEVC series • VD4, HD4, EMax2 • Unigear ZS1 Digital, ZX1.2, SafeRing/Safeplus, UniSec/LeanGear, MNS Digital • Rigel/Mercury compact secondary substation • UFES, REA10x, EMax 2, TVOC-2 • Relion 611, 615, 620 series, REX640 • SSC600, Relion SMU615 • Is-limiter • Surge arrestor (MWD) • COM600S, SYS600, MView, Mlink, MNS Digital Gateway, ABB Ability Condition Monitoring
• Increased asset utilization • Optimized total cost of ownership • Protection of capital investment • Increased operational efficiency • Trusted partner for long term partnership, solution oriented, on-site support	• Short circuit current limiters facilitating system augmentation • Power automation system AND dedicated/advanced protection (to secure each part of the network) • Gas insulated, air insulated switchgear and equipment layout • Intelligent substation asset analytics aiding predictive maintenance	• Is-limiter • Relion 611, 615, 620 series, REX640 • Relion SMU615, SSC600 • VD4, HD4, EMax2 • Unigear ZS1 Digital, ZX1.2, SafeRing/Safeplus, UniSec/LeanGear, MNS iS,MNS Digital • ARx600, ABB Ability Edge gateway, MNS Digital Edge gateway • MySiteCare, MySiteCondition, MyRemoteCare • Clionet Data Care, MVAM , Asset Health Center, MService, ABB Ability Condition Monitoring, ABB Ability EDCS • SUE3000 • ESSPro PCS • PCS100 AVC -40
• Ambient insensitivity	*(product characteristics)*	All equipment can operate in harsh climate (temperature and humidity)

X. Conclusion

Using the suggested F&B plant use case, all necessary solutions have been suggested, which in turn have been mapped to specific ABB products and solutions in the power distribution area are clearly identified, justified.

These ABB solutions and products are further mapped to the identified key customer KPIs. Based on the above, it is quite clear that ABB's products and solutions can ensure a major contribution towards making a safer, more reliable and smarter F&B process.

XI. References

[1]	Internal presentations from ABB's F&B segment business
[2]	http://www.fb.bito.com/dk-en/food-beverage-basics/temperaturzonen/das-thema/
[3]	http://www.silverson.com/us/resource-library/application-reports/soft-drink-manufacture-preparation-of-sugar-syrups
[4]	http://wiki.zero-emissions.at (Pasteurization_in_food_industry)
[5]	http://new.abb.com/products/robotics/applications-by-industry/food-and-beverages/applications/packing
[6]	http://www.foodengineeringmag.com
[7]	http://www.abb.com – for all product information mentioned in Section VII (Appendix – 1)
[8]	http://electrical-engineering-portal.com/electrical-distribution-architecture-in-water-treatment-plants