C6 - 00

SPECIAL REPORT FOR SC C6

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(Preferential Subject 1)

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Special Reporters

1. INTRODUCTION

The Scope of SC C6 is to assess the technical impacts and requirements, which a more widespread adoption of Distributed Energy Resources (DER) and a larger proportion of undispatchable power generation could impose on planning and operation of distribution systems. In parallel, the SC also assesses enabling technologies and innovative solutions for DER integration in active distribution systems. Rural electrification, demand side integration methodologies and application of storage and electric vehicles as DER are also within the scope of this SC.
Within this scope for the CIGRE 2021 General Session, three preferential subjects were proposed:

- PS1: Advanced Distribution System Design Incorporating Distributed Energy Resources
- PS2: Enabling Technologies and Solutions for Distribution Systems
- PS3: System Operation Challenges with Increasing Use of Distributed Energy Resources

A total of 74 papers were selected for discussion at the General Meeting, 25 for PS1, 19 for PS2 and 30 for PS3. The main issues for these papers are summarized below and questions are proposed in relation to these papers to initiate a lively and profitable discussion at the General Meeting.

2. PREFERENTIAL SUBJECT 1 – Advanced Distribution System Design Incorporating Distributed Energy Resources

Special Reporter: Samuel Jupe, UK
Moderators: Mark McGranaghan, USA and Jason Taylor, USA

The areas dealt with in this subject area are:

- Active Distribution System Planning Considering Energy Storage;
- Planning for Electric Vehicles and Demand-Side Response in Active Distribution Systems;
- Control Considerations in Active Distribution System Planning;
- Active Distribution System Modelling Accounting for DER;
- Distribution System Planning for a Large Uptake of Battery Energy Storage Systems.

PS1 regroups 25 papers. The authors come from 19 different countries and five continents, which clearly demonstrates international breadth of contributions, diversity of applications and widespread interest in the topic.

For the purposes of discussion, the papers were grouped into five subtopic themes:

1. Active Distribution System Planning Considering Energy Storage (Papers C6-106, C6-107, C6-108, C6-110 and C6-111);
2. Planning for Electric Vehicles and Demand-Side Response in Active Distribution Systems (Papers C6-113, C6-116, C6-117, C6-118, C6-124);
3. Control Considerations in Active Distribution System Planning (Papers C6-120, C6-123, C6-126, and C6-127);
4. Active Distribution System Modelling Accounting for DER (Papers C6-122, C6-119, C6-114, and C6-115);
5. Distribution System Planning for a Large Uptake of Battery Energy Storage Systems (Papers C6-104, C6-101, C6-102, C6-103, C6-109 and C6-112).

Subtopic 1 – Active Distribution System Planning Considering Energy Storage (Papers C6-106, C6-107, C6-108, C6-110 and C6-111)

These five papers broadly deal with the improvements in power system operation that can achieved when energy storage systems are considered as part of the planning process. The contribution of energy storage to capacity adequacy, when applied to island power systems, is presented in **Paper C6-106 (Greece)**. Research on the balanced control of a flexible group of energy storage systems is presented in **Paper C6-107 (China)**. Moreover, **Papers C6-108 (Italy)**, **C6-110 (Russia)** and **C6-111 (Spain)** respectively deal with ancillary service considerations for DSO-owned storage, transient performance improvements when applying energy storage to synchronous distributed generation and the location of energy storage to reduce losses in LV networks with high penetrations of PV systems.

Question 1.1

What are the relative advantages (or disadvantages) of taking a probabilistic approach to planning for energy storage system deployment, rather than a deterministic approach? What are the key steps needed in the planning approach?

Question 1.2

Energy storage systems can be used for the provision of a number of services – which services are most viable and why? Are there any technical drawbacks in delivering the service provision?

Subtopic 2 – Planning for Electric Vehicles and Demand-Side Response in Active Distribution Systems (Papers C6-113, C6-116, C6-117, C6-118, C6-124)

These five papers focus on planning for Electric Vehicles and Demand Side Response in Active Distribution Systems. **Paper C6-113 (UK)** deals with accounting for the uncertainty associated with consumer-led demand side response. **Paper C6-116 (Turkey)**, **C6-117 (Jordan) and C6-118 (China)** respectively deal with a genetic algorithm to optimise the effectiveness of electric vehicle charging stations, an anecdotal account of the impact of EV charging on the Jordan power system and new control and communications equipment for ordering the charge of electric vehicles. **Paper C6-124 (Gulf States)** concludes this subtopic with a discussion on voltage control in active distribution networks.

Question 1.3

Which major factors should be considered when planning Active Distribution Systems in the context of increased DER such as Demand Side Response (DSR) resources and Electric Vehicles (EV)?

Question 1.4

How can the volatility and uncertainty associated with these forms of DER be managed, and planned for, effectively? What technical issues result from both a 'lunchtime' reverse power flow peak (due to excess PV generation) and a 'tea-time' forward power flow peak (due to excess EV charging)? How can these issues be addressed?

Subtopic 3 – Control Considerations in Active Distribution System Planning (Papers C6-120, C6-123, C6-126, C6-127, C6-YM-PS1)

These five papers focus on control considerations in Active Distribution System planning. **Paper C6-120 (Austria)** presents the achievements, experiences and lessons learned from the European Research Infrastructure ERIGrid demonstrator, related to the validation of power and energy systems. **Papers C6-123 (Spain)** and **C6-126 (Germany)** focus on innovative solutions for the smart management of power grids and Smart Transformer use in net-zero energy factories. **Paper C6-127 (Austria)** presents a reduction method for planning cross-energy carrier networks, using a cellular approach and applying it to stability assessments in low-voltage networks. **Paper C6-YM-PS1 (The Netherlands)** considers the challenge of optimal medium-voltage distribution system expansion planning in an integrated energy system.

Subtopic 3 includes a showcase paper and invited presentation from one of CIGRE's Young Members - S.S. Harmsen (The Netherlands) **–** within the Next Generation Network (NGN).

<u>Question 1.5</u>

Which particular elements of monitoring and control systems need to be considered in Active Distribution System planning? Is there an advantage in using a decentralized approach rather than the centralized approach? Can all elements of the ADS (including assets and DER) be optimized and controlled in a coordinated way? If not, how is the control objective established and control priority determined?

<u>Question 1.6</u>

Do power system assets need to be virtualised in order for control solutions to be effective? What advantages and disadvantages are there to aggregating and virtualising assets for the purposes of monitoring and control?

<u>Question 1.7</u>

How can net-zero carbon emissions be achieved through the deployment of Active Distribution Systems and what factors should be considered as the highest priority?

Subtopic 4 - Active Distribution System Modelling Accounting for DER (Papers C6-122, C6-119, C6-114, and C6-115)

These four papers broadly consider Active Distribution System modelling taking account of DER. **Paper C6-122 (USA)** considers the installation of DER in Distribution Automation Schemes. **Paper C6-119 (Argentina)** presents a conceptual framework for sub-transmission expansion planning of active distribution systems in South American distribution networks. **Paper C6-114 (USA)** presents modelling considerations for assessing smart inverter functions using an illustrative case study from Northern California. **Paper C6-115 (UK)** focuses on the use of advanced modular FACTS to increase flexibility of distribution networks and enable the connection of more DER.

<u>Question 1.8</u>

How can 'big data' be used and handled effectively for Active Distribution System modelling when accounting for DER? How critical is it to model all the various aspects of DER (for example: Power system behaviour, communications and control systems, economic performance) and how is this achieved?

Subtopic 5 – Distribution System Planning for a Large Uptake of Battery Energy Storage Systems
(Papers C6-104, C6-101, C6-102, C6-103, C6-109 and C6-112)

These six papers broadly deal with distribution system planning for a large uptake of Battery Energy Storage Systems (BESS). **Paper C6-104 (South Africa)** presents lessons learnt from the 800 MWh utility-scale BESS project in South Africa. **Papers C6-101 (Brazil)** and **C6-102 (Brazil)** focus on the analysis of voltage stability indices and the benefits accrued from installing BESS in south American distribution grids. for a Distribution Grid with Photovoltaic and Battery Energy Storage Systems. **Paper C6-103 (Brazil)** outlines the technical, economic and regulatory challenges with installing BESS in 13.8 kV distribution networks. **Paper C6-109 (Canada)** presents the implementation of BESS for frequency and power profile regulation, and spinning reserve management. **Paper C6-112 (USA)** provides considerations for energy storage in distribution system planning.

Question 1.9

Does the business case for energy storage system deployment always rely on stacked services to be viable? If stacked services are not possible/achievable, would the deployment of energy storage systems still result in a positive cost-benefit analysis?

3. PREFERENTIAL SUBJECT 2 – Enabling Technologies and Solutions for Distribution Systems

Special Reporter: Britta Buchholz, Germany
Moderators: Alexandre Aoki (Brazil), Yasuo Matsuura (Japan), Irina Melnik (the Netherlands), and Jayakrishna Pillai (Denmark).

State-of-the-art

In order to reach the global target of CO_2 reduction, the future of the energy system will be based on renewable electricity. Since 2020, there are more ambitious goals to reduce CO_2 in various countries. Still, the global community must accelerate energy transformation, as the current pace and targets set by governments are far away from being ambitious enough to succeed.

Distribution systems will face most challenges in the context of energy transformation. In some regions, distribution systems include high, medium and low voltage levels, in other regions distribution systems include medium and low voltage whereas high and highest voltage are part of (sub-) transmission systems. To cope with the challenges, enabling technologies include digital solutions as well as new hardware developments, and also new processes and bankability of new technologies are needed. Market environment is important, as often technologies follow market incentives.

Related activities in the Study Committee include but are not restricted to:

- WG C6-35 Distributed energy resources aggregation platforms for the provision of flexibility services
- WG C6-28 Hybrid systems for off-grid power supply
- WG C6-38 Rural electrification
- WG C6/D2.32 Utilization of data from smart meter system

In 2020, we welcomed a very diverse set of 19 papers, given by authors from 13 different countries from 5 continents including South America, North America, Europe, Asia and Australia. In addition, two invited papers from NGN were included in the 2021 session. The moderator team and authors represented distribution system operators, industrial suppliers as well as academia. The papers cover mainly innovative power and energy management solutions for applications with high shares of distributed energy resources based on renewables such as solar PV and wind, and battery energy storage systems. This report is in 2 parts, one part on islands and remote areas, and the second part on regional and urban distribution systems.

Subtopic 1 - Islands and remote areas

Paper C6-212 introduces variable speed diesel engines to keep isolated systems stable with high shares of renewables in Australia. The promising technology to tap power from overhead earth wire of EHV transmission line for remotely located loads in India is presented in Paper C6-216.

Question 2.1

Could the authors and other experts share an update on experiences with the presented examples as well as other innovative enabling technologies to provide sustainable electricity for all in ***remote areas?***

Paper C6-215 presents a techno-economic feasibility study in order to dimension a PV-Diesel-battery energy storage system for the representative application of a remote touristic village in the mountains of Bosnia and Herzegovina in Europe. This village experiences significant seasonal differences in demand and generation. This is typical for remote touristic villages, both in mountains and on islands.

Question 2.2

Could authors and experts share experiences with feasibility studies and further case studies for touristic islands and mountainous areas? How has the challenge of seasonal variations been solved? To increase knowledge sharing, it would be interesting to learn about online platforms where references are already collected in different regions.

Papers cover all project phases in integrating distributed energy resources into different types of distribution systems with new enabling technology and solutions, including simulation of such systems. Once the dimensions of distributed energy resources including battery energy storage systems and loads are defined, the next phase is detailed engineering. For that it is important to perform power system studies including transient behaviour of the system when PV, wind or loads cause step changes in power. For such studies, models of all assets are requested.

Papers showed examples and results of such power system studies and control strategy development for the islands of Madeira modelling the LV distribution system and embbebed renewable generation (C6-211) and Porto Santo where the whole generation and distribution system was considered (C6-209). Both European Portuguese Islands have the political goal to reach 100% renewable energy supply for the island. Paper C6-220 showed a state estimator model for the Low Voltage distribution system in the European country Hungary. An energy management for off-grid systems in Spain is presented in (C6-217). The NGN contribution (Russia) explains optimization algorithms for remote territories in Russia.

Question 2.3

Power system studies are requested prior to project implementation. Do the authors or further experts have operational experience with such systems, and how does the monitored performance relate to the previously performed power system studies? Can the authors share lessons learned to improve power systems simulations?

The demonstration project for a virtual power plant of the European island of Scilly in UK is described in Paper C6-208.

Question 2.4

What are key success factors for the presented and planned demonstration sites for islands, and how have they these factors been monitored?

Subtopic 2: Regional and urban distribution systems

Paper C6-201 presents the working group results on aggregation platforms to provide flexibility services in different countries and contexts.

Question 2.5

Aggregation platforms are one important element in providing flexibility services. Are there new experiences with such aggregation platforms, and further new approaches to provide flexibility services in ***larger distribution systems****?*

New developments include research on algorithms for cyber physical systems and for nested microgrids in North America, (C6-204), or research on "Cellular systems" in the German KOPERNIKUS program (C6-207), and multi-microgrid system´s resilience in Austria (Young Member contribution). There is a diversity of names and definitions for such systems in different geographies in the world. The papers show, how technology follows the regulatory context in a certain country or region.

When developing a project, based on power system studies, the control strategy for the application is implemented in the control application engineering. The control system is then tested in a Hardware-in-the-loop (HIL) test facility, some with "Control HIL", others even with "Power HIL". Authors presented such test set-ups at the Distribution System Operator facilities in Colombia (C6-218) and USA (C6-205), at an industrial site in Germany (C6-206) and at research facilities in Spain (C6-210), Korea (C6-203), New Zealand (C6-221) and USA (C6-204).

Test facilities have different targets. System operators are responsible for stable operation and maintenance of their industrial or distribution systems, and need to familiarize their staff and management with new technology, including change of processes. Further, tests are important to create confidence in the new technology.

Question 2.6

What are the key targets for tests at the distribution operator´s facilities? Are there already experiences with setting up and operating such test facilities?

Question 2.7

At research sites, focus lies on application and further development of benchmarks and standards. Has there been progress in developing benchmarks for testing control strategies? Could you share lessons learned?

Following laboratory tests, demonstration sites are the next step. Paper C6 202 presents demonstrations for an industrial site in USA with advanced microgrids control system, that will be operated as isolated grid until grid connection will be approved. The NGN contribution from US shows project progress on an urban community microgrid in USA.

Paper C6-203 describes Optimal Energy Management and Control for Load Management in V2G EV-integrated Microgrid. This paper shows a very good example for project development from sizing over system studies, HIL test and demonstration on site in Korea.

Question 2.8

What are key success factors for the presented and further demonstration sites for urban and industrial projects, and how have they been monitored?

Question 2.9

Where are the barriers that prevent accelerating the energy transformation towards a 100% renewables deployment?

4. PREFERENTIAL SUBJECT 3 - System Operation Challenges with Increasing Use of Distributed Energy Resources

The advent of distributed energy resources (DERs) is changing the way power is generated and transmitted to the electric grid. DERs aggregated can be used to serve the grid and enable a two-way flow of energy. Greater levels of these interconnected resources reinforce the need to ensure the reliability of the Power System during both normal operation and in response to disturbances. Increasing amounts of DER can change how the distribution system interacts with the Power System and may transform distribution utilities into active sources for both energy and essential reliability services such as ramp and frequency response. These dramatic changes for the distribution system, which can alter not just the flow of power but also the responses to various types of disturbances, must be understood and addressed in the planning and operation of the grid.

Topics addressed by PS3 comprise the subtopics:

- Enhancing flexibility, reliability and resilience.
- Providing grid services through aggregators.
- Aggregator interaction.

This preferential subject is addressed by 31 papers.

C2-C6-301 presents the latest results of the EPRI contribution to the assessment of the Demand Response for which regards small consumer loads (water pumps, electrical heaters, air-conditioning.

C2-C6-302 presents the latest results of a study to obtain the conditions for which some wind parks can be resynchronized with the network during reconstruction.

C2-C6-303 presents the summary of Brazilian power system and recommendations for addressing the uncertainty and variability of the Renewable Energy Sources and Distributed energy resources including use of Storage

C2-C6-304 provides insights to strike a balance between allowing DER aggregation as widely as possible and the reliability of the transmission grid or the efficiency of the organized wholesale electric markets.

C2-C6-305 presents the results of a research that aims at comparing different kind of control strategies for demand response for FFR.

C2-C6-306 addresses the problem of degrading inertia and primary frequency control as a result of the integration of “intermittent” RE generation into the Senegal power system grid.

C2-C6-307 presents an online special protection scheme for automatic overload elimination on the transmission and high voltage distribution system for a network disturbance by optimally curtailing wind generation

C2-C6-308 presents the results to moving from zonal forecasting to more granular nodal forecasting to address the increased volatility resulting from high penetration of renewable energy resources

C2-C6-309 presents the summary of smart grid implementation in Apulia, Italy known as the “Puglia Active Network”

C2-C6-310 focuses on preventive distribution system operational scheduling, mitigating the impacts of a progressing wildfire by avoiding power interruption of critical loads.

C2-C6-311 presents the objectives and setup of an aFRR-pilot in the Dutch electricity system.

C2-C6-312 presents a tool that is designed to forecast system inertia and resulting RoCoF for severe disturbances with respect to local areas.

C2-C6-313 explores the use of Distributed Energy Resources (DER) to facilitate restoration of the power system following a total or partial system shutdown.

C2-C6-314 presents latest developments in the dimensioning procedure for FRR in Germany especially take into account the greater impact of forecast errors of power generation from RES.

C2-C6-315 presents two different methods for breaking down centralized optimal power flow problem into distributed sub sections.

C2-C6-316 presents methods to maximize the use of existing transmission grid by incorporating component ratings into contingency analysis for ensuring a secure system(n-1).

C2-C6-317 describes a DER platform that enables matching the demand side and Resource Aggregators based on response speed, capacity and duration.

C2-C6-318 describes an aggregation system of storage devices that enables load frequency control using hierarchical hybrid control (HHC).

C2-C6-319 addresses the frequency regulation in Faroe Islands in light of the 100% RE generation envisioned for 2030.

C2-C6-320 reports on the planning, execution and the results of an experimental power system restoration test at the Amprion transmission grid (Germany and Luxemburg).

C2-C6-321 presents fundamental modelling aspects and discusses key opportunities that can emerge from integration of a low-carbon, distributed electricity system with other energy vectors, and particularly hydrogen.

C2-C6-322 provides summary of practical experience with grid forming converters in the DSO grid in South Australia.

C2-C6-323 describes the participation of a wind farm on AGC control in Spain.

C2-C6-324 presents an adaptive synchro-phasor estimator based on multi-self-calibration and multi-self-switching to achieve high precision and fast response for fundamental-harmonic synchronous phasor measurements in a variety of conditions, such as steady-state, sub steady-state, sub dynamic-state, dynamic-state, sub transient-state, and transient-state.

C2-C6-325 presents a ubiquitous power dispatch and control technologies of renewable energy based on Cyber Physical Social Systems (CPSS).

C2-C6-326 presents Software tools for smart grid operations to improve the coordination of distributed generators (DG).

C2-C6-327 focuses on the ability of DR/DGs for inclusion in Automatic Frequency Restoration Reserve (aFRR) services.

C2-C6-328 describes how lift irrigation (LI) projects can be used to aid system operation for controlling frequency and voltages.

C2-C6-330 describes the integration of very large generators with increasing distributed generation in the power system operation of Gujrat, India.

C2-C6-331 details the Virtual Power Plant concept, architecture and the methodology as well as the applications of the concept that can be scalable for different voltage levels and for broader generation portfolios (Project EU-SysFlex).

Question 3.1

Papers C2-C6-328, C2-C6-323, C2-C6-318, C2-C6-319, C2-C6-313, C2-C6-312, C2-C6-307, C2-C6-306 and C2-C6-305 discuss enabling frequency, regulation and black start services through distributed resources. To what extent can RES and Distributed generation reduce the reliance on large generators for these services?

Question 3.2

The concept of virtual power plant is discussed in paper C2-C6 331. What capabilities for electric storage are required to make this feasible on a large scale? E.g., how much time should be planned for electric storage to supply?

Question 3.3

Papers C2-C6-328, C2-C6-323, C2-C6-318, C2-C6-319, C2-C6-313, C2-C6-312, C2-C6-307, C2-C6-306 and C2-C6-305 discuss enabling frequency, regulation and black start services through distributed resources. How will the role of traditional generation (commit and dispatch type resources such as coal and gas) change in the future with increasing volumes of distributed generation? E.g., will they still be required for back up energy or ancillary services? Similarly, how do we see the role of transmission and interconnections across systems change with increasing DER/RES?

Question 3.4

Paper 316 suggests maximizing wind generation by using ambient transmission ratings. What impact would this have on transmission maintenance?

Question 3.5

Papers C2-C6-330, C2-C6-326, C2-C6-325, C2-C6-324, C2-C6-322, C2-C6-321, C2-C6-317, C2-C6-316, C2-C6-315, and C2-C6-308 discuss the tools and technology needed to operate the grid with high RES and DER generation. Most of these rely on real-time measurements and visibility of the system. What measures should be taken on communication protocols to ensure system reliability? How will we ensure good data to accurately assess system reliability?

Question 3.6

All papers describe various aspects of operating the grid reliability with DERs. A fundamental question remains with regards to reliability. Should system reliability criteria such as n-1 change with RES and DER? Why and why not? If yes, how should it change. For example, contingency reserves plan for single largest generator contingency. With DER, how would we identify the largest generation loss since it could come from multiple DERs due to no wind in the area?

Important Dates

Please kindly note that intended contributions should be forwarded to Study Committees in advance for a prior screening and a good organization of the Group Discussion Meeting.
Experts who wish to contribute to the SC C6 Group Discussion Meeting should upload their contribution on the *Registrations platform* – "Contributions to Group Discussion Meetings" section - using existing account and own credentials before **August 4th, 2021**.
Prepared contributions comprise power point presentation with max 3 slides and a written contribution with max 1000 words per contribution. The contribution can be prerecorded and must not exceed 3 min. 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. Important points:

- *Access to contribution uploading is given only to duly registered delegates. As a consequence, registration to CIGRE Session should be finalized before uploading contribution(s) online. Register now for the Session Click here*
- *Contributions uploading will be open at the beginning of May.*

Contributions will be made available to Study Committee Chair and Special Reporters for reviewing and comments. Any recommendations or changes to the contributions will be provided to the contributors by the special reporters directly on Registration platform by **August 14th, 2021**. Contributors are encouraged to visit their account on the Registration Platform to see the result of this review.

If necessary, on Tuesday **24 August 2021** during the SC C6 Poster Session all experts with Prepared Contributions can contact Chair, Secretary and Special Reporters of SC C6 between 9.00 – 12.30 in Hall Ternes with their final contributions.
The **SC C6 Session** is scheduled for Wednesday **25 August 2021**, in Room Bleue.

During the Session the Chairman may call for spontaneous contributions. Attendees who provide a **spontaneous contribution**, are allowed to deliver a text for the Session Proceedings. This text is also required to be uploaded to the Registrations platform within a maximum delay of two weeks after the SC C6 Session (thus by Wednesday **8 September 2021**).