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Editorial

By Michel Augonnet
President of CIGRE

Dear Friends and Colleagues:

Welcome to the June edition of ELECTRA.

As we move into the hotter months in the Northern Hemisphere and the colder months in the South, we face – as we do every year – a growing awareness that the planet and meteorological changes continue to be some of the biggest challenges faced by the electricity industry. Hurricanes in North American before the usual season. Fires already spreading across Canada. Flooding in Europe and Asia. Maintaining power flow is vital to all regions and even more so when climate is complicated.

Of note in this edition is a formula for a new HV operational system resilience index developed by members of SC C1. Their work shows that it is possible to identify areas where improvements can be made to enhance reliability and reduce the risk of power outages – often caused by large natural phenomenon - thus the implementation of measures to increase the resilience of electrical grids will be essential in ensuring the security of energy supply.

TECHNOLOGY E2E: Evaluation of grid operational resilience stressed by energy transition and by climate change: new metrics (SIRI) and countermeasures by Chiara Vergine, Enrico M. Carlini, Gabriele Biasiotti, Simone Talomo, Luigi Calcara, Massimo Pompili and Antonio Iliceto.

GLOBAL CONNECTIONS: Nicolas Chamollet, Convenor of CIGRE Working Group C1.50 - Global sustainable energy system coupling electricity and hydrogen describes a road map for implementing 'ONE SUN ONE WORLD ONE GRID': an intercontinental power grid from Europe to South-East Asia with India as the fulcrum of a global power pool embryo. The article compares different scenarios of cooperation, some leading to significantly increased use of RES and generation cost reduction.

There is also a **GLOBAL LEADERSHIP PERSPECTIVES** piece on how to estimate the ideals alignment amongst staff when changes are made within a company.

LIFE OF ASSOCIATION: CIGRE International Symposium Trondheim 2025 - Call for papers, and important dates for registration.

The Steering Committee held in May in Shenzhen was an occasion to witness the impressive initiatives and progress made in the development of RES and digital technologies for the Energy Transition in China.It was also a time to focus on membership renewal and timely membership fee settlement via the National Committees.

The registrations for the **Paris Session** are progressing very well with an all-time record of registrations in one month (more than a 1000), a full house of exhibitors, and 1,200 papers presented at the Session.

Some of you may also wish to take the opportunity to attend events at the 2024 Paralympic games which will be slightly overlapping with the CIGRE session. For those who are interested, the calendar of events is easily available **here**.

Hoping to greet you at the Palais des Congrès in August!

Best regards,
Michel Augonnet

Road map for implementing 'ONE SUN ONE WORLD ONE GRID': an intercontinental power grid from Europe to South-East Asia

ONE SUN ONE WORLD ONE GRID (OSOWOG) has a geographical perimeter composed of 117 countries from Europe, Africa, and South-East Asia, across seven time-zones and representing one-third of the global power demand. According to the IEA-WEO-2020 Sustainable Development scenario, the electricity load will progress from 8,200 TWh in 2022 to 16,300 GWh by 2050.

By Nicolas CHAMOLLET
Convenor of C1.50 - Global sustainable energy system coupling electricity and hydrogen

Introduction

The central scope of work of Phase 2 is the identification of major interconnections to valorize untapped RES potential such as hydro, solar, and wind power. This assessment is based on an economic adequacy forecast study of the perimeter from 2022 to 2050, including:

- Assessment of existing/planned grid strengthening,
- Review of possible transmission technology,
- Preliminary line routing,

- Modelling and economic optimization, and
- Assessment of the cost of generation facilities, opportunity costs (capacity avoidance costs, environmental costs related to the program/initiative), and landed cost on the Indian periphery.

The first concrete objective is to identify two or three cross-border power interconnection projects that can be initiated within one or two years, considering India as the fulcrum of an intercontinental interconnected power system embryo.

Regional power system initiatives are playing a key role, expanding on the study perimeter, from numerous bilateral initiatives to regionally planned initiatives mainly in the framework of economic communities promoting mutual interests

In this context, 15 zones have been defined, based on a proper geographical scalable modelling. In South-Asia region, one zone represents each country. Other regions are represented by one zone each. The following map illustrates this grouping:

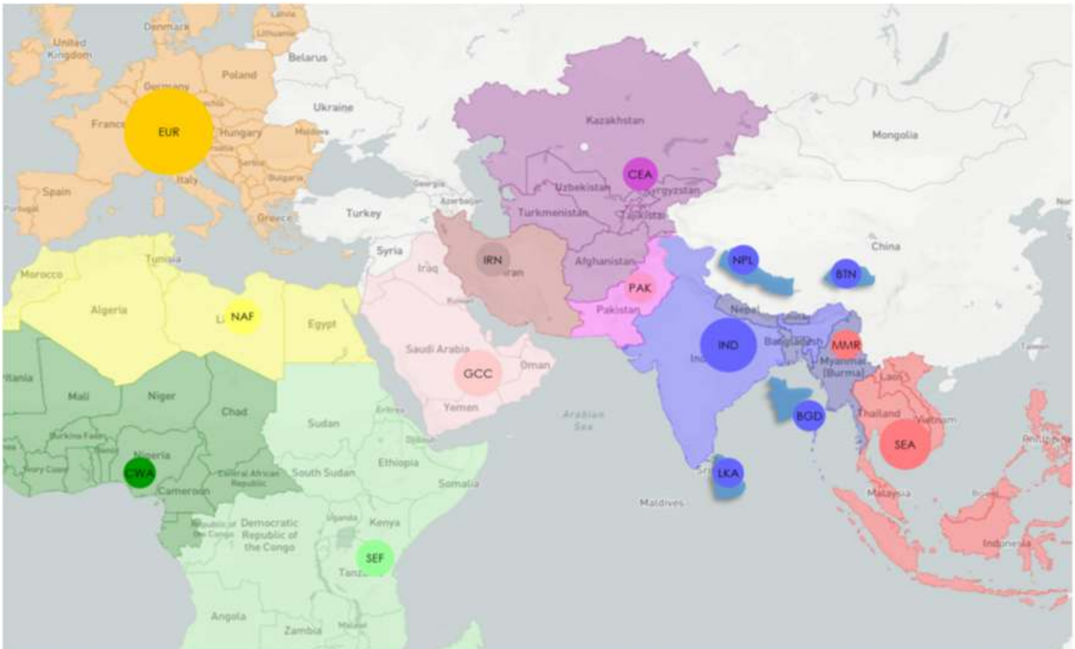

Figure 1 - Regional organizations are fostering connectivity, shaping the landscape of electricity connectivity for RES integration

Regional initiatives are fostering connectivity, shaping the landscape of electricity connectivity for RES integration, spreading influence, overlapping, and revealing junction countries which could become the energy hubs of a future Euro-Asia intercontinental power market.

For each of the 15 zones, hourly load pattern has been defined from 2022 to 2050 representing 254,208 hourly values. For multi-countries zone, load pattern of each country has been considered in the aggregated zonal load pattern.

Shaping a future intercontinental power system originating in India and spreading throughout Europe, Africa, and South-East Asia

There are 19 potential power corridors representing a cluster of multiple cross-border power lines between the 15 zones:

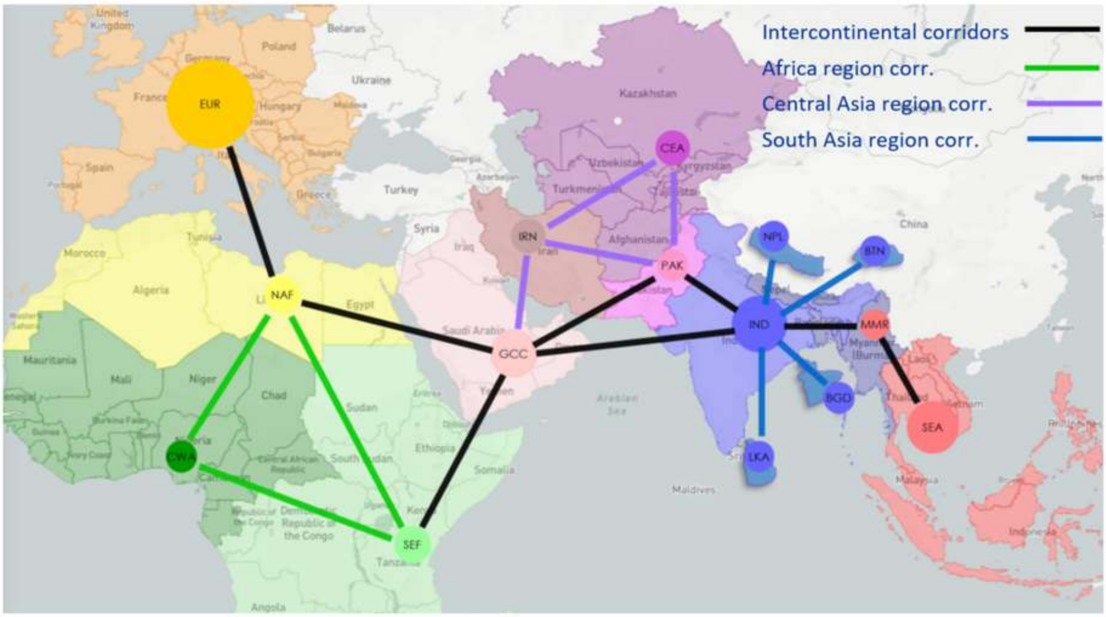

Figure 2 - 19 potential corridors (cluster of power cross-border lines) to link the 15 zones

Each Corridor modelling is based on:

- Terminals selected among capitals, major cities, large power plants, existing substations (400 kV+) in meshed networks,
- Length: realistic line routing along existing corridors (roads, railways, etc.),
- Techno: OHL-HVDC or USC-HVDC + Inverters,
- Initial capacity = sum of the capacities of all cross-border lines in operation,
- Economic parameters for future development (in competition with power generation and storage,
- Economic life at 30 years.
- Losses: %/km + %/inverter
- Unit installed capacity cost ($/GW) for futures development: low cost and high cost (4 x low cost) defined a range cost to consider grid sensibility in the overall power system cost,
- Internal reinforcement coefficient:
  - from 0 to 10 GW: Initial cost
  - from 10 to 20 GW: Initial cost x 10
  - from 20 to 30 GW: Initial cost x 40

This increase in costs accompanying the installed capacity is justified by the need for significant strengthening of regional transmission networks and the acquisition of the remaining less suitable land.

Currently only one intercontinental corridor is operational between Europe and North Africa with a capacity of 1.4 GW, and regional corridors are developed essentially around India.

Toward a future intercontinental power system based on reducing (or not) carbon emissions and/or (or not) power exchanges

Five scenarios built according two political dimensions: grid expansion and CO_2 reduction

- **Slow progress (Scenario 1)**: Business as usual with limited cooperation and no SPC pricing ambitions (except Europe).
- **Market cooperation (Scenario 2)**: Win-win regional collaboration (power exchanges) without SPC (except Europe) ambitions.
- **Own green transition (Scenario 3)**: Ambitious individual SPC without regional collaboration (interconnections are restricted).
- **Green power pool (Scenario 4)**: Common SPC agreement, and common regional power pool including common regional transmission plan to foster massive and efficient RES deployment.
- **IEA net zero (Scenario 5)**: A fifth scenario, which could be defined as a "super" scenario 4, has been added to explore consequences of SPC proposed in IEA net zero emission scenario.

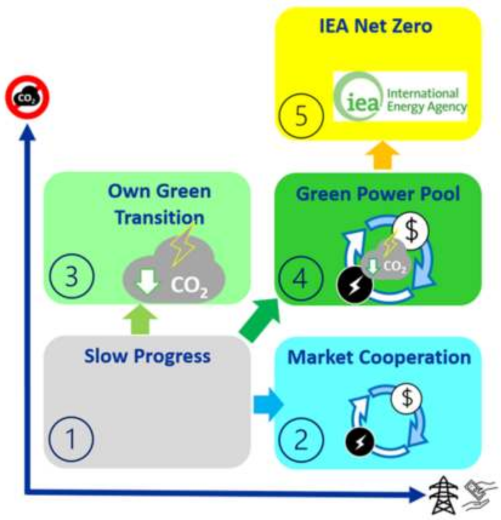

Figure 3 - Scenario building

OSOWOG 2022-2050 Roadmap: An eco-sustainable intercontinental power system to be develop between Europe, Africa, Middle East, and Asia, with India as the fulcrum of a global power pool embryo

By 2030, there is an eco-sustainable interest to develop an intercontinental power backbone from Europe to South-East Asia

From 2022 to 2030: There is a need to start the development of an intercontinental power backbone from Europe to South-East Asia:

- OSOWOG roadmap could start with an intercontinental power backbone from India to South-East-Asia, and from India to Middle East via Pakistan.
- From Middle East to North-Africa, there is already an interconnection between Saudi-Arabia and Egypt under construction, and interconnections crossing the Mediterranean Sea are already planned in the Med-TSO Ten-Year Network Development Plan.

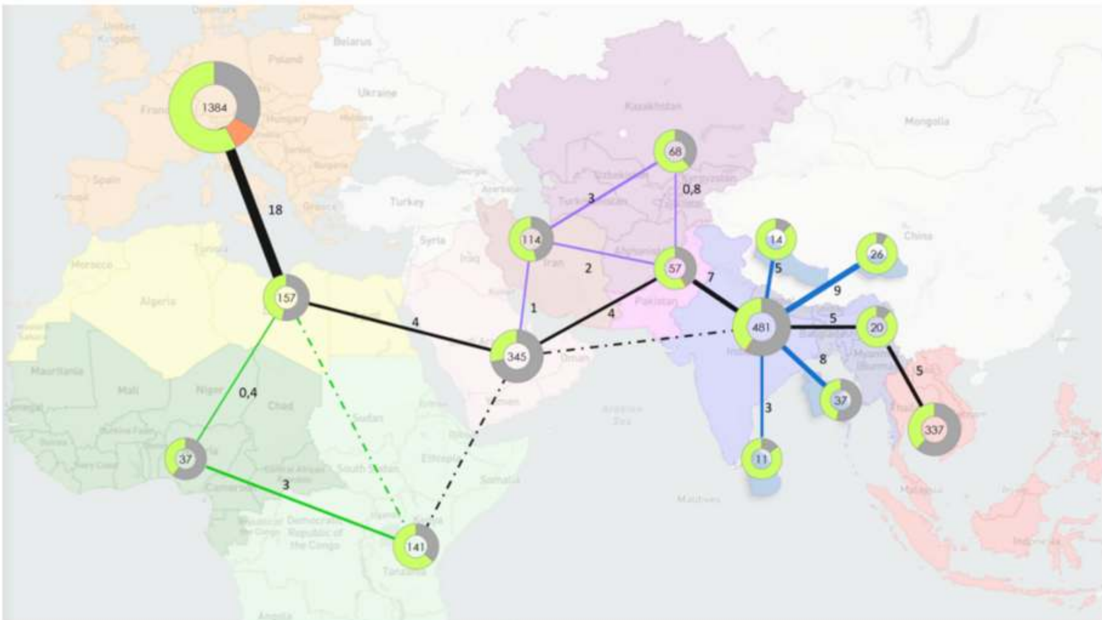

Figure 4 - Installed capacities by 2030 (GW, weighted results)

By 2040, technology maturity and India's power needs could lead to the develop a valuable direct 2 GW under-sea cable between India and GCC

Western direct corridor India to Middle East could be deployed by 2040 with a first capacity of 2 GW for an investment of about two billion dollars.

Each corridor from North-Africa to South-East Asia could increase by about 1 GW. Overall, 11 GW of cumulated corridors could be committed for an investment of $5,6 billion.

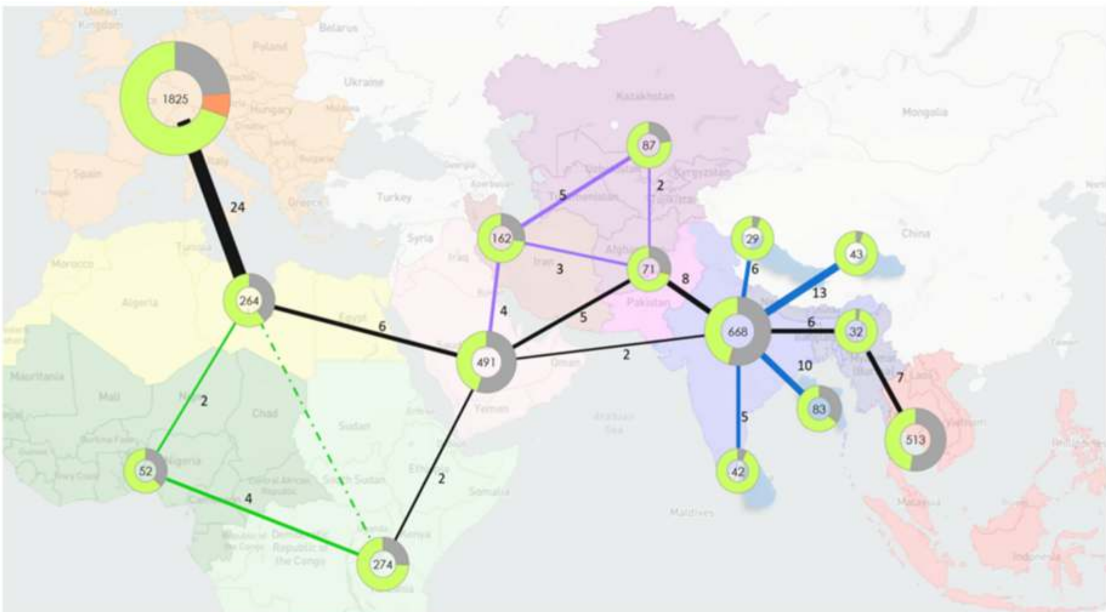

Figure 5 - Installed capacities by 2040 (GW, weighted results)

By 2050, sum of intercontinental power corridors could hit 49 GW for $25 billion investment, from which 24 GW around GCC

Overall, the sum of intercontinental corridors (black color on the following map) development hit 49 GW for $25 billion of investment.

From India, Western and Eastern corridors hit 13 and 8 GW representing respectively 26% and 16% of cumulated intercontinental corridors capacity.

24 GW of cumulated power corridors developed around Middle East: corridors from GCC represent 78% of the investment thereby confirming the importance of the GCC as power hub to develop OSOWOG initiative.

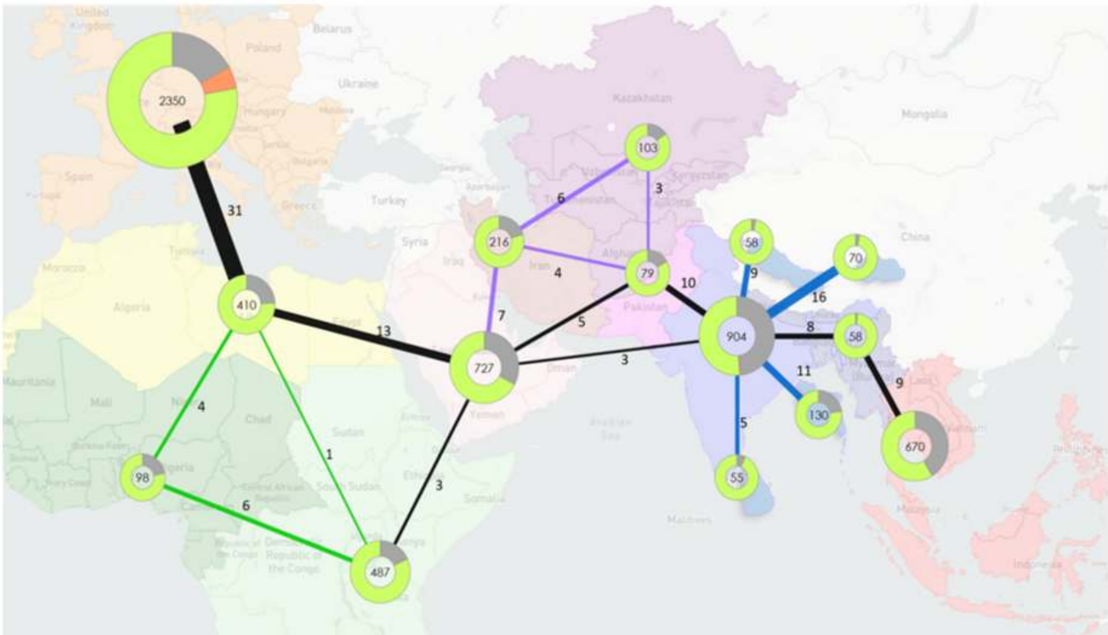

Figure 6 - Installed capacities by 2050 (GW, weighted results)

By 2050, the generation mix capacity increase from 2,300 GW to 6,400 GW (3-fold), including RES from 750 to 4,600 GW (6-fold)

From 2022 to 2050, total production capacity could produce a three-fold increase from 2,300 GW to 6,400 GW and production investments 6-folds increase from $56 to $320 billion/yr.

Distribution of production investment switch from Europe to other zones, and switch from fossil-fuel to renewable by 2050.

From 2022 to 2050, RES capacity should increase from 750 GW to 4,600 GW (x6). PV capacity development is about triple of wind.

Storage capacity could eight-fold increases from 3,100 (2022) to 25,000 GWh (2050).

By 2050, carbon emission restrictions could lead to massive RES development, decreasing unit electricity costs ($/MWh) by 50% without collaboration and to 60% with an intercontinental power grid, increasing the benefice by 20%

Outside North-Africa - Europe, major intercontinental power flows are concentrated on the backbone GCC – Pakistan – India – Myanmar and driven by RES pooling. Around India, hydro generation is the main driver to develop cross-border power flow.

India is the most important power importing zone with import volume progressing from 365 TWh/yr in 2030 to 795 TWh/yr corresponding to 20% of yearly demand by 2050. India's power imports are mainly coming from Nepal, Bhutan, and Myanmar hydro power.

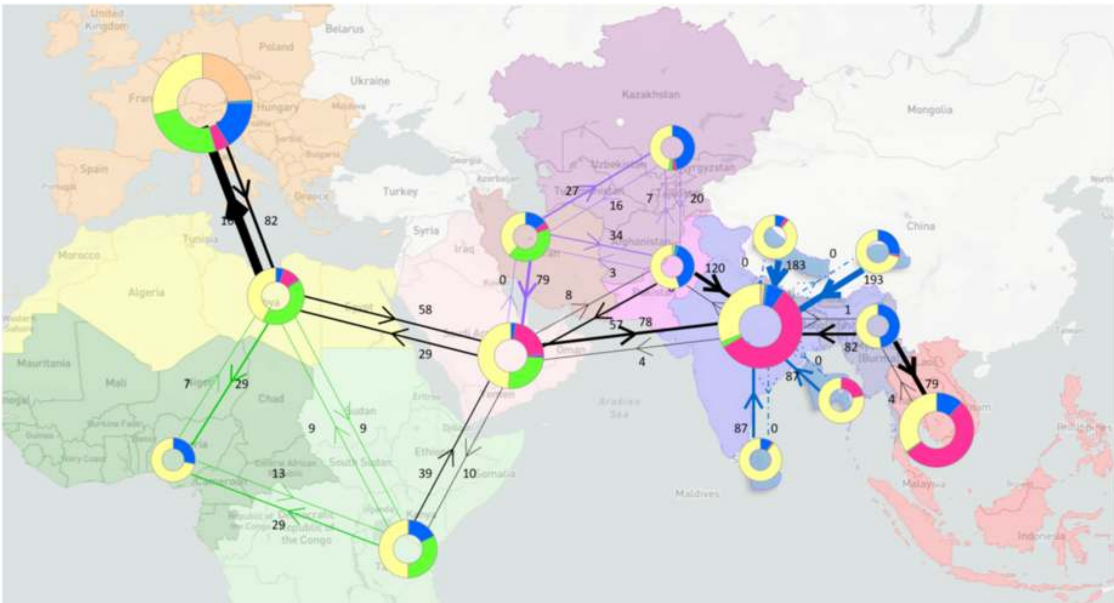

Figure 7 - Yearly power exchanges (Green Power Pool 2050, TWh)

The overall unit electricity cost ($/MWh) decreases by 50% thanks to RES with negligible variable cost, and by 60% by adding intercontinental power corridor development

The overall unit electricity cost ($/MWh) decrease by 50% from 19 to 10 $/MWh thanks to the development of RES production technologies with negligible variable cost, and development of power corridors.

Thanks to massive RES and power corridors development, unit electricity cost decreases faster in scenario 4 (green power pool) than other scenarios, by 60%, from 20 to 9 $/MWh.

By 2050, unit electricity cost in scenario 4 (green power pool) is 20% lower than scenario 1 (slow progress) and 10% lower than scenario 3 (own green transition).

International agreement on the shadow price of carbon progress could drive carbon emission decreases by 80%. Adequate SPC rent ($billion/yr) distribution among countries engaged in a common sustainable vision could permit the financial investment in sustainable switch of power generation

With international SPC implementation, carbon emission intensity could be reduced by 80% by 2050 in scenario 4 (green power pool) and by 78% in scenario 3 (own green transition).

Without SPC, CO2 emissions intensity increase by 10% in scenario 1 (low progress) and scenario 2 (market cooperation) by 2050.

Common SPC rent ($billion/yr) could widely support huge RES investments:

- Total investment until 2050 is estimated between $7,2 billion (scenario 4) and *8 billion (scenario 3).
- Average SPC rent decrease progress from 21,000 in 2022 to $8 billion/yr in 2050.

Adequate SPC rent ($billion/yr) distribution among countries engaged in a common sustainable vision could permit the financial investment in the sustainable switch of power generation.

— Main Takeaways

The study perimeter incorporates an heterogenous electricity power landscape from Europe, via Africa, the Middle East to Asia including 117 countries representing 33% of the load, growing to reach 40% in 2050.

Compound annual growth rate is about 2,4%.

South Asia GDP growing to become the main load center.

From North-Africa to South-East Asia, there is an eco-sustainable profit to develop an intercontinental power backbone

By 2030, cumulated installed capacities could reach 25 GW for a budget of about $7.5 billion.

By 2050, cumulated installed capacities could hit 49 GW from which 24 GW would be developed around the GCC region.

From India:

- Eastern power corridor toward South-East Asia to be developed with 5 GW by 2030, up to 8 GW by 2050.
- Western power corridor toward GCC could be developed via Pakistan in a first stage with 7 GW by 2030.
- Direct India-GCC power corridor could be developed in a second stage with 2 GW by 2040.

From GCC:

- Western power corridor to North-Africa could increase from 3 GW currently under construction up to 13 GW linking MedGrid power pool to Pan-Arab power pool.
- Interconnection with South-East Africa could be deployed 2 GW by 2040 and up to 3 GW by 2050.

International agreement on SPC decreases carbon emission by 80%

Carbon emissions intensity increases by 10% in scenario 1 (slow progress) and in Scenario 2 (market cooperation) by 2050.

Carbon emissions intensity decreases by 78% in scenario 3 (own green transition) and by 80% in scenario 4 (green power pool).

Power interconnections decrease green generation switch extra costs by 20%

The extra cost to develop green power production mix to meet the CO_2 emission target by 2050 without international collaboration is about 60%. Scenario 3 (own green transition) is 60% more expensive than scenario 1 (slow progress).

Development of power corridors to pool RES in a common intercontinental power market decrease green power production mix extra costs by 20%. Scenario 4 (green power pool) is 20% cheaper than scenario 3 (own green transition).

– How far is the ‘Green Deal’? By pooling RES with an intercontinental power backbone would be easier to build than a common agreement to set SPC progress, leading to the necessary financing for RES investment

1. OSOWOG aims to share renewable energy sources in a common power pool but also the investment effort and the income.
2. Implementation of a SPC agreement could provide the income necessary to support the huge switch to a green power production mix in developing countries.
3. Promoting energy connectivity and regional cooperation could be a strong driver to foster a global transition to clean developing power systems.

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GLOBAL CONNECTIONS

Operating a 2GW power system on 100% distributed resources

by Dr Jenny Riesz

AEMO, Manager, Operational DER Management

The South Australian region of the Australian National Electricity Market (NEM) supplies demand in the range of 1-3 gigawatts (GW), with a similar geographic size to the United Kingdom, and one double-circuit AC interconnection to the rest of the NEM [1].

On December 31, 2023, the entire South Australian region experienced negative operational demand, reaching a record of -26 megawatt (MW) of demand in the region at 1:30pm, with distributed (rooftop) photovoltaics supplying 102% of the 1.5 GW of underlying customer demand in the region. Distributed PV continues to grow at a rapid rate, and further reductions in minimum demand (growing more negative) are forecast by late 2024.

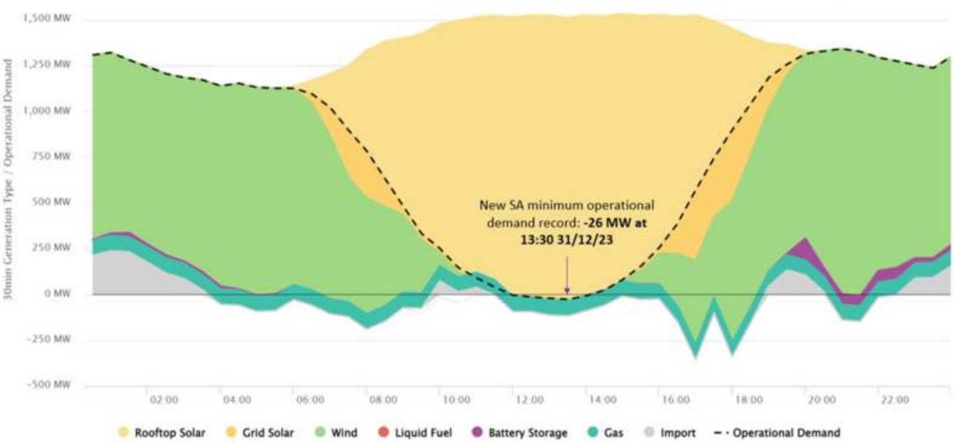

Figure 1 - 31 December 2023 - South Australia

In recent history, the South Australian region has experienced an unplanned separation from the rest of the NEM approximately once per year. This means it is important that the South Australian region can survive a separation and operate as an 'island' for an extended period if necessary, including through periods of very high generation from distributed PV.

Such an event occurred in late 2022, when on November 12, severe thunderstorm activity led to non-credible contingency events on multiple transmission lines, including failure of a double circuit tower supporting two 275 kilovolt (kV) lines, which resulted in synchronous separation of the majority of the SA power system from the rest of the NEM [2]. SA was operated as an island until temporary structures were erected approximately 1 week later, allowing one circuit to return to service on November 19, reconnecting the SA island to the rest of the NEM.

During the week of SA island operation, very high levels of distributed PV generation were forecast in South Australia. This included a maximum capacity factor of 71% (equating to a maximum output of 1,600 MW from DPV in SA) on November 17, 2022. To enable secure operation of the island power system through this week of extreme distributed PV generation, a suite of management measures was drawn upon.

Managing distributed PV "shake-off"

AEMO has investigated numerous disturbances where large amounts of distributed PV were observed to "shake-off" (disconnect) in response to a power system fault [3]. For example, in a disturbance in South Australia on March 3, 2017, AEMO estimates that 40% of the distributed PV in the region disconnected. AEMO has quantified this behaviour over many disturbances and developed power system models in Root Mean Square (RMS) and Electromagnetic Transient (EMT) platforms that are designed to capture this shake-off behaviour [4]. Those models estimate that approximately 32% of distributed PV and 13% of underlying load could shake-off in response to a severe but credible fault in the South Australian metropolitan 275 kV network. To manage this risk, when operating South Australia as an island in November 2022, AEMO dispatched co-optimised frequency reserves to manage this credible contingency, accounting for anticipated distributed PV shake-off.

Active power management of distributed PV

To maintain sufficient frequency reserves, AEMO optimised the dispatch of large generating units to minimise the credible contingency size as much as possible and maximised the availability of frequency reserves. AEMO then had no other option except to instruct network service providers to reduce the distributed PV shake-off risk to within secure levels, by curtailing distributed PV. This necessitated curtailment of 400-600 MW of distributed PV, as shown in Figure 2. AEMO directed network service providers to maintain operational demand above the indicated thresholds. To AEMO's knowledge, this is the first time in a gigawatt scale power system that active power curtailment of distributed rooftop PV systems has been enacted at this scale in order to maintain power system security.

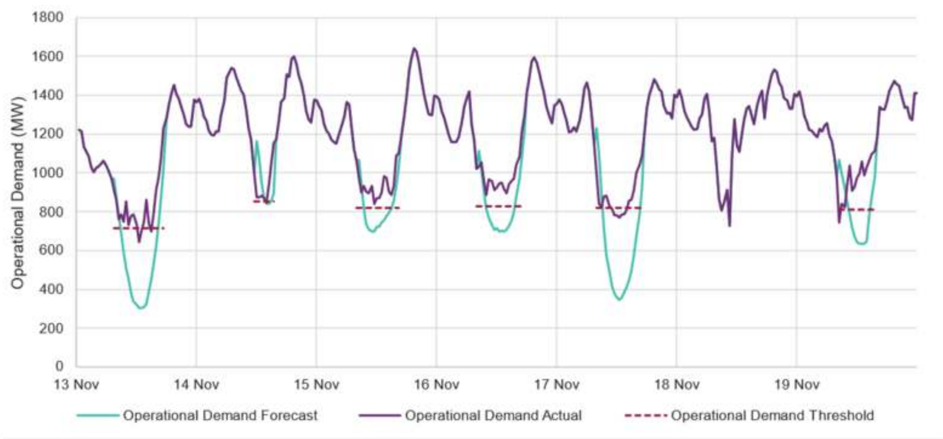

Figure 2 - Operational demand in South Australia during the November 2022 incident

Acting on AEMO's instruction, the distribution network service provider (SA Power Networks) utilised a number of agreed methods to maintain operational demand above the required thresholds:

- Curtailment of SCADA-controlled generation systems (200 kW and larger);
- Curtailment of small-scale solar via remote disconnect and reconnect capabilities, mandatory in South Australia since September 2020;
- As a last resort, increasing distribution network voltages at the feeder level to trigger overvoltage disconnection of legacy PV.

At the time of the event, approximately 517 MW of small-scale distributed PV should have been available for remote disconnect/reconnect. However, it is estimated that only ~40% of this capacity responded correctly during this event, with most of the erosion of response being related to incorrect commissioning. The response rate was especially low on the first few days, likely due to communications and power losses affecting the distribution network and internet and telecommunication services (related to the severe weather conditions in the initiating event).

It is estimated that at least two-thirds of the DPV curtailment during this event was delivered by raising distribution network voltages. Without this capability, AEMO would have likely been unable to maintain a secure operating state in South Australia during high DPV periods.

Improved standards and compliance

New Australian Standards (AS/NZS4777.2:2020) introduced more rigorous requirements for disturbance ride-through capabilities for new distributed PV installed in the NEM. This new standard became mandatory from 2021. However, compliance with the new standard has been poor, with only ~40% of new systems in early 2022 being set correctly to the new standard [5]. AEMO has worked with the 13 largest DER product manufacturers to implement voluntary changes to product menus and commissioning systems and implement remote updates, improving compliance in the field up to ~80% by early 2023, and targeting 90% by late 2023 [6]. This should plateau continuing growth in DPV shake-off risks.

SA Power Networks is currently rolling out a service offering called Flexible Exports, in which time- and location-varying export limits are remotely issued to small scale solar over an Australian implementation of IEEE-2030.5 Common Smart Inverter Profile, which also provides emergency remote curtailment functionality. Early experience indicates that this may address many of the issues with remote disconnect/reconnect compliance experienced in the November 2022 event, including:

- Enabling exports up to 10 kW for correctly commissioned systems, which incentivises compliance;
- Using live telemetry to implement a capability test, which enables solar installers to verify correct device responses; and
- Configuring systems to gradually reduce to a low 1.5 kW default export limit upon communications failure.

However, many of these compliance measures for both AS/NZS4777.2:2020 have relied on significant effort from DER product manufacturers and installers, much of it voluntary. Stronger governance frameworks are required to define roles and responsibilities for measuring, enforcing and maintaining compliance.

Lessons learned

Key lessons learned from experiences integrating distributed PV in the NEM include:

1. Ensure suitable DER standards that rigorously define disturbance ride-through capabilities. This must be done early, prior to significant rollout of distributed resources.
2. Ensure suitable governance frameworks that define the roles and responsibilities for measuring and enforcing compliance with those DER standards, addressing both the time of commissioning, and ongoing monitoring.
3. Robust remote communication capabilities can enable bulk curtailment of distributed systems in emergency situations, while providing a foundation for more sophisticated capabilities to be developed over time.
4. New datasets will be required to monitor the behaviour of distributed resources and load, allowing assessment of behaviours and development of suitable models. Arrangements to collect this data must be in place early. Important datasets in the NEM have included:
   a. An accurate record of the standing data of all DER devices installed in the network, including the system size and device type, manufacturer, installation date and installation location.
   b. Individual device level monitoring on a sample of ~20,000 inverters with 1-5s resolution measurements of active power, voltage, and frequency, with the sample set being representative of the fleet by vintage, manufacturer, device type, size, and location.

High speed measurements (~20ms or less) at a range of radial load locations at varying voltage levels in transmission, sub-transmission and distribution networks.

The rate of distributed PV continues to grow rapidly in the NEM, and AEMO's work program to achieve secure power system operation with an ever-increasing proportion of customer load supplied by distributed resources continues [7].

Banner & thumbnail credit: Bossiema on iStock

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[1] There is also one smaller DC interconnection
[2] AEMO (May 2023) Trip of South East – Tailem Bend 275 kV lines on 12 November 2022, aemo.com.au/-/media/files/electricity/nem/market_notices_and_events/power_system_incident_reports/2022/trip-of-south-east-tailem-bend-275-kv-lines-november-2022.pdf
[3] AEMO (May 2021) Behaviour of distributed resources during power system disturbances, aemo.com.au/-/media/files/initiatives/der/2021/capstone-report.pdf
[4] AEMO (November 2022) PSS®E models for load and distributed PV in the NEM, aemo.com.au/-/media/files/initiatives/der/2022/psse-models-for-load-and-distributed-pv-in-the-nem.pdf
[5] AEMO (April 2023) Compliance of Distributed Energy Resources with Technical Settings, aemo.com.au/-/media/files/initiatives/der/2023/compliance-of-der-with-technical-settings.pdf
[6] AEMO (December 2023) Compliance of Distributed Energy Resources with Technical Settings: Update, aemo.com.au/-/media/files/initiatives/der/2023/oem_compliance_report_2023.pdf
[7] AEMO, DER Operations, aemo.com.au/en/initiatives/major-programs/nem-distributed-energy-resources-der-program/operations

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Evaluation of grid operational resilience stressed by energy transition and by climate change: new metrics (SIRI) and countermeasures

For the High Voltage (HV) electrical grid, concepts and applications related to resilience have become quite common, even at the planning stage. According to the definition reported by CIGRE WG C4.47, power system resilience is the ability to limit the extent, severity and duration of system degradation following an extreme event and it is achieved through a set of key actionable measures to be taken before, during, and after extreme events.

By
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Luigi Calcara, Massimo Pompili - University of Roma "La Sapienza", Italy
Antonio Iliceto CIGRE- Chairman of SC C1 (Power System Development & Economics)

Each negative event should give additional information useful for improving the system according to the general principle of lessons learned.

Furthermore, when talking about resilience of electrical networks it is also necessary to consider the recent need to even better adapt and reinforce the grid to take into account the ongoing energy transition and climate change. In fact, our global population is rapidly expanding, and current energy models are no longer sustainable. Simultaneously, there is a global call for a unified commitment to accelerate the decarbonization process. In addition, extreme weather events are increasing rapidly worldwide: system operators such as TSOs must be able to adapt quickly to this framework, identifying methods and operational strategies that can cope with such threats when their intensity exceeds the limit of infrastructural resilience.

With the aim of evaluating the ability to face the effects of extreme events or critical issues that could arise in the climate change and energy transition context, an innovative metric for operational resilience evaluation is proposed.

— Climate change and energy transition

An efficient HV transmission system is crucial for accompanying green energy transition considering the larger use of Renewable Energy Sources (RES), cost reduction principles, sustainability, and resilience. This process is moving on in a general contest of climate changes which already are worrying the European citizens and electrical system operators. In 2023, extreme weather led to severe socio-economic impacts. It was the warmest year on record at 1.45 ± 0.12 °C above the pre-industrial average, and extreme heat affected many parts of the world. Wildfires in Hawaii, Canada, and Europe led to loss of life, the destruction of homes, and large-scale air pollution. Flooding associated with extreme rainfall from Mediterranean Cyclone Daniel affected Greece, Bulgaria, Türkiye, and Libya with particularly heavy loss of life in Libya [4].

Over the last 20 years the temperature in Europe has increased significantly and with it the number of droughts and heatwaves. In addition, storms, floods, and snowfall are more intense than in the past (examples in Fig.1).

Figure 1 -Vaia WindStorm (2018) and SnowStorm (2019) in Alpine Italian region (Trentino Alto-Adige)

These new climatic conditions (extreme weather events) pose an increasing danger to HV electrical systems and substations.

To measure power system resilience with respect to these events, both qualitative and quantitative metrics are often used. Normally, quantitative indicators are based on single event curves giving an estimation of the extent of the damage to the system before the recovery. These curves assume shapes normally known as resilience triangles or trapezoids. The integrals of the energy not supplied are strictly correlated with the power system resilience. In this framework, indicators as degree and duration of degradation, rate of restoration, and overall performance are normally used.

During extreme negative events, a major importance is given to operational resilience, which refers to the ability of an organization to maintain its core functions and continue to provide its critical services during and after a disruptive event. It includes information flows and technologies, recovery actions, processes, people, and supply chains. It aims to minimize the impact of disruptions and ensure that the organization can recover quickly.

An innovative metric for operational resilience evaluation, named H or SIRI (SIte Resilience Index), is based on a function that considers data of Energy Not Supplied (ENS), maximum Power (Pmax), and infrastructural reliability of different HV substations. The main advantages of this innovative index are:

1. to consider both of the magnitude of the event and the characteristics of the affected portion of the grid in terms of reliability and power consumption;
2. to allow the evaluation of operational resilience for each HV substation (point of delivery), making possible comparisons;
3. to allow the evaluation of the impact of an outage of a part of the electrical grid, both at regional and/or at national level, making comparisons possible and evaluations of more urgent improvements (both infrastructural and related to operational resilience).

SIte Resilient Index (SIRI)

Starting from the data of Energy Not Supplied (ENS), maximum Power (Pmax) and infrastructural reliability of one HV electrical substation/system it is possible to define a new resilience index able to measure the overall ability to withstand negative events. This index may be evaluated for each HV site, as in the following:

$$SIRI = \frac{\mathrm{ENS} \cdot \mathrm{Reliability}}{Pmax} [\mathrm{hours}]$$

in which the Reliability indicates the probability that the negative events will not occur in a given time period and is the complementary of the failure rate of a component or system.

The index SIRI is then given by the product of two terms, namely ENS and Reliability/Pmax which identify a family of hyperbolae on the plan Reliability/Pmax and ENS. By plotting these hyperbolae on a graph, it is possible to envisage the relationship between ENS and the maximum power which may be supplied by a given HV system/substation. The more critical HV systems/substations are represented in the upper hyperbolae and the criticality decreases moving down along the other curves. On the left side of the plan are the sites deserving more attention since they are characterized by high values of the power and low values of infrastructural resilience and therefore for these sites grid reinforcement should be prioritized.

This situation is depicted in Figure 2 representing all the HV substations located in one Italian Region (Trentino-Alto-Adige). The index SIRI has been evaluated for all the outages related to snow/ice and storms registered in the period 2017-2021.

The same situation is represented in Figure 3 which displays the relationship existing between the relevant outages (in terms of ENS) and each HV substation.

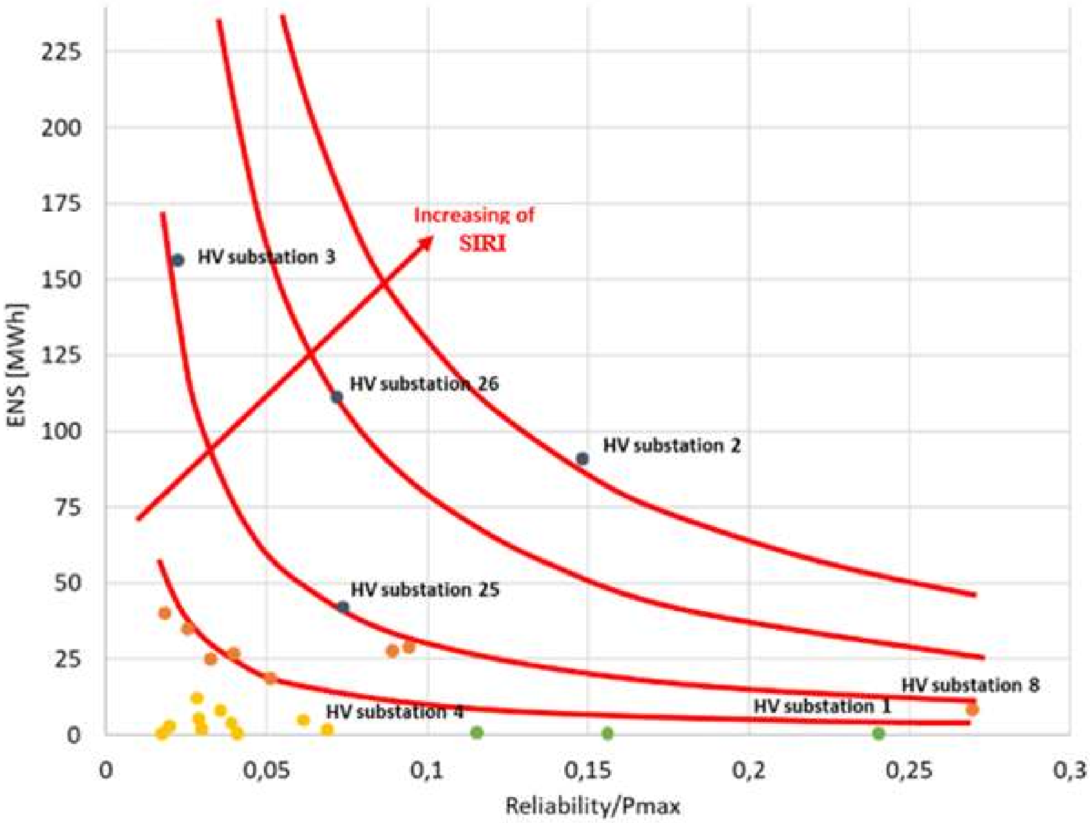


Figure 2 - Family of hyperbolises on the plan Reliability/Pmax and ENS to identify the SIte Resilient Index (SIRI) for different HV substations in Trentino-Alto-Adige region (events of 2017-2021)

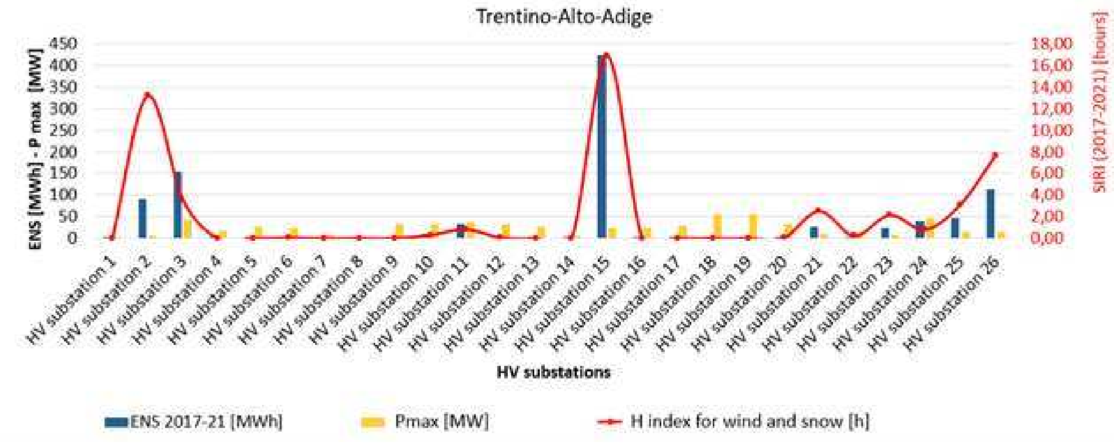


Figure 3 - Relationship between the relevant outages (in terms of ENS) and each HV substations located in Trentino-Alto-Adige (events of 2017-2021)

Conclusions and C1 work on resilience issues

The resilience of high voltage electrical grids is a critical issue in ensuring the security of energy supply, particularly in the face of extreme weather events caused by climate change. As the electrical system is subject to constant changes in demand, generation capacity, and operational conditions, it is important to develop metrics that accurately capture the system's ability to adapt to changing conditions.

In this paper a new operational resilience index is developed and presented to help TSOs evaluate the actions needed to increase the resilience of the electrical system. By monitoring and analysing these quantitative metrics, it is possible to identify areas where improvements can be made to enhance reliability and reduce the risk of power outages. In the final analysis, the implementation of measures to increase the resilience of electrical grids will be essential in ensuring the security of energy supply and the well-being of society, also in view of the ongoing energy transition.

SC C1 (Power System Developments and Economics), is deeply involved in Resilience issues, often jointly with other SCs; currently WG C1.47, joint with C4, addresses the internalisation of resilience analysis already into the planning stage of grid developments and components design. The two SCs will hold a physical workshop in Paris session on Resilience issues.

One of C1 Preferential Subjects for Paris 2024 General Session is on Resilience, and has attracted 14 papers.

References

1. CIGRE C2 Technical Brochure 833, "Operational strategies and preparedness for system operational resilience", 2021
2. L. Campisano, P. Ferretti, S. Neri, C. Quaciari, M. Pierno, E. M. Carlini, "Tools and strategies for managing critical grid situations and extreme weather events", IEEE, 2020 AEIT International Annual Conference
3. Ch. Vergine, E.M. Carlini, G. Biasiotti, S. Talomo, L. Calcara, M. Pompili, "An innovative metric for evaluating operational resilience of the high-voltage grid", 4th CIGRE SEERC Conference, Istanbul, 2023

4. State of the Global Climate 2023, https://wmo.int/

Thumbnail credit: NOAA on Unsplash

Maturity in Cybersecurity - Should We Shoot for the Stars?

Study Committee D2 is going through an interesting era where the energy transition towards a low-carbon energy supply chain demands all players in the energy market to innovate and find new efficient solutions in information systems, strengthen their cybersecurity posture, and maintain and develop agile telecommunications infrastructure to exchange the ever-increasing amount of data between all parties.

By Victor Tan

Chair of Study Committee D2, CISSP, CISM

I thought of providing an overview to those who may not be familiar with what our Study Committee does, by showing you our role in the above three focus areas in the context of the electricity supply chain (Figure 1).

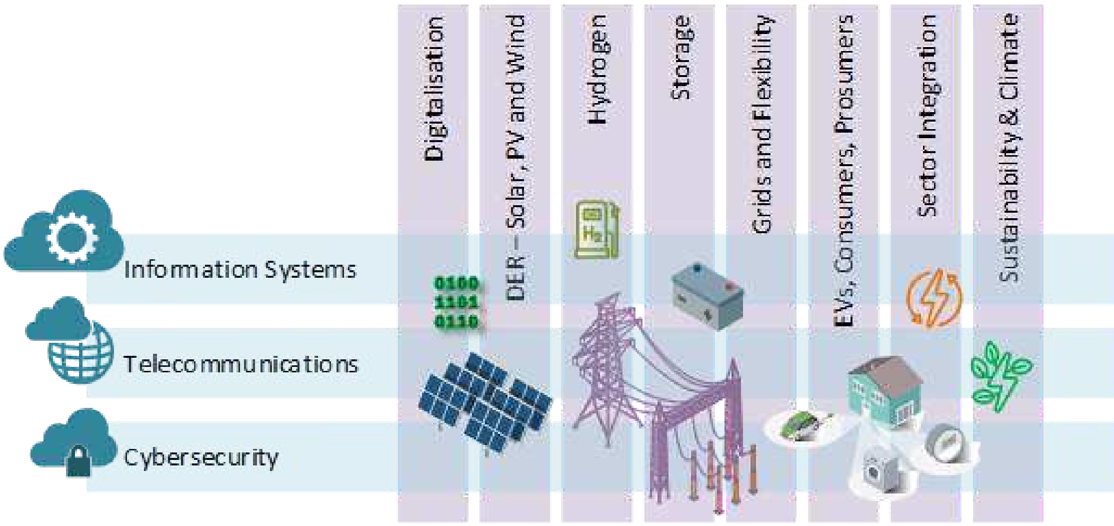


Figure 1 – CIGRE Study Committee D2 Focus Areas in the context of energy transition in the electricity supply chain

In this article, I would like to share some thoughts on one of our important focus areas, which is cybersecurity for power utilities.

In the area of cybersecurity, we have intense efforts underway to strengthen the cybersecurity posture of the electricity industry using a standards-based approach. Reference standards are being used and adopted to improve the cybersecurity posture of organisations in our industry, including the ISA/IEC 62443, ISO/IEC

27001, National Institute of Standards and Technology (NIST) Publications, regional and national standards such as the North American Electric Reliability Corporation Critical Infrastructure Protection (NERC-CIP), Australian Energy Sector Cyber Security Framework (AESCSF), European Union Agency for Cybersecurity (ENISA) guidelines and many others that apply within specific jurisdictions.

The central theme of these standards, regulations and best practices, is that securing critical infrastructure is a multi-layered approach which involves all aspects in an organisation – from the areas such as strategy, risk management, workforce management, and asset management, to operational areas such as vulnerability management, cybersecurity design, and implementation of systems.

Given the extensive breadth and depth with which cybersecurity permeates all aspects of an organisation, many find undertaking these improvement efforts challenging.

In my view, cybersecurity never has a true endpoint; it is an ongoing process. Organisations journey through it, learning from deficiencies and mistakes, continuously improving, and becoming more adept at achieving a stronger cybersecurity posture over time.

This is where the notion of capability maturity model (CMM) is relevant, which views cybersecurity as a journey of improvement rather than an end goal. The CMM was originally developed in 1986, to enable better assessment of maturity in the area of software engineering. This concept has since been used to improve other areas, including cybersecurity.

In cybersecurity, we have an equivalent maturity model called the Cybersecurity Capability Maturity Model Framework (C2M2) developed by the US Department of Energy and Homeland Security. Indeed, many cybersecurity standards and best practices are informed by the notion of capability maturity as a continuous process for improving cybersecurity.

Capability maturity models outline different levels of maturity that organisations can achieve. These levels range from basic, such as maintaining good documentation, to the most advanced, which involves having optimised plans and measurable metrics for cybersecurity objectives. Essentially, these models are collections of practices designed to enhance an organisation's cybersecurity stance. The practices are ranked based on their rigour - the more rigorous the practice, the lower the risk of breaches or compromises. However, advancing through these levels becomes increasingly challenging. It's crucial to understand that the process of continuous improvement doesn't end, even when reaching the highest maturity level.

I view the cybersecurity maturity model as similar to the concept of quality in manufacturing and engineering, where higher quality means a product closely matches its specified standards. Similarly, in cybersecurity, a higher maturity level indicates that an organisation's processes closely align with cybersecurity best practices, making them more robust and well-defined. As maturity increases, errors, mistakes, and deviations from these practices decrease.

Figure 2 and Figure 3 illustrate this analogy with normal distribution curves. As a simplistic description of the analogy, around the centre of the curve, are clusters of best practices, and the left and right tails of the curve are extremes and can be viewed as practices that deviate from the best practices, i.e. bad or questionable practices. In this analogy, deviations from the mean are deviations from optimal cybersecurity practices.

A low-maturity organisation, represented by a wider curve, may have a wider tolerance in implementing these practices and may let more questionable and bad practices slip through (Figure 2) – there is more deviation from the best practices. For instance, a bad practice— also known as an 'anti-pattern' [1] — includes not changing default passwords on protection relays. A questionable practice involves either forcing users to change passwords too frequently [2], such as every 30 days, or allowing the same password to be used indefinitely, even when there are signs of a security breach.

On the other hand, a high-maturity organisation adopts best practices more rigorously (Figure 3), resulting in less deviation from the best practices. A best practice example is requiring Multi-Factor Authentication (MFA) for high-risk situations, such as remote access.

Just as a narrower distribution (lower standard deviation) in manufacturing signifies higher consistency and quality, a high-maturity organisation in cybersecurity shows a 'tighter' adherence to best practices (narrower spread), reflecting stronger, more consistent cybersecurity measures.

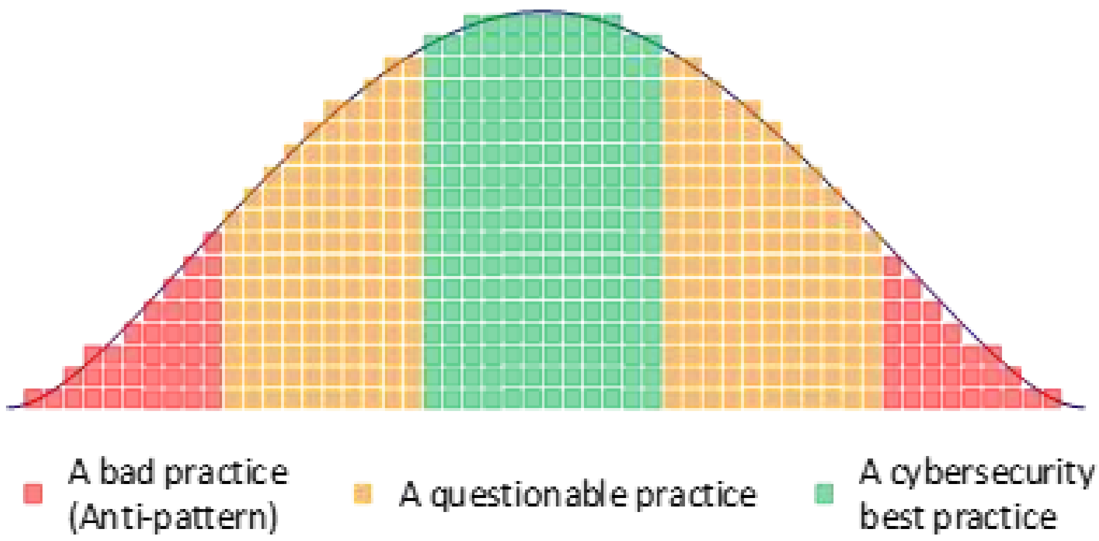


Figure 2 – Cybersecurity practices distribution curve for a low maturity organisation: the curve is wider around the centre (mean), where a larger number of questionable and bad cybersecurity practices slip through its operations

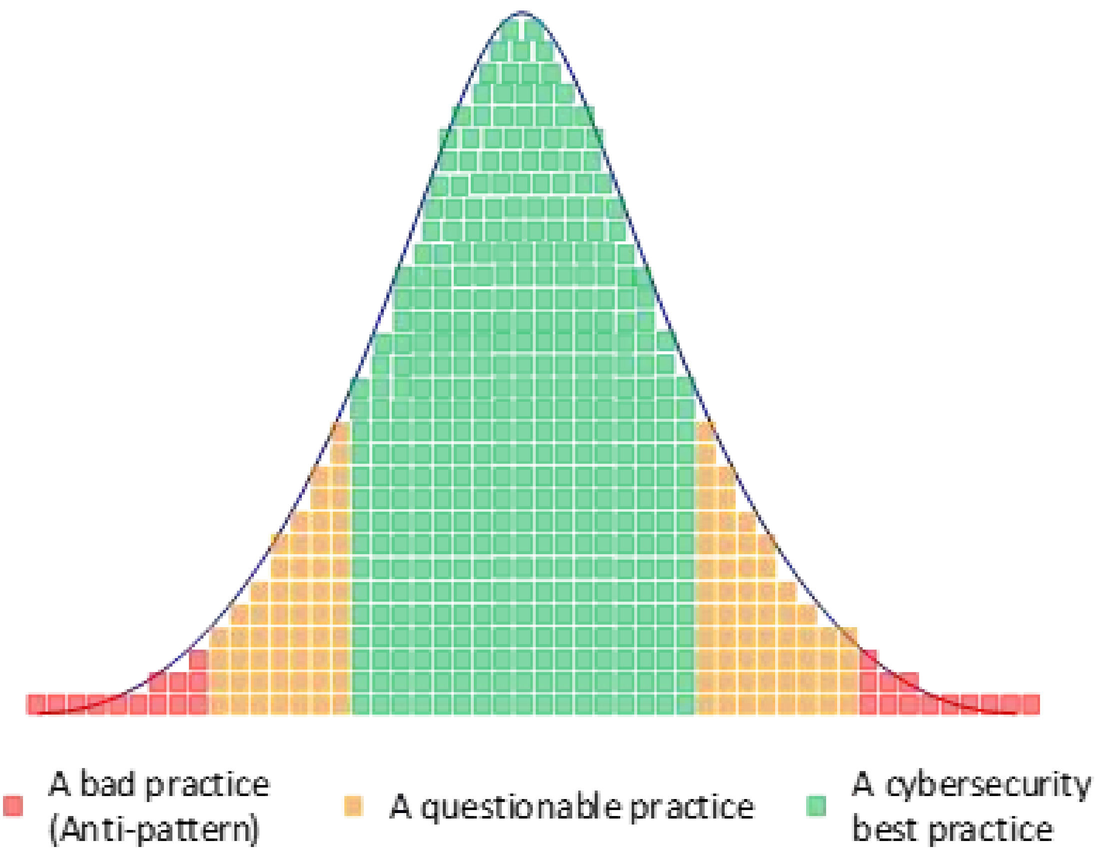


Figure 3 – Cybersecurity practices distribution curve for a high maturity organisation: the curve is narrower around the centre (mean), where significantly more best practices are adopted than the less optimal practices

Organisations that achieve a high level of cybersecurity maturity generally implement robust practices across all areas of cybersecurity. It's crucial to acknowledge that, even in these organisations, human errors and sub-optimal practices can occur. Learning from these mistakes and integrating the lessons into an ongoing improvement process is essential. This, again, has a parallel analogy in engineering and manufacturing, where feedback loops and iterative processes are vital to achieving excellence.

Should all organisations aim for the highest level of cybersecurity maturity, incorporating as many best practices as possible while eliminating all sub-optimal practices? Ideally, yes. However, realistically, an organisation should pursue a maturity level that suits its specific needs and circumstances.

What is “fit for purpose” for an organisation, may not be for another, and is often determined by factors specific to an organisation, such as the risks that it faces. In cybersecurity, this is referred to as a risk-based approach. For example, the owner of a small low power output renewables generator may well have much lower risks (financial, operational, safety, etc.) than the risks faced by a country’s large transmission power utility. Of course, if this small generator exchanges data with the distribution or transmission network or connects to the national grid, then its connection to the grid will need to comply with the additional cybersecurity requirements specified by the relevant authorities. Despite this requirement, the generator will likely face lower risks in other operational aspects compared to a large utility. The grid might enforce zero-trust cybersecurity principles, for example, treating the small generator as a low-trust entity and hence perform additional validation for data exchange, or apply additional cybersecurity controls at the connection to the grid. This approach to cybersecurity and the differing levels of trust and risk management between entities like the small generator and the grid is a complex subject that warrants its own detailed discussion. Essentially, the level of inherent risk varies across different companies.

Having a higher level of maturity would invariably incur additional cost and effort, and these would eventually need to be passed on along the electricity supply chain, to the consumers or the taxpayers. Indeed, the C2M2 states that "Striving to achieve the highest MIL (maturity indicator level) in all domains may not be optimal. Companies should evaluate the costs of achieving a specific MIL versus its potential benefits" [3]. Unless there is a regulatory mandate to comply to a certain maturity level on specific cybersecurity standards, organisations should assess the appropriate "fit for purpose" target maturity level.

In summary, the adoption of cybersecurity initiatives is critically important, given the ever-growing threats to critical infrastructures in the electricity industry. There are many aspects to consider bringing an organisation through the cybersecurity improvement journey which may seem overwhelming. However, this should not dissuade or discourage companies from starting their cybersecurity journey, or improving their cybersecurity posture, by first identifying the appropriate "fit for purpose" maturity level of cybersecurity desired, and then taking the incremental steps to achieving it through adoption of the appropriate levels of best practices within the cybersecurity standards and guidelines.

Still on the topic of cybersecurity, I would like to close by highlighting what our Study Committee is working on in the area of cybersecurity. Two interesting cybersecurity working groups are as follows:

- WG D2.51 – Implementation of Security Operations Centres (SOC) in Electric Power Industry as Part of Situational Awareness System.
- WG D2.54 – Regulatory Approaches to Enhance Electric Power Utilities' Cybersecurity Frameworks.

Both working groups will have the publication of their Technical Brochures estimated to be at the end of this year or early next year.

Cybersecurity is just one part of the three areas we cover. With so much happening in our Study Committee in the areas of Artificial Intelligence (AI), drones, cloud computing, 5G, and telecommunications networks, just to name a few, I am looking forward to providing an update in these areas in our next CIGRE publications.

The upcoming Paris Session is going to be an exciting one for our Study Committee with a record-breaking number of papers in the above areas, including cybersecurity. I am already looking forward to the discussions and the exchange of ideas to be had with SC D2 members and experts worldwide in August this year.

References

1. D. Budgen, Software Design, Addison-Wesley, 2023.
2. P. e. a. Grasi, "NIST Special Publication 800-63B," National Institute of Standards and Technology (NIST), 2020.

3. F. e. a. Muneer, “Cybersecurity Capability Maturity Model (C2M2),” US Department of Energy, Office of Cybersecurity, Energy Security and Emergency Response, 2022.

Thumbnail credit: Maximalfocus on Unsplash

Questions for assessing the degree of alignment within your team

This article, and the assessment tool discussed, is based on the Vanry material on Building Alignment. The questions rely on and are related to the distinctions made within the more detailed paper on Building Alignment. This article provides a brief introduction to the concept and principles of alignment and offers a tool that leaders can use to assess the degree of alignment within their teams. Beyond assessing the level of alignment, the questions provide leaders with suggestions on what they might do to improve the level of alignment if they find that it is not sufficient for what they are trying to achieve.

By Mikel Vanry and Stewart Ramsay, Vanry Associates

Alignment is a commitment we make to support a decision —
word, thought and deed
It's a choice we make
No one can compel us into alignment

— For the sake of what do we build alignment?

Creating and sustaining relationships

- In our personal relationships we engage with others around mutually beneficial goals in our lives. These relationships may be with partners, family members, friends, volunteer peers, etc.
  - Although often not spoken about explicitly, our relationship holds the goals that we mutually aim towards,

- Alignment to these goals supports harmony between us.
- In our work and professional lives, we seek to strengthen and build sufficient relationships to hold the results we have mutually committed to producing together.
- Particularly in organizational settings (where many people have knowledgeable and informed assessments about what is happening and what should be done) alignment offers an alternative to the 'agree/disagree' approach that frequently occurs during or after decision making.

Improving the effectiveness and efficiency of the enterprise

- Alignment supports active involvement and authenticity in the decision-making process, as well as the implementation of decisions.
- It allows even those who disagree to contribute their expertise and points of view toward the best outcome possible
- Effective Alignment reduces waste by eliminating situations or where individuals feel the need to be:
  - 'compliant' with decisions,
  - inauthentic in their support,
  - resigned that the direction/decision has little or no meaning for what's important to them,
- Alignment, as a practice, is vital to change leadership and change management.

"It is amazing how many people can hide in the cracks of misalignment between executives in an organization"

MIKEL VANRY

_ Our claims about building alignment in relationships

While alignment is necessary and valuable when applied to the 'things' of the enterprise, we focus here on building alignment as it applies to people and relationships.

Building alignment is a social, conversational practice among decision makers and those affected by the decisions

Alignment is a position that one takes individually, in relation to a decision made or direction taken by another person or group

- It is not that we are 'in alignment' with another 'person' — rather, we are in alignment with a particular decision that has been made or a direction that has been declared or invented together.
- It is specific, not an orientation or position of "in general."

- After a decision is made or direction declared, each person affected decides their position relative to the decision/direction.
- Even before a decision is made, we might "test" the extent of alignment with those affected, depending on which decision model is used.

Building alignment is a practice that extends beyond the affected individuals declaring their position and committing to sustain their promise

- Our personal declaration of alignment will have implications on others that we work with or relate to in our personal lives.
- Decisions, large or small, significant or low impact, form the fabric of any relationship or network of relationships.
- We frequently make decisions that affect others, often many;
- We react to decisions, and in reacting hold opinions of our own,
- for or against each decision.
- The work we undertake is affected by the decisions of others as are our identities and concerns.
- When making decisions we are obligated to consider choices about our decision building method, the transparency of that process to others, and/or the impact of any decisions on others. Who will be affected and in what way?

> **The intention of alignment is to produce unity, particularly unity of action, over time**

Common goals or objectives call for alignment

- When two or more people are working effectively together, they are working towards something together; they share a common goal, mission or intention.

Starting from a position of alignment in a relationship enables faster and more effective decision making, builds trust and reduces confusion for those in and around the relationship.

Building alignment is not a decision-making process

- Prior to declarations of alignment, a declaration/decision is made.
- Once a decision is made, alignment is the process of "truing-up" with the decision itself.
- We may choose to seek confirmation of alignment from those involved. Leaders may choose to seek input about what level of alignment of those affected.
- Our promise to support a decision is what lies at the heart of building alignment;
- If we have aligned on decisions previously in our relationship it may be easier for us to align in support of future ones.

Alignment is not linked with hierarchical position. Anyone can seek alignment from anyone

- A couple, prior to getting engaged, might seek alignment about family aspirations.
- Two co-workers can align on an idea and a unified way to proceed toward a goal; they may each have different views, neither 'right or wrong' or 'mine vs yours.'

Alignment is not equal to agreement; it is not compliance or simply remaining quiet about what we think

- We can be aligned with decisions even when we have a view that there was a better or a preferable alternative.
- When aligned, we set aside the other options and take on the decision as our own. Previously held views we had (or still have) about the decision are invisible to anyone else, and ideally to ourselves.
- Alignment is not "telling our own truth" in relation to a decision or direction. If we remain attached to our own view, we abandon any commitment to what the decision-maker may see or want.

This assessment tool is intended to be used in conjunction with the Vanry material on Building Alignment. The questions rely on and are related to the distinctions made within the reading on Building Alignment.

The questions can be used to assess the group as a whole or can be used to assess each individual within the group as a means of identifying growth opportunities and uncovering blind spots, for the leader, the group, or the individuals.

> **Building alignment is a crucial aspect of fostering intentional relationships**

Levels of alignment

There are at least four observable stages of Alignment people move through to reach the condition we usually assess as Fully Aligned. Most of the time, Executives/Leaders are satisfied by the achievement of the first level and delighted if they get evidence of the second level.

1. They commit to support the decision (in word and deed) because they understand the decision in terms of it making sense to them.
2. They can clearly see and articulate how their support of the decision (in word and deed) will drive changes in themselves, their people, their plans, priorities, resource deployment, etc.
3. They demonstrate their commitment to the decision through their day-to-day actions, decisions, and interactions with others.
4. They are able to interact with others in a manner that has those other people align themselves with (support in word and deed) the original decision.

Questions for assessing the degree of alignment within your team

Suggested Procedure: For each question, please assign the number / description below that best describes your team's behavior. Complete, and then total the numbers.

1. **Behavior not observable**
2. **Behavior occasionally observable**
3. **Behavior often observable**
4. **Behavior almost always observable**

With 24 questions in total – the minimum alignment score would be '24' maximum possible is '96'

1. On Alignment Itself

Does each person on the team clearly understand the goal or direction they are being asked to align with?

Standards/Tests:

- Can each person describe the goal or direction in their own words as well as in the style and language in which you presented it?
- Can each person articulate the request in pragmatic terms—how their (as well as their people's) roles, priorities, and work practices will be changed by the adoption of the new direction?
- Can each person articulate both the risks and the benefits (or value case) for this new goal or direction?

Does each person understand the underlying concept, standards and practices of alignment?

Standards/Tests:

- Can each person articulate the distinctive characteristics of alignment? The things that make it different from, say, agreement or buy-in?
- Does each person speak in the language of personal accountability when making the commitment and when they promise to sustain that commitment over time?

- Does each person speak to alignment as a means to unite the group and as a means to collaborative action?

2. On Alignment with What, Exactly

Standards/Tests:

- Is each person able to articulate to your satisfaction what they believe they've committed to supporting?
- Do you assess each person to be focusing on the same thing as you are in your request for each person's alignment?

3. On Sustaining Alignment

Standards/Tests:

- Is each person competent at sustaining their alignment over time?
    - Does each person treat the adopted "decision" as their own - in word and deed? (Have you or have the others observed this in them?)
    - Does each person return to their team and engage with that team until that team is able to align on the goal/direction declared?
    - Does each person redirect hallway gossip to the benefit of what is now the adopted goal/direction?
    - Does each person take up their concerns about continued alignment with you (as the person they committed to in the first place) rather than a third party?

- Does each person declare missings or misalignment in 1-on-1, or appropriate group settings, for the true purpose of resolving questions, and not simply for the drama of "upsetting the apple cart"?
- Has each person been consistently responsible in declaring the things about which they are out of alignment, and taken responsibility for making sure that their declaration is heard by you
- Has each person asked for coaching in building his capacity to align, and in building their direct reports' capacities to align?
- When a member of your team is engaged by others about their possible misalignment, does each person:
    - Quickly get over the initial discomfort?
    - Appreciate the other for what both communicate to be an act of commitment to the individual's and the collective's success?
    - Readily explore what it is that has the other person concerned?
    - Allow the other's view to be as legitimate as their own view?
    - Authentically engage with the challenger to see what it is that appears inconsistent about his behavior in relation to his declared intent?
- Does each person declare breakdowns in their alignment (as appropriate) and take action or seek support to become re-aligned?
- Does each person declare when they cannot align themselves unless something about the current situation is changed?
- Does each person bring useful/real proposals for re-aligning themself?
- Does each person allow the group to move forward while they work to become re-aligned? (i.e. - listening, internally testing)

Total Score (out of a possible 96)

Paris Session 2024: The Next Generation Network Forum

The 2024 Paris session is fast approaching, and an international organising group is planning the well-known Next Generation Network (NGN) Forum, which will take place on Wednesday the 28th of August from 11am to 2pm Paris time in the Palais des Congrès. This event has been held during the last five Paris sessions in addition to being held during the e-Session in 2020 and the Virtual Centennial Session in 2021. It has become a can't-miss event for students and young professionals attending the Paris session to meet and learn from other NGN groups and CIGRE experts and to see how NGN members are benefiting from their participation in CIGRE.

By Phillip Coughlan

The purpose of the event is to showcase NGN contributions to CIGRE and highlight the work being undertaken by NGN groups across the globe. Senior CIGRE leaders regularly attend the event and offer their time as guest speakers. In addition, they are always willing to participate in an interactive Q&A discussion with the audience to offer further insights to NGN members in the audience. Another key feature of the forum is to not only ask thought-provoking questions, but to also discuss them through a practical and feasible lens, with a view that audience members can leave the forum more informed and inspired to pursue their goals within the power systems industry.

The details of this year's forum are still being developed, but quite a lot of information can already be shared. We are pleased to confirm that the CIGRE Vice President – Technical and Technical Council Chair, Marcio Szechtman will present.

His presentation will focus on the rollout of new initiatives to assist NGN members, and students and young professionals more broadly, within CIGRE to get the most out of their CIGRE experience. As always, we encourage any audience members to ask questions and take advantage of Marcio's expertise to maximise their understanding of the organisation and what it can offer young people.

Another key pillar of the event has been the opportunity to hear from specific NGN groups around the globe. We are currently in discussions with several NGN groups to confirm the presentation line up. This is not only an opportunity to hear about the unique initiatives of some of the NGN groups, but it is also an opportunity for NGN members to share their contributions in front of an international audience. It is our hope that by showcasing NGN groups at various stages of their development it will inspire growth and engagement within other NGN groups that might be just starting out or looking to become a chartered NGN group. While the current CIGRE community consists of power system professionals across more than 90 countries and from 61 National Committees, there are only 33 officially chartered NGN groups with several additional groups in various stages of development.

A feature of any forum is the opportunity to hear from guest speakers who are leaders in our industry. These speakers can offer insights, statistics and theories that may not yet be commonplace to further spark discussion not only during the forum, by way of Q&A, but also after the forum during the Paris session. Hopefully, these discussions extend back to each attendee's company or university to create positive change. This year, our guest speaker is Rena Kuwahata from the International Energy Agency (IEA). There is a lot happening in our industry at present, and there are few that are more informed to speak to some of these changes than Rena. It is important to act during these times of prolific change and transition and Rena's presentation will no doubt be a catalyst to empower us all to drive this transition forward.

We look forward to seeing you all at this year's Paris session and hope you stop by our NGN Forum to participate in this signature event. Furthermore, there will also be an NGN booth setup throughout the session as part of the technical exhibition. We encourage you to also stop by the NGN booth as it will be staffed at all times with NGN representatives who can offer knowledge or support to other students and young professionals.

Banner & thumbnail: photo NGN Forum Session 2022

CIGRE NGN: Discussion with Anamaria Iamandi

CIGRE would like to introduce a new section in Life of the Association: Interviews from Women in Engineering and Next Generation Network. A lot of focus is given to senior CIGRE members and these interviews will present younger members and let them explain what CIGRE means to them. These Q&A interviews are short but allow us to have a new, younger perspective on CIGRE membership; they tell us what interests them in their work, as well as what their projects and goals are. These are the voices of our industry's future. Please share with young people on your teams and encourage their membership in CIGRE!

PhD Engineering, Sept 2023, 7 years in industry

Current position:

- Senior Protection, Control & Automation engineer at the National Dispatching Center, Romanian Power Grid Company, CNTEE Transelectrica SA.;
- Associate professor at the National University of Science and Technology "Politehnica" of Bucharest;
- Secretary General of CIGRE NGN Romania

CIGRE WG: B5/C4.79 "Protection roadmap for low inertia and low fault current"

What lead you to your present career or job?

Anamaria: During my high school classes, I was passionate about math and physics, and I knew that I wanted to fructify them in my professional activity. Later, I was involved in a project whose purpose was to raise awareness about the importance of our actions regarding environmental sustainability. That project helped me to understand what are the key factors which could influence climate change, with power and energy being at the top of the list. Therefore, after graduation, I had no doubts that I wanted to study power systems engineering.

What are you working on now that would interest ELECTRA readers?

A.: My field of expertise and interest focuses on protection, control, and automation equipment, synchrophasor measurement systems, and digital substations.

As a protection engineer, I am dealing with protection and control equipment, protection, control, and automation parameter calculations, and establishing the protection philosophies for high voltage power plants and substations. In addition, I am involved in ENTSO-E activities, representing the Romanian TSO in the "Protection Equipment" working group.

What has been the biggest challenge with your work?

A.: The biggest challenge of my work is also the beauty of my work: to ensure both a secure and reliable operation of the power system in accordance with our TSO's performance indicators while facing the current emerging challenges resulting from power system evolution: consumption evolution, the emergence of new generating units, demand changes for cross-border transmission lines, decommissioning of conventional generation units, etc.

What has been your biggest challenge balancing work and personal life?

A.: Last year was challenging for me as I was in the last year of my PhD study. I had to finish my PhD thesis while maintaining the same level of productivity and involvement in my work activity as I didn't want it to affect my job or career.

I was lucky enough to have the support of my family, friends, and colleagues, who constantly encouraged me, giving me all the support needed to perform, to stay focused, and to have confidence in my work.

How did you get involved in CIGRE?

A.: I got involved in CIGRE thanks to my former director, who was also my mentor. He is not only a valuable specialist in the power system field but also a great lecturer, paying attention to the importance of constant learning, encouraging young engineers to get involved in scientific activities like conferences, research projects, study committees, etc.

In my first year of work, he invited me to participate at a CIGRE conference organized by CIGRE's Romanian National Committee – "*International Regional South-East European Conference*," a biennial event meant to promote young engineers.

There I learned about the CIGRE structure and the membership facilities and since then I have participated at all CIGRE events organized by the CIGRE Romania NC. I have also participated at the CIGRE Paris Sessions and Southeast European Regional Council Conference and currently I am involved in CIGRE WG B5/C4.79 "Protection roadmap for low inertia and low fault current."

What do you feel is CIGRE's 'added value'?

A.: The entire CIGRE concept is 'added value' as by its structure and organized events, it creates the communication facilities needed to gather specialists at the same table from different power system areas: universities, utilities, producers, and services suppliers whose major goal is the same – to ensure the needs of the power system.

Why would you recommend CIGRE membership to others?

A.: As I stated before, CIGRE is a good communication binder between different entities, offering the opportunity to interact with valuable specialists from all power systems fields and to share knowledge based on real world experiences.

Also, CIGRE provides the resources and opportunities to have knowledge about both the global and local challenges facing power systems.

Where do you see yourself in 15 years?

A.: I definitely see myself still working in the energy field. I consider myself lucky to work in the field I am passionate about, as we are currently living in a very dynamic world.

I am committed to staying updated with the industry trends and to be open to new challenges and responsibilities. I plan to continue developing my skills to be able to share my experience and to mentor the next generation of engineers.

Do you have one major goal or do you have a bucket list? Are you willing to share this information?

A.: My major goal is to constantly develop my knowledge and skills in order to be a valuable specialist in the power system field.

What would you like to see change in our industry in the future?

A.: I strongly believe that communication and sharing knowledge between different parties is the key factor to success regardless of the activity field or one's years in industry. I would like to see that our industry is willing to gather at the same table power system professionals from different fields and different levels of experience, giving them the same level of confidence. The CIGRE community is a good ambassador, which embodies the essence of sharing information.

If you are a WiE or NGN member and wish to be featured in an upcoming ELECTRA edition, please contact ***ELECTRA Editorial Team****. If you are reading these and wish to join CIGRE, please* ***visit this page****.*

CIGRE Africa - CIGRE Academy Seminar on Electrical Substations

Jointly organised by CIGRE and "UMEME" Consortium

By Koji Kawakita – Chair SC B3 & Hugh Cunningham – Chair Tutorial Advisory Group, SC B3

University of Dar es Salaam (UDSM) - Tanzania
6 - 7 March 2024

In March 2024, Study Committee B3, Substations and Electrical Installations, assembled a team of experts to travel to Tanzania to deliver a seminar to local industry experts on substations. This was organised by CIGRE together with UMEME Consortium as part of a larger 8-day event. The event was facilitated by Prof Santos Kiwhele (Director of Power Systems, UDSM).

The session was opened by Prof Bakari M. M. Mwinyiwiwa (Principal, College of Engineering and Technology, UDSM), along with a welcome presentation from Mr Antonio Iliceto (Africa WG Chair and Chair SC C1). Then Mr Koji Kawakita (Chair SC B3) gave an introductory presentation on the activities of CIGRE and SC B3. The event was well attended with 50 attendees in persons and a further 20 attendees connected remotely.

The following key topics were also presented by our SC B3 experts during the 2-day CIGRE element :

Contemporary Design of Low Cost Substations in Developing Countries (TB 740)	Philip Konig
Substation Uprating and Upgrading (TB 532)	Akira Okada
Considering Life Extension Operations as part of a Substation's Initial Design	Mark Peffer
Gas-Insulated Substations, Design Review, Erection & Commissioning Proven Practices	Mario Andrés Montoya Arango
Service continuity Guide for HV GIS above 52 kV (TB 870)	Dik van Houwelingen
Saving Through Optimised Maintenance in AIS (TB 660)	Koji Kawakita

The session was engaging with positive feedback from attendees and will provide an excellent template for future similar events.

At the end, attendees were awarded a certificate for participation in the seminar.

Opening Session: Santos Kihwele, Dik van Houwelingen, Mario Andrés Montoya Arango, Philip Konig, Mark Peffer, Aviti T Mushi, Koji Kawakita, Federico Santi

Philip Koenig, Koji Kawakita, Akira Okada

Awarding of Certification to a participant

Banner & thumbnail credit: Moses Londo on Unsplash

Distinguished Member Awards 2024

This award recognizes the contribution of the CIGRE Members to their National Committee wether technical or administrative. Any long-standing individual Member of CIGRE who has contributed significantly to the activities of the CIGRE NC and whose active participation and contribution in the technical activities of CIGRE can be proven is eligible for this award.

Arab States of the Gulf

Nasser ALSHAHRANI	Hashim AL ZAHRANI

Argentina

Gustavo BARBERA

Australia

Sarath PERERA	David BONES
Gary BRENNAN	Ray BROWN
Angela KLEPAC	Andrew HALLEY
Don GEDDEY	

Brazil

Alexandre RASI AOKI	André Luiz MUSTAFA
Roberto ASANO JUNIOR	

Bosnia & Herzegovina

Zijad BAJRAMOVIĆ	

Canada

Mike BARTEL	Chen WANG
Kankar BHATTACHARYA	William CHISHOLM
Howard SEDDING	

China

Zhiyong YUAN	Zhiyuan HE
Bin LIU	Hongzhu TAO
Chun DENG	Ying LIU
Ning LI	

Croatia

Božidar FILIPOVIĆ GRČIĆ	

Denmark

Per CHRISTENSEN	Filipe FARIA DA SILVA

France

Olivier GRABETTE	Matthieu CABAU
Manuel MARTINEZ DURO	Cécile ROZE
Samuel NGEFEU	

Germany

Mark REUTER	Marc FOATA
Johannes SEILER	

India

Pravinchandra MEHTA	Rajesh SURI
Bankim PRAVINCHANDRA SONI	

Iran

Faramarz GHELICHI

Ireland

Robert DONAGHY

Italy

Maria Rosaria GUARNIERE	Chiara VERGINE
Angelo L'ABBATE	Arman DERVIŠKADIĆ

Japan

Hiroshi MURAKAMI	Naohiro HOZUMI
Shinta FUKUI	Masahiro HANAI
Katsuhito SAWADA	Tsuneo KOBAYASHI
Takayuki KOBAYASHI	Shoshi KATAKAI
Toshiyuki OSAKI	

Mexico

Enrique BETANCOURT RAMIREZ

Netherlands

Wessel BAKKER	Jacco SMIT
René TROOST	

Poland

Maksymilian PRZYGRODZKI	Marcin LIZER

Romania

Marius Nicolae OLTEAN	Mihai Constantin MARCOLT

Russia

Nailya CHEMBORISOVA	Vladimir TULSKY
Stanislav UTTS	Alexander VOLOSHIN

Serbia

Jelena LUKIĆ

Slovenia

Aleš KREGAR

South Africa

Prince MOYO	Thomas MAGG

Spain

Alfredo QUIJANO LÓPEZ

Thailand

Suriya PRUNGKHWUNMUANG	

United Kingdom

Stuart GRATTAGE	Antony ZYMELKA
Donald Leigh WILLIAMS	David WALKER
Colin DAVIDSON	Andre CANELHAS

United States

Rana MUKERJI	Earle C (Rusty) BASCOM III
Amanda OLSON	

CIGRE Ordinary & Extraordinary General Assemblies - Assemblée Générale Ordinaire & Extraordinaire du CIGRE

CIGRE Ordinary and Extraordinary General Assemblies on June 2024

In accordance with French law, and in order to approve the accounts of the previous year, CIGRE organizes an Ordinary General Assembly every year in June.

According to Article 7 of the CIGRE Statutes, the Ordinary General Assembly of CIGRE members is convened at least once a year.

The Ordinary General Assembly can take place by correspondence.

This correspondence can be done by electronic means, or by any other classical or modern means.

In June 2024, the CIGRE Association organizes an Ordinary and an Extraordinary General Assemblies by electronic means.

At the end of May 2024, the members of CIGRE entitled to vote received an e-mail with a personal code giving them access to the agendas,

the electronic voting ballot and the documents relating to the two General Assemblies.

The CIGRE Central Office will close the voting on Friday June 28, 2024, at 5:00 pm (UTC+2).

Assemblée Générale Ordinaire et Extraordinaire du CIGRE Juin 2024

Dans le cadre de la Législation Française, et afin d'approuver les Comptes de l'année précédente, le CIGRE organise une Assemblée Générale Ordinaire chaque année en Juin.

Selon l'Article 7 des Statuts du CIGRE, l'Assemblée Générale Ordinaire des membres du CIGRE est convoquée au moins une fois par an.

L'Assemblée Générale Ordinaire peut avoir lieu par correspondance.

Cette correspondance peut être réalisée par voie électronique, ou par tout autre moyen classique ou moderne.

En juin 2024, l'Association CIGRE organise une Assemblée Générale Ordinaire et Extraordinaire par voie électronique.

Fin Mai 2024, les membres du CIGRE habilités ont reçu un courrier électronique avec un code personnel

leur donnant accès aux ordres du jour, au bulletin de vote et aux documents relatifs aux deux Assemblées Générales.

Le Bureau Central du CIGRE clôturera les votes le Vendredi 28 Juin 2024, à 17h00 (UTC+2).

Banner & thumbnail credit: uschools on iStock

SC B3

Substations and electrical installations

by Koji Kawakita, Chair & Samuel Nguefeu, Secretary

This report summarises the Study Committee (SC) B3 “Substations and Electrical Installations” activities in 2023 and recent updates.

Introduction

For CIGRE and SC B3 members worldwide, 2023 has again found its sparkle. The CIGRE SC B3/A3 Joint Colloquium in Birmingham, UK, brought together many experts for lively discussions and networking.

With the COVID pandemic under control, face-to-face events have resumed and CIGRE activities are returning to normal. At the same time, online meetings and online tools have been utilised to establish a more efficient style of activities during the year.

Substations continue to play a key role as nodes within electrical networks, providing the capability for the network to deliver safe, reliable energy with high availability under above circumstances.

To support the realisation of a sustainable society with energy transition, substations’ research & development continues to advance in new technologies and applications that offer substation owners and operators the flexibility, security and stability they need to continue to expand their systems efficiently and environmentally friendly. These activities align with and anticipate the "CIGRE 2023 Strategic Plan - Entering CIGRE's 2nd Century - Horizon 2030" published by CIGRE last year.

The focus area for SC B3 is the coordinated design and operation between transmission and distribution to facilitate more flexible and active distribution networks. Facilitating this connectivity to support the integration of decentralised renewable energy resources, energy storage, and more active customer participation with bilateral power flow is increasingly essential. At the same time, these challenges need to consider asset management practices that can identify the best use of installed assets by optimising their functionality, interventions and lifetime.

The challenges mentioned above have resulted in several new initiatives:

- Dealing with the increased impact on substation design and new applications to support energy transitions such as integrating renewable energy resources, energy storage systems and other installations.
- Mitigating environmental, health, safety and security impacts, including the reduction of Green House Gas emissions and the substation carbon footprint

- Substation design, operation and maintenance resilience against natural disasters and threats (terrorism, epidemic, physical/cyber, etc.)
- Optimising substation asset intervention (retrofit, uprating, upgrading, renewal, extensions).
- Increased substation operational efficiency and availability.
- Integration of intelligence for digitalisation.
- A new set of skills for new technologies, knowledge transfer and high standards of education in developing engineering skills.

These solutions aim to include the needs of developing communities, emerging economies, and established industrialised countries.

The SC B3 mission is to:

- Facilitate and promote the progress of engineering and the international exchange of information and knowledge in the field of substations and electrical installations.
- Add value to this information and knowledge by synthesising state-of-the-art best practice and developing recommendations and guidance.

SC B3 has a keen focus on the rapid changes in the utility industry, with an eye on design concepts and new environmentally green and sustainable materials for energy transition.

— Strategy and Direction

The SC B3 strategy and direction are continuously reviewed to ensure it meets our stakeholders' needs. Our current strategic plan covers the period from 2018 to 2028. The main technical directions are the following.

T1. New substation concepts

Development of new concepts including bus arrangements, hybrid solutions, new applications and functions. The impact from distributed generation and power flow control systems including specification of corresponding design/layout criteria for substations constituting integral parts of totally optimised networks. Reduction of carbon footprint impact through new technologies.

T2. Substation ownership issues

Organisational aspects including human resource and training needs, in-service support, software management including quality control and maintenance. Management of assets including environmental, health, safety, and security.

T3. Life cycle management

Monitoring in-service experience, substation condition assessment, aspects of maintenance outsourcing, short- and long-term needs, opportunities for cost reduction, spare parts. Increased utilisation (life extension, upgrading, and dynamic loading), refurbishment /renovation concepts, and investment strategies, principles for combining existing and new equipment, accounting for specific demands from network-reliability and customer demand-side points of view.

T4. Integration of intelligence for digitalisation on substations

New digital technologies (Artificial Intelligence, Internet of Things, 3-Dimensional technology, etc.) and applications will be used in all substation design, operation, and management aspects. Identify the opportunities offered by the increased use of advanced information and communication technologies.

A key focus is considering how to improve the opportunities for younger member participation in connection with CIGRE "Next Generation Network" as well as increasing the involvement of women experts in our activities coordinating with the "Women in Engineering" initiative.

— Membership and Experts

Our work continues through the support of our national committee representatives, substation specialists and experts from across the globe. We are working with country representatives, 24 regular members plus an additional 4 members representing electricity sectors other than transmission and 15 observer members. Strategic/Customer/Tutorial advisory group and Quality Assurance team also support our work in their respective roles.

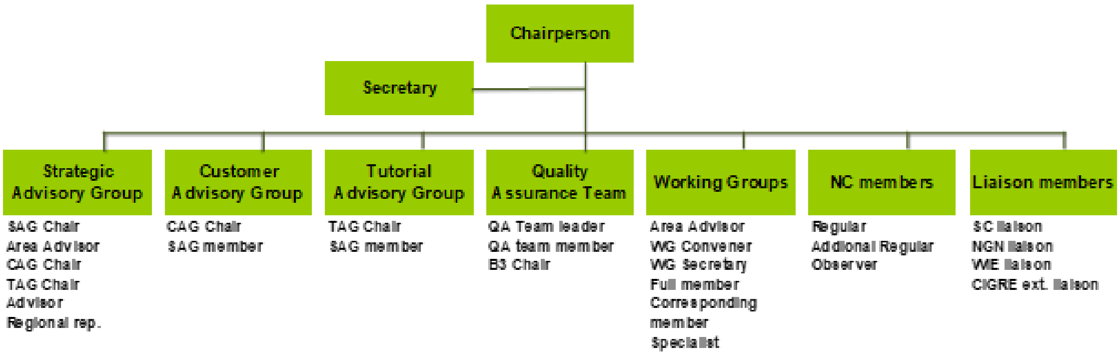


Figure 1 - Study Committee B3 Organisational Structure

— 2023 Colloquium and Participating Symposium

2023 B3/A3 Colloquium, Birmingham, UK 9th-12th May 2023

The objective of the Colloquium is to share the latest thinking and developments in SF6 and its alternatives, both for new products and management of existing populations.

Aiming to address the resonance for our sector around reducing and managing our dependence on SF6, so with this in mind the event considered the following questions within our community.

- The impact of delivering Net Zero for Substations and HV Equipment - is it all about SF6 alternatives?
- What is the role for the Circular Economy on Substations and HV Equipment in a Net Zero Future?

The Colloquium delivered remarkable results.

- 160 participants including international experts from 24 countries.
- 6 Oral sessions with 39 excellent papers.
- A plenary session which discussed the future outlook of SF6 and its alternatives for the T&D sector.
- 5 Tutorials held by world-leading experts on developments of alternative materials to SF6, asset management and GIS service experience.
- 9 Working Group meeting were hosted.
- 2 Training courses led by world-leading experts introducing key aspects of GIS substation design and managing substation assets.

2023 Symposium, Cairns, AU 4th-7th September 2023

B3 participated in the Symposium as part of the Study Committees.

- More than 1300 delegates participated total.
- 235 papers were accepted from 35 countries, including 15 B3 papers from 5 countries with 300 attendees.
- 2 B3 tutorial topics were presented.
- 1 B3.64 WG meeting

— 2023 B3 annual meeting

The Study Committee B3 annual meeting was held on 5 September 2023 during the Symposium in Cairns, Australia.

At the meeting, 2024 preferential subjects highlighted energy transition and sustainable substation management, member interests for new WG topics, and so forth were discussed. Daniel Stafford, B3 liaison of NGN and Tara-lee MacArthur, representative of WiE were invited to the meeting to present each organisations activities and discussions with B3 members for mutual understanding.

The Australian panel members of the host NC were invited to the meeting to share information and engage in a lively exchange of views.

The next annual meeting for Study Committee B3 will be held on 29 August 2024 during the 2024 Paris Session.

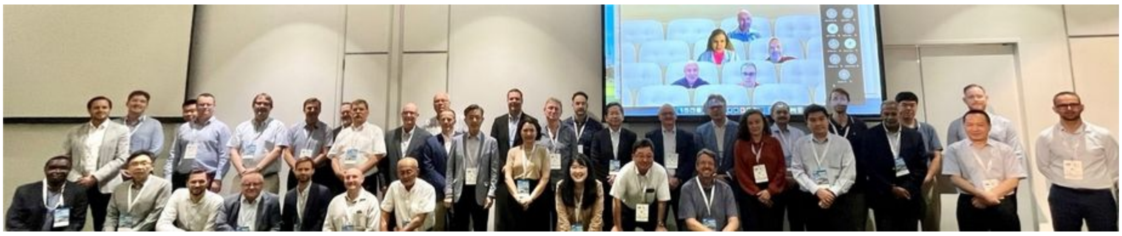


Figure 2 – Study Committee B3 annual meeting group photo

— CIGRE Africa Academy SC B3 Seminar

Many Sub-Saharan African countries face a significant challenge: a large number and percentage of people need access to electricity. The region's high demographic and economic growth underscores the critical need for reliable power as a fundamental enabler of development.

As a key player in supporting the growth of Sub-Saharan Africa through electrification, CIGRE has taken on the mission to contribute to this cause.

There is a growing demand for technical seminars, and we have been specifically requested to organise a seminar on SC B3. In response to this demand, B3 conducted CIGRE Academy Seminars on Substations, jointly organised by CIGRE and the "UMEME" project, 6-8 March 2024, in Dar es Salaam, Tanzania.

The first two days consisted of seminars and questions. A lively exchange of views on various topics took place with the audience members.

6 experts from B3 presented on the following topics.

Contemporary Design of Low Cost Substations in Developing Countries (TB 740)	Philip Konig
Substation Uprating and Upgrading (TB 532)	Akira Okada
Considering Life Extension Operations as part of a Substation's Initial Design	Mark Peffer
Gas-Insulated Substations, Design Review, Erection & Commissioning Proven Practices	Mario Andrés Montoya Arango
Service continuity Guide for HV GIS above 52 kV (TB 870)	Dik van Houwelingen
Saving Through Optimised Maintenance in AIS (TB 660)	Koji Kawakita

Working Groups

The Working Groups (WGs) are the "engine room" of CIGRE technical work. Our WG are arranged in 4 key work areas, which facilitate how we organise our work, bringing together our global experts to focus their understanding to achieve our objectives. Area advisors coordinate and align working group activities to the SC B3 Strategy, with responsibilities to support SC B3 Chairperson. Young members are particularly encouraged to join WGs as supporting or active members.

Figure 3 - SC B3 Work Areas

SC B3 has more than 370 experts in 14 active Working Groups, including 7 Joint Working Groups (5 B3 lead) and 1 SF6 Green book project, focusing on activities in 4 different topic areas as of 31st March 2024 (Figure 4).

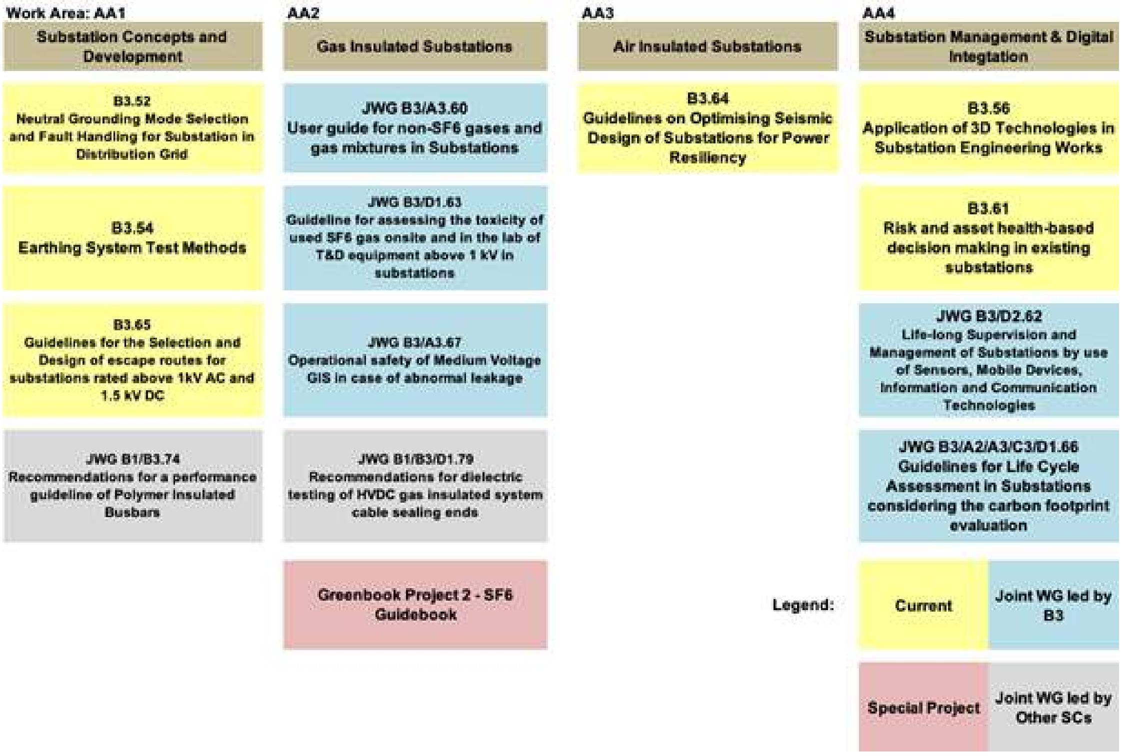


Figure 4 – Study Committee B3 WGs

New WGs that were recently approved include:

- **JWG B3/A2/A3/C3/D1.66** - Guidelines for Life Cycle Assessment in Substations considering the carbon footprint evaluation
- **JWG B3/A3.67** - Operational safety of Medium Voltage GIS in case of abnormal leakage

Many new topics are currently under discussion such as:

- Process Requirements for Commissioning and Inspecting Substations
- Guidelines for managing black start resilience in substations
- Experience in offshore substation operation and maintenance
- Earthing system design guidelines for high voltage substations

WGs are not possible without support from national committees in nominating suitable experts and specialists to participate in the work. We value and encourage all national committees to review each new terms of reference and to consider appropriate experts available to support them.

CIGRE active Working Groups / Call for experts

Publications

6 Technical Brochures (TBs) were published in 2023 for Study Committee B3 including

- TB 895 - Impact on Engineering and Lifetime Management of Outdoor HV GIS - WG B3.57
- TB 898 - Knowledge transfer of substation engineering and experiences - WG B3.58
- TB 907 - Mobile Substations Incorporating HV GIS - WG B3.41
- TB 914 - Guidelines for SF6 end-of-life treatment of T&D equipment (>1 kV) in substations - JWG B3/A3.59
- TB 920 - Concepts for on-site HV testing of GIS after installation, extension, retrofit or repair - WG B3.50
- TB 930 - Review of substation busbar component reliability - WG B3.49

The following working group brochures are expected to be completed in 2024:

- **B3.52** - Neutral grounding mode selection and fault handling for substation in distribution grids
- **B3.54** - Earthing system testing methods
- **B3.56** - Application of 3D technologies in substation engineering works
- **B3/A3.60** - User guide for non-SF6 gases and gas mixtures in Substations
- **Green Book: SF_6 Guidebook** - a Springer publication

Tutorials and Workshops

Tutorials and workshops are important opportunities to share new knowledge of substation concepts and developments, management, and challenges. Tutorials are based on the outcomes of our study in WGs and their associated TBs. Tutorials can be arranged in association with any CIGRE event and are an excellent way for our experts to present their work and share knowledge. Six tutorials and two workshops were held in 2023.

Birmingham, UK – A3&B3 CIGRE UK Joint Colloquium, 8-12 May 2023

- Asset Health Indices for Equipment in Existing Substations
- Service Continuity Guide for HV GIS above 52 kV
- Impact on Engineering and Lifetime Management of Outdoor GIS
- Substation Training Course - Introduction to GIS

- Substation Training Course - Introduction to Asset Management

Virtual, India - CIGRE India & CBIP conference, 6 July 2023

- Study Committee B3 Global B3 Activities and Future Vision

Cairns, Australia - CIGRE Cairns Symposium 2023, 4-7 September

- Knowledge transfer of substation engineering and experiences
- Air insulated substation design for severe climate conditions

Bucharest, Romania - CMDM 2023, 31 Oct.-2 Nov. 2023

- Service continuity Guide for HV GIS above 52 kV

The following tutorial will be delivered this year,

Paris, France – Paris Session 2024, 25-30 August 2024

- Guidelines for SF_6 end-of-life treatment of T&D equipment (>1 kV) in substations

Events

Upcoming special events for the SC B3 include:

- Paris, France – **2024 CIGRE Session**, 25 -30 August 2024
- UAE - **CIGRE GCC POWER 2024 Conference & Exhibition**, 11-13 November 2024
- Klingenberg, Germany – **2025 SC B3 and A3 Joint Colloquium**, 24-28 March 2025
- Trondheim, Norway – **CIGRE Trondheim Symposium**, 12-15 May 2025

- Montreal, Canada – **CIGRE Montreal Symposium**, 29 September - 2 October 2025

CIGRE SC B3 Outstanding Service Award

The Outstanding Service Award of CIGRE SC B3 is granted by the SC Chair annually to two of its members in recognition of outstanding participation in and contribution to the SC's technical work. In 2023, this award was delivered to Jeff Camden (US) and Tony Chen (UK).

Jeff has participated in several WGs in the past and was Secretary of the **Technical Brochure 898**: "Knowledge transfer of substation engineering and experiences." In addition, he moderated the B3 Workshop "Knowledge Transfer of Substation Engineering and Experiences" at the 2022 Paris Session.

Tony has participated in several WGs in the past and was Secretary of the **Technical Brochure 914**: "Guidelines for SF6 End-of-Life Treatment of T&D Equipment (>1kV) in Substations." In addition, he played an important role at the 2023 B3&A3 Joint Colloquium in Birmingham, UK, as Session Chair, Plenary Session presenter, and member of the local organising committee.

Conclusions

2024 is my last year as Chairperson, and Mark McVey (US) has been nominated as a replacement from September 2024. He is highly experienced and motivated and will be an excellent Chairperson.

I would like to express my sincere gratitude to all the members of the Study Committee, advisory groups, and working groups for their unwavering support during my term as Chairperson since 2018. Your patience and dedication are truly appreciated, especially in navigating challenging situations like the pandemic.

I'm also grateful to the affiliated organisations for the support of their members in developing the electricity network for the energy transitions.

It has been a privilege to work with all of you over the past six years, and I am truly grateful for the opportunity. SC B3 will continue to address new challenges together with experts, focusing on the rapid changes in the energy industry for a sustainable and environmentally friendly future.

Thank you for the best moments of my life.

Koji Kawakita

Contact

Contact of the Chair and/or the Secretary of the Study Committee →

SC B4

DC systems and power electronics

By Joanne Hu, Chair, & Rebecca Ostash, Secretary

— Scope of work

The scope of SC B4 covers DC systems and Power Electronics (PE) equipment in both transmission and distribution systems. The study committee also addresses DC Converters for the integration of renewables (WTGs and PVs) and energy storage as well as power quality control. SC B4 covers the full spectrum of DC systems and PE devices including specification, design, implementation, operation, maintenance, refurbishment of DC systems and FACTS devices. B4 also covers the new technologies/concepts of DC and FACTS needed for enabling the energy transition.

— Current and trends

The DC market especially VSC based HVDC transmission capacity continues to grow globally. HVDC suppliers are slowly ramping their capacity of engineering and equipment manufacturing/production to meet the DC market demand. In 2023, two VSC-HVDC projects were commissioning out of nine planned. The average number of planned/executed HVDC projects for the next six years is estimated to be about ten per year. Assuming moderate and accelerated suppliers' delivery capacity, most likely the DC delivery capacity up to 1800GW and 2600GW can be achieved by 2050.

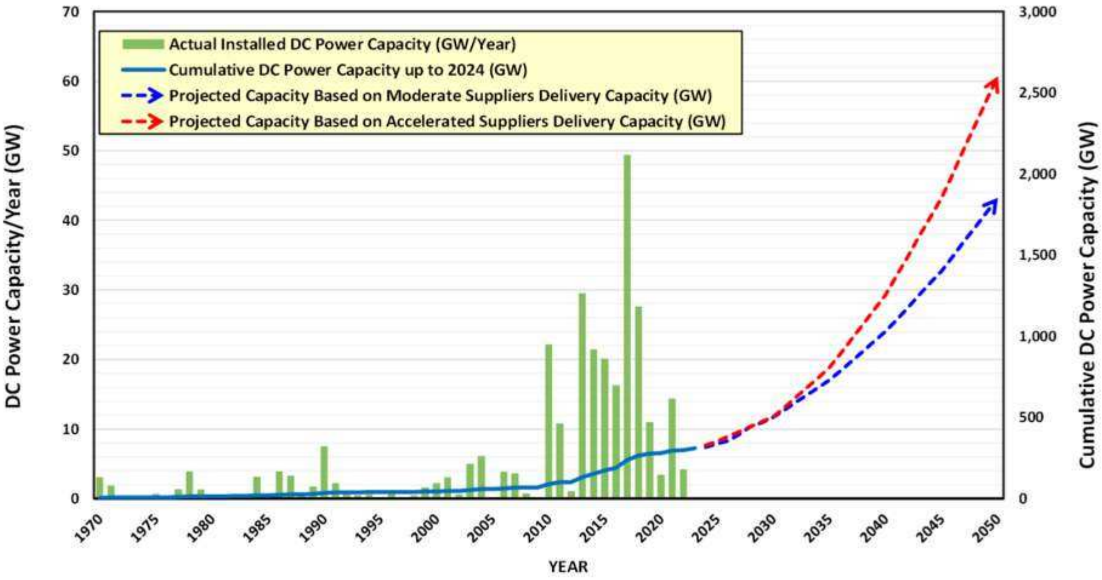


Figure 1 - DC Power Transmission Capacity (1970-2050)

In addition to the point-to-point DC connections, the technologies, standardized requirements and multi-vendor interoperability associated with multi-terminal HVDC and HVDC Grids are further advanced to provide flexible and reliable interconnection and integration of the existing and future power grids for power transfer and energy exchange, including those involving offshore wind farms and energy islands.

The Flexible AC Transmission System (FACTS) market is also growing with increased power rating of Static Var Compensator (SVC) and Static Synchronous Compensators (STATCOM) projects to support the transmission of AC power, improve voltage stability and support the change of generation patterns within the AC networks. PE devices are being more widely used in the distribution system for power quality control and voltage regulation.

Structure and membership of SC B4

SC B4 is organized with four advisory groups, NGN group, WiE group and twenty Working Groups as well as twenty-four regular members and twelve observers as shown in Figure 2. The members of SC B4 come from transmission system operators (TSOs), manufacturers, utilities, distribution system operators (DSOs), consultants, universities, and research institutes.

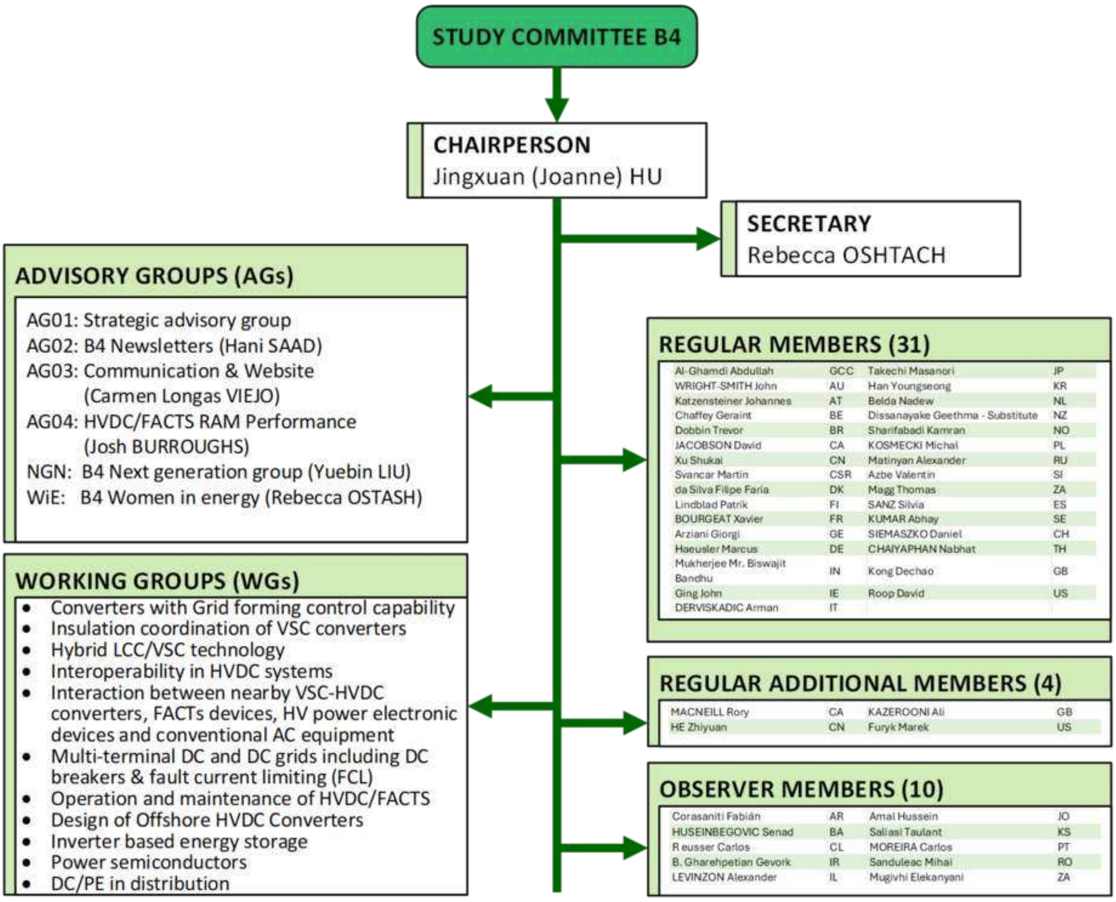


Figure 2 – Organization of Study Committee B4

Working Group focuses

The focuses of B4's Working Groups include the following areas:

- HVDC Digital Twin
- AC Network Equivalents for HVDC and FACTS Project Studies
- Grid forming converters including HVDC, FACTS and energy storage system.
- Interaction between nearby VSC-HVDC converters, FACTs devices, HV power electronic devices and conventional AC equipment
- Electric energy storage systems embedded in HVDC systems
- HVDC for renewable generation such as PV interconnection
- Dynamic active and reactive power supporting devices for VSC HVDC Systems
- Power semiconductor
- Offshore DC converter design aspects
- Interoperability in HVDC system
- Integration of DC systems to meshed DC/AC Transmission networks
- Harmonization of voltage designations and definitions across different HVDC component technologies
- Insulation coordination of VSC converters and DC cables
- Hybrid LCC/VSC technology
- DC system/converter modelling
- DC grids including DC breakers, fault current limiting
- Operation and maintenance of HVDC/FACTS
- PE in distribution system

Completed Working Groups

One working group completed their work and published Technical Brochures in 2023. Two WGs have submitted TBs for publication.

TB 909 - Guidelines for Subsynchronous Oscillation Studies in Power Electronics Dominated Power Systems - JWG C4/B4.52

- **WG B4.81**: Interaction between nearby VSC-HVDC converters, FACTs devices, HV power electronic devices and conventional AC equipment *(TB to be published)*
- **WG B4.84**: Feasibility study and application of electric energy storage systems embedded in HVDC systems *(TB to be published)*

Active Working Groups and Joint Working Groups

SC B4 has thirty (30) active Working Groups including twenty-two (20) B4 WGs and nine (9) joint WGs with other SCs as well as one (1) joint task force:

B4.64	Impact of AC System Characteristics on the Performance of HVDC schemes
B4.69	Minimizing loss of transmitted power by VSC during Overhead line fault
B4.71	Application guide for the insulation coordination of Voltage Source Converter HVDC (VSC HVDC) stations (Completed internal review)
B4/B1/C4.73	Surge and extended overvoltage testing of HVDC Cable Systems (Completed internal review)
B4.79	Hybrid LCC/VSC HVDC Systems (Completed internal review)
B4.82	Guidelines for Use of Real-Code in EMT Models for HVDC, FACTS and Inverter based generators in Power Systems Analysis
B4.85	Interoperability in HVDC systems based on partially open-source software
B4/A3.86	Fault Current Limiting Technologies for DC Grids
B4.87	Voltage Source Converter (VSC) HVDC responses to disturbances and faults in AC systems which have low synchronous generation
TF B4/B1.88	Insulation coordination procedure for DC cable systems in HVDC stations with Voltage Source Converters (VSC)
B4.89	Condition Health Monitoring and predictive maintenance of HVDC Converter Stations
B4.90	Operation and maintenance of HVDC and FACTS Facilities
B4.91	Power-electronics-based transformer technology, design, grid integration and services provision to the distribution grid
B4.92	STATCOMs at Distribution Voltages
B4.93	Development of Grid Forming Converters for Secure and Reliable Operation of Future Electricity Systems
C2/B4.43	The impact of Offshore Wind power hybrid AC/DC connections on System Operations and System design

B4.94	Application of VSC-HVDC in a System Black Start Restoration
B1/B3/B4/C4/D1.95	Harmonization of voltage designations and definitions across different HVDC component technologies
C4/B4.72	Lightning and Switching Induced Electromagnetic Compatibility (EMC) issues in DC power systems and new emerging power electronics-based DC equipment
B4.95	Developments in Power Semiconductor Technologies and Applications in HVDC/FACTS
B4.96	HVDC connection of power system with high proportion of photovoltaic (PV) generation
C4/A3/B2/B4.75	Guide to procedures for the creation of contamination maps required for outdoor insulation coordination
B4/C4.97	Benchmarking of simulation Models for control interaction in meshed AC networks with multiple converters
C1/B4.49	Offshore transmission planning
B4.98	Design considerations in integration of DC systems to meshed DC/AC Transmission networks
B4.99	Design and Construction of offshore Voltage Sourced Converter (VSC) Stations
B4.100	Dynamic Active and Reactive Power Supporting Devices for VSC HVDC Systems
B4.101	Industrial Implementation and Application of Grid Forming Energy Storage Systems (GFM ESS)
B4.102	Technical Requirements and Scenario Considerations on Grid-Forming Capabilities of VSC-HVDC Systems
B4/C4.103	AC Network Equivalents for HVDC and FACTS Project Studies
B4.104	HVDC Digital Twin

CIGRE active Working Groups / Call for experts

HVDC Green Book progress

The CIGRE Green Book on High Voltage DC Transmission Systems is taking shape. Twenty-three (23) Chapters out of the projected fifty-three (53) total chapters have been published and are available at: **High Voltage DC Transmission Systems: HVDC | SpringerLink**. These chapters can be used as stand-alone reference documents.

An additional fourteen (14) chapters have been submitted for publication. The rest of the chapters are in various stages of being drafted.

*CIGRE Green Books are available for purchase on our partner's website **Springer**.*

*If you are an **Individual** CIGRE Member, please **contact us** to benefit from a 40% discount on your purchase (please indicate your **Individual** active member number and your National Committee in your message).*

Tutorials and workshops in 2023/2024

2023 Muscat Symposium	Mar. 8, 2023	Guide to Develop Real Time Simulation Models (RTSM) for HVDC Operational Studies
2023 Vienna Colloquium	Sept. 14 2023	B4.81- Interaction between nearby VSC-HVDC converters, FACTs devices, HV power electronic devices and conventional AC equipment
2023 Vienna Colloquium	Sept. 14 2023	B4.84- Feasibility study and application of electric energy storage systems embedded in HVDC systems
2023 Vienna Colloquium	Sept. 14 2023	B4.87- Voltage Source Converters (VSC) HVDC responses to disturbances and faults in AC systems which have low synchronous generation.
2023 Vienna Colloquium	Sept. 14 2023	Solid state transformer
2024 Paris Session	Aug. 26 2024	Hybrid LCC/VSC HVDC
2024 Paris Session	Aug. 28 2024	Interoperability

2023 CIGRE B4 Colloquium

In 2023 B4 colloquium, forty-one papers covering varies topics in the area of HVDC and Power Electronics were selected and presented in eight sessions.

Post and planned SC meetings

SC B4 held the SC meeting on September 11th 2023 in Vienna. A total of eighty (80) members and guests attended the meeting. SC B4 will host an SC meeting in Paris, on August 27th 2024.

Participation in Regional meetings, Colloquia and Symposia

SC B4 will participate in two CIGRE symposia in 2025.

- Trondheim Symposium (May 2025)
- Montreal Symposium (September 2025, lead SC)

Liaisons ans relations with other CIGRE Study Committees and organisations

SC B4 continue to collaborate with other Study Committees (A3, B1, B3, C4, D1, etc.) to promote joint effort and knowledge sharing to achieve the best outcome of the study committee work. SC B4 also cooperates with IEC TC115, IEC/SC22F, CENELEC and IEEE.

SC website and newsletters

SC B4 actively updates the **B4 website** to post news and share the latest information of SC B4 activities.

We have published fifteen issues of our B4 newsletter to date since October 2020. Our B4 newsletters are tailored to capture and share the latest activities from our B4 community at international/national levels, identifying opportunities, addressing challenges, sharing best practices and latest technologies in DC systems & Power Electronics. In addition, we also share our vision and insight into B4-associated topics/areas, particularly in the context of energy transition. B4 Newsletters are well received by our B4 members. You can read and download B4 newsletters **here**.

B4 Women in Energy (WiE) Group

We initiated a WiE group within B4 and had a kick-off meeting in May 2022 and several on-line and in-person meetings since then. The goals of B4 WiE are to increase women involvement in B4 through membership, working group participation (convenor or member), leadership, mentorship, knowledge and experience sharing as well as to participate in CIGRE WIE forums at Paris sessions and include WIE slot at all future B4 events.

Contact

Contact of the Chair and/or the Secretary of the Study Committee →

SC B5

Protection and automation

By Rannveig S. Løken, Chair, & Richard Adams, Secretary

Introduction

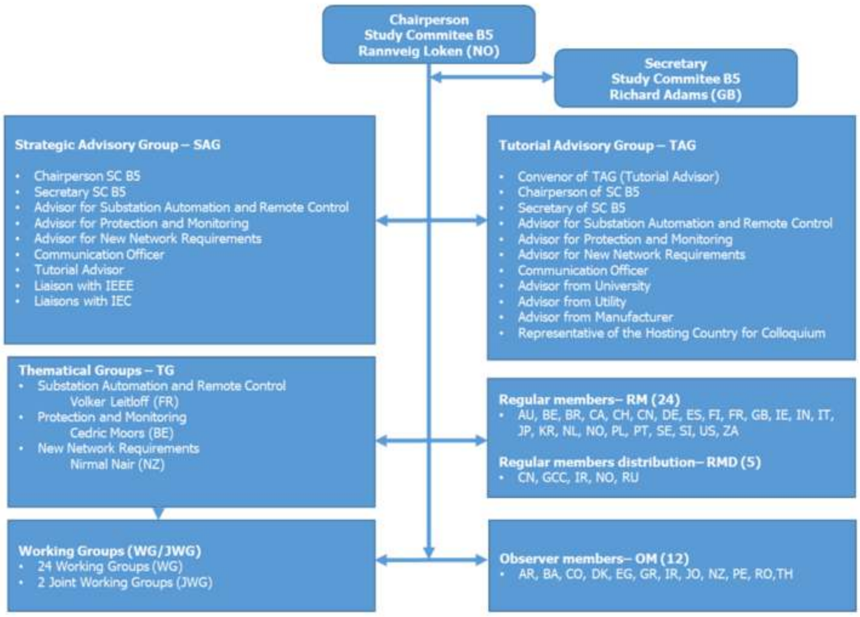
This report reviews the organisation, processes, results and activities of Study Committee B5 (SC B5) in the year 2023. CIGRE Study Committee B5 - Protection and Automation, or SC B5 for short, focuses on Protection, Control, Monitoring and Metering and aims to cover the whole Power system, end-to-end related to this topic, from transmission systems to distribution systems, including generation.

Objectives

Study Committee B5 promotes the synthesis and dissemination of state-of-the-art practices, recommendations and information about Power System Protection and Automation on a worldwide basis. Its main activities cover the principles, design, application and management of power system protection, substation control, automation, monitoring, recording, and metering, as well as the associated internal and external communications and interfacing for remote control and monitoring. SC B5 aims to give independent analysis of different protection and substation automation solutions and to be provider of high-quality unbiased publications and contributions to the electrical supply industry. Members of SC B5 from all regions of the world provide a global perspective on the issues and challenges facing the protection of electrical power systems, aimed at top and medium management and technical staff of utilities, suppliers and consultants, universities, and research centres, including young and experienced engineers and standardisation organisations.

Organisation

To attain its objectives, SC B5 is organized as shown on Picture 1. Five advisory groups support the decisions of the chair and secretary: the Strategic Advisory Group (SAG), the Tutorial Advisory Group (TAG), and three Strategic Thematic Groups (TG) specialised in Substation and Automation, Protection and Monitoring, and New Network Requirements, respectively. The study committee is formed by twenty-four regular country members, five additional regular members from distribution, twelve observer members, twenty-four Working Groups (WG), including two Joint Working Groups with other Study Committees organisation.



Picture 1 – SC B5 Organisation

The mission of the Strategic Advisory Group (SAG) is to advise the chair about strategic issues related to the activities of the committee, helping in the elaboration of the SC Strategic Plan. The Tutorial Advisory Group (TAG) advises about the organisation and promotion of tutorial activities of the committee, selecting the topics for the tutorials, the presentation material, appointment of lecturers and monitoring their quality. The three permanent Strategic Thematic Groups (TG) organize the proposals of new Working Groups and Preferential Subjects related to Substation Automation, Protection and Monitoring, and New Network Requirements for discussion and voting during SC B5 meetings and select reviewers of the final reports of the Working Groups.

Table 1, 2 and 3 shows the WGs that were active at the end of 2023, organised by Strategic Thematic Groups (TG), with their respective conveners.

WG B5.51	Methods & Applications of Remotely Accessed Information for SAS Maintenance and Operation, L Li (CN)
WG B5.56	Optimization of Protection Automation and Control Systems, P. Kreutzer (CH)
WG B5.59	Requirements for Near-Process Intelligent Electronic Devices, X. Lei (CN)
WG B5.63	Protection, Automation and Control System Asset Management, M. Petrini (IT)
WG B5.68	Optimisation of the IEC 61850 Protection, Automation and Control Systems (PACS) engineering process and tools, C. Bloch (FR)
WG B5.69	Experience gained and Recommendations for Implementation of Process Bus in Protection, Automation and Control Systems (PACS), A. Apostolov (US)
WG B5.71	Protection, Automation and Control Systems Communication Requirements for Inter-Substation and Wide Area Applications, C. Moors (BE)
WG B5.73	Experiences and Trends related to Protection Automation and Control Systems Functional Integration, B. André (FR)
WG B5.75	Documentation and version handling related to Protection, Automation and Control functions, S. Khot (CA)
WG B5.77	Requirements for Information Technologies (IT) and Operational Technology (OT) managed of Protection, Automation and Control Systems (PACS), E. Casale (IT)
WG B5.81	Obsolescence Management for Protection, Automation and Control Systems, J. Wright (GB)

Table 1 - Active B5 Working Groups in the field of TG 51 - Substation Automation and Remote Control

WG B5.55	Application of Travelling Wave Technology for Protection and Automation, A. Guzman (US)
WG B5.57	New challenges for frequency protection, V. Terzija (GB)
WG B5.58	Faster protection and network automation systems: implications and requirements, A. Podshivalin (RU)
WG B5.65	Enhancing Protection System Performance by Optimising the Response of Inverter-Based Sources, F. Filho (BR)
WG B5.74	Busbar Protection Considerations When Using IEC 61850 Process Bus, P. Flores (BR)
WG B5.83	Protection for modern distribution networks, T. Yi (CN)
JWG B5/C4.79	Protection Roadmap for Low Inertia and Low Fault Current Networks, A. Tsylin (DK)

Table 2 - Active B5 Working groups in the field of TG 52 - Protection and Monitoring

WG B5.64	Methods for Specification of Functional Requirements of Protection, Automation, and Control, I. Patriota (BR)
WG B5.72	Modelling, Assessment, and Mitigation of Protection Performance Issues caused by power plants during Dynamic Grid Events, S. McGuinness (IE)
WG B5.76	Architecture, Standards and Specification for metering system in a Digital Substation and Protection, Automation and Control (PACS) Environment, R. Marcenko (CH)
WG B5.78	New requirements of network protection and control for renewable energy integration, N. Nair (NZ)
WG B5.82	Education, Qualification and Continuing Professional Development of Engineers in Protection, Automation and Control, M. Kezunovic (US)
JWG B5.C4.61	Impact of Low Inertia Network on Protection and Control, R. Zhang (GB)

Table 3 - Active B5 Working groups in the field of TG 53 - New Network Requirements

Technical Activities

In 2023, three new WGs were suggested during the SC B5 meeting in the CIGRE Symposium in Cairns in Australia, and the first two were approved by the Technical Council Chair in 2024, to address current issues related to protection and automation of power systems:

- **WG B5.84** - Recommendations and constraints for development and interfacing of virtual Intelligent Electronic Device implemented in Protection, Automation and Control Systems, Convenor D. Macdonald (GB)
- **WG B5.85** - Protection, Control and Supervision principles of “Grid Stabilizing Generation”, Convenor A. Gehm (DE)

CIGRE active Working Groups / Call for experts

Two WGs completed their work and were disbanded following publication of their Technical Brochures:

TB 896 - Protection for developing network with limited fault current capability of generation - WG B5.48

TB 891 - Protection, Automation and Control Architectures with Functionality Independent of Hardware – WG B5.60

Additionally, a Second edition of the SC B5 Green Book “IEC 61850 Principles and Applications to Electric Power Systems” was published to address some initial quality issues.

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The best paper from SC B5 during the CIGRE Symposium in Cairns in Australia was;

- SC B5, 1395 "Design Decisions of Process Bus Technology for a Distribution Utility", Ray ROBINSON, Ben ARMSTRONG, Kyle MALVERN, Endeavour Energy, Australia.
- The paper was published in CIGRE Science & Engineering (CSE) in December 2023.

Picture 2 – SC B5 Meeting 2023 (Cairns)

Keynote speeches

To disseminate the activities of CIGRE, members from SC B5 have participated and presented Keynote speech during:

- August CIGRE's 2023 Colombia, El fascinante mundo de las protecciones y la automatización, online
- October APAP 2023 International Conference on Advanced Power System Automation and Protection, Xuchang, China, online

Tutorials

To promote the discussion of current issues related to protection and automation, and as part of its mission to help the dissemination of knowledge about protection and automation, the following tutorials were presented by SC B5 members in 2023.

SC B5 Tutorial during CIGRE Symposium in Cairns in Australia related to applying synchrophasor technology for protection of the power system

- Synchrophasor Introduction and Concepts
- WGB5.62 TB 843 Summary - Life Cycle Testing of Synchrophasor Based Systems used for Protection, Monitoring and Control
- Market Operator AEMO Wide Area Monitoring System (WAMS) Synchrophasor Project & Associated Standard Data Guidelines
- South Australia Wide Area Protection Scheme (WAPS) Synchrophasor Application associated with increased renewables and interstate connection
- Powerlink Synchrophasor WAMPAC Anti-islanding scheme Application
- Synchrophasors – TasNetwork’s Experience and Applications
- Applications of Synchrophasors to distribution networks - An Evaluation of a grid scale data acquisition trial
- Transpower New Zealand Synchrophasor Synchronism Check Auto-reclose Application

Picture 3 – SC B5 Tutorial session at Cairns Symposium

CIGRE Symposium in Cairns, Australia and SC B5 Discussion Sessions

The main forum for technical debates about Protection and Automation in 2023 was the CIGRE Symposium in Cairns in Australia and the SEAPAC sessions that took place during the same event. SC B5 conducted six sessions where papers were presented related to the following main topics:

- Session 1 focused on protection, automation and control issues related to operational experience. Approximately 130 people attended the session, and 4 papers with authors from 4 different countries were presented.
- Session 2 focused on protection issues related to unconventional sources, low and unusual fault current, and low system inertia. Approximately 130 people attended the session, and 5 papers with authors from 4 different countries were presented.

- Session 3 focused on experience feedback with IEC 61850 based substations. Approximately 130 people attended the session, and 5 papers with authors from 3 different countries were presented.
- Session 4 focused on applications for protections, automation, control and monitoring. Approximately 150 people attended the session, and 5 papers with authors from 4 different countries were presented.
- Session 5 focused on design and time synchronization of IEC 61850 based substations. Approximately 150 people attended the session, and 5 papers with authors from 3 different countries were presented.
- Session 6 focused on experience with asset management of PAC systems. Approximately 150 people attended the session, and 4 papers with authors from 4 different countries were presented.

SC B5 took part in the CIGRE Australia B5 panel arranged South East Asia Protection Automation and Control (SEAPAC) sessions in September 2023. This event was a parallel event to the CIGRE Symposium in Cairns, and 22 papers were presented in 4 sessions.

CIGRE Paris session in August 2024

SC B5 will take part in the CIGRE Paris session in August 2024 with the following preferential subjects:

- PS1: Practical experiences and new developments of process bus
- PS2: Acceptance, commissioning, and field testing for protection, automation and control systems

CIGRE Symposium in Trondheim, Norway and CIGRE SC B5 Colloquium in Osaka, Japan 2025

In 2025, SC B5 will take part in two main events:

- The CIGRE Symposium in Trondheim, Norway, May 2025, along with 10 other SCs, and papers submitted will be presented during the Symposium.
- The CIGRE SC B5 Colloquium in Osaka, Japan, July 2025, where the SC meeting will also take place.

The International Symposium is hosted by the Nordic Regional Council of CIGRE (NRCC) in Trondheim, Norway on May 12–15, 2025. The CIGRE NRCC 2025 symposium in Trondheim will be on the theme: Changes Needed in The Power System - for the Energy Transition. This will be divided into two topic streams:

- PS1: Integration of renewable energy resources to the grid
- PS2: Technologies supporting the power grid for energy transition to carbon neutral energy production.

The CIGRE SC B5 Colloquium hosted by the Japanese National Committee, will be held at the Osaka International Convention Center (Osaka, Japan) from June 30 to July 6, 2025.

The following three preferential subjects will be discussed during the SC B5 Colloquium.

- PS1: Interoperability of IEDs of different manufacturers and technologies integrated in one PACS
- PS2: PACS Life Cycle Performance and Longevity
- PS3: Experiences and possibilities on revised principles and policies related to modern protection IEDs

CIGRE SC B5 Outstanding Service Award

In recognition for their contribution to the activities of CIGRE, SC B5 has nominated and supported the following recipients for awards in 2023:

The Outstanding Service Award of CIGRE Study Committee B5 - Protection and Automation is granted by the SC Chairman annually to members in recognition for outstanding participation and contribution to the activities of the Study Committee. For 2023, the award went to **Volker Leitloff**, from France in recognition of his contribution, commitment and dedication to the objectives of CIGRE. He is a recognised expert in Protection, Automation and Control systems, he is the advisor of TM51, a member of the SAG of SC B5, and has also been frequent contributor to CIGRE Working Groups. The award ceremony was conducted by the Chair of SC B5 during the SC B5 Meeting in Cairns.

Picture 5 – Award ceremony SC B5, (picture Tromsø, Norway 2024)

— Strategic Planning

The strategic plan of CIGRE Study Committee B5 – sets out the strategic technical directions to be followed by the B5 Committee over the period 2023–2032 in order to address the main objectives set by CIGRE Technical Committee.

Based on this analysis, the following technical directions were validated by SC B5 Strategic Plan for the period 2023-2032:

- Influence and Contribute towards Protection and Automation Global Expertise
    - Providing Key Technical SC B5 PACS information to Executives, Regulators, Policy Makers and Technology Innovators
    - Increase brand and visibility of SC B5 PACS amongst membership, research academics, trade associations, regulators, policy makers and government.
    - Developing Marketing avenues and platforms to support leading edge innovative concepts of B5
    - CIGRE B5 Africa Strategy
- Supporting CIGRE Power System of the Future Vision: SC.B5 Strategy
    - Understand and influence the development of new technology and practices for all voltages and systems

- Supporting CIGRE Peoples and Skill of Future Strategy: SC.B5 Efforts
    - Engaging actively with Central Office efforts towards operation Excellence

Details about the process adopted by SC B5 and the complete result can be found in the Strategic Plan.

Conclusions

The year of 2023 was full of achievements for SC B5, a result of the voluntary work of dedicated individuals and organisations, including the secretary, advisors, conveners, special reporters, members and observers from many countries around the world. For the future, the strategic directions set by SC B5 aim to facilitate the human development and application of new technology to improve the efficiency of the engineering, design, operation and maintenance of protection and automation of electric power systems and keeping the spirit of collaboration that distinguishes CIGRE among organisations around the world.

Contact

Contact of the Chair and/or the Secretary of the Study Committee →

TB 927 | WG D1.70

New Laboratory Methodologies for Investigating of Insulating Liquids — Further Developments in Key Functional Properties

The scenery of insulating liquids is continuously changeing, requiring questioning existing standards and seeking answers for reproducing of phenomena in service in the lab, as well as methods for determining of the life span of liquids. Questions concerning environmental, health and safety are more actual than ever. All those properties can be considered as functional requirements for liquids. The aim of the brochure has been to look on some of them and propose solutions, e.g. for the fault free gassing of some liquids in service, for the use of oxidation inhibitor as an ageing marker in mineral oils, evaluation of methods able to distinguisch between individual hazardeous compounds like PAC/PAHs as well as the measurement uncertainty for thermal characteristics of insulating liquids.

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— Scope/Methodology

Two main methods have been used throuhout the brochure :

1. Performing of Round Robin Tests on

- thermo-oxidative gassing of insulating liquids
- methods for determination of hazardeous PAC/PAH compounds as sum and as individual compounds
- additives in mineral oils and ester liquids
- thermal properties of insulating liquids

and

2. Referencing as many as possible real cases describing

- thermo-oxidative gassing and the correlation to the elaborated RRT
- change of ageing parameters with inhibitor depletion

Description of the Technical Brochure

The **first chapter** of the brochure deals in a Round Robin Test aiming at developing a method for elaborating of the possible thermo-oxidative stray gassing of isulating liquids from different origin – mineral oils, synthetic and natural esters and silicon liquids. This Cigre WG has been run along the last update of IEC 60296 and the results have been included in its last revision from 2020.

The thermo-oxidative behaviour of some natural and synthetic esters, as well as silicone liquids has been explored under the same conditions.

The major findings out of the Round Robin Test are :

- Uninhibited mineral oils, as well as passivated oils tend to develop gases like hydrogen and ethane when exposed to temperstures of 105°C (max. top oil temperature for mineral oils). This phenomena, called also « stray gassing » is strongly enhanced in the presence of copper and air.
- The development of ethane with the investigated natural multi unsaturated esters takes place even in the absence of air. The presence of copper (in air or nitrogen) reduces the amount of hydrogen in comparison to the test conditions without copper.

The **second chapter** of the brochure describes real cases of thermo-oxidative « stray gassing » reported.

A typical example shown on Figure 1 is a family of 53 free breathing transformers 20 – 31,5 MVA, 60 kV, manufacturing year 2003 – 2014 filled with uninhibited oil. The gas-in-oil analysis shows a continuous moderate development of ethane and methane, but no increase of ethylene, hydrogen or acetylene.

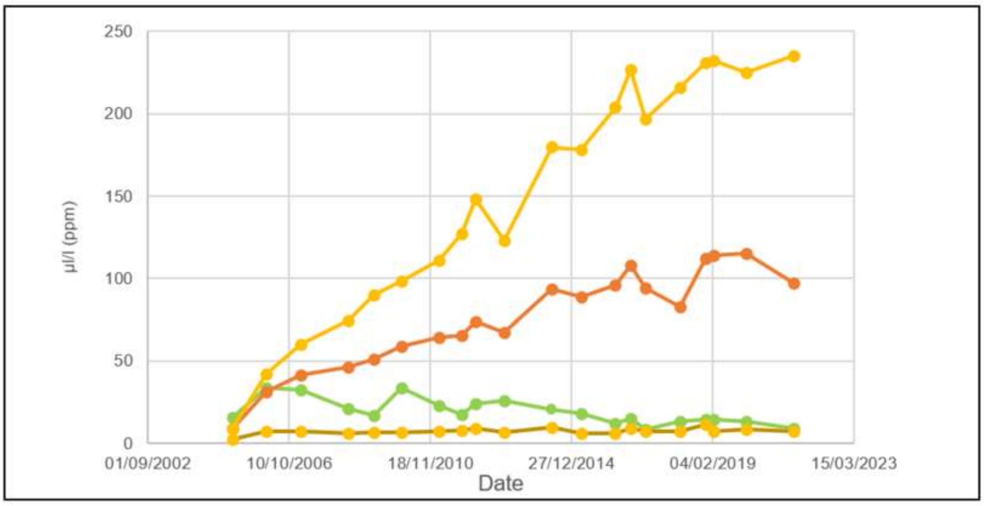

Figure 1 - Exemplary development of gases due to Stray Gassing with time (yellow line – ethane, brown line – methane, green line – hydrogen, violet line – ethylene)

Although the gas evolvement in case of « stray gassing »is due to the oil constituents, existing interpretation schemes may indicate overheating and be a cause of concern for users . Very often the question arises whether this behaviour can be corrected. Some examples show, that reclaiming procedures with a subsequent inhibiting can mitigate the problem (Table 1).

Gas	**2009, prior reclaiming (ppm)**	**2 years after reclaiming (ppm)**
Hydrogen	45	32
Methane	96	8
Ethane	205	20
Ethylene	30	5
Carbon monoxide	579	332
Carbon dioxide	5986	4412
Oxygen	6150	24850
Nitrogen	55493	68080

Table 1 - Development of ethane and methane after regeneration of the insulating oil

The **third brochure chapter** deals with methods for identification of PCA/PAHs in mineral insulating oils. Round Robin Tests based on methods for sum and individual identification for those compounds have been carried out.

The **fourth chapter** of the brochure is dedicated to methods of identification of additives not only in mineral oils but also in ester insulating liquids. A Round Robin Test has been performed by means of a HPLC (High Pressure Liquid Chromatography) method. The used procedure delivered quite good results with mineral oils, but had still interferences with ester liquids. The results are promising, nevertheless further investigation and improvement of the method is necessary.

The **fifth chapter** of the brochure is dedicated to the ageing monitoring in insulating liquids via inhibitor consumption. In this chapter several examples of transformer in service have been described, where the continuous depletion of the inhibitor has been correlated to the further oil parameters (Figure 2).

Figure 2 - DBPC (di -t-butyl-p-cresol) consumption and change of Acidity (TAN), IFT and DDF of oil from transformer in a hydro power plant

Some ideas for alternative methods for the measurement of oxidation stability in natural esters have been described.

The **sixth chapter** of the brochure deals with a Round Robin Test dedicated to the measurement uncertainty of thermal properties of insulating liquids – kinematic viscosity, density, thermal conductivity and specific heat capacity at different temperatures. The highest deviations in the measurement results are in the thermal conductivity, due to convection.

Conclusions

Functional properties of insulating liquids are important for the design of electrical equipment. Although numerous standards, describing different functional properties in unused state and in service exist, there is always a need of update, especially when other insulating liquids like ester liquids are entering the market.

A laboratory method describing the thermo-oxidative stray gassing of mineral oil, as well as synthetic and natural ester liquids has been developed.

This method is able to differentiate between fault gas development, due to the constitution of the insulating liquid and due to failure in the electrical equipment. In the present criteria for evaluation of gas-in-oil analysis according to IEC 60599, stray gassing is considered for a T1 fault, e.g. a thermal fault at a temperature < 300 °C. Since stray gassing can take place at normal operating transformer temperatures and mainly in uninhibited oils (which were prevalent during the development of those criteria) it will make sense to have a critical review of those criteria.In service examples manifistating stray gassing at normal operating temperatures, as well as possibilities for its mitigation are reported.

In order to prevent oxidation ester insulating liquids shall be additivated. Tests for the qualitative and quantitative determination of those additives in mineral oils, natural, synthetic ester liquids, as well in silicone liquids have been carried out among several laboratories. The measurement uncertainties show that those methods shall be further developed and updated in international standardisation.

The gravimetric method IP 342 for carcinogenic PCA adopted in international standards relies on the fact that the principal carcinogens of virgin oils are 3-7 ring PCA which are readily extractable into dimethyl sulfoxide (DMSO). It is rapid and easy to use, but has chemical limitations in its applicability: Round Robin tests have shown that methods like EN 16143 are necessary for the identification of individual EPA restricted PAH marker.

The determination of thermal characteristics of insulating liquids is connected with different measurement uncertainty for different parameters. The highest spread of results has been identified with the determination of thermal conductivity at higher temperatures due to convection. Du to this fact it is worth considering of measuring of thermal conductivity at ambient temperature.

On the basis of experimental data and service evidence can be concluded that the depletion of oxidation inhibitor in inhibited mineral oils is a good indication for prediction of the life span in service.There are some values implemented in international standards concerning mineral oil. This approach can in future be extended to ester insulating liquids as well.

TB 931 | WG A3.40

Technical requirements and field experiences with MV DC switching equipment

Today's power grids are generally powered by AC electricity. Energy flow was historically from generation in power plants, through transmission and distribution, to the consumer. Recently, this structure has begun changing through the addition of generation sites distributed throughout the transmission and distribution systems. Beyond the baseline demand for safe operation under load and fault conditions, the additional generation connections stress the physical boundaries of AC networks. These changes are influencing the capacity of the network, its short circuit level, and the level of control that is capable with the tools and technology available today.

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DC power brings a strong set of attributes for grids and energy delivery challenges, including lower distribution losses and higher power carrying capacity. Another trend is the increase in sources and loads that generate and operate at DC, with almost half of electricity today arriving to its point-of-use as DC. Moreover, DC power is extremely useful in industrial applications, electrified transportation, and resource production including offshore oil, gas, and wind power. Combined with recent advances in solid state devices, power electronics systems like voltage source converters and DC-to-DC converters, there is a significant opportunity to enable greater use of DC across these important applications. More advances in these base technologies are still needed to further enable increased usage of MVDC grid systems.

The lingering risk of electrical fault scenarios under overload and short circuit conditions remains a primary hurdle preventing the growth of DC markets. In AC networks, electricity alternates direction periodically, naturally providing a "zero crossing" of current, which allows electrical faults to easily be extinguished by a variety of switching technologies. DC networks deliver power without zero crossings, which prevents breaking of the current in both load and fault conditions for most of the AC switching equipment. Innovations and developments in MVDC switching devices and circuit-breakers would enable the above-mentioned efficiency improvements, changing the way electricity is delivered and controlled across the power grid.

DC has been deployed for us in high-voltage systems for decades. HVDC systems are used to bridge long distances exceeding the physical, electrical and/or economic limit of AC transmission or link systems of conflicting parameters (like frequency). Previous CIGRE Working Groups have covered many of these HV related aspects already and published in some Technical Brochures.

Most DC applications today are low voltage, as electronics typically operate at this voltage level. This applies to both loads and generation. Typical examples for loads are computer and control, converter driven motors and machinery, audio, and video equipment as well as modern lighting based on LED technology. Though this equipment has been in use for quite some time, it has been limited to single applications for end-users, and not yet extended into grids. There are many reasons this hasn't occurred, but one of the primary blockers is the lack of readily-available products and standardization. Without this kind of equipment readily available and understood, engineering projects that must meet standard technical and safety requirements is very challenging. With several new standards appearing and larger projects materializing, this is changing. These LV topics, however, will not be further considered within the Technical Brochure, as this Working Group is solely focused on MV.

There have been very few active MVDC distribution grids with voltages between 1 kV and 52 kV in the past. Exceptions are converter-based network links, typically as a point-to-point connection to bridge an appreciable distance, or two networks of different parameters. These applications do not contain additional switching equipment besides of the converters and will only briefly be touched within this Technical Brochure. Previous CIGRE works investigated the feasibility of MVDC grids and described potential MVDC distribution systems. The meshed structure of these future potential networks will require the use of switching equipment in a similar magnitude as it is known from existing AC systems. The type of equipment, their operation and specification is significantly different from AC because of the different physical nature but also the control of DC systems. The most common switching device needed in these MVDC grids would be DC circuit-breaker to meet the primary task of interrupting load and fault currents as is readily done today by MVAC circuit-breakers. While load switching and fault interruption are quite different operations in AC grids, these switch operations are much more similar to each other in DC. This fact significantly impacts the design of MVDC circuit-breakers. To ensure adequate and reliable system performance, additional equipment beyond the MVDC circuit-breaker is required, and this equipment is described in this Technical Brochure. Some of them are similar to devices deployed in AC networks, while others can be substantially different.

The challenges of today's power grids and the need for more energy efficient operation leads to emerging MVDC applications. This Technical Brochure describes potential use cases and applications of MVDC networks. Some of them are already apparent and widely discussed in the industry while others are expected to become relevant in the future as additional evidence of technical solutions becomes available. The drivers for using MVDC over MVAC are many. In some cases, it is a technical requirement, while in others MVDC is the better economic solution. Most considerations cover the classical MV range up to 52 kV, while recommendations are given up to a voltage level of 100 kV DC.

Another chapter details projects and installations using MVDC. Two kinds of application are considered here: point-to-point connection and meshed grids containing switching equipment, while the focus is on the latter one. Except for existing applications of DC railway systems, all other projects are pilot installations in different stages, with most evaluating capability through trial and error. A scale is used to indicate the maturity of these installations. Based on their character as individual pilot projects there is little field experience so far and no substantial commercial judgement is possible at the time of writing this Technical Brochure.

The primary purpose and focus of this Technical Brochure is given to projects with MVDC switching equipment, rather than projects with just converters. The brochure outlines baseline operating parameters of the switching equipment and any special functional capabilities or requirements, with any relevant comparisons drawn to the operation of MVAC equipment. Differences are highlighted for DC equipment when it is caused by the physical difference of DC networks, leading to a different design approach. These considerations are accomplished with experience from testing DC switching equipment, both in the field and in test laboratories. Laboratory experiences drives recommendations for ratings in this Technical Brochure. Additionally, there are numerous recommended topics to consider for future test specification and standardization.

The reader will get a comprehensive overview of trends and potential applications for MVDC switching equipment. Existing projects in various stages of completion will illustrate the variety of layout and design. The description of various types of switching equipment will support a deeper understanding of DC circuit- breaker requirements. The testing section gives guidance to improve testing in future, based on previous test experience. It shall be mentioned, however, that limited technical requirements for MVDC switching equipment are included, as there is not yet sufficient data to support detailed requirement recommendations. There is insufficient data on the specific features of MVDC networks as compared to HVDC networks, and may have a specific impact on MVDC circuit-breaker requirements. DC switching equipment in service is still limited at the time of writing this TB.

— Scope

The following area have been covered in the TB by the Working Group:

Application of MVDC switching

MVDC switching applications are naturally limited to medium-voltage DC systems. This chapter describes various applications for MVDC switching by describing the networks and systems in which they would serve. While this section focuses on the nature of the MVDC switching applications, much of the remainder of the Technical Brochure provides details and context on the level of maturity of these applications. Some of these applications are more mature, while other applications are nascent and still require further proof of concept.

Projects and installations of MVDC systems

This chapter describes a variety of active and planned projects where MVDC systems, concepts, principles, or technology were deployed or investigated. Primary focus is given to those projects where DC switching equipment is used, and each project is rated on its maturity level from “theoretical concept” up to “standard practice in the field.” Some additional projects are added at the end of the chapter which operate at MVDC but use converters and no other switching equipment. They are important projects for gaining experience with MVDC systems but fall outside of the scope of the brochure.

Types, interrupting principles and specific requirements of MVDC switching equipment

In general, DC systems are meshed networks and characterized by their high short-circuit current rate of rise due to the small inductance and high amount of capacitance in the DC system. MVDC systems need to be equipped with MVDC circuit-breakers with both load and fast current extinction. Furthermore, disconnectors, load break and earthing switching switches as well as additional equipment are required for isolating, grounding and reconnecting distribution facilities in the MVDC system.

This section describes the types of switching equipment and practices that are most relevant for MVDC systems, as best practices differ across LV, MV and HVDC. The functions, duties and differences between the various DC switching methodologies are discussed.

Testing of MVDC switching equipment

This section provides the Working Group’s recommendations for best practices on testing principles associated with MVDC switching equipment.

A proposal is given for the definition of rated DC voltage for MVDC. This topic is controversially discussed in various standardisation teams throughout the globe. The Working Group analysed the current status and concluded a recommendation for definition in standards.

— Conclusions

This brochure presented a summary of the current state of MVDC applications and projects in industry today. Generally, the state of the art in DC switching is understood, and while it is applied much less often at medium voltage than low voltage (< 1.5 kV) or high voltage (> 52 kV), some non-grid medium voltage applications are reaching maturity and allowing for exploration into grid applications. The non- grid applications where MVDC is readily available include railway and marine (ship). There are numerous pilot and trial applications of MVDC grid-style systems, however there are not yet significant deployments of MVDC grid systems. As the technology has matured in HVDC systems, projects that are looking to apply the benefits of DC at medium voltage have begun to appear. These include point-to-point power transfer links (not unlike HVDC), renewable generation interconnection for generation sites of lower capacity, and low-loss distribution for remote communities. There are not many known deployments of these types of projects at MVDC when compared to MVAC, indicating that the benefits and economics of MVDC may not yet be sufficient to drive widespread adoption.

Any of these applications of course requires equipment that can manage the flow of electricity by the system operator. HVDC systems have driven technology improvements in converter technology for decades, however these advances have still been unable to eliminate fault current out of the converters, and still struggle to sufficient limit the current and duration of the fault current. Interruption systems for MVDC switching equipment are available, but the industry approach has generally been one of increasing the capability of LVDC interruption technologies to meet the capacity needs of MVDC systems. The amount of technology development in this space, the number of standards being developed, and the increase in frequency of technical publications around MVDC (inclusive of this publication) show that progress is being made.

This Technical Brochure therefore summarizes the current state of this research and these applications into a set of recommendations for (i) rated voltages in standardisation and (ii) testing of MVDC switching and interruption equipment. There are many similarities in the test methodologies of MVDC switching equipment when compared to MVAC switching equipment, including dielectric performance both before and after the interrupting tests and consideration of reignition and restrike. There are of course many significant differences, including the construction of the test circuits at laboratories, and the basic interrupting requirements of MVDC equipment. This Technical Brochure summarizes a variety of circuit topologies that can be used to source the fault currents required for evaluation of MVDC switching equipment, and summarizes the kinds of performance parameters that MVDC switching should be expected to meet.

Further Work

Monitoring and investigation into the kinds of MVDC applications deployed in industry should continue to be monitored, and tracking of the quantity and quality of projects and their maturation levels will help the industry see how MVDC is advancing and where the technical developments are occurring. By continuing to use the maturity rating system used in this Technical Brochure, such information can provide a unique view in the change over time of MVDC projects.

Testing procedures and standards will continue to mature and morph over time as technology continues to improve, more offerings are created and tested, and more field deployments generate more data on performance of MVDC switching equipment. It is of particular interest to see if the test circuits in use today and proposed within the brochure require modification, removal and/or addition to meet the needs of the industry's applications.

TB 932 | WG C6.43

Aggregation of Battery Energy Storage and Distributed Energy Resources

Battery energy storage systems (BESS) are increasingly installed in distribution grids in conjunction with other distributed energy resources (DER). These resources are photovoltaic (PV) systems and other distributed generation, including generation from renewable energy resources (RES), such as wind and small hydro. One of the roles of BESS, in support of the wide deployment of renewable energy resources, is to meet the requirement for energy balancing to mitigate resource variability and intermittency and make the combination of BESS and renewable DER dispatchable. This balancing feature is applicable to smaller, roof-top PV installations (behind the meter) connected to the low voltage (LV) grid and to larger PV or wind farms connected to medium voltage (MV) distribution feeders. In the latter case, the combined installation feeds energy directly into the distribution system.

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Scope

BESS are key enablers for the implementation of active distribution system functions and for providing a range of grid services at the distribution level. Grid services include voltage support, feeder power flow control, load and hosting capacity management, local energy and capacity provision, and reliability and resilience services in the event of contingencies and exceptional weather events. In this technical brochure (TB), it is assumed that these services are provided to the MV and LV distribution system. However, they can also be provided to support the operation of the transmission grid.

BESS can be embedded in distribution systems in smaller units deployed in large numbers at low voltage levels in conjunction with PV systems, for example. In the case of wide deployment of a large number of distributed BESS and PV systems, these need to be aggregated and controlled using DER management systems (DERMS) to fully exploit their potential to provide grid support and services.

The TB is targeted towards distribution system operators and BESS project developers. It addresses issues associated with BESS deployment, configuration, design and management in the context of high penetration of renewable energy resources (RES) in distribution systems, including PV systems. The brochure includes information and discussions of BESS design and deployment, interconnection and integration requirements and aggregation of BESS with existing DER. It addresses economic and business case considerations. Life cycle considerations are discussed in relation to the different types of applications and BESS design. Findings of previous working groups on BESS and related issues in distribution systems have been included as appropriate.

Description of the TB

The Technical Brochure is composed of five chapters and three appendices. Chapter 1 introduces an overview of battery services to MV and LV networks, BESS aggregation, technologies and electricity markets. Chapter 2 describes the grid support services required for a wide deployment of DER, and provides a characterization of the services enabled by BESS and their inverter interfaces. Chapter 3 deals with aggregation approaches for the provision of grid services from a large number of distributed BESS. Chapter 4 presents BESS operating constraints in terms of battery technology, weight, maintenance, and coordination with other controllers. The impact of battery operation on the battery life cycle is also discussed. Chapter 5 deals with regulatory and legal frameworks including technical considerations for BESS grid service delivery, regulatory and market considerations, market participation, regulatory issues for aggregators and regulatory impacts on BESS management and operation. The appendices provide information on frequency support (for island systems), BESS aggregation approaches and aggregated BESS deployment examples and projects.

BESS for provision of grid services at MV and LV networks

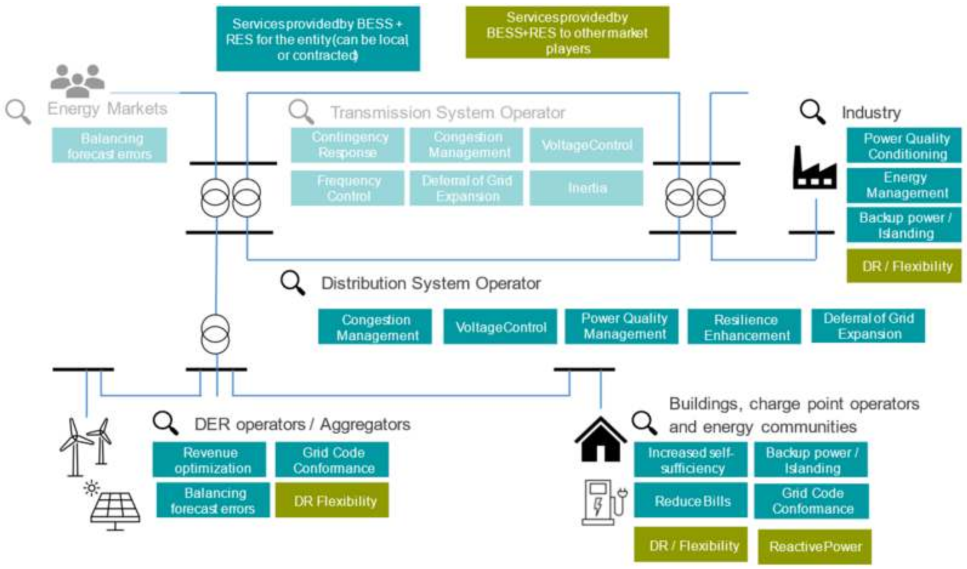

Figure 1 - Main stakeholders, use cases and capabilities of BESS in conjunction with RES at MV and LV distribution level

Figure depicts how DER, including BESS, are deployed and how services are provided to the grid and other systems in the grid. This diagram is used to present entities, use cases (marked in turquoise colour) and capabilities (marked in green) of BESS in conjunction with the renewable energy resources (RES) installations. Transmission system operators (TSOs) and energy market operators are considered out of scope of this TB.

Support Services for Distribution System Operators

Congestion management: introducing BESS for congestion management means it is possible to utilise generation that would otherwise have been curtailed.

Voltage regulation: voltage limit violations can be mitigated by BESS providing local voltage support services.

Power quality management: controllable inverter interfaced BESS can be used to smooth voltage ramps and condition power injection to reduce harmonics in the system.

Resilience enhancement: DER and BESS can enhance the resilience of their distribution grids after disturbances, by their proper scheduling and by reconfiguring their networks, including emergency islanding. BESS hybrid PV schemes can also provide black start services for parts of the distribution network.

Deferral of grid expansion: BESS can supply short-term peak loads avoiding the need for increasing generation capacity through costly infrastructure upgrades. BESS can help defer grid investments in peak capacity resources. BESS applications have also been used to support N-1 redundancy in the context of reinforcement deferral.

Support Services for DER Operator/Aggregator

Meeting grid codes: BESS can be added to existing and new installations of DER and ensure grid code conformance of large installations of renewable generation or charge points

Revenue optimization: BESS can enable arbitrage of energy when prices fluctuate significantly throughout the day by storing energy at times of low prices and increasing feed-in at times of high prices.

Flexibility services: The controllability of BESS allows demand side response to be performed and offered as a service by all BESS connections.

Minimising forecast errors: BESS can minimise forecast errors to balance load and RES production for local self-supply, if beneficial.

Support Services for Residential and Commercial Buildings/Energy Communities/Industries

Home energy management systems can use combinations of BESS and DER to optimize power generation according to different objectives, such as a maximization of self-consumption or balancing EV charging and heat pumps. Additionally, when power cuts are common, BESS can provide backup power for appliances behind the meter. For individual owners, aggregated BESS can offer access to energy markets, minimization of energy costs and synergies with other energy carriers. Benefits are also provided to community owners participating in local energy trading and to municipalities.

BESS operating conditions – business considerations

Four battery technologies are discussed, namely lithium-ion, lead acid, flow batteries, and sodium-sulphur. Each battery technology has a suitable or preferred power level and energy density level. These levels can be a reference or constraint for the battery application. For instance, lead-acid batteries are characterized as low power - low energy batteries, while vanadium redox batteries or lithium-ion batteries belong in the medium power - high energy battery categories. Battery weight varies depending on the technology, with lithium-ion having the smallest indicator, and lead-acid having the largest; while this is unlikely to impact battery operation directly, it can limit battery technology selection and installation location based on installed capacity/volume. There are several short-term operating considerations depending on battery technologies, e.g. heating of battery modules at rapid change of SOC for lithium-ion batteries and degradation of lead acid batteries at extreme SOC values and sulfation accumulation when batteries are left partially or fully discharged. Similarly, there are maintenance constraints specific to battery technologies that need to be considered in long-term operation of BESS. Finally, for battery life cycle cost, the BESS installation cost is one of the many factors to be considered. Other factors include recycle/disposal cost and cost for operation and maintenance.

Regulatory and legal framework

As the deployment of storage in distribution grids and their participation in markets is new and evolving rapidly with significant impact on the energy transition, regulators need good information on existing distribution planning approaches. Lack of this information may be considered as barriers or constraints on regulatory proceedings. Such barriers include lack of inclusion of storage in interconnection rules, and the lack of clarity as to whether and how existing interconnection rules apply to storage systems or lack of inclusion of acceptable methods that can be used for controlling export of limited-and non-export systems in interconnection rules, lack of information about the distribution grid and its constraints that can inform where and how to interconnect storage, etc.

The regulatory environment can pose barriers to the deployment of energy storage. Market rules and regulations do not always clearly address whether entities may own and operate storage assets and how, if at all, the cost of investments in storage assets can be recovered. In addition, market participation is inhibited when uncertainty exists about the ability of storage project owners to recover costs of storage when used for multiple applications.

Regulatory reform for BESS requires the definition of BESS as components of the power grid. Standards are a useful way to define the relationship of storage from its interconnection to participation in markets. Understanding these relationships – from storage as a component to a market participant – is important for guiding regulatory reform. Figure 2 illustrates the standards and guides developed by the IEEE Standards Association and the regulatory framework applicable to DER, including BESS, in the USA. They cover DER grid interconnection requirements (IEEE Std 1547), DER aggregation (IEEE Std 2030.1 and a DER regulatory framework (FERC 2222).

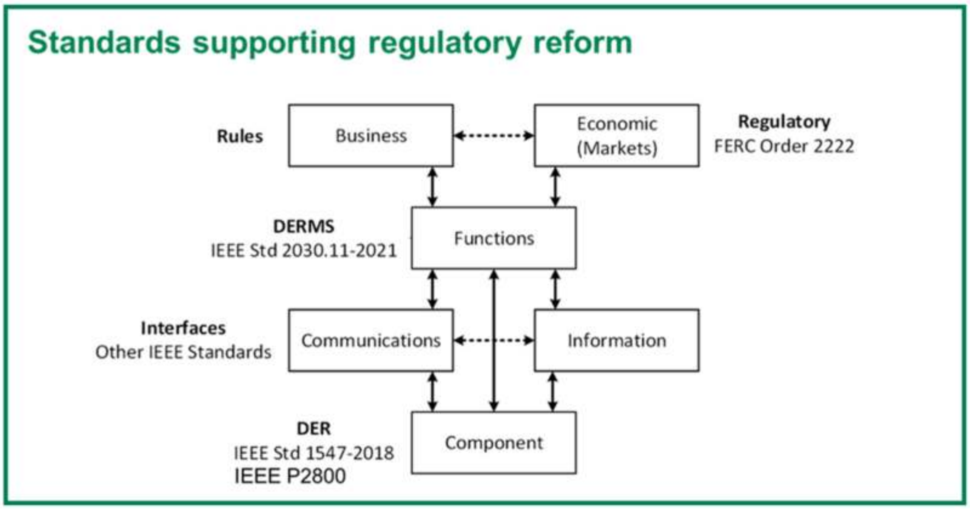

Figure 2 - Standards supporting regulatory reform

TB 933 | WG D1.66

Requirements and application of UHF PD monitoring systems for gas insulated systems

In the TB, the hardware and software requirements of modern ultra-high frequency (UHF) partial discharge monitoring (PDM) systems for gas insulated substations/lines are determined. It is based on abundant collected knowledge from the field combined with understanding the expectations and needs of GIS end-users. Its purpose is to provide comprehensive technical guidance to help users choose a PDM system best fitting their real needs and their level of PD knowledge. Ideally, a PDM system should reliably detect, monitor, and interpret the signals from incipient PD defects, so that asset managers can take prompt and appropriate actions to prevent equipment malfunction. This TB provides guidance for more effective use of PDM systems for GIS.

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Introduction

The Ultra High Frequency (UHF) method was introduced in the late 1980's for Partial Discharge (PD) measurements and is used worldwide by gas-insulated switchgear (GIS) manufacturers routine testing, on-site acceptance testing, and by numerous utilities for online PD monitoring.

The well-known two-step sensitivity verification procedure for UHF PD measurement systems was published for the first time by CIGRE Task Force 15/33.03.05 in ELECTRA in 1999. Subsequently, manufacturers and users of GIS gained a lot of experience in the application of the proposed sensitivity verification method. In 2016, a follow-on document, TB 654, was published by CIGRE WG D1.25, building on the original 1999 paper, but going into more detail and providing supporting by examples. A sensitive UHF PD measurement is only the first step in the PD risk assessment procedure aiming to detect critical PD defects in GIS, as proposed by CIGRE WG D1.03 (TF09) and described in TB 525.

Asset management is obliged to optimise costs over the life of electrical transmission equipment, and at the same time, to meet ever higher levels of performance. The benefits of PD diagnosis on GIS have been continuously evaluated, and in 2017, a relevant TB 674 was published by WG B3.24. This document evaluated the pros and cons justifying an investment decision for PDM systems.

In this TB, attention is focused on the technical and hardware and software requirements of a modern PDM system applied to GIS. A survey of current UHF PDM technology was performed to collect available knowledge from the field and understand the expectations and needs of the users.

The resulting technical guidance will help users choose a PDM system best fitting to their needs and their level of PD knowledge.

Structure of the Technical Brochure

Chapter 1 “Introduction” presents the scope of the WG D1.66 activity in the context of Study Committee D1 activity.

Chapter 2 “Demands on modern GIS PD monitoring” presents the new drivers and expectations of today’s condition monitoring systems. The statistics of GIS dielectric failure rate are presented, the root cause for the failures of these GIS component are analyzed, and the measures that could help avoid these failures in the future are indicated.

Chapter 3 “Functions and features of current PDM systems” describes the technical advantages and disadvantages of different monitoring solutions currently available on the market together with the minimum basic requirements of a GIS PDM system. The following functions and features are considered: signal detection and coupling, PDM system hardware, noise discrimination, data transmission and control systems, and the PDM system’s operating software. The strengths and weaknesses of current PDM systems are summarized in a concise summary table.

Chapter 4 “Requirements for UHF PDM systems” is the most significant chapter, containing the following sections:

- Automated recognition of PD defects
- Practical considerations of the CIGRE Sensitivity Check on UHF PDM Systems
- UHF signal attenuation profile measurements
- PDM system commissioning
- Use of PDM systems during HV acceptance tests
- Warning and alert procedure

- Risk assessment procedure
- GIS PDM system outputs to utility asset management
- Maintenance of PDM systems over their lifetime

Chapter 5 “Example of system implementation”. The two examples illustrate how the effectiveness of a PDM system can be improved if features like automated evaluation of defect type, time of flight measurement, attenuation profile, and more sophisticated warning and alert level settings are incorporated into the system.

Chapter 6 “Conclusions and recommendations for future work”: the main areas for improvement of GIS PDM systems are covered.

An **Appendix** is included which discusses the special considerations associated with HVDC GIS.

Finally, a comprehensive, detailed **glossary** of the terms used in the brochure is included both to assist newcomers to the field and to encourage consistency in usage in future work in the field.

— Demands on modern GIS PD monitoring

Changing needs for GIS PDM Systems

To understand the requirements of on-line PDM systems in the current and foreseeable future, it is important to understand the drivers for such systems, which have changed in recent years due to many factors. The improved capability in technology has influenced some of these changes, but the larger influences are the direct and indirect demands on the energy sector made by the end consumer. The energy sector must now respond to the increased demand and dependency on electricity, but with much higher pressure on the cost of delivery. Even with enhanced functionality, the effectiveness of a PDM system cannot be solely based on its operating in isolation. It is as equally important that GIS owners understand that they need to use their PDM system in the most effective way to maximise the reliability of the GIS.

Statistics of dielectric failure in GIS

Based on feedback from earlier generations of GIS, more recently developed GIS technology exhibits a higher degree of reliability. That is the outcome of the 3rd CIGRE international enquiry on reliability of HV equipment, as well as of the service experience collected by the GIS User Forum, a non-profit organization of about 30 German, Austrian, and Swiss system operators.

The first generations suffered from teething failures and component outages. However, recent generations of GIS exhibit much better reliability, demonstrating the benefits of further technological development. Obviously, the teething faults could be significantly reduced by improving the design and the quality assurance measures in both the factory and on site. Also, the distinct increase of the failure rate following a certain period in service is absent as well. This tendency is also confirmed by recent failure statistics analysis emphasizing increased service time. The root causes for these failures are analyzed and measures that could help to avoid these failures in the future are mentioned.

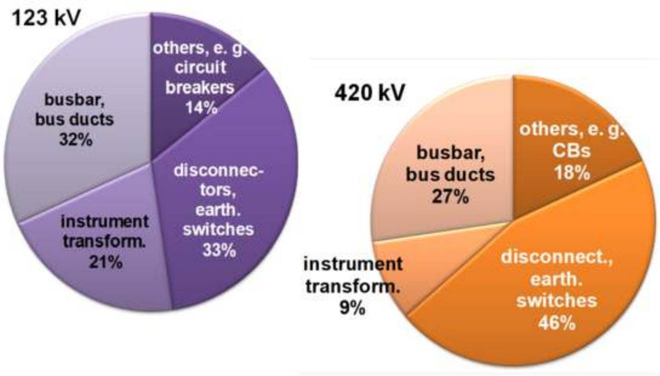


Figure 1 - Main root causes of failures in 123 kV and 420 kV GIS

Functions and features of current PDM systems

The technical advantages and disadvantages of different monitoring solutions currently available on the market are shown and the minimum requirements for a GIS PDM system are given in the TB. The UHF detection method as well as PDM system hardware elements and software features are carefully described in order to make the utilities aware of the consequences of the different technical solutions available and to assist them choosing between them. It foreseen that this Technical Brochure will act as a reference both to help utilities assess GIS PDM systems and to draft specifications for them.

The SWOT (strengths, weaknesses, opportunities and threats) for current PDM systems are summarized in the TB. The list of weaknesses is presented in Table 1.

Weakness	**Technical weaknesses:**
	External noise discrimination is often challenging to setup; external disturbances often generate false alarms
	Expert systems are not efficient or accurate
	Alert/warning procedure do not consider results from the sensitivity check and from the signal profile evaluation
	Other types of weaknesses:
	Present PDM systems run in stand-alone mode (i.e. they operate in isolation from other monitoring systems)
	FAT for PDM systems are not defined or standardized, making it difficult to assign and assess pass/fail criteria
	Data format and displayed information (graphs, trends, PD patterns, etc.) are not standardized and not compatible between systems of different vendors; PD amplitude reference points are clearly specified
	Computers and some DAQ boards of PDM systems have to be replaced after several years of operation; long-time quality and robustness are limited, component obsolescence (a problem intrinsic to electronic hardware)
	Retrofitted GIS PDM systems do not come with Sens check 1 results, means setting a proper impulse level for Sens check 2 at site sometimes hard to determine
	Use of multiplexing detection methodologies introduces the risk of delay in detecting PD sources exhibiting low pulse-rates; Use of narrow-band detection methodology without spectrum analysis (wideband scanning) risks missing severely frequency band-limited PD signals

Table 1 - Weaknesses of current PDM systems

Automated recognition of PD defects

After detection of PD activity, further steps are necessary and PDM systems should provide an efficient and automated evaluation of the PD defect´s type. In this paper, the results of a round robin test (RRT) are presented. A set of data files, representing the five typical PD defects seen in GIS, were used to test the efficacy of the available pattern recognition algorithms. The results of the RRT are compared with the results from human experts. The recognition algorithms tested show a wide variation in performance and indicate that there is still much room for improvement of the different classification algorithms. Other tests for PD identification are also proposed such as e.g.: application of real-size GIS test setups with all well-known PD defects combined with typical interference signals, or alternatively, use of compact HV test cells containing the usual well-known PD defects, again combined with typical interference signals.

UHF signal attenuation profile measurements

An important step in the commissioning of a PDM system is the sensitivity check according to CIGRE TB 654. The procedure is divided into two steps, the first being carried out in a laboratory and the second on site at the final GIS installation. For the sensitivity verification Step 2, artificial pulses, the magnitude of which were determined in Step 1, are injected in one sensor and acquired at the adjacent sensors. If the UHF signal can be measured at the adjacent sensor, the sensitivity in the section of GIS between the two sensors is sufficient for detection of PD equivalent to the defect used in the Step 1 measurement (typically, a moving particle producing 5 pC apparent charge according to IEC 60270). By means of these measurements, an attenuation profile between the adjacent sensors can be established, assuming that the attenuation follows a more or less linear profile along the propagation path (Figure 2).

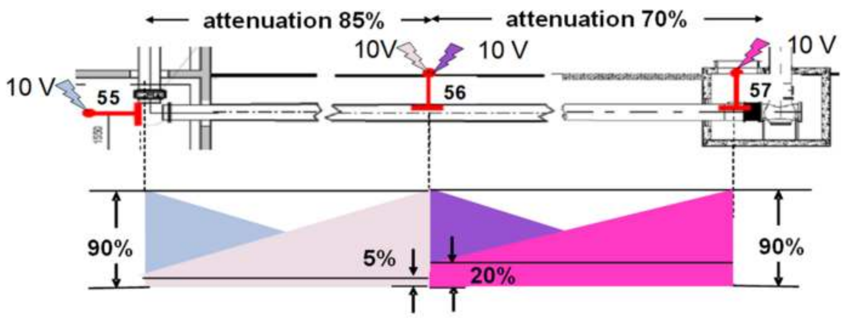


Figure 2 - Attenuation profile acquired at sensitivity verification, Step2

Warning and alert procedures

One of the most pressing challenges facing GIS PDM systems is to significantly reduce the number of false alarms, and for this purpose, a novel warning/alert procedure is proposed. As part of this, a proposal is that the results from the UHF Sensitivity Check (CIGRE TB 654) and from PD Signal Attenuation Profile measurements are used to set the optimum signal amplitude threshold value for all of the UHF sensors, and to define the response of the PDM system when those pre-set threshold levels are exceeded. In addition, the accurate and reliable automated PD defect type recogntion as playing a privotal role in both reducing false alarms and revealing defects which actually pose risk to operation has to be implemented.

A flowchart for the proposed alert procedure is shown in Figure 3. An adjustment factor of p dB has been applied to the threshold level for both a protrusion type and a particle on insulation type defect.

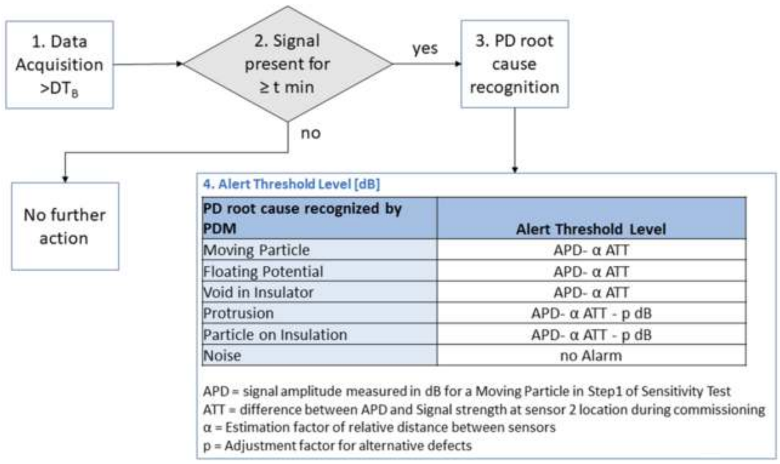
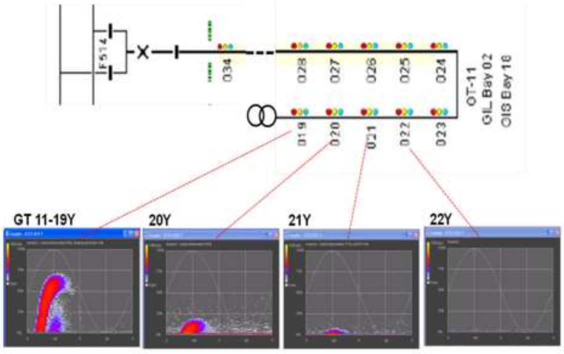


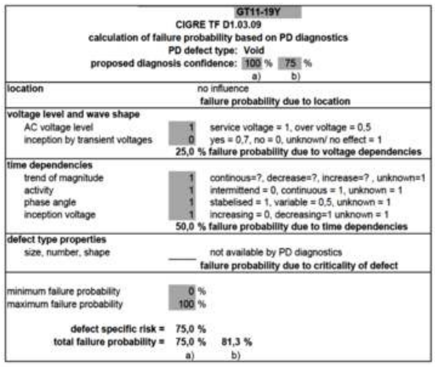
Figure 3 - Proposed Alert Procedure

— Risk assessment procedure

Rapid, efficient, and effective risk assessment based on PD diagnostics is mandatory and must take technical as well as non-technical parameters into consideration. The technical impact parameters estimate the probability of a failure in the GIS, and the non-technical impact parameters (e.g. cost of loss of service, spares availability, age of the GIS, etc) estimate the consequences in case a failure occurs. The goal of this process is to formulate a risk index which can provide reliable guidance as to which action should be taken. The approach often wished for - the concept of an asset health 'traffic light' - is presented in the TB. Practical examples confirm the advantage of defect's localization performed by Time-off-Flight measurements or signal profile measurements. The former requires an additional measuring system, while the latter necessitates a very structured evaluation of the TB 654 sensitivity verification. The special challenges encountered when applying PDM systems to three-phase encapsulated GIS and HVDC GIS are also covered.

An example of Risk Assessment procedure when the signal was acquired at service voltage is presented in Figure 4. The PD inception was not directly related to a transient voltage. The activity was continuous and its phase position stable.




GT11-19Y
CIGRE TF D1.03.09
calculation of failure probability based on PD diagnostics
PD defect type: Void
proposed diagnosis confidence: 100 % 75 %
a) b)

location — no influence
failure probability due to location

voltage level and wave shape
AC voltage level — 1 — service voltage = 1, over voltage = 0.5
inception by transient voltages — 0 — yes = 0.7, no = 0, unknown/ no effect = 1
25,0 % failure probability due to voltage dependencies

time dependencies
trend of magnitude — 1 — continous=?, decrease=?, increase=? , unknown=1
activity — 1 — intermittend = 0, continuous = 1, unknown = 1
phase angle — 1 — stabelised = 1, variable = 0.5, unknown = 1
inception voltage — 1 — increasing = 0, decreasing=1 unknown = 1
50,0 % failure probability due to time dependencies

defect type properties
size, number, shape — ____ — not available by PD diagnostics
failure probability due to criticality of defect

minimum failure probability — 0 %
maximum failure probability — 100 %

defect specific risk = 75,0 %
total failure probability = 75,0 % 81,3 %
a) b)

— Conclusions and recommendations

The demands on modern PD monitoring indicate that:

- The full effectiveness of PDM systems cannot be realized when they are operated in ‘stand-alone’ isolation. It is equally important that GIS owners understand that they need to use their PDM systems wholistically to maximise their effectiveness and ultimately, the reliability of their GIS.
- A further value of PDM is to efficiently support decisions about maintenance and end-of-life replacement, particularly as more evidence regarding asset health is being demanded by external stakeholders.

The areas in which current PDM systems need to improve are indicated:

- Much more work must be done to meet the challenge posed by external RF interference; such external disturbances generate false alarms far too often.
- Expert systems are not yet mature, plus alert/warning procedures could be made more effective by considering results from the sensitivity check and signal profile measurements.
- PDM systems must provide more accurate automated evaluation of the PD defect ´s type.

Practical aspects of the UHF CIGRE Sensitivity Check for UHF PDM system and with reference to the CIGRE TB 654 are discussed. Because of the attenuation of UHF signals in GIS, a sufficient number of UHF PD sensors has to be installed in a GIS in order to cover all of it with sufficient sensitivity to detect critical PD defects. Again, the overall effectiveness of PDM systems on GIS depend on this factor.

Determination and evaluation of UHF signal attenuation profile evaluation is presented in different case studies. It is emphasized that a direct correlation cannot be made between the RF signal amplitude recorded by UHF measurements and the apparent charge [pC] values obtained from standardized conventional (IEC 60270) charge-based measurements. The more complex RF signal propagation environment presented by 3-phase encapsulated GIS is underlined and GIS OEMs must pay close attention to carrying out the CIGRE TB 654 Step 1 test in a comprehensive way so as to arrive at an artificial pulse generator amplitude which is realistic for the given PD defect chosen.

The commissioning procedure of a PDM system shall cover a wide range of topics including: documentation, the quality of the parts, the system's functionality, its sensitivity, and e.g. its cyber security. The commisioning procedure of a PDM system is described, documents and functional requirements are listed and relevant standards are indicated.

A novel warning/alert procedure is proposed. It recommends using the results from the CIGRE TB 654 UHF sensitivity check along with UHF signal attenuation profiles to set threshold values for each UHF sensor. In addition, the requirement for more accurate and reliable automated PD defect type recognition is emphasized as playing a pivotal role in both reducing false alarms and revealing defects which actually pose risk to operation.

Risk assessment based on PD diagnostics considers technical as well as non-technical impact parameters as indicated in TB 525. The technical impact parameters estimate the failure probability and the non-technical impact parameters estimate the consequences in case of a failure. The goal of this process is to obtain a risk index which can give an indication of which action should be taken. The most preferred approach is the concept of the asset health 'traffic light'. In this TB, the methodology mentioned above is illustrated by means of two case studies which consider PD signals recorded by PDM systems in two different substations.

The examples of PDM system implementation illustrate how far the ability of a PDM system can be improved if features such as automated evaluation of defect type, time of flight measurements, attenuation profile, warning and alert level etc. are incorporated into the system.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