DISCUSSION MEETING

SUMMARY

Study Committee C2

Power System Operation and Control

28 August 2024

Chairman: **Jayme Darriba Macêdo**

Secretary: **Flávio Rodrigo de Miranda Alves**

Special Reporters: **Vivek Pandey (PS1) and Ronan Jamieson (PS2)**

1. INTRODUCTION

The 2024 discussion meeting of Study Committee C2-Power System Operation and Control was held on August 28th, 2024 in Amphitheatre Bordeaux, Level 3, at the Palais des Congrès, in a full day session.

The scope of SC C2 covers the technical, human resource and institutional aspects and conditions for a secure and economic system operation of power systems in a way that is in compliance with requirements for network security, against system disintegration, equipment damages and human injuries, and security of electricity supply.

Unbiased and high-quality knowledge dissemination to the power systems community by CIGRE Study committees is a strong pillar for the development and performance of power systems.The ongoing energy transition is driving the addition of weather sensitive and energy limited energy resources in the grid. There is growing demand for space heating/cooling, digitalization, electrification of transport sector, induction cooking and emergence of new class of bulk load like electrolysers and data centres. This is dramatically changing the electrical energy consumption and power flow patterns in the power system. Vulnerability of the power system to extreme weather events/low probability high impact events is rising on account of climate change and other factors. Considering the ongoing energy transition as well as growing threats to power system the focus of preferential subject 1 was to explore alternatives to create operational resilience to extreme/unpredictable events while the focus of preferential subject 2 was to explore pathways to enhance flexibility, strengthen operational planning studies and restoration strategies in the power system having high share of inverter based resources in the grid.

SC C2 had 2 PSs and 54 papers coming from 33 national committees.

An overview of the main conclusions of each PS is given next.

2. RUNNING OF THE MEETING

The Discussion Group Meeting was chaired by the Study Committee Chairman, Jayme Darriba Macêdo, from Brazil, with Vivek Pandey, from India, and Ronan Jamieson, from United Kingdom, as Special Reporters and Flávio Alves, from Brazil, as SC C2 Secretary.

3. CONTRIBUTIONS TO PREFERENTIAL SUBJECT 1

Preferential Subject 1: Create operational resilience to extreme/unpredictable events

• Natural phenomena forecasting applied to operation planning studies & real time decision support.

• Threats and hazards from other systems that affect supply/demand of electricity.

• Lessons learned & best practices to deal with high impact/low probability events on system operation.

Special Reporter: Vivek Pandey

In Preferential Subject 1, 24 papers from 15 national committees were presented which included 01 NGN paper from China. The contributions highlighted the threats to reliability of power system due to weather extremes, natural disasters, geomagnetic induced currents, resonance, voltage instability, declining inertia, and challenges associated with inverter-based resources. Lessons learnt and best practices related with operation planning with growing uncertainties, solar PV power prediction in snow bound areas, vegetation management, application of synchro phasors for - linear state estimation, reliability assessment and estimation of oscillation modes. Use cases of deployment of machine learning for alarm management, case studies highlighting strategic interventions for ensuring resource adequacy, mitigation methods for potential resonance over voltage, validation of 3-dimensional empirical geo electric field model have been shared. Lessons learnt from grid disturbances and possible strategies for co optimization of multiple distributed resources to improve speed of system restoration have been discussed in the papers.

PS1 received 16 prepared contributions from 7 national committee viz Brazil, Ireland, Japan, Russia, United Kingdom, United States of America, Vietnam, Sweden and Germany. In addition, there were around 15 spontaneous contributions from national committees of Sweden, Germany, Brazil, India including four by an NGN member from India. There was one paper presentation by an NGN member from China.

Contributions under the PS1 sub-topic 1 highlighted emerging threats to power system from extreme and unpredictable events, geomagnetic induced currents, natural disasters, weather extremes, HVDC equipment failure, low system inertia, fault ride through issues, floods, cyclones. The discussions focused on resource adequacy assessment, system security, flexibility, resiliency and deployment of new technologies for decision support. Risks from supply chain constraints in natural gas, cyber security, largest contingency from load side, fresh-water shortage were flagged. Concerns were expressed on impact of disruptions in power system on other sectors like traction.

The prevailing challenges associated with operational planning and resources adequacy assessment was highlighted. Members expressed that reliance only on historical data to predict the future could be risky because of unpredictability of the future. It was suggested to consider transmission constrains in the resource adequacy planning. Suggestions included review of traditional metrics for resource adequacy assessment, considering the locational aspects and intertemporal impacts of storage and other energy limited resources in short term resource adequacy for few days ahead. There was a consensus on need for integrated resource planning, balanced portfolio of diverse generation technologies to support reliable operations, considering long duration energy storage, interconnection with neighbours, demand side flexibility for addressing resource adequacy concerns. Adequate compensation and incentives are required to enhance flexible resources

Contributions highlighted threats to power system from geomagnetic induced currents, natural disasters, weather extremes, HVDC equipment failure, low system inertia and fault ride through issues. Various measures to enhance system resilience such as installation of bulk power system stabilizer (BSS), black start relay, sharing of electrodes in HVDC stations, long duration energy storage, demand side flexibility, enhancing system inertia by using motor-generator set/virtual synchronous inertia/synchronous phase modifier, vegetation management, strengthening of compliance testing of inverter-based resources, review of

under frequency load shedding schemes, rate of change of frequency settings, review of reliability standards and implementation of emergency control systems were recommended.

For ensuring system security with emerging vulnerabilities, members emphasized, need for more realistic models to simulate power system dynamics as well as impact of geoelectric field on the power system, assessment of static and dynamic reactive reserves in addition to active power reserves, review of under frequency load shedding schemes and rate of change of frequency settings review of reliability standards, strengthening of compliance testing of inverter-based resources, better vegetation management, implementation of emergency control systems installation of bulk power system stabilizer.

Several strategies to enhance system resilience were suggested. Installation of black start relay to facilitate charging of lines during restoration, sharing of electrodes in HVDC stations, new black start restoration generation facilities, creating flexibility in network topology through intrinsic enhancements in strategic substations with the help of busbars arrangements, busbar splitting, exchanging circuit bays. Topology optimization analysis was recommended by members for congestion alleviation. Long duration energy storage, demand side flexibility enhancing system inertia by using motor-generator set in combination with storage batteries, virtual synchronous inertia/synchronous phase modifier, Deployment of V2G and B2G along with topology optimization, Integrate multiple forecast /advance warning and geo spatial mapping of the critical infrastructure to improve the lead time for reaction and mitigation measures, Deployment of emergency restoration system and training for disaster resiliency training, Communication back up and auxiliary supply for communication system, Integrate grid forming capabilities in various devices could be considered Human capacity building for reinforcing operational awareness

Two contributions shared the experience of artificial intelligence applications - to anticipate vulnerability to commutation failure and to facilitate the search and access to operating procedures. Integration of AI/ ML technologies with WAMS could be explored. Integrating technologies SCADA/EMS and WAMS for assist decision support. More automation for state estimator tuning and Integrated visualisation tools for the operators was suggested

During the general discussions there were concerns regarding emerging challenges for human performance at the control center and the application of new technologies for decision support. Members opined that reliability of automated decision making and human performance is critical for reliable operations. Collaboration for improving operator training, need for improving modelling tools were stressed upon. Reinforce the offline support to real-time control centre operations

There was one presentation (C2-11877) from NGN under PS1 presented the possibilities of harnessing the vehicle to grid technologies for enhancing speed of post-event power restoration. It proposed co-optimization of multiple distributed resources such as electric vehicles, electric buses, photo voltaic storage bus stations and mobile energy storage systems to enhance flexibility of regional power scheduling, improve speed of post-event power restoration.

4. CONTRIBUTIONS TO PREFERENTIAL SUBJECT 2

Changes on system operation and control considering the energy transition

• Disturbances and system restoration in power systems with a high share of inverter-based resources.

• Flexibility and ancillary services for high-RES share environments.

• Power system operation strategies & operation planning studies considering a high share of RES.

Special Reporter – Ronan Jamieson

This preferential subject focuses on the three streams that are at the heart of managing and operating a safe, secure and reliable energy network that society expects. The transition from a predictable and scheduled fossil fuel-based system to a highly variable weather-based system needs new strategies and methodologies to enable this transition. Planning, operating and restoring these RES based systems are the biggest technical challenge for our generation of engineers and the next.

In Preferential Subject 2, 31 papers from 24 national committees were presented. In addition, there was 1 NGN paper from America. The energy transition is forcing changes in how system operation and control are managed by System Operators and those connecting to these changing networks. The papers submitted highlighted the range of challenges that are being faced due to this transition, PS2 submissions covered the complete timeline from

- planning the network, one paper seeks to optimise outage planning process to improve access, while others examined, offered insights and suggested methodologies to improve power system studies to ensure the reliability of the network.
- Outlining services that will need to be provided to the network operators in terms of flexibility and ancillary series. Numerous papers present results of the impact of using these services to manage system voltage control, inertia and frequency control using wind and batteries combinations.
- to post event strategies that will enable quicker restoration from the increasing number of Inverter based resources available the System Operator. Many papers outline learnings and strategies from disturbances due to increasing amounts of wind and solar connecting to their systems and increasing understanding and sharing of knowledge should reduce number and impact of these disturbances.

PS2 received 25 prepared contributions from 15 national committees.

Prepared contributions based on sub-topic 1 seeks to answers some of the challenges faced by System Operators and Users of the network from the growing penetration of Inverter based resources and challenges they pose in terms of causing system disturbances (e.g., high amounts of solar in specific regions) and in a worst-case scenario requiring system restoration. There were 10 prepared contributions addressing the questions asked and the consensus was that there will be no slowdown of these resources connecting to the network, and at the moment there is no reason they should be, assuming the correct testing approaches are used and the models provided are of sufficient quality.

The main theme of discussion for sub-topic 2 was based on understanding how flexibility and ancillary services are suitably available and utilised (and how should they be incentivised to connect - e.g. via a regulated or market environment). The reduction in system parameter like inertia due to a high share of RES impact other parameters like system voltage and frequency, therefore these RES need to provide services to assist in managing the overall system security and reliability. 5 prepared contributions helped answer some of these sub-topics challenges.

Better planning strategies should ensure smoother system operations, and these strategies are the focus of sub-topic 3. These strategies based on the different contributions submitted argue that all power systems require better power system study techniques, computational approaches and understanding and modelling of the interactions of the Inverter based resources. 10 prepared contributions highlight and provide solutions to the required strategies.

The NGN paper (C2-11872) shared experiences with the new challenges and solutions faced by power system operations as a consequence of the current trends in the energy transition and the resulting high share of Renewable Energy Sources (RES) and Inverter-Based Resources (IBRs). It also highlights the need for appropriate monitoring tools to provide fast and reliable situational awareness for operators to monitor and assess the real-time state of the power grid.

In the spontaneous contributions part, PS2 had a total of 21contributions. The spontaneous contributions lead to serval highly interactive discussions among the session members, these contributions covered a wide range of subjects from the complexities of modelling demand, are ancillary services really ancillary now or should they be considered as essential (especially if they are considered for system reliability). Other contributions considered the amount of demand that could be flexible and how reach the end consumers to increase participation.

6. CONCLUSIONS

The Group Discussion Meeting of SC C2 during the CIGRE Session have once more revealed the challenges and the increasing complexity that power system operation is facing and will continue to face in the future. There are major areas where developments are happening:

- Resource adequacy planning with growing uncertainties
- Solar PV forecasting in snow bound areas
- Demand side flexibility
- Geomagnetic induced current simulations
- System Protection Schemes
- System resiliency
- Deployment of artificial intelligence in power system
- Deployment of Wide Area Monitoring Systems
- Enhanced usage of wide area monitoring systems to assist in identifying system disturbances and solutions as early as possible
- Improved power system studies to better simulate potential issues early in the planning process thereby enabling early identification of solutions
- Improved understanding and shared learning on how to optimise frequency control using wind, solar in combination with battery storage
- The growing use of advanced computation techniques (machine learning, genetic algorithms) to speed up the process of finding an optimise solution

In conclusion, system operations and control will keep on developing innovative solutions and concepts to operate the power system today and in the future as the energy transition increases.