CIGRE Study Committee C4

PROPOSAL FOR THE CREATION OF A NEW WORKING GROUP[1]

WG N° C4.47	**Name of convenor:** Malcolm van Harte (SOUTH AFRICA) **Email address**: vhartem@eskom.co.za **Name of Co-convenor:** Dr Mathaios Panteli (UK) **Email address**: mathaios.panteli@manchester.ac.uk

Strategic Directions #[2]: 1	**Technical Issues #[3]:** 8

The WG applies to distribution networks[4]: Yes / ~~No~~

Potential Benefit of WG work #[6]: 3

Title of the Group: Power System Resilience (PSR WG)

Scope, deliverables, and proposed time schedule of the group

Background

The concept of resilience is of growing importance in the engineering, business, and natural science disciplines. This has led to interesting debates and attempts to define its role and scope in these different fraternities. In recent years, the impact of natural and man-made hazards on critical infrastructure, such as electricity, water, telecommunication, etc., has resulted in governments elevating the requirements to enhance the ability of critical infrastructures to absorb, prevent, and/or respond appropriately to the disruption of essential services (Berkeley Iii, Wallace, & NIAC, 2010; Government, 2010; UK Cabinet Office, 2011).

Despite the various efforts to scope and define resilience, there is no universal resilience definition, as this is a multifaceted and dynamic concept that is defined in the context of the discipline/field (Alexander, 2013; Kasthurirangan & Srinivas, 2010; Sanchis & Poler, 2013). Resilience is more than simply "the ability to bounce back" after a failure; an organisation seeking to be highly resilient needs to also continuously focus on aspects related to the potential for multiple failures at all levels of the organisation (Van Harte, Koch, & Rohde, 2011). Other fields of study (psychology, ecology, system safety, organisational resilience, and disaster management) offer alternative approaches to characterising resilience (Koch, Van Harte, Correia, & Van der Merwe, 2013).

Electrical infrastructure is one of the critical infrastructures that influence other essential services, such as telecommunication, water, etc. (Stapelberg, 2010). A major electricity-related incident can, therefore, have a significant impact on a country (Van Harte et al., 2016); it is, thus, critical that the electricity sector pursue resilience strategies. While reliability in the electricity sector is widely viewed as the ability of a critical infrastructure to "keep the lights on" in the face of "typical" and credible threats, resilience is viewed by some as the ability to face extreme events (the so-called high-impact low-probability (HILP) events), possibly never experienced before, and recover rapidly when "the lights go out" (Berkeley Iii et al., 2010; Panteli & Mancarella, 2015d). Power systems have been planned and operated to be reliable; however, this does not mean that they are resilient to HILP events.

The proposed working group should explore how a number of resilience conceptual models and case studies are utilised to demonstrate the application of resilience thinking in the electrical sector. This requires the demonstration of the conceptual difference between traditional reliability engineering and resilience engineering techniques. The resilience models may suggest that building a resilient power system would require a range of strategies to enhance the organisational and engineering capabilities in order to safeguard the system and react to these extreme conditions. Furthermore, new resilience-oriented metrics that go beyond the traditional reliability ones need to be developed, which would enable the impact quantification of these extreme events and the development of risk-based resilience and adaptation strategies, accounting for the interdependencies among critical infrastructures.

Scope

The aim of this working group would be to provide the baseline for enabling the shift from old, traditional reliability-oriented paradigms to resilience-oriented thinking and engineering.

1. **What are the current efforts being made to protect critical infrastructure?**

   Compile a literature scan of the current utility efforts and research conducted in the resilience field. Design and conduct an international survey, considering the scope of the Power System Resilience Working Group (including the regulatory framework, legislation, impact of physical attack on a substation, etc.). The survey results will assist the WG to obtain a view of the different efforts in the utilities, universities, and interested bodies. It may provide opportunities for collaborative efforts and alignment. The working group will summarise the survey results to capture a snapshot of activities and business practices implemented to support the implementation of assessment and management of the resilience of the power system. Furthermore, it will assist the working group to liaise with leading institutional efforts in the field of resilience.

2. **What is the definition of power system resilience in the electricity sector?**

   Despite the different attempts by organisations worldwide in the power and energy engineering communities to define resilience, there is not as yet a universally accepted definition, as resilience is a multidimensional and dynamic concept; hence, it is critical to review the existing approaches to power system resilience in order to derive the key features that set it apart from the traditional concept of reliability and to propose a framework for defining resilience in a way that would be widely accepted by the engineering community.

3. **What are the appropriate approach and methodology to be followed in analysing power system resilience?**

   Particularly natural hazards and extreme weather can have catastrophic impacts on a power system, usually resulting in large and sustained power interruptions. The first step would, thus, be hazard modelling and spatiotemporal vulnerability analysis of the network to such events. This should be complemented by a multiphase dynamic resilience assessment and advanced time-domain modelling of the network response to the external shock. Network and outage management during these events is also highly critical, catering for both operational and infrastructure resilience.

4. **What metrics should be used to quantify the resilience performance of a power grid in the face of a disaster (high-impact, low-probability event)?**

   The traditional reliability indices – for example, expected energy not supplied (EENS) or loss of load frequency (LOLF) – are not sufficient for resilience engineering purposes. Risk-based and resilience-oriented metrics should be used for quantifying resilience performance during such high-impact, low-probability events. These metrics should be capable of modelling and quantifying the actual response of the network during such events, for example, how fast and how low resilience drops during an HILP event and how fast it recovers. Spatial and temporal criticality analysis is also critical, from the individual network components to socio-technical systems and the human factor.

5. **How do we decide on, and plan, investment portfolios for boosting resilience?**

   In order to plan and achieve adaptation and resilience to HILP events, the need for a risk-based decision-making approach has to be recognised, which will enable the development of adaptive investment portfolios, with the aim of an optimum trade-off between investments in infrastructure and smart/operational mitigation strategies. This would help to achieve both resilience and cost targets.

6. **How should we define the critical infrastructure and the interdependencies among critical infrastructures?**

   Given the increasing level of complexity and interactions among sectors, it is critical to move towards "system-of-systems" thinking and engineering that capture multiple critical infrastructures and their interdependencies. For example, we should evaluate how multiple outages in a power system can cascade or escalate to interdependent infrastructures, for example, water and gas.

7. **What are the policy and regulatory framework to create the environment to encourage the adoption of prudent decision-making?**

   The PSR WG has to suggest a regulatory framework and the policy required to encourage utilities to adopt appropriate operational and investment decision-making to consider HILP events. The existing standards provide the guidelines for the former type of event, but less information and fewer guidelines are provided for the latter type of event. These should, thus, be updated (amended?) to serve as the baseline for developing networks with built-in resilience and flexibility.

Deliverables:

☒ Technical Brochure and Executive summary in Electra

☒ Electra report

☒ Tutorial[5]

Other Deliverables:

☒ International surveys on existing extreme events, practices adopted and regulatory models in Energy Industry

Time Schedule: start: October 2017 **Final Report**: December 2020

Approval by Technical Committee Chairman: M. Waldron

Date: 11/10/2017

Notes: [1] or Joint Working Group (JWG), [2] See attached Table 2, [3]See attached Table 1, [4] Delete as appropriate, [5] Presentation of the work done by the WG, [6] See attached table 3

Table 1: Technical Issues of the TC project "Network of the Future" (cf. Electra 256 June 2011)

1	Active Distribution Networks resulting in bidirectional flows
2	The application of advanced metering and resulting massive need for exchange of information.
3	The growth in the application of HVDC and power electronics at all voltage levels and its impact on power quality, system control, and system security, and standardisation.
4	The need for the development and massive installation of energy storage systems, and the impact this can have on the power system development and operation.
5	New concepts for system operation and control to take account of active customer interactions and different generation types.
6	New concepts for protection to respond to the developing grid and different characteristics of generation.
7	New concepts in planning to take into account increasing environmental constraints, and new technology solutions for active and reactive power flow control.
8	New tools for system technical performance assessment, because of new Customer, Generator and Network characteristics.
9	Increase of right of way capacity and use of overhead, underground and subsea infrastructure, and its consequence on the technical performance and reliability of the network.
10	An increasing need for keeping Stakeholders aware of the technical and commercial consequences and keeping them engaged during the development of the network of the future.

Table 2: Strategic directions of the TC (ref. Electra 249 April 2010)

1	The electrical power system of the future
2	Making the best use of the existing system
3	Focus on the environment and sustainability
4	Preparation of material readable for non-technical audience

Table 3: Potential benefit of work

1	Commercial, business or economic benefit for industry or the community can be identified as a direct result of this work
2	Existing or future high interest in the work from a wide range of stakeholders
3	Work is likely to contribute to new or revised industry standards or with other long term interest for the Electric Power Industry
4	State-of-the-art or innovative solutions or new technical direction
5	Guide or survey related to existing techniques. Or an update on past work or previous Technical Brochures
6	Work likely to have a safety or environmental benefit