SPECIAL REPORT FOR SC C1

SC C1 - By its very nature, the Development and Economics of the electricity system – without forgetting asset management – necessitates foresight. Indeed, network planning requires an appropriate time horizon to be considered in order to avoid making bad short-term decisions. As a result, the questions of "the future", relating to climate change, and therefore to resilience, to the necessary synergy between the different energies, and also the seriousness of the need for and the evolution of the energy mix towards carbon-free means of production are very much in the scope of C1. The three preferential subjects illustrate this appropriately.

We welcome Prepared Contributions from all delegates (rather than just from the author concerned) in response to the questions of the Special Reporters.

1. All prepared contributions must be uploaded to the "Contributions to Group Discussion Meetings" section of the Registrations platform for review by the Special Reporters. Once registered, each delegate will be given an account and credentials. Registration for the CIGRE Session must be completed before uploading contributions online. Register now for the Session - click here
2. Intended contributors should upload their contributions using the account and credentials provided upon registration. Contributions may be uploaded from early May and these will be made available to the Study Committee Chair and/or Special Reporters for review and comment – the deadline for uploading contributions is **Wednesday 11th August 2021**. Contributors are encouraged to visit their account on the Registration Platform to see the result of this review. A guide for contributors, as well as templates and sample pages, will be available on the CIGRE Centennial website - see Group Discussion Meetings in the top menu bar.
3. Special Reporters will review each prepared contribution (PowerPoint voice-over presentation with a maximum of 5 minutes plus a written contribution in Word with a maximum of 1000 words). A guide for contributors, as well as templates and sample pages, will be available on the CIGRE Centennial website - see Group Discussion Meetings in the top menu bar.
4. Any recommendations or proposed changes to the contributions will be provided to the contributors by the Special Reporters directly on the Registration platform by **Thursday 12th August 2021**. Contributors are encouraged to visit their account on the Registration Platform to see the result of this review.
5. Any requested edits to your contribution must have been agreed with the Special Reporter and uploaded (by you) to the Registrations Platform by **18:00 Central European Summer Time on Friday 13th August**.
6. For registered delegates who are willing to provide their contributions live, through a TV channel connection, please specify it and this may be arranged depending on technical conditions. Spontaneous contributions cannot be organised.

PS1: POWER SYSTEM RESILIENCE PLANNING

Valdson Simões, Special Reporter

Given the increasing threats from human and natural hazards, including climate change, this subject aims to discuss: evaluating, improving, and measuring power system resilience in system planning; economic assessment; and, asset management. It has attracted 30 papers from 23 countries, and they have been grouped into five sub-topics which are key focus areas for SC-C1.

Sub-topic a) New approaches for power system planning criteria

Papers C1-102, C1-111, C1-115, C1-118, C1-121, C1-123 and C1-130 from 7 countries relate to transmission planning - describing how to manage congestion and self-generation. They include contributions on how to improve substation resilience, the benefits of system resilience against extreme weather events, and increased resilience brought about by grid hardening interventions. These themes address new approaches in the application of power system planning criteria and reliability (security, adequacy, resilience) assessment.

Question 1.1
Recognising that greater resilience of an electric system is obtained by investing in increased reliability, safety and flexibility of the transmission system, what are the main paradigm changes necessary in the planning phase of the expansion of an electric network, including new policy proposals?

Sub-topic b) Renewable energy sources and resilience in island systems

Papers C1-104, C1-105, C1-107, C1-113, C1-116, C1-119 and C1-128 from 7 countries relate to: renewable energy sources and island systems, including; systems with 100% variable renewable energy; conceptual models and concerns relating to curtailment analyses; large-scale offshore wind power; and, a wind power hub. This addresses an important part of a problem that affects many countries globally, i.e., how to more economically, reliably and sustainably combine strongly growing variable renewable energy contributions into the electric system. Small islands often need to cope with very high electricity prices; as the fuel is usually transported on small boats to these islands, transportation makes up a large part of the total electricity costs. Solar and wind power plants are normally very cost effective because they only need to be transported once; thereafter, no fuel is required, and maintenance requirements are low.

Question 1.2
What are the most suitable business models for renewable energy applications on islands?

Question 1.3
How can offshore wind plants contribute to improving the resilience of the system to which it is connected, and what are the potential benefits of this kind of generation?

Sub-topic c) Interconnection for higher resilience

Papers C1-108, C1-109, C1-114, C1-124, and C1-125 from 4 countries relate to interconnections, with contributions on: benchmarking amongst transmission utilities; interconnections in Asia, Europe and Middle-East; and, criteria for TSOs reporting on power systems. The European Union is increasingly considering energy cooperation with Central Asia, as this is a relatively close region with energy resources. Locally produced electricity - that is, predominantly gas and hydroelectric and, potentially, solar and wind energy - offers opportunities for electricity trading.

Question 1.4
What are the technological advances towards higher transfer capacity architectures and the technical-economic challenges to redesign these electrical interconnection networks?

Sub-topic d) Improved resilience from generation & transmission planning

Papers C1-101, C1-110, C1-120, C1-126 and C1-127 from 5 countries relate to generation & transmission planning, with contributions describing mathematical models and how to manage different types of generation connection to the main interconnected transmission system.

Question 1.5
As it is of growing importance in power system development, particularly in developing countries, what are the current and future energy development proposals to meet energy needs without harm to the environment where technological advances in the production, delivery and utilization of electricity are important for resolving conflicts between energy and the environment?

Sub-topic e) Policies and tools for increasing resilience

Papers C1-103, C1-106, C1-112, C1-117, C1-122 and C1-129 from 6 countries relate to: electricity policies; the use of structured expert judgement in relation to unreliability events; developments in mathematical models; and, a transmission grid geographic database as a tool to aid transmission planners in improving transmission system resilience.

Question 1.6
What are the strategic and more general points to be addressed in the regulatory framework to improve the efficiency of the electric system, and for establishing a regulatory strategy whose implementation could increase the efficiency and resilience of the system?

PS2: ENERGY SECTOR SYNERGIES FOR DECARBONISING EFFICIENTLY

Mattias Jonsson, Special Reporter

This preferential subject aims to discuss various ways to obtain decarbonisation through energy sector synergies. Particular areas that are addressed include:

- Planning approaches addressing energy sector synergies across power, gas, transport, heating/cooling, and new energy carriers, in order to optimise overall decarbonisation efficiency whilst supporting local development.
- How do these planning approaches include aspects of energy conversion and storage, technical and economic sector interfaces?

The subject includes 11 papers from 9 countries, divided into three sub-topics, which are areas of

focus for SC-C1. Sharing of data and experiences from real schemes when responding to the questions is encouraged.

Sub-topic a) Electric Vehicles

Papers C1-201, C1-202, C1-204 and C1-209 from 4 countries relate to electric vehicles, including topics such as charging cycles, transportation patterns, Vehicle2grid (V2G), probabilistic modelling, smart charging, and regenerative train braking systems. Numerous studies show that smart charging for electrical vehicles may reduce the stress on the electric network significantly. The need for enhanced flexibility in decarbonised systems to manage, e.g., disturbances and forecast deviations is also discussed.

Question 2.1
What technical and market measures are available to facilitate the smart charging of electric vehicles that is expected to become the societal norm?

Question 2.2
Travel habits are an important factor when charging patterns for electric vehicles are modelled. Assuming that all cars will be self-driving by 2035, how would that affect the travel habits and, in turn, the modelling in power system planning?

Question 2.3
In a scenario where the future transportation fleet is predominantly fuelled by green hydrogen (produced using large scale electrolysers) and offered at local hydrogen refuelling stations rather than each vehicle being equipped with an individual battery that requires charging from the grid, what would be the impact on the electric system?

Question 2.4
It is common practice that different meteorological conditions, particularly temperature, are considered in conventional load forecasting and modelling. Is there a need to cater for the temperature effect on the battery performance, as the battery performance (at least to a certain extent) is temperature dependent, when widespread usage of electric vehicles and V2G-usage is modelled in power system assessments?

Question 2.5
V2G-solutions are expected to offer supporting services to the electrical power system but the implementation has yet to be realised on a wide scale. Regenerative braking systems in electrified railways also have the ability to support the power system. What potential grid services can electric transportation systems offer to the power system and how should they be catered for in the long term planning of power systems?

Question 2.6
Different power sources, e.g., hydrogen, batteries, and electric roads, are being considered as successors to petroleum in the future road transportation system. Similar discussions are ongoing for transportation by sea and air. In what ways can the uncertainty related to these alternative developments be managed in the long term planning of the electric power system to ensure expedient security, adequacy and investment in assets?

Sub-topic b) Sector Coupling

Papers C1-205, C1-206, C1-207 and C1-208 from 4 countries relate to integrated energy sector systems such as sector coupling, power to gas, local area energy operators, and district heating & cooling networks. The ability to co-ordinate the operation of and investment in different energy carriers may lead to synergies and contribute to reduced costs and emissions.

Question 2.7
In order to deliver a "one energy system" based on the co-ordinated operation and planning of various energy carriers, energy sources, energy users, and storage facilities, what is required from business models, market designs, and regulations?

Question 2.8
For energy systems based on the co-ordinated operation and planning of various energy carriers, energy sources, energy users, and storage facilities, what developments are currently most important in terms of technical equipment and simulation tools?

Question 2.9
For large scale power to gas installations used to convert and store excess electricity from renewables, what aspects determine the optimal location of the electrolysers with respect to the generating plant and the end users? Furthermore, what factors will be important to consider when numerous power to gas installations are incorporated into an existing electric power system?

Question 2.10
In what ways can sector coupling be used to provide additional flexibility to the electric power system?

Question 2.11
What factors are important to consider when district heating becomes an integral part of the long term planning of electric power system?

Sub-topic c) Enablers of decarbonisation

Papers C1-203, C1-210 and C1-212 from 3 countries relate to the contribution to decarbonisation of innovative resource utilization. The enablers include interconnectors, cross border trade, renewable generation, sources of flexibility, and the closure of thermal power generation.

Question 2.12
For continental system studies which aim to optimise resource utilisation across a large geographical area, what level of detail should the power system model contain to obtain meaningful results and what indicators should be represented in the cost-benefit analysis?

Question 2.13
In what ways, and for what benefits, can meshed off-shore networks and hybrid solutions be incorporated in power grids interconnecting countries and continents?

Question 2.14
What assessments and solutions are available in the long term planning of power systems to address adequacy issues following the replacement of conventional power plants by weather-dependent

renewable generation?

Question 2.15
In what direction will electrical power system develop: towards global interconnected systems or small self-sufficient off-grid solutions?

PS3: DISTRIBUTED ENERGY RESOURCES IN TRANSMISSION PLANNING

Séverine Laurent, Special Reporter

This subject relates to distributed energy resources in transmission planning, and covers: tools, techniques, data, and holistic approaches that combine technical assessments, incentives, and reliability impacts on customers. It has 20 papers from 15 countries to be discussed in 3 sub-topics which deal with focus areas for SC-C1.

Sub-topic a) Integrated development at various scales

Papers C1-301 and C1-318 discuss the regulatory changes that took place in Brazil and Chile relating to the network planning required to enable the growth of renewable energies. They provide visibility of the renewable energy connection potential (301) and of improvements in the overall integration of networks (318). Papers C1-303 (Sweden), C1-319 (Switzerland) and C1-316 (UK) take a comprehensive approach to network planning - ranging from trans-country scale to distribution network scale by covering intermediate voltage levels. Paper C1-320 (Switzerland) presents an even more local approach than distribution level. Finally, paper C1-309 (Ireland) covers a fundamental aspect for the future of networks - tools to aid the understanding of complex phenomena; it also covers the new engineering challenges posed by the integration of renewable energies and the management of external stakeholder communication.

Question 3.1
Will integrated development at various scales lead to larger data platforms and models to ensure overall consistency?

Question 3.2
What is the future for intermediate voltage networks and what purpose will they serve?

Question 3.3
How does this integration cater for the rise of a proven need for self-sufficiency and autonomy - sometimes at very small scale?

Sub-topic b) Deeper integration of renewables in the system

This section deals with the deeper integration of renewables in the system. Paper C1-307 (Austria) proposes a wider integration of renewable energies in North Africa and the Middle East and, at the same time, a reduction in the use of fossil fuels; this is achieved by taking advantage of the wind potential and of the pooling offered by networks. Paper C1-308 (Taiwan) suggests an integrated vision with the same purpose in Taiwan. Paper C1-310 (Japan) describes the renewable connection scheme process developed in Japan by optimizing the use of the network. Paper 305 (UK) offers probabilistic analyses based on smart data.

Papers C1-311 (Australia) and C1-312 (Spain) address the system issues linked to the massive

arrival of renewable energies and the measures to increase the permissible penetration rate (including CSPRs). Finally, paper C1-315 (Korea) presents the contribution of storage coupled to renewable energies for supplying an island - the approach also covering the quality aspects of electricity supply.

Question 3.4
Would specific mechanisms promote the connection of renewable energies and improved sharing of existing capacities?

Question 3.5
What are the challenges in terms of the predictability and controllability of renewable energies to increase their integration threshold?

Question 3.6
Should "cradle to grave" approaches be implemented to ensure the efficiency of the solutions developed in terms of CO_2 reduction?

Sub-Topic c) Integration of HVDC links into the existing grid

This last section contains 5 papers dealing with large-scale simulation models allowing the integration of HVDC links, sometimes meshed, into AC networks. OPF modules, comprising several climate scenarios are also integrated – see papers C1-302 (Belgium), C1-306 (UK) and C1-313 (Germany). Paper C1-314 (Korea) addresses the issue of network stability. Finally, paper 304 (Greece) presents a holistic approach on a techno-economic optimal way to supply all Aegean islands by HVDC link with the continent, avoiding the construction of local CO_2 emitting plants.

Question 3.7
Probabilistic models are becoming essential due to the integration of renewable energies and new uses of electricity. At the same time, future uncertainties are greater than ever: what approaches should be developed to aid planning decisions in an uncertain future?

Question 3.8
Is the development of an HVDC meshed network, potentially trans-country via off-shore, likely to become a reality in the medium term?