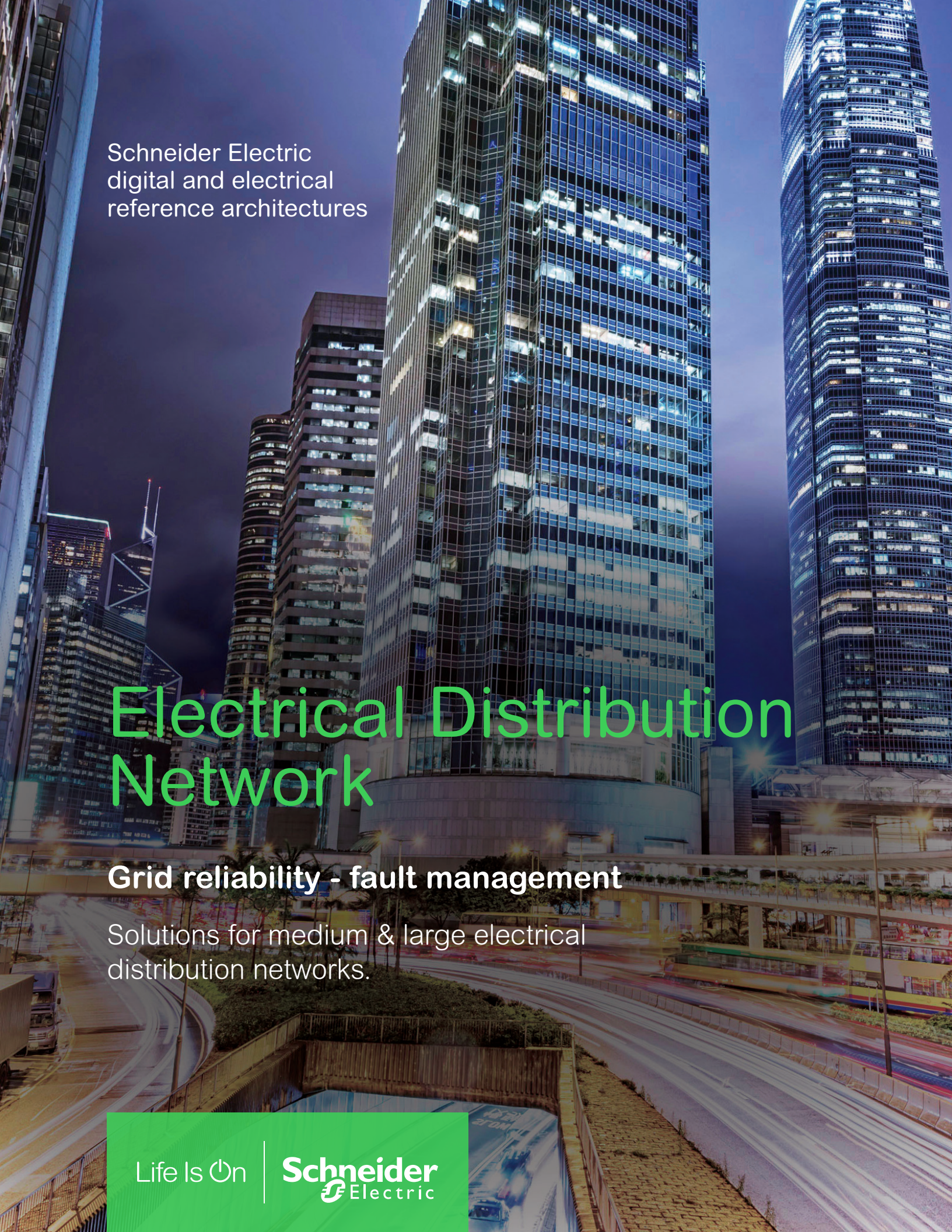


Schneider Electric
digital and electrical
reference architectures

Electrical Distribution Network

Grid reliability - fault management

Solutions for medium & large electrical distribution networks.

Life Is On | Schneider Electric

Contents

Context

Grid modernization is a strategic initiative for many electricity companies and one key concern is the improvement of grid reliability. They want to reduce the level of outages seen by the end-user.

Total outage time seen by end-users is made up of:

- Unplanned outages: electrical faults within the distribution circuits
- Planned outages: maintenance, retrofit
- Major events: flooding, storm, typhoon

Most relevant indicators for network availability assessment are:

- Long interruption ≥3min*: SAIFI, SAIDI, ASAI, ENS
- Short and transient interruption <3min*: MAIFI

*This is a typical value. The threshold can vary from one electricity company to another.

Each utility has its specific rule for monitoring, accounting and reporting network availability. Reporting quality and accuracy depend on the observability in the network and workforce management.

Problem to solve

An electrical distribution company wants to reduce the duration of outages seen by end-users;

- Reducing the time to locate and isolate the faults
- Quickly defining reconfigurations, enabling progressive re-energization of the system
- Optimizing mobilization of resources for repair and full recovery of normal situation

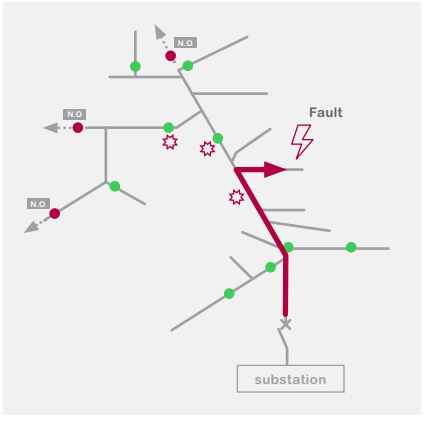
This set of actions is defined in one major process of electrical distribution companies: the FLISR process. (Fault Location, Isolation and Service Restoration).

FLISR process describes procedures for:

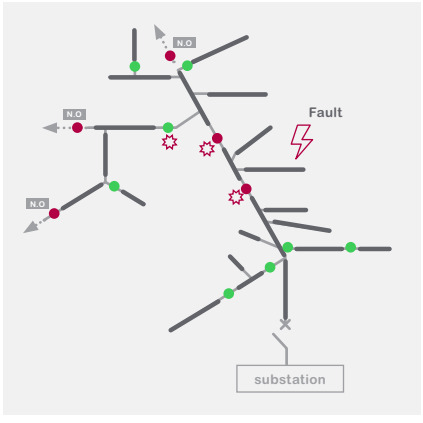
- Fault detection and localization
- Fault isolation
- Service restoration, including:
  - Reconfiguration to restore customers with main and alternative sources (with normally open points)
  - Repair and restore the faulty part

FLISR process coordinates:

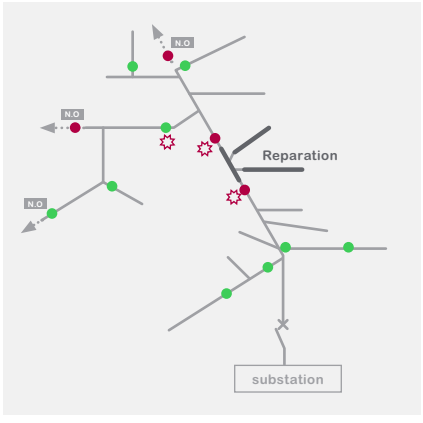
- Automatic operations of reclosers, sectionalizers, RMUs
- Manual operations by field crews



Fault happens in the circuit



Upstream protection disconnects the whole branch



Faulty section is isolated

Functional breakdown

FLISR process functions includes following sub-functions

Fault detection	Fault localization	Fault isolation	Service restoration
Detect fault	Analyze the fault passage data	Define degraded reconfiguration	Define corrective actions
Open faulty circuit	Localize fault on diagram	Send open/close commands	Define successive reconfigurations
Indicate fault passage	Localize fault on map	Open/close circuits	Repair circuit
			Acknowledge fault repair
			Send open/close commands
			Open/close circuits

Constructional breakdown

These functions / sub-functions will be covered by products, software and services as described below.

Fault detection	Fault localization	Fault isolation	Service restoration
Protection relay	ADMS (NM/TA/FL/FLISR...)	ADMS	ADMS (OMS/CM/LAR...)
Circuitbreaker	ArcFM	Circuitbreaker	Field services engineers / maintenance team
Recloser		Recloser	Circuitbreaker
Fault passage indicator		Sectionalizer	Recloser
			Sectionalizer

Solution general description

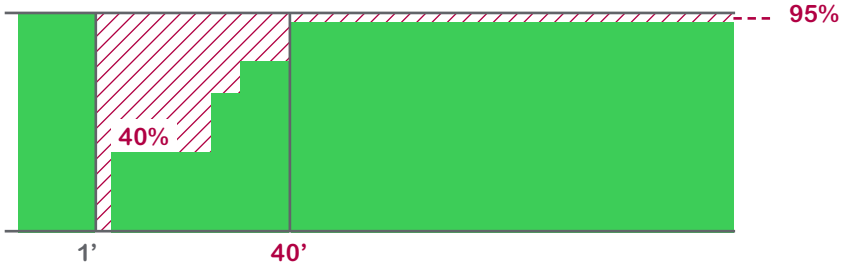
“Remote control switching – centralized solution” consists in an optimized* architecture based on motorized and communicating switchgear (circuit breakers, reclosers, sectionalisers) and communicating Fault Passage Indicators (FPIs).

The whole system is controlled and managed by an **ADMS** (Advanced Distribution Management System).

- Solution is developed as a centralized and unique system for managing large scale distribution networks
- FLISR activities are optimized with network actual status by switching optimization algorithms in analytic modules (ADMS)

In addition to **FLISR** module, the system can include several other ADMS modules for further resiliency improvement benefits: **OMS** (Outage Management System), **CM** (Crew Management), **LAR** (Large Area Restoration).

This solution allows very fast localisation of faults and automatic reconfiguration of the network. Typical interruption duration (in minutes on horizontal axis) and interruption impact depth (% of non-impacted customers).
(red zone is “interruption”)

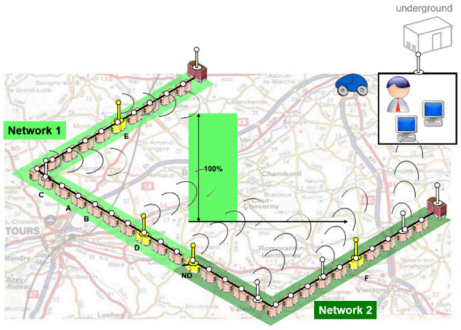


*Schneider Electric proposes consulting services to optimize the quantity and location of each type of device in order to obtain the best “investment vs. performance” result. See details at the end of this document.

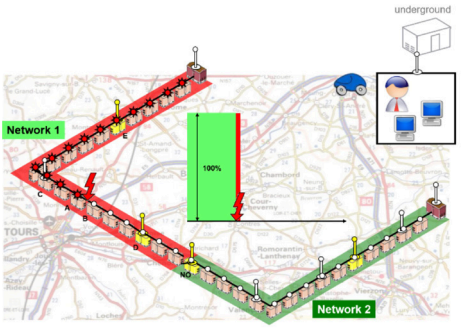
Case #1 – Underground “ring type” network

For this type of network topology, Ring Main Units (RMUs) are used as electrical distribution switching devices. Circuit breakers and switches are motorized and the RTU is communicating.

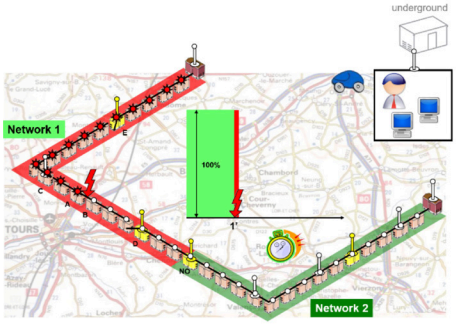
FLISR sequence description – example of underground “ring” network:



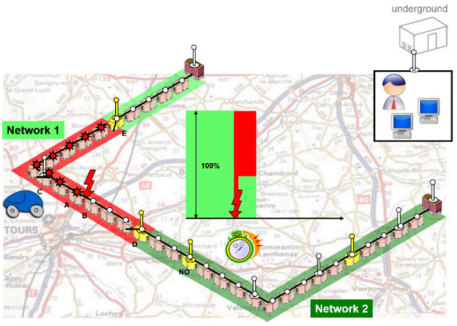
This simple network taken as an example is a loop made of 2 sections: “Network 1” and “Network 2” connected via a Normally Open point “NO”.



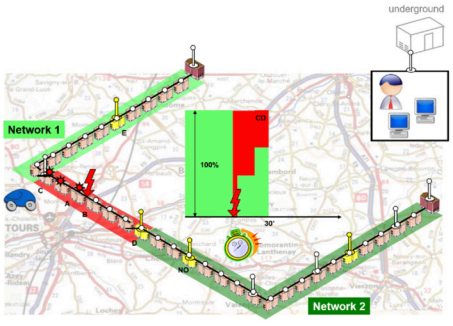
When a fault occurs in “Network 1”, this whole section is de-energized. “Network 2” remains energized. Thanks to communicating devices fault is localized between “C” and “D”.



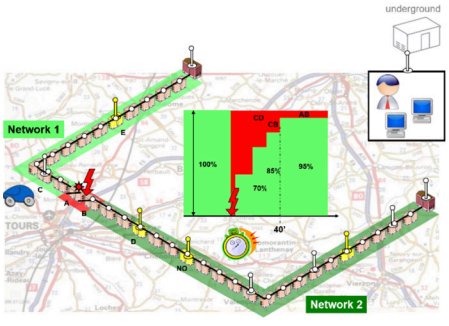
Knowing the fault location, system opens the remotely controllable switches in D and E. It recloses NO so that portion of “Network 1” between D and NO is re-energized. It also opens E to re-energize the upstream portion of Network 1.



Grid operator can send the field engineer to site to locally open C and reduce the faulty area.



E can be closed again to re-energize the E-C section. Field service team can visually identify the exact fault location between A and B.

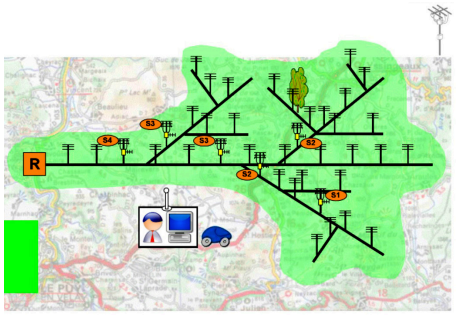


They open A and B. Then C and D can be closed again.Only A-B section is de-energized. Repair can take place before full recovery of the system.

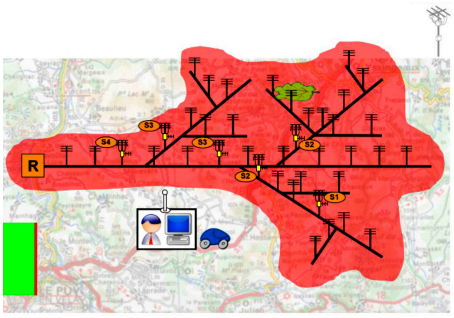
Case #2 – Overhead radial network

For this type of network topology, reclosers and sectionalizers are used as electrical distribution switching devices. Sectionalizers and FPIs can be communicating or not.

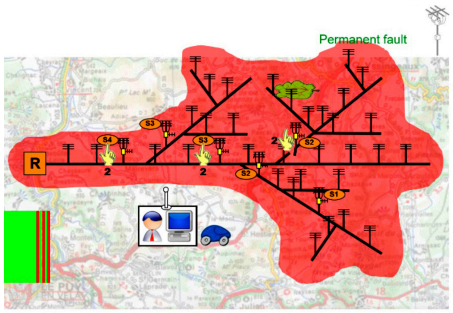
FLISR sequence description – example of overhead radial network:



This is a simple example of over-head radial network with one upstream recloser “R” and several sectionalizers: S1 to S4. (Number indicates quantity of reconnections it can see before being open).

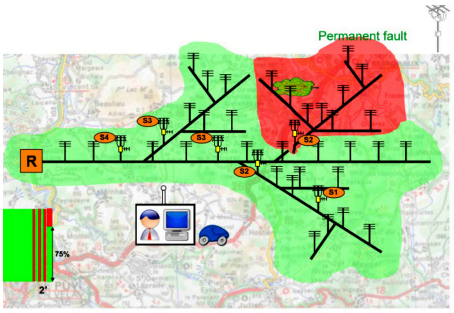


When a permanent fault occurs in the Network, the upstream recloser disconnects the system and then try to reconnect it several times.

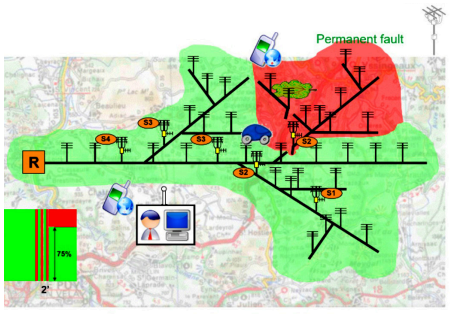


If the fault is still present after the 2nd reconnection, R will try to reconnect a 3rd time but, before that, S2 sectionalizer* will automatically open.

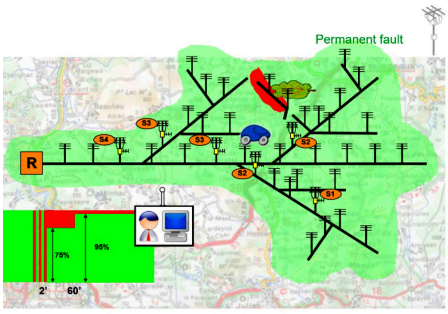
*Only S2 sectionalizers which have seen fault current.



R reconnects the remaining part of the network without the faulty portion. Information on fault location (S2) allows field services team to go for inspection to the faulty area.

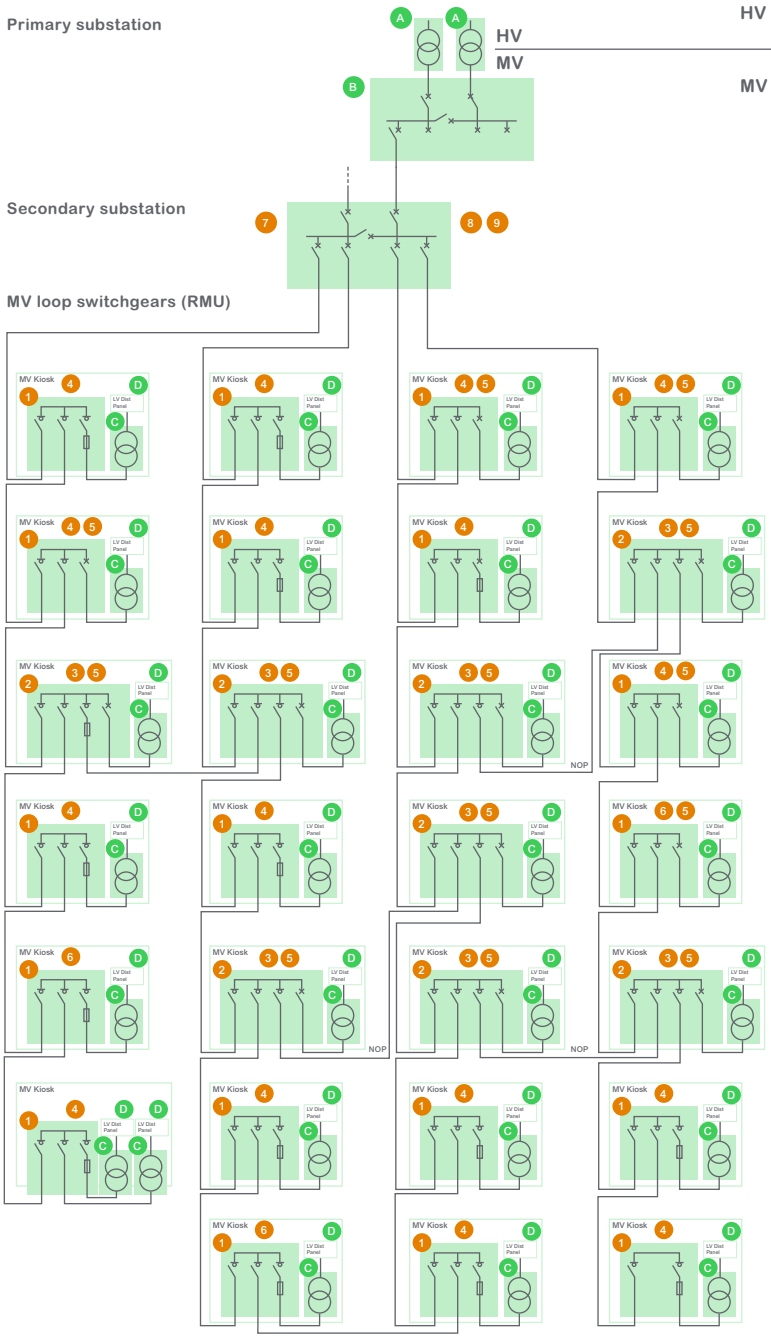


Field services team will isolate further the faulty area using the local switching devices.
From their instructions, S2 recloser will be remotely closed again to re-energize other sections of this branch.



Field services team will proceed to the repair of the faulty section before reconnection for full recovery of the system.

Electrical Architecture – Underground “ring type” distribution network example



A MV/HV Power Transformers
Minera MP

B MV Primary Switchgear
Schneider Electric ranges
(GHA, GMA, CBGS 1, WS, PIX, MCSet, F400, CBGS-0, WS-G...)

Protection Relays
Easergy range
(P5, Vamp V321)

Power Meters
PowerLogic ranges
(ION, PM...)

7 MV Secondary Switchgear

FBX SM6 DVCAS
(and also: Flusarc, Ringmaster, PremSet...)

Inside the Switchgear

8 Protection Relays
Easergy P5

9 Power Meters
ION & PM Ranges

1 RMU

RM6 FBX Ringmaster

Inside the RMU

4 Fault Passage Indicators
Easergy Flair 2XD

5 Protection Relays
VIP 400 - VIP 410

6 Fault Passage Indicators with Com
Easergy Flair 23DM

2 Smart RMU

Smart RM6 Smart FBX

Inside the SMART RMU

3 RTU
Easergy T300

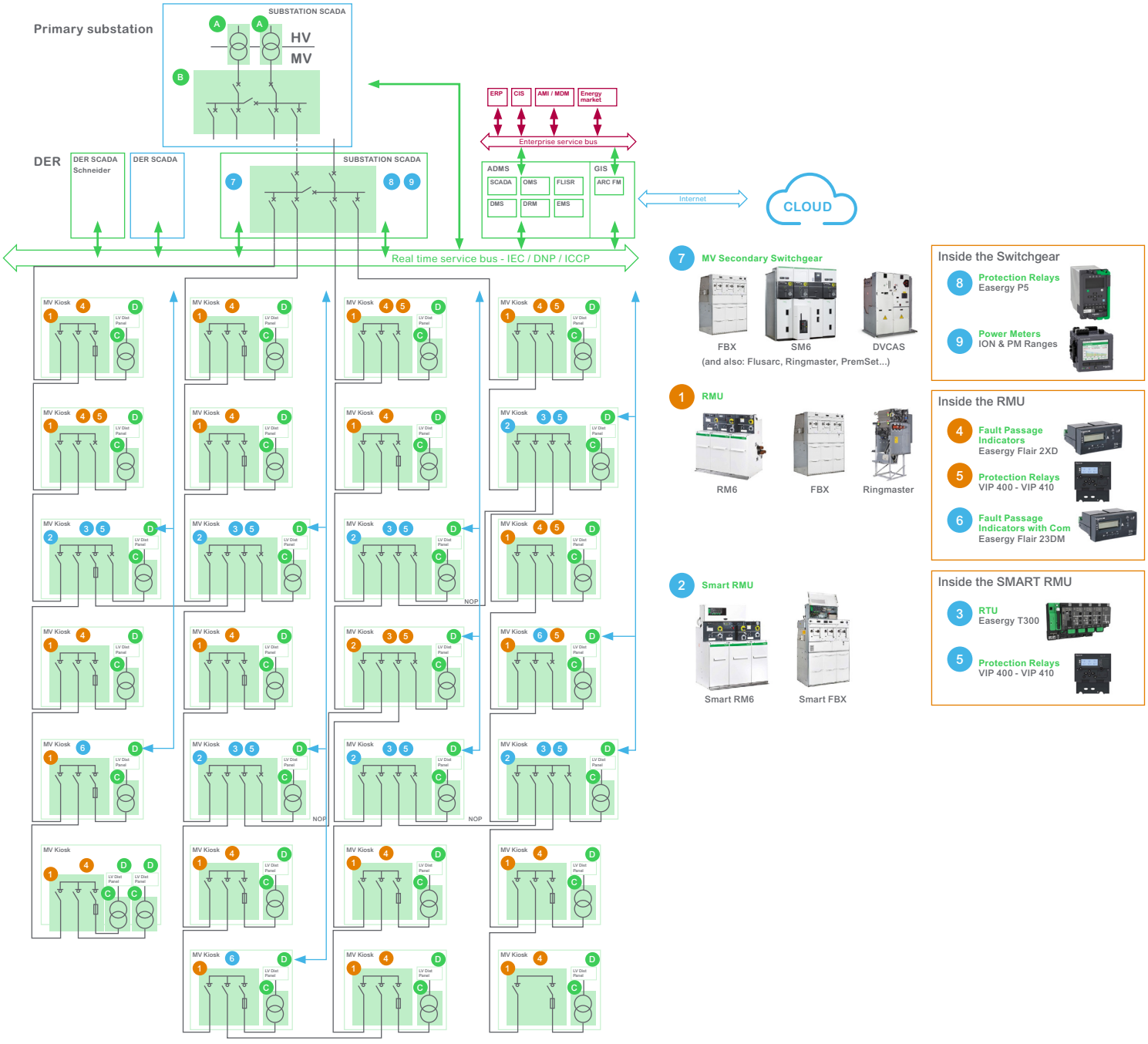
5 Protection Relays
VIP 400 - VIP 410

C MV/LV Distribution Transformers

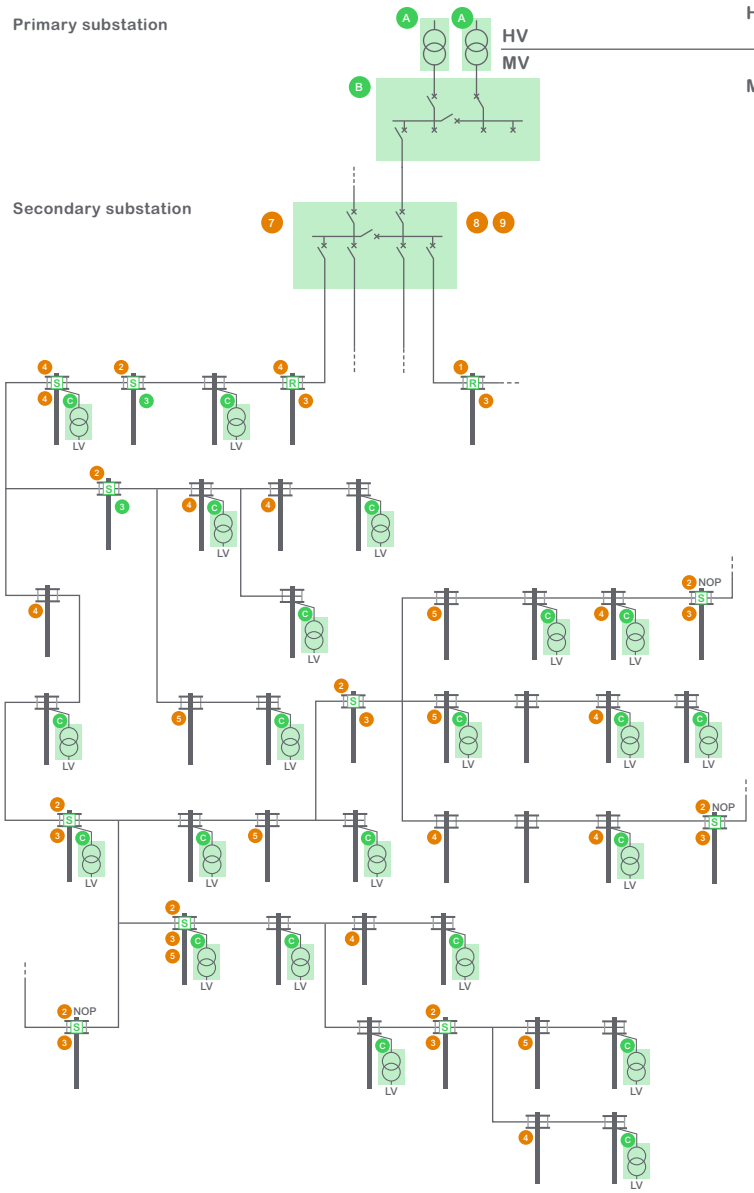
Minera S Grid Minera Ground Mounted Trihal

D LV Distribution Panel

Digital Architecture – Underground “ring type” distribution network example



Electrical Architecture – Overhead “radial type” distribution network example



A MV/HV Power Transformers
Minera MP

B MV Primary Switchgear
Schneider Electric ranges
(GHA, GMA, CBGS 1, WS, PIX, MCSet, F400, CBGS-0, WS-G...)

Protection Relays
Easergy range
(P5, Vamp V321)

Power Meters
PowerLogic ranges
(ION, PM...)

7 MV Secondary Switchgear

FBX SM6 DVCAS
(and also: Flusarc, Ringmaster, PremSet...)

Inside the switchgear

8 Protection Relays
Easergy P5

9 Power Meters
ION & PM Ranges

1 Reclosers

E Series U Series W Series

2 Sectionalizers

RL Series

3 Control Box

ADVC Ultra ADVC Compact

4 Fault Passage Indicators

Easergy Flite 116-SA Easergy Flite 3xx

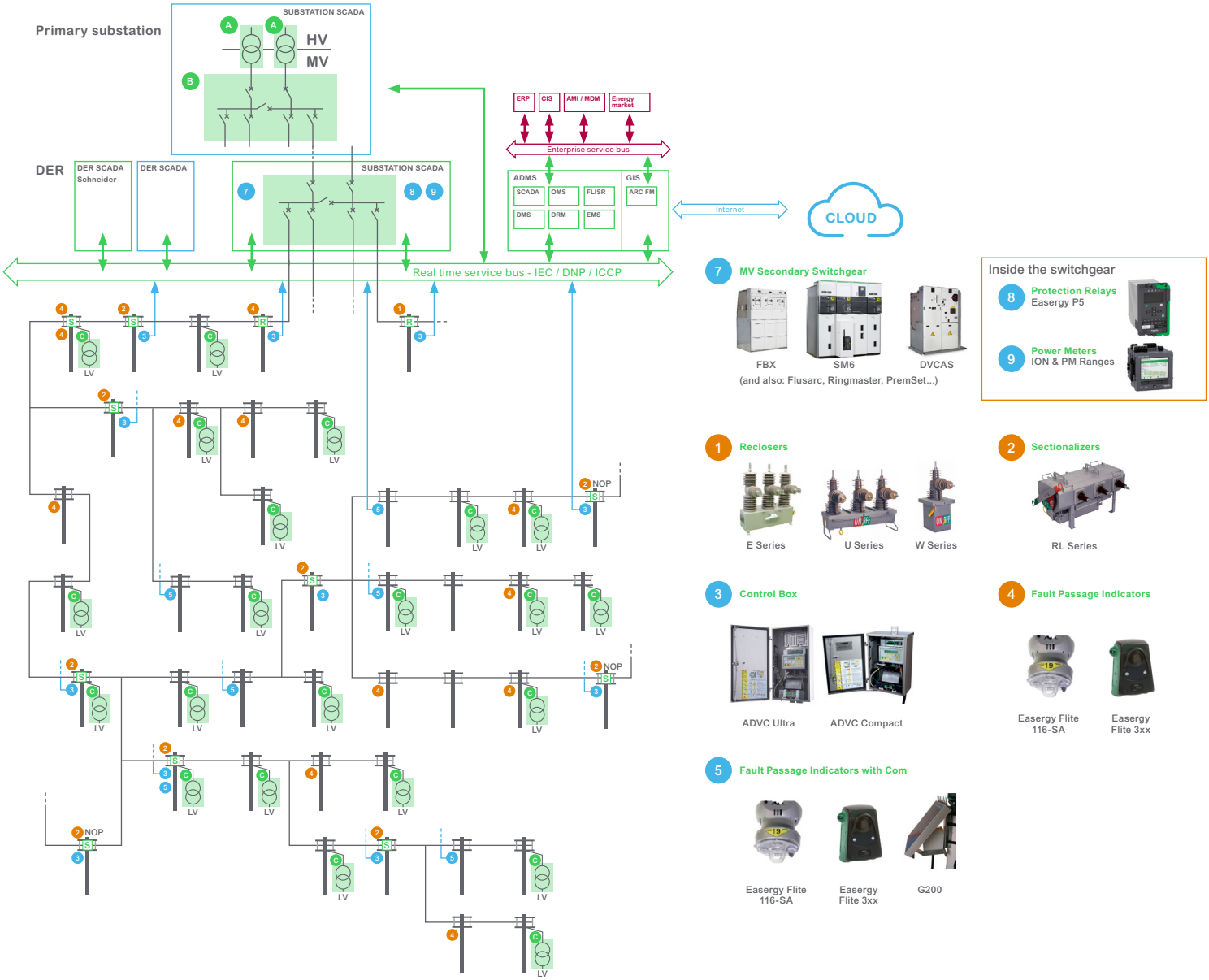
5 Fault Passage Indicators with Com

Easergy Flite 116-SA Easergy Flite 3xx G200

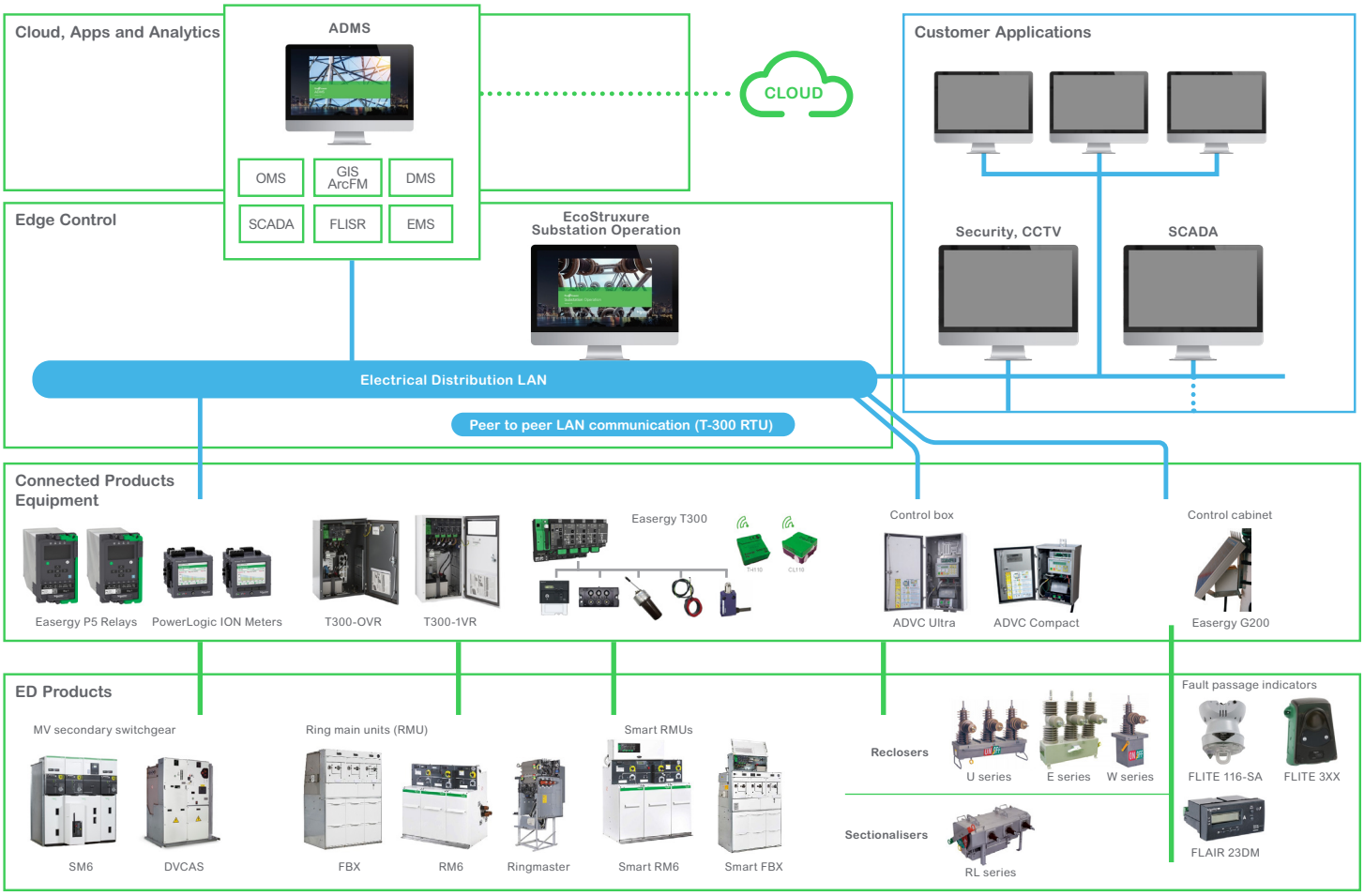
C LV Distribution Panel

Minera Pole Mounted Minera Ground Mounted Minera S Grid

Digital Architecture – Overhead “radial type” distribution network example



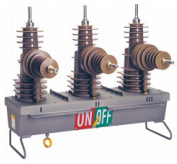
EcoStruxure™ Grid architecture

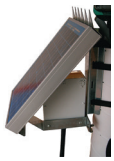


Schneider Electric products used in the use case

Network function	Product name	Main technical characteristics		Link to offer / spec
ADMS	**EcoStruxure™ ADMS**	Advanced Distribution Management System with following modules: - DMS - OMS - SCADA - FLISR - GIS (ArcFM)		learn more
SCADA	**ESO (EcoStruxure Substation Operation)**	SCADA digital control system for substation automation based on PACiS technology.		learn more
Protection relay	**Easergy P5**	MV protection relay from over-current to differential protection, with arc flash protection, LPCTs, LPVTs, redundant Ethernet communication, and IEC 61850.		learn more
Power meter	**ION range**	PowerLogic ION 9000 advanced power quality		learn more
Power meter	**PM range**	Power Logic PM 8000 / PM7000 compact, high performance power meters.		learn more
RMU	**“Smart” RM6**	Gas insulated switchgear, up to 24kV with T-300 RTU. Short Time current rating up to 21kA, rated for internal arc up to 20kA AFLR with options.		learn more
RMU	**“Smart” FBX**	Gas insulated switchgear, up to 24kV with T-300 RTU. Fully SF6-insulated RMU switchboard, available in compact or extensible installation footprints. Short Time current rating up to 25kA, rated for internal arc up to 25kA AFL with options.		learn more

Network function	Product name	Main technical characteristics		Link to offer / spec
RMU	**RM6**	Gas insulated switchgear, up to 24kV. Short Time current rating up to 21kA, rated for internal arc up to 20kA AFLR with options.		learn more
RMU	**FBX**	Gas insulated switchgear, up to 24kV. Fully SF6-insulated RMU switchboard, available in compact or extensible installation footprints. Short Time current rating up to 25kA, rated for internal arc up to 25kA AFL with options.		learn more
RMU	**Ringmaster**	Hi-reliable Gas Insulated Switchboard for underground secondary distribution. For indoor and outdoor applications, up to 13.8kV.		learn more
RTU	**Easergy T-300**	- Remote Terminal Unit made of: - - HU250: head unit communication gateway - - SC150: switch controller module - - LV150: transformer and low voltage monitoring module - - PS25/PS50: power supply module		learn more
RTU box	**Easergy T-300 IV1**	Remote Terminal Unit box for indoor installation, with T-300 RTU.		learn more
RTU box	**Easergy T-300 OVR**	Remote Terminal Unit box for outdoor installation, with T-300 RTU.		learn more

Network function	Product name	Main technical characteristics		Link to offer / spec
Recloser	**E-Series**	Light-weight reclosers up to 38kV and 170kV BIL.		learn more
Recloser	**U-Series**	Light-weight reclosers up to 27kV and 125kV BIL.		learn more
Recloser	**W-Series**	Single-phase reclosers up to 24kV		learn more
Sectionalizer	**RL-Series**	3-Phase load break switch / sectionalizer up to 38kV.		learn more
Auto recloser control box	**ADVC Compact**	304 grade stainless steel cabinet. ADVC monitors the CB and provides protection, measurement, control, and communication functions (connected via a control cable to the recloser).		learn more
Auto recloser control box	**ADVC Ultra**	316 grade stainless steel cabinet. ADVC monitors the CB and provides protection, measurement, control, and communication functions (connected via a control cable to the recloser).		learn more
Fault Passage Indicator	**Easergy Flite 110-SA**	Fault Passage Indicator for overhead network (No communication option)		learn more

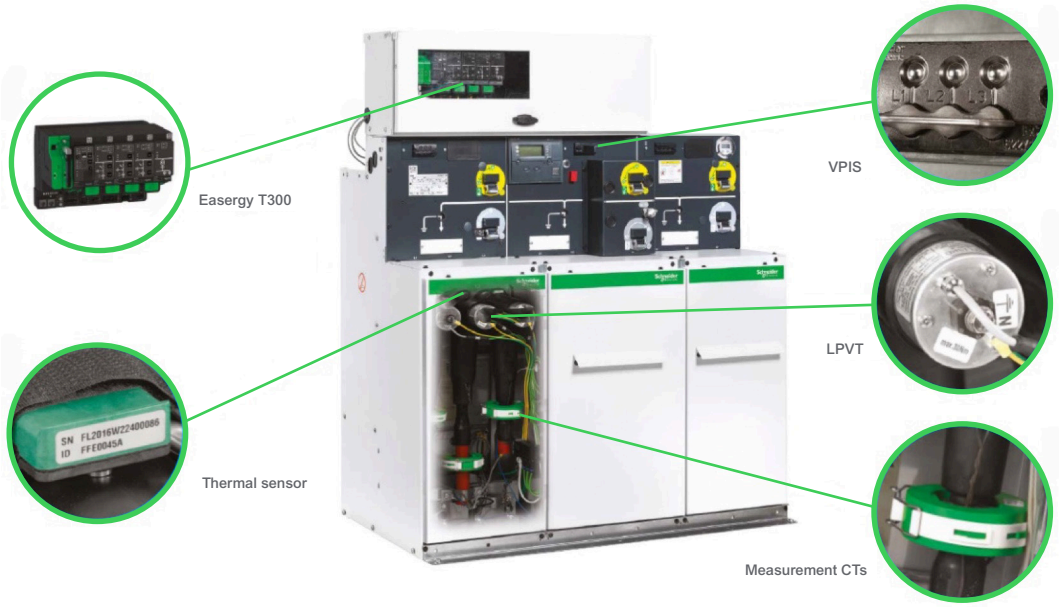
Network function	Product name	Main technical characteristics		Link to offer / spec
Fault Passage Indicator	**Easergy Flite 116-SA**	Communicating Fault Passage Indicator for overhead network, communicates wirelessly with G200 RTU.		learn more
Fault Passage Indicator	**Easergy Flite 3xx**	Communicating Fault Passage Indicator for overhead network, communicates wirelessly with G200 RTU.		learn more
FPI accessory	**Easergy G200**	RTU available in 2 housings: • Pole-mounted, with external DC supply from solar panel (G2GF) • Box to be connected to another RTU or part of a switch local control cabinet (G2SF).		learn more

Zoom on Smart RMU

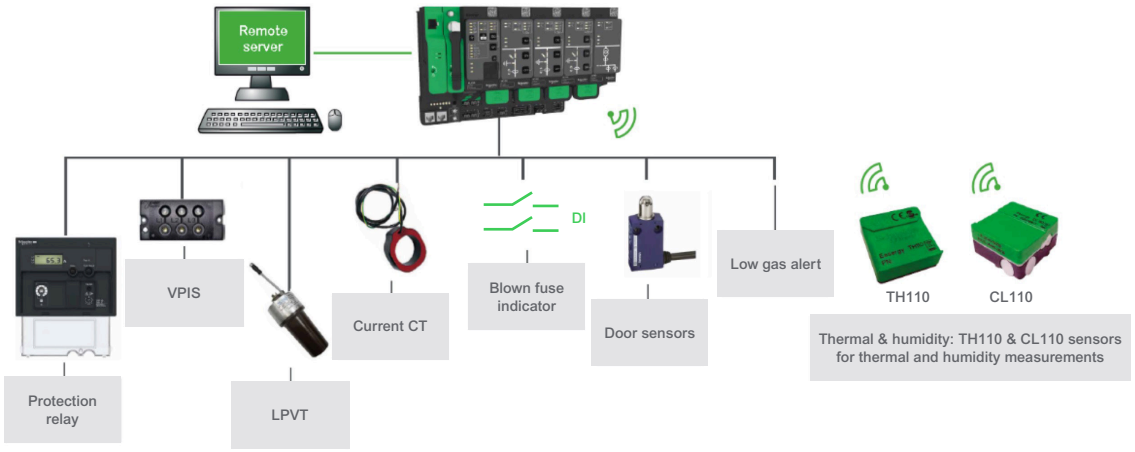
The Smart RMU is equipped with a Smart RTU gathering data from all connected sensors. These data is sent to the central ADMS system for the global network control and monitoring.

Example of Smart RMU: Schneider Electric “Smart RM6”

Smart RM6 is equipped with an **Easergy T300** RTU gathering data from connected sensors and IEDs and embedding algorithms for automatic reconfiguration of the network.



T-300 RTU with its connected devices



Special Case – “Self-healing solution” for a critical area of the network

The “self-healing” architecture is based **Smart RMUs** connected “peer to peer”. Smart RMUs are **Motorized Ring Main Units (Auto-RMU)** including Easergy T300 (RTU) embarking algorithms to manage “self-healing grid” functionality.

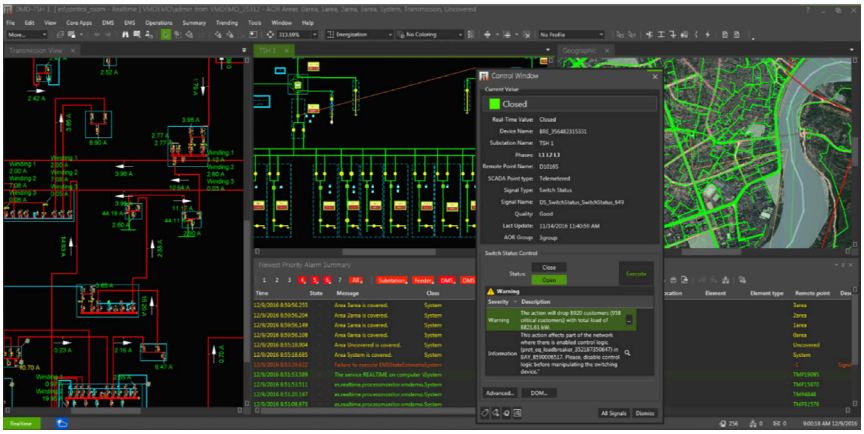
- Solution designed for underground networks featuring open-loop architectures; tailored for high continuity of supply, high-density load areas
- Decision-making algorithms in the RMU to provide coordinated switching
- Using high-speed and modern communication technologies
- Possibility to connect to SCADA or DMS system for information, alarm notification or data retrieval

Control is done at RMU level. The Smart RTUs talk to each other to manage the automatic reconfiguration and reconnection of the electrical distribution network. Communication with the ADMS / SCADA system provides remote status and situation information.

This solution allows the fastest localisation of faults and automatic reconfiguration of the network.

Zoom on ADMS (Advanced Distribution Management System)

Schneider Electric’s EcoStruxure ADMS provides the most comprehensive network management solution, including monitoring, analysis, control, optimization, planning, and training tools that all function on a common representation of the entire electrical distribution network.



By merging distribution management (DMS), outage management (OMS), and supervisory control and data acquisition (SCADA) systems into one secure, unified solution **with more than 50 advanced functions**, it can maximize the benefits possible from a growing foundation of intelligent grid devices, distributed renewable energy, advanced metering, and all things smart grid.

Network operation

- Switching & Validation
- Topology Analysis
- Temporary Elements
- Tracing
- FLISR (Fault Location, Isolation, Service Restoration)
- Large Area Restoration
- Switching Order Management
- Crew Management
- DG Management
- Load Shedding
- Work Order Management
- Under-Load Switching
- Load Transfer/Load Relief
- Dynamic Equipment Rating
- Model Readiness

Operation planning and optimization

- Volt/VAR Control
- Network Reconfiguration
- Near-term Load Forecasting
- Short-term Load Forecast
- Demand Response Management
- Electrical Vehicles Management

HV EMS

- State Estimation, Load Flow
- Contigency
- Optimal Power Flow
- Generators Control
- Breaker Capacity
- Reactive Reserve Monitoring

SCADA

- Remote Control
- Alarming, Trending, Tagging

Core DMS

- Network Model
- Load Flow
- State Estimation
- Performance Indices

Mobility

- Web Access Clients
- Field Crew Support

OMS

- Trouble Call Management
- Incident Management
- Outage Reporting/Statistics

DMS network analysis

- Energy Losses
- Reliability Analysis
- Fault Calculation
- Relay Protection Analysis
- Breakers/Fuses Capacity
- Contingency Analysis
- Low Voltage Analysis
- Harmonic Analysis
- Historian Analysis/Reports
- Phase Balancing

DMS network planning

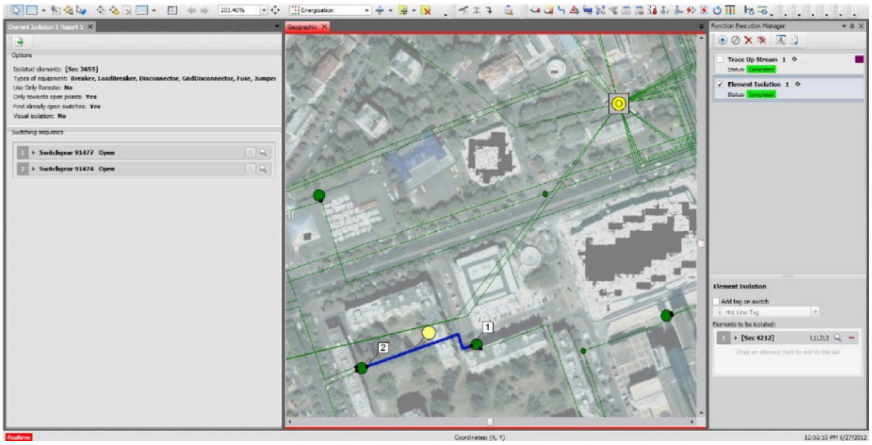
- Long (Medium) Term Forecasting
- Optimal Capacitor Placement
- Optimal Voltage Reg. Placement
- Network Construction Planning
- Network Automation
- Conductor Reinforcement
- Customer Connection

Part of the Network Operation Control Applications, **FLISR (Fault Location, Isolation and Service Restoration)** presents a collection of tools used for detection, location, isolation of faults and restoration of service for all de-energized customers. FLISR can be used in manual semi-automatic and automatic mode.

Each application, which can be used as part of FLISR, is also available as a separate application:

Fault Location (FL) application supports detecting the location of the fault. It calculates locations where faults could have occurred by analyzing the fault pattern, available real-time information acquired from field devices, including, fault indicator outputs, fault magnitude at various locations on the feeder, and protective relay tripping.

Element Isolation (EI) determines which switching manipulations are required to isolate a selected element. EI makes it possible to define the type of equipment used for isolation.



Service Restoration (SR) used for determining an optimal plan of switching actions for restoring supply on the de-energized part of a distribution network.

Large Area Restoration (LAR) determines a plan for restoration of supply to large parts of the network that remain de-energized due to:

- A fault in a supply transformer (HV/MV transformer) or an MV busbar in the supply station (HV/MV station)

- The isolation of an element for maintenance purposes in a supply station

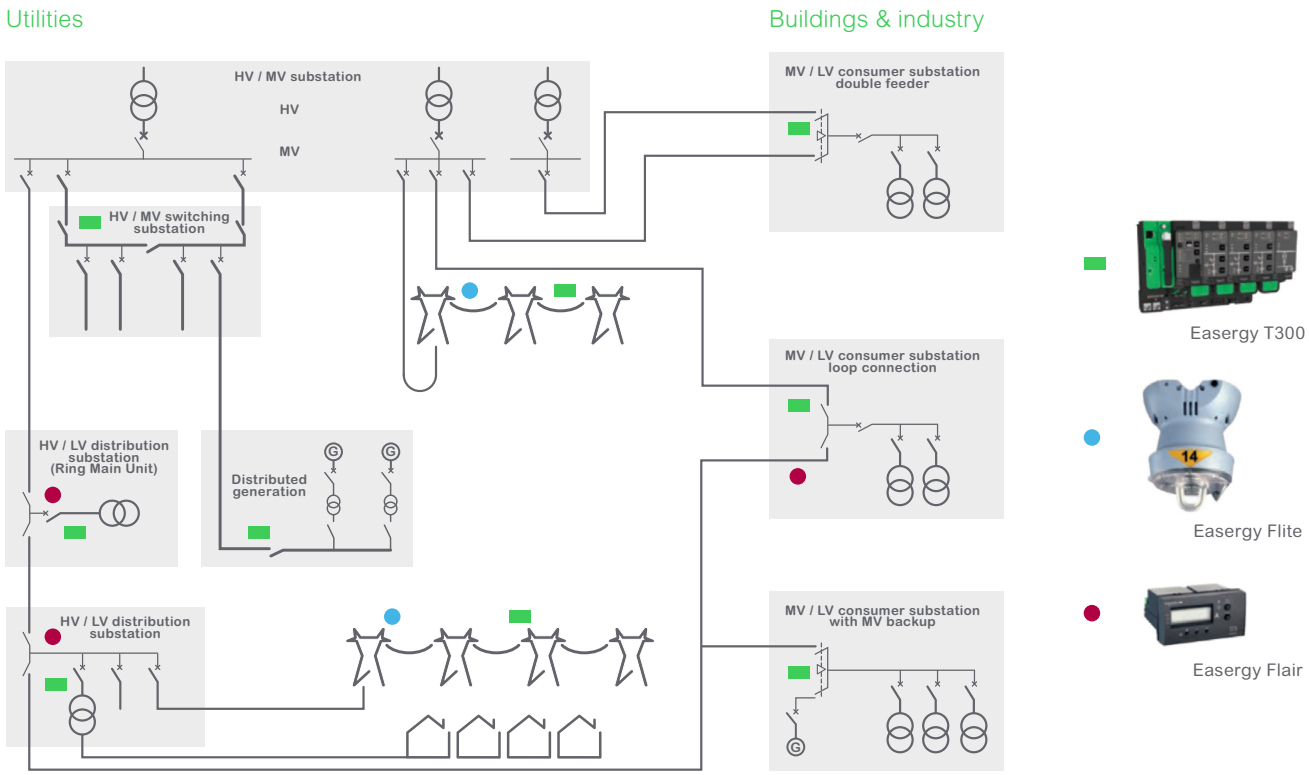
Ecostruxure Grid service offers

Consultancy services

Schneider Electric consultancy services can provide recommendations for the type, quantity and location of devices required to upgrade the system to reach the expected level of performance.

Modernization solutions include the implementation of a combination of connected/not connected Fault Passage Indicators (FPIs), and motorized/unmotorized, locally and remotely operable reclosers, sectionalizers, RMUs, and/or Smart RMUs.

Example



Consultancy Services provide recommendations for an optimised level of automation of the electrical distribution system, in line with performance expectations (expected SAIDI & SAIFI levels) and budget.

Taking into account the modernization strategy, a study is performed to estimate the best quantities and locations of the key devices - Fault Passage Indicators (FPIs), Reclosers, Ring Main Units (RMUs / Auto-RMUs), Remote Terminal Units (RTU) - to best serve the different applications for fault management and operational efficiency.

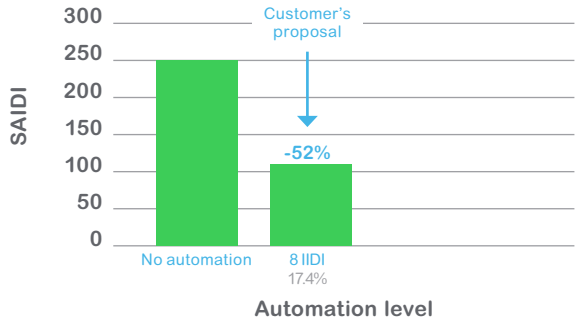
For small size electrical distribution networks, modernization can start from installation of standard FPI without communication, relying on operations/maintenance personnel to visually inspect and/or perform manual operation of reclosers.

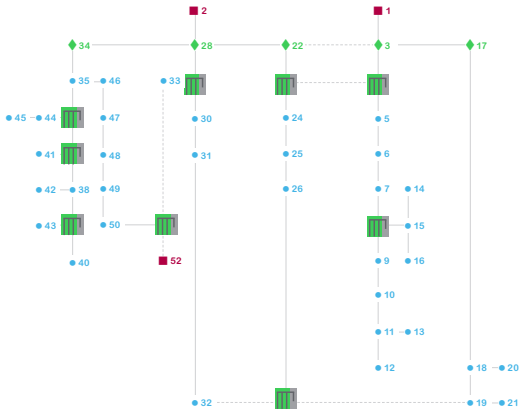
For larger electrical distribution networks, it will include communicating FPIs, motorized and communicating switching devices (Auto-RMU) controlled by an ADMS and its optimization algorithms, allowing for dynamic reconfiguration of the network.

For further details about the consultancy services proposed for this project, please refer to the related “Consultancy Services Technical Specification” document.

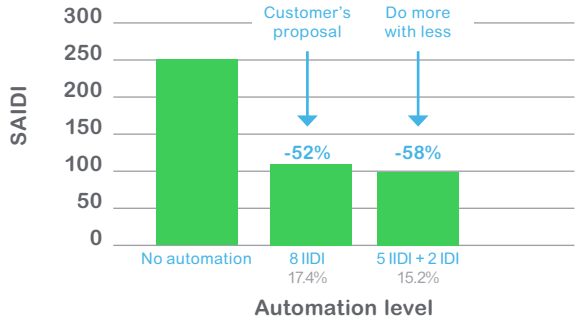
Study results example:

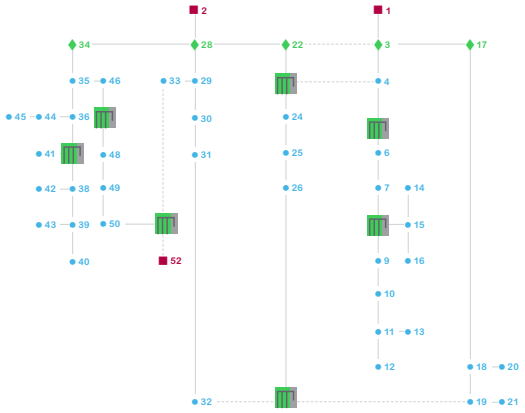
1. Customer initial idea = 8 RMUs 4 functions (IIDI) → **SAIDI improved by 52%**



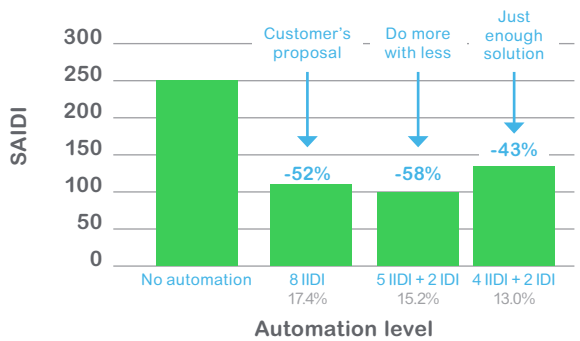


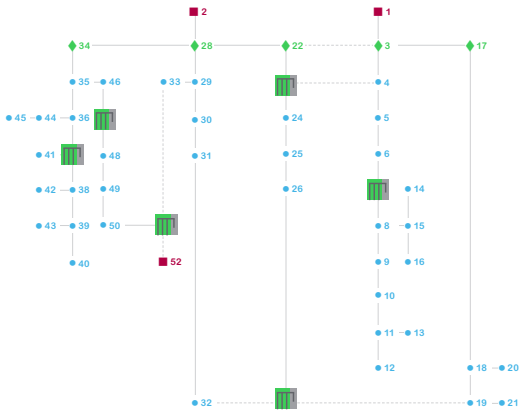
2. Proposal 1 after study = 7 RMUs (5x4 functions (IIDI) + 2x3 functions (IDI)) → **SAIDI improved by 58%**





3. Proposal 2 after study = 6 RMUs (4x4 functions (IIDI) + 2x3 functions (IDI)) → **SAIDI improved by 43%**





This third example is the “Just Enough” solution selected by the customer as it enabled the SAIDI target to be reached with the least number of RMUs.

List of acronyms

AC	Alternate Current
ACB	Air Circuit Breaker
ACR	Automatic Circuit Recloser
ADMS	Advanced Distribution Management System
AERC	Automation Equipment with Remote Control
AFE	Active Front End
A-FLR	Authorized Front Lateral Rear
AHF	Active Harmonic Filter
AIS	Air Insulated Switchgear
APR	Automatic Progressive Reconnection
ARMU	Automatized Ring Main Unit
ASAI	Average Service Availability Index
ATS	Automatic Transfer Source
CAPEX	Capital Expenditure
CB	Circuit Breaker
CT	Current transformer
DC	Direct Current
DCC	Distribution Control Centre
DCS	Distributed Control System
DER	Distributed Energy Resources (Wind, Solar, EV, …)
DOL	Direct On-Line
DP	Distribution Points
ENS	Energy Not Supplied
F&S	Fire and Security
FPI	Fault Passage Indicator
FU	Functional Unit
GCU	Generator Control Unit
GIS	Geographical Information System
HMI	Human Machine Interface
HV	High voltage
HVAC	Heating Ventilation and Air Conditioning
IAC	Internal Arc Containment
IEC	International Electrotechnical Commission
IED	Intelligent Electronic Device
IEEE	Institute of Electrical and Electronic Engineers
IGBT	Insulated Gate Bipolar transistor
IMPR	Intelligent Motor Protection Relay
IPMCC	Intelligent Power and Motor Control Center
LCD	Liquid Crystal Display
LV	Low voltage
LSC	Loss of Service Continuity
MAIFI	Momentary Average Interruption Frequency Index
MCC	Motor Control Center
MCCB	Molded Case Circuit Breaker
MV	Medium Voltage
NOP	Normally Open Points
OEM	Original Equipment Manufacturer
OLTC	On Load Tap Changer
ONAN	Oil Natural Air Natural
OPEX	Operating Expenditure
PAC	Programmable Automation Controller
PEI	Peak Efficiency Index
PFC	Power Factor Correction
PLC	Programmable Logic Controller
PCC	Power Control Center
POC	Point Of Connection
PQ	Power Quality
PWM	Pulse Width Modulation
QS	Quick Study
RMU	Ring Main Unit
RTU	Remote terminal Unit
S/S	Substation
SAG	Semi Autogenous
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
SS	Soft Starter
SSIS	Screen Solid Insulated Switchgear
TCO	Total Cost of Ownership
THD	Total Harmonic Distortion
TOC	Table of Compliance
UPS	Uninterruptible Power Supply
VCB	Vacuum Circuit Breaker
VSD	Variable Speed Drive
VT	Voltage transformer

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