

Schneider Electric
digital and electrical
reference architectures

Electrical Distribution Network

**DER Integration – Maximize DER penetration
while minimizing curtailment**

Solution for medium and large electrical
distribution networks

Life Is On

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Context

The decision on **grid modernization is a strategic initiative** which is challenged at the highest level in the electric company organizations.

In many distribution networks worldwide, the operation and management in the distribution network is limited to planning, equipment maintenance and trouble shooting.

Grid modernization will bring more automation possibilities and intelligent management. It can **fundamentally change** the way utility operates the network and interact with end-users. Managing these changes is difficult: most electrical companies take years to decide to move ahead.

Schneider Electric can accompany electrical distribution companies to set up a direction guideline for the development of their network. It is important to “think ahead” in order to refine the goals and define the right solution to align with the expectations on performance and development of the network.

This document is a use-case illustration about DER integration.

Problem to solve

The impact of DER connections to the distribution network is no more a new subject.

Network operators know that every time a DER generation feeds **into** a network it **rises** the voltage **at** the connection point. With high DER penetration rate, the voltage over the whole network will increase, and **can** quickly become a big issue **if it is not managed properly** (overvoltage, exceeding the **acceptable** limits).

The high DER penetration also goes with possible reverse power flow, or in other words, distribution network can feed back power to the upstream network while the network are basically not designed to work in such condition. The protection plan is no more appropriated, possible imbalance between phase can occur if many dispersed generators are present among the network ... and so on.

To deal with all technical issues, the first and simplest solution adopted by many electrical companies over the last years was **to do nothing and limit the DER integration** to a what we call a “**safe level**”. But it is not an acceptable solution any more. With new energy policy targets on “go to green”, “mix energy”, “demand response”, the reality/fact is that “more and more DER come to distribution network”. Some Electrical Companies affirmed its willingness to go up to 100% of DER integration.



There is no place for doubt, technical issues of DER impacts must be handled. But how? In the distribution network with high DER penetration, it is very complicated to handle DER generation as it is coming from multi technologies sources (PV, wind, battery, biomass, cogeneration...) with inverter interfaces. Generation units can be owned by utility but also by third party.

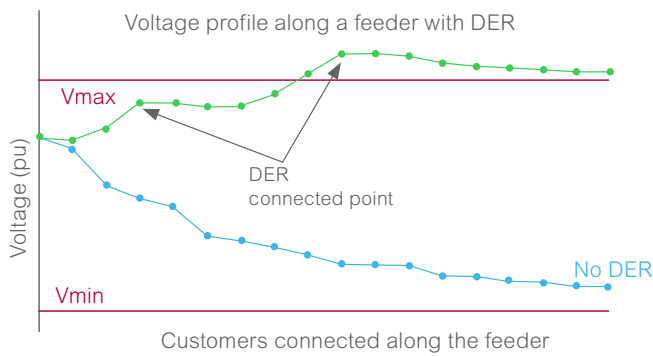
Network operator must deal with not only operating constraints but also interaction between multiple actors. Operating the networks cannot be performed only based **on experience and manual operations**. Automation, communication and intelligent aid tools are the keys functions to be introduced to network operation. Of course, adding more functions, mostly automation and communication, brings more constraints which are still new for network operator such as complexity, resilience, big data management, digital security.

Accompany the customer during this journey is to help him finding out the answers to the questions: In my distribution network, when and how DER integration will become an issue (Or do I already face issues)? What is currently my “safe level” limit for DER integration? What do I have to do if I want or need to go above this limit?

DER impacts on distribution grids

Technical issues:

- Increase voltage at the DER connection points and around them
- Possible reverse active power flow
- Equipment rating limits exceeded
- Increased short-circuit currents
- Intermittency and uncertainty of generation vs. Fluctuations of consumption
- Imbalance between feeders and phases



Regulations:

- Energy policy targets (security of supply and quality of service vs. Environment and economic efficiency)
- Mix energy market (price and tariff regulations)
- Demand response (value of flexibility)
- Grid code requirements



Technology issues:

- Multi-technology sources
- Inverter-based Generators with low or no inertia and fast dynamic response
- Limited capacity to provide network support services (voltage support, reactive power supply, harmonic emission control or mitigation...)



Communication and cyber-security:

- Increase complexity and big data management
- Communication infrastructure and performance
- Digital Security and Resilience



Schneider Electric recommended approach

Schneider Electric proposes a system approach in 3 steps:

When and how do we need to handle the growing DER penetrations in distribution network?

- 1 Network assessment and long-term target forecasting**
what is the maximum DER penetration rate at which the system operates satisfactorily, under existing infrastructure and without requiring any upgrade?
- 2 Upgrading grid planning and operation with DER integration plan**
The complexity of power systems requires technical capacity for effective planning, forecast, and operation strategies.
- 3 Optimising network expansion**
Microgrid, demand response, and energy efficiency technologies, new infrastructures....

Every approach shall start with an assessment of existing network. Each utility is unique and has different requirements. It is key to understand about their challenges today, their expectations and their vision on network development in next years. This will be a very good start to accurately define the goals of the modernization project.

Typically, a hosting capacity analysis is a good analysis to be performed first. It provides to the utility exactly “What is the maximum DER penetration rate at which the system operates satisfactorily, under existing infrastructures and without requiring any upgrade?” An example will be given for more insights, in the next chapter.

Taking results from the **hosting capacity analysis** and review of target forecasting, we will have a good picture of the existing network and its actual margin to the safe limits.

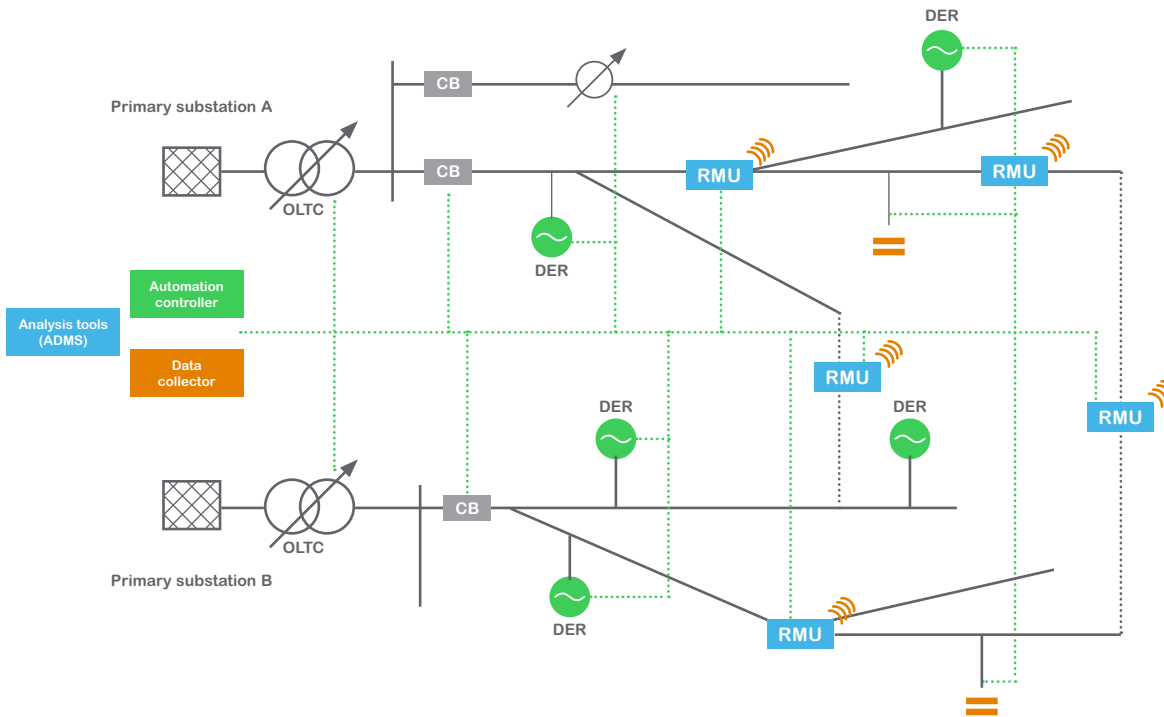
It will help to define what are the weak points, where to focus on, how to optimize network operation. Our experience shows that the network is often not operated at its optimum capacity. Introducing automation, communication and intelligent aid-for-decision tools will help to drive the maximum capacity of the network, without requiring adding new infrastructure (wires, feeder or substation).

Finally, when all possibilities have been explored and shows there is a need for network expansion for preparing future development, new set-up/concepts can be then proposed: microgrid, demand response management system or adding new infrastructure.

Our fully integrated solution

We need 4 key elements for an effective management of DER integration:

- The use of efficient equipment,
- The optimization (Quantity and location) of smart and connected equipment,
- The optimization of DER's deployment (Location, size)
- The adoption of advanced analysis tools (ADMS - DERMS)



It is important to understand DER integration must be considered in both planning phase and operation phase.

Typical functions used for Planning phase:

- Network reinforcement
- Capacitor placement
- Network Automation (RMU)
- Voltage regulator Placement
- Customer Connection
- Hosting Capacity
- DER Integration planning
- Forecast (near, short, long term)

and for Flexible Operation:

- State Estimation
- Optimal Power Flow
- Volt/Var Optimization
- Reconfiguration
- Load shedding
- LV analysis
- Load phase balancing
- DERMS monitoring, awareness and control
- Automatic aggregation & Constraint Management
- Volt VAR Watt Optimization

Customer case example

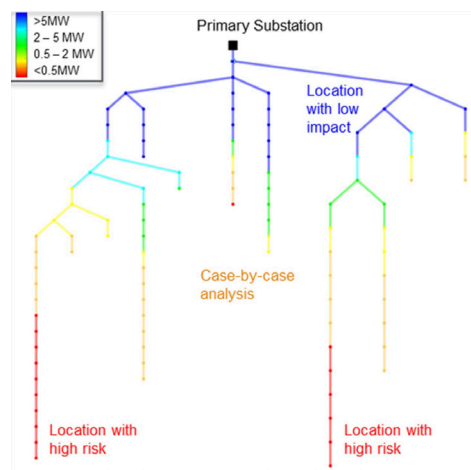
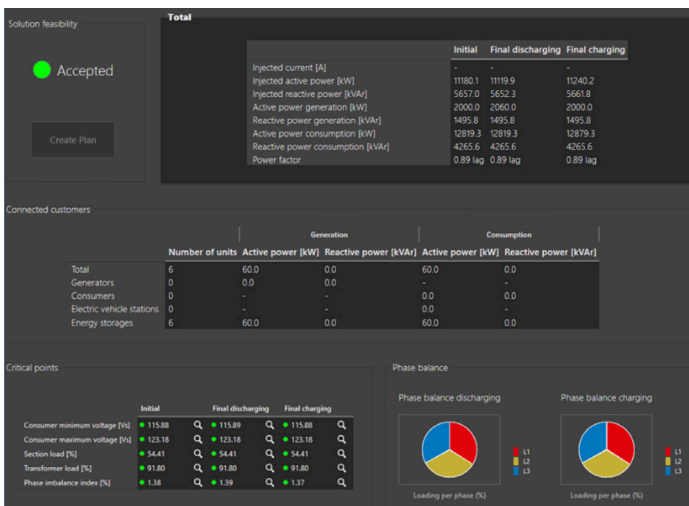
1

Network assessment and long-term target forecasting

What is the maximum DER penetration rate at which the system operates satisfactorily, under existing infrastructure and without requiring and upgrade?

As mentioned before, every approach shall start with an assessment. Taking a picture of today's situation allows to better describe the future.

Here is an example of a **hosting analysis** tool and the result displayed on a “heat map”:



The **hosting capacity** is reported as a “heat map” at node level, feeder level, transformer area, substation level, whole system level. From this map, we can see the DER possible locations ranked by risk level.

Nodes at the end of feeder line only have a small DER hosting capacity, smaller than nodes close to the primary substation.

Based on this heat map, whenever a request for connection of a DER is done, network operator run the tool and see very clearly and exactly where the connection is possible (green part and above), it would be questionable in the yellow part and for sure, it is not possible in the red part.

Then specific studies can be done to validate the feasibility of this DER connection by evaluating exactly the impact of this DER in different network operating conditions.

The impact study will also show out where are the weak points, where to changes in operation (network reconfiguration), if protection setting must be updated ... etc.

The hosting capacity can be done to existing situation but also for any future development scenarios with forecast data.

2

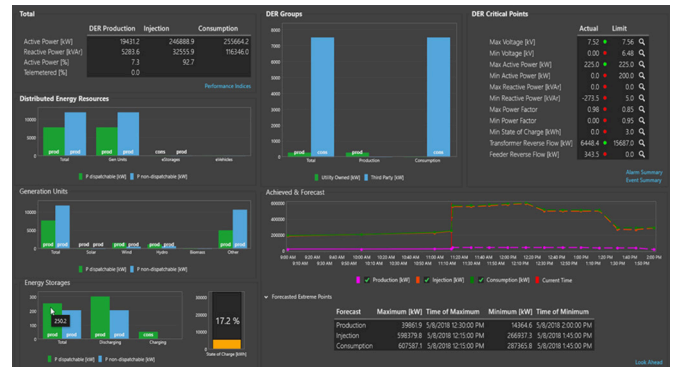
Upgrading grid planning and operation with DER integration plan

The complexity of power systems requires technical capacity for effective planning, forecast, and operation strategies.

The second step is about the integration of the DER in the network planning and operation.

To include DER in the network operation, operator must be aware about its actual available power, its capacity to increase or decrease its output, and if it is absorbing or generating power. Operator must also be able to send set-points to the DER units (Which must be able to receive it as an input command).

The difficulty is that DER can be renewables which are intermittent and variable generation systems. The set-point optimization must be done dynamically, in real time and with a good quality of forecast in both long, short and near time-frame. Suitable communication infrastructure and engagement model with Independent Power Producers must also be set up.



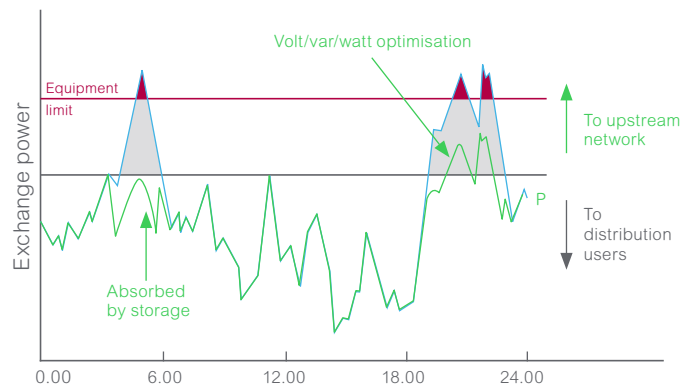
ADMS – DERMS: DER Monitoring window

Here is a typical example of Volt / Var / Watt optimization curve.

In this example we can see 2 problems:

- Feed-back power from distribution network to upstream network, (Grey area of the curves)
- Power flow exceeding equipment capacity (Primary transformer or line),

To solve these issues, if the upstream network cannot accept reverse power flow, the operator can use battery or other type of storage system to absorb the temporary excess power. If the upstream network can accept the reverse power flow, a Volt/Var/Watt optimization can be performed and is enough to redirect power flow in the network to avoid overloading of specific equipment. This can help preserve storage power for more suitable/appropriated situations.



Required capabilities:

- Near and short-term forecasting
- DERMS monitoring, awareness, control and commanding
- Volt Var Watt Optimization
- Watt Var Flexibility
- Network reconfiguration

3

Optimising network expansion

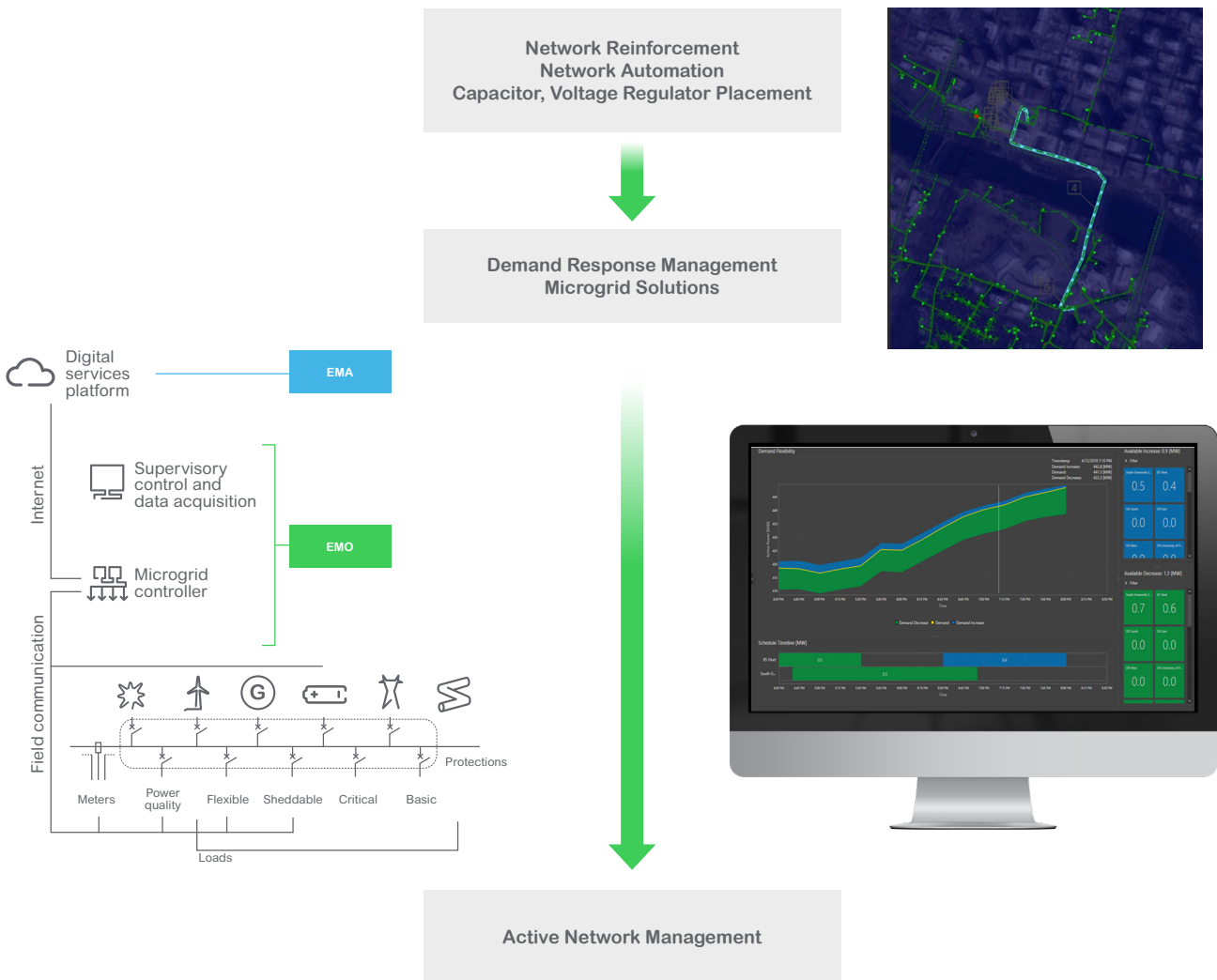
Microgrid, demand response, and energy efficiency technologies, new infrastructures....

When the network is operated close to its maximum capacity or possibility, it is time to think about an “expansion project”.

Adding new infrastructure (Wires, feeders or substations) calls for big investment and study must be done not only for the new part but also for re-structuring and refining the operation management of the whole network.

Other options include the possibility to introduce the concept of “Demand response management” with a microgrid solution involving participation of commercial aggregator.

All this is related to the preparation process towards the “active network management” – solution of the future.

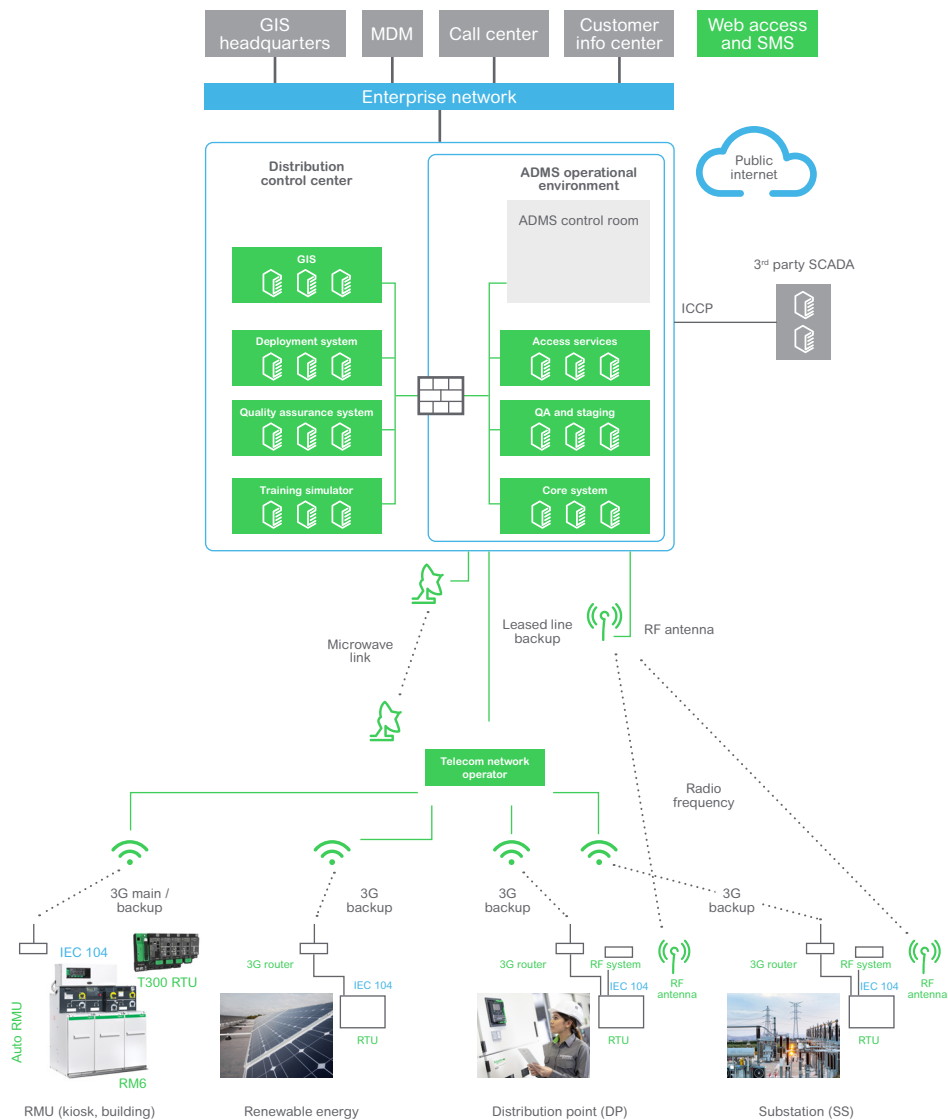


ADMS – DERMS solution deployment

ADMS – DERMS solution is the platform that will enable the deployment of the system approach recommended by Schneider Electric for Electrical Distribution companies facing increasing DER penetration.

List of major items constituting an ADMS – DERMS solution:

- Geographic Information System (GIS),
- Advanced Distribution Management System (ADMS),
- DERMS for monitoring, awareness, control and command,
- Telecommunication System,
- Implementation of RMUs,
- Modernization of Substation Automation system,
- Refurbishment of control rooms



General recommendations

Successful integration of DER into distribution networks relies strongly on **effective planning** and **flexible operation** strategies

Deployment of solutions requires:

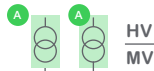
- Use of efficient equipment (Transformers, VAR compensation systems, ...)
- **Optimizing the use** of our smart and connected equipment (Protection relays, Power meters and sensors, Smart RMU's, Smart transformers...), as it mainly constraints and qualifies the value-added of all intelligent control systems
- Optimizing the **deployment** (location, size) of DER
- Having and adopting **advanced analysis tools** (Optimization algorithms and Realtime operation helping-hand) = ADMS & DERMS



Electrical architecture – Underground “ring type” distribution network example

Orange =	Schneider Electric components involved in the technical losses improvement process.
Green =	Other Schneider Electric components.

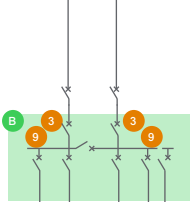
MV/HV Transformers



HV side

A MV/HV Power Transformers
Minera MP

Main MV switchgear



MV side

B MV Switchgear
Schneider Electric ranges of MV switchgear

9 Protection Relays
Easergy range

3 Power Meters
ION & PM ranges

MV loop switchgears (RMU)



E RMU



1 RTU cabinet

Inside the RTU cabinet



2 Smart RMU



Inside the RTU compartment of the Smart RMU



5 MV/LV Transformers with Self-controlled Tap Changer



Minera S Grid

6 High efficiency MV/LV transformers



Minera Ground Mounted
(High efficiency design)



Trihal
(High efficiency design)

7 LV capacitor banks



VarSet

8 Active harmonic filters



AccuSine PCS+

C MV/LV distribution transformers



Minera Ground Mounted
(Standard design)



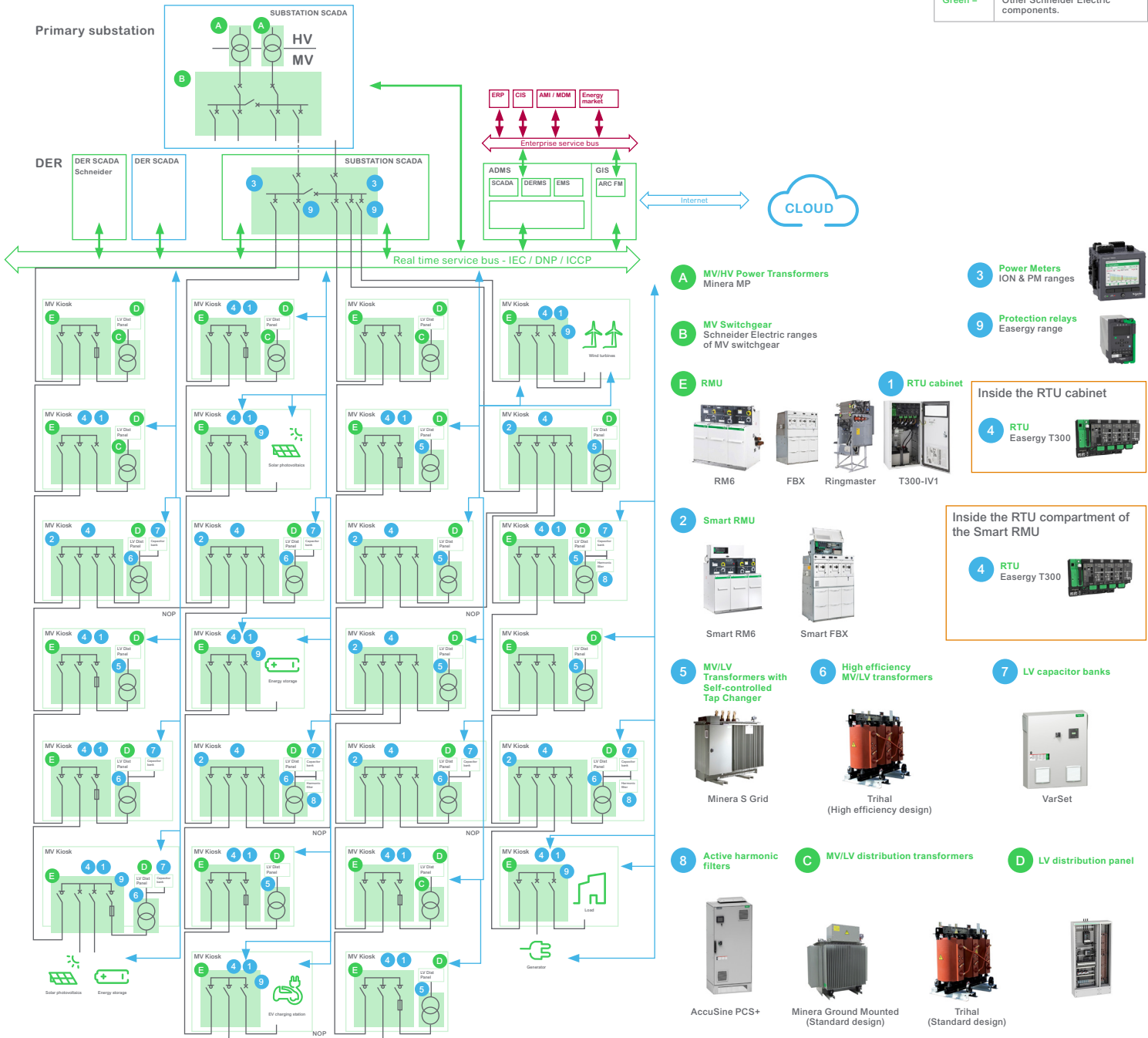
Trihal
(Standard design)

D LV distribution panel



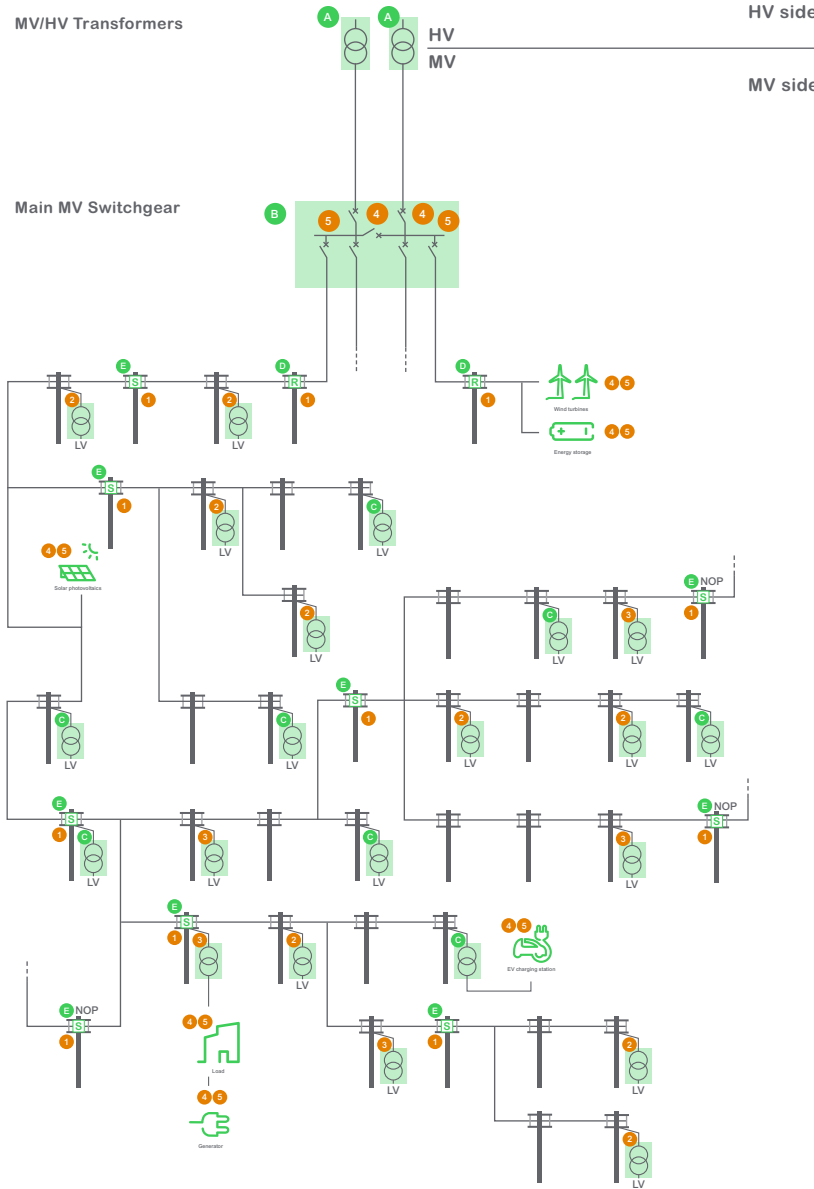
Digital architecture – Underground “ring type” distribution network example

Blue =	Schneider Electric components involved in the communication with the ADMIS for technical losses improvement process.
Green =	Other Schneider Electric components.



Electrical architecture – Overhead “radial type” distribution network example

Orange =	Schneider Electric components involved in the technical losses improvement process.
Green =	Other Schneider Electric components.



HV side **A** MV/HV Power Transformers
Minera MP

MV side **B** MV Primary Switchgear
Schneider Electric ranges of MV switchgear

5 Protection Relays
Easergy range **4** Power Meters
ION & PM ranges

D Reclosers



E Sectionalizers



1 Control Box



2 High efficiency MV/LV transformers



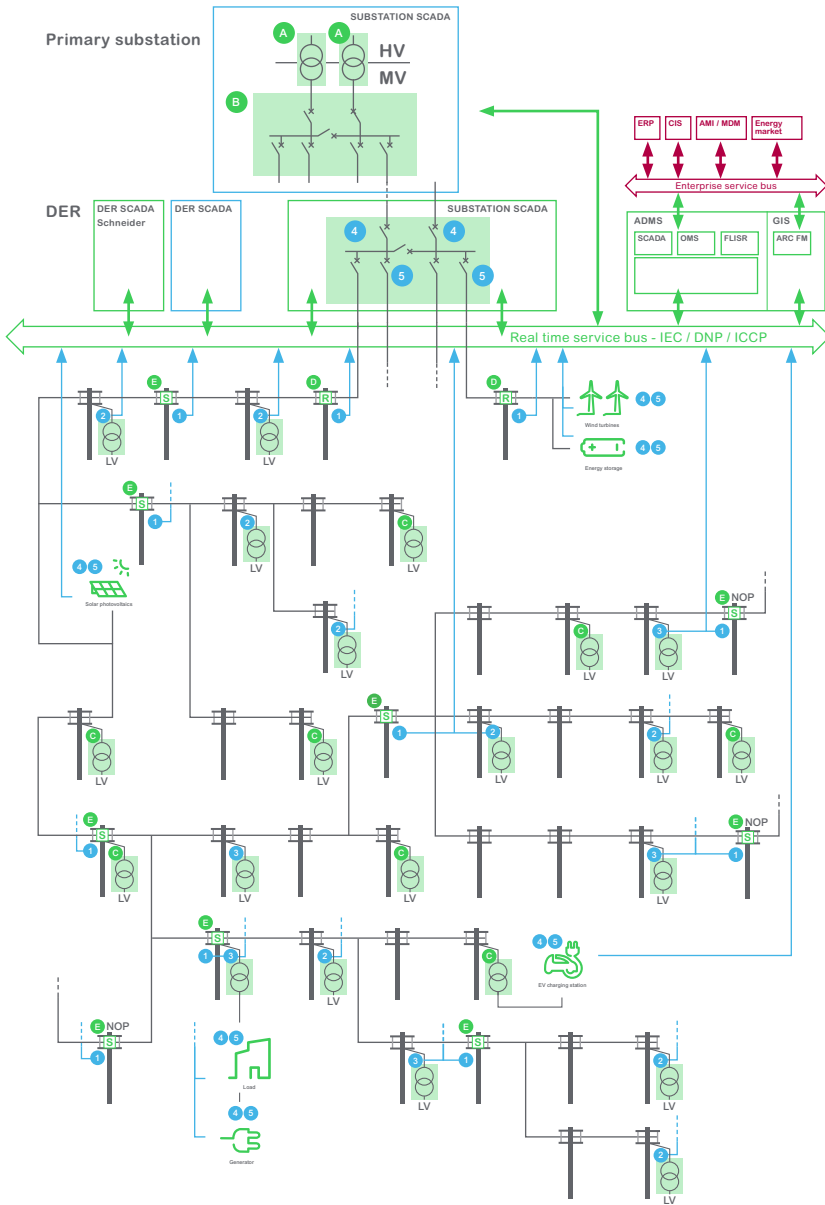
3 MV/LV transformers with self-controlled tap changer

C MV/LV distribution transformers



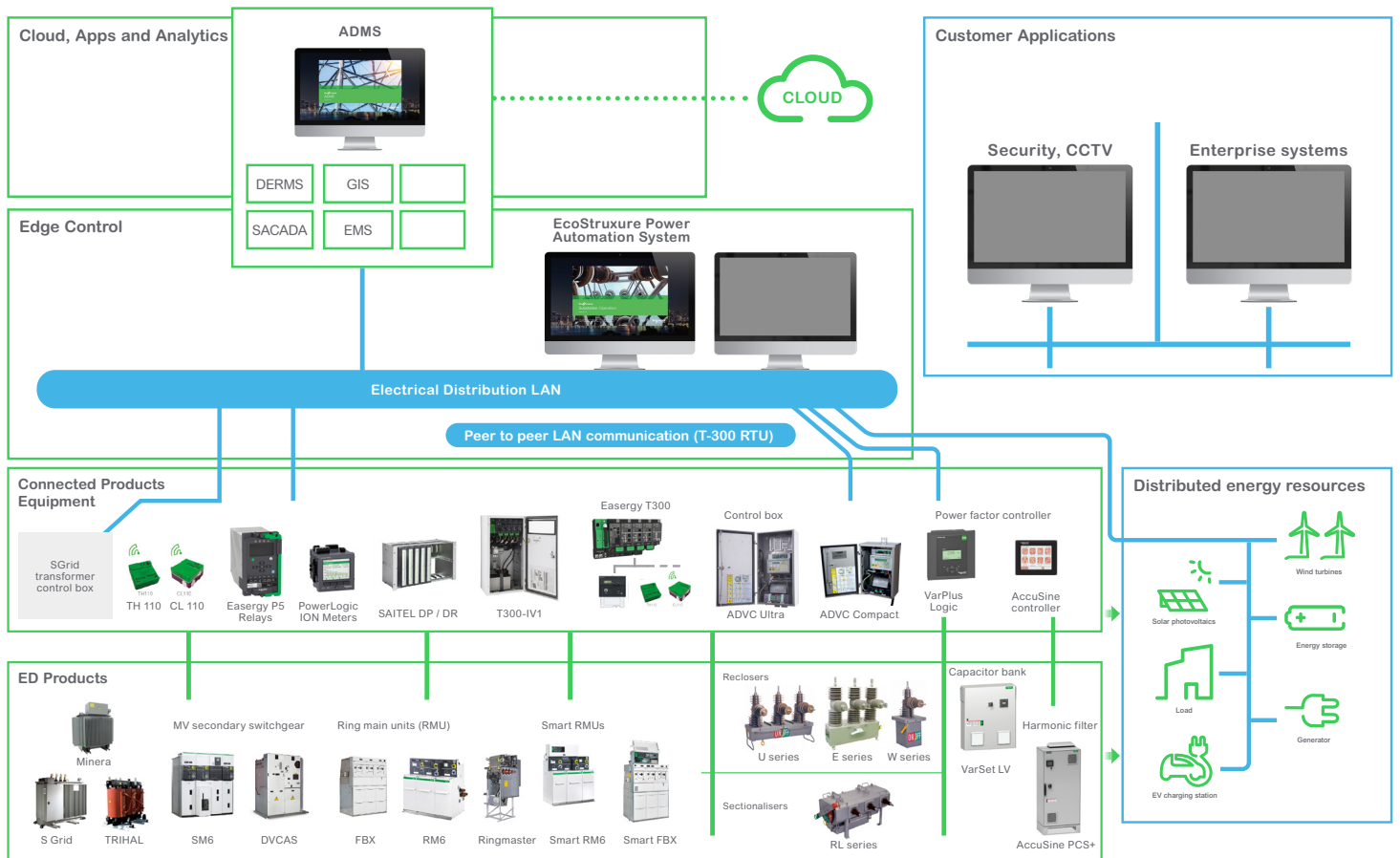
Digital architecture – Overhead “radial type” distribution network example

Blue =	Schneider Electric components involved in the communication with the ADMIS for technical losses improvement process.
Green =	Other Schneider Electric components.










- A** MV/HV Power Transformers
Minera MP
- B** MV Primary Switchgear
Schneider Electric ranges of MV switchgear
- C** MV/LV distribution transformers
Minera Ground Mounted (Standard design)
Minera Pole Mounted (Standard design)
- D** Reclosers
E Series
U Series
W Series
- E** Sectionalizers
RL Series
- 1** Control Box
ADVC Ultra
ADVC Compact
- 2** High efficiency MV/LV transformers
Minera Ground Mounted (High efficiency design)
Minera Pole Mounted (High efficiency design)
Minera S Grid
- 3** MV/LV transformers with self-controlled tap changer
- 4** Power Meters
ION & PM ranges
- 5** Protection relays
Easergy range








EcoStruxure grid architecture






Schneider Electric products included 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, EMS and SCADA - DERMS - Operation planning and optimization		learn more
SCADA	EcoStruxure Power Automation System	SCADA digital control system for Substation automation based on PACiS technology		learn more
SCADA	EcoStruxure Power SCADA Operation	Power SCADA for Electrical System		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 metering		learn more
Power meter	ION and PM ranges	Power Logic PM 8000 / ION7650 & ION7400 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	<ul style="list-style-type: none"> - 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
Recloser	E-Series	Light-weight reclosers up to 38kV and 170kV BIL.		learn more

Network function	Product name	Main technical characteristics		Link to offer / spec
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
LV Capacitor bank	VarSet LV	Smart LV Capacitor bank with VarPlus Logic controller		learn more
Harmonic filter	AccuSine PCS+	Active harmonic filter for harmonic mitigation, power factor correction and load balancing.		learn more

Network function	Product name	Main technical characteristics	Link to offer / spec
Transformer	SGrid	Smart Grid MV/LV Transformer Oil immersed transformer with self-controlled tap changer. (Eco-design compliant)	 learn more
Transformer	Minera HE+	High Efficiency MV/LV Transformer Mineral oil type, amorphous transformer. Optional Off-Circuit Tap Changer (OCTC) or On-Load Tap Changer (OLTC).	 learn more
Transformer	Trihal	Efficient and connected "cast resin" type MV/LV Transformer. Optional On-Load Tap Changer (OLTC).	 learn more



Ecostruxure Grid - Services 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 solution enabling efficient integration of more DER with adequate safety will consist in the implementation of an ADMS - DERMS system together with the implementation of Smart connected products.

Consultancy Services are proposed to provide recommendations for an **optimised level of modernization** of the electrical distribution system, in line with performance expectations (Expected level of DER penetration) and budget.

Taking in account the modernization strategy, study is performed to estimate optimal quantities and location of the key devices: Smart Ring Main Units, Smart transformers, Smart Capacitor banks...to best serve the DERMS application.

For further details about the Consultancy Services proposed for this project please refer to the related "Consultancy Services Technical Specification" document.



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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se.com/smart-grid



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