# The Future of the Grid: operating reliable power systems to achieve a clean energy transition

Discussion document on the knowledge exchange held on the 13th of September 2023, 08:00 – 17:00

ESRG
ENERGY SYSTEMS RESEARCH GROUP
University of Cape Town

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# 1. Introduction

Globally, the transition from conventional power generators to high levels of variable renewable and distributed energy resources is already challenging traditional models of system operations. Yet achieving global net zero greenhouse gas emissions and universal energy access goals will crucially depend on reliable, stable, and decarbonised electricity systems. The reorganisation of electricity systems to integrate and manage high levels of variable renewable energy (VRE) and the associated investment in grid infrastructure are critical interventions in meeting global climate and development goals and South Africa's just transition aspirations but are not without their challenges.

A two-day international dialogue, learning and knowledge exchange on the effective operation of high variable renewable energy power systems was facilitated by the University of Cape Town, in partnership with the Presidential Climate Commission (PCC); and supported by the Australian High Commission in South Africa. It was held on the 13th-14th September 2023, Johannesburg, South Africa. This document provides a high-level discussion summary of the knowledge exchange conference that took place during on the 13th September 2023.

This knowledge exchange builds on two previous dialogues and one training webinar hosted by the PCC related to energy system planning and operations.

- The first dialogue was held on the 14th July 2022 and explored energy systems planning and balancing with a focus on how to balance electricity demand and supply in a manner that supports climate-compatible economic development.[1]
- The second dialogue on energy security and technological change explored electricity system reliability and sustainability in the context of technological changes. It was held on the 4th August 2022.[2]
- The training webinar on the 7th September 2023 focussed on an introduction to power systems concepts and theory from a technical perspective and an introduction to power systems planning in the real world.[3]

The knowledge exchange brought together global system operators and grid experts to South Africa with the goal of synthesising lessons and insights from power systems that share similar characteristics with the South African system. The focus of the exchange was to deepen the understanding in South Africa of this crucial area; to support the building of networks and peer-to-peer learning relationships that are critical to drive implementation; and prepare stakeholders for the transition to a higher VRE power system in support of clean air, energy security and access, and climate goals.

This document provides a discussion summary of the key themes from the learning exchange on operating reliable power systems to achieve a clean energy transition.

[1] See: Energy Systems, Planning, and Balancing
[2] See: Energy Security and Technology
[3] See: The Future of the Grid: Training Webinar on Power System Basics

# 2. Key themes from the international experience of operating reliable power systems to achieve a clean energy transition

This section provides a high-level discussion summary of the lessons learnt with respect to grid management in the context of operating increasing shares of VRE as presented at the knowledge exchange international conference.

The global decarbonisation agenda has led to carbon reduction and net zero commitments by many countries. In Ireland, net zero is to be achieved by 2050, after aiming to supply 40% of electricity by renewable energy sources by 2020, which increases to 80% by 2030. Denmark aims to achieve net zero by 2050 and 100% variable renewable energy supply by 2030. The UK committed to an 80% reduction in greenhouse gases by 2050 and aims to close all coal power stations by 2025. Different states in the United States have different climate change goals, California for instance has ambitious renewable energy goals, aiming to have 60% of energy by renewable energy and to achieve net zero by 2045.

The increase in variable sources of generation causes many intensified or new hurdles to electricity system control in South Africa. Typically, renewable generation sources are located in areas where traditionally electricity was not generated, are less dispatchable and more asynchronous, causing problems for the grid, as well as system stability and control. Paradoxically, as increasing levels of renewable generation are deployed, there will be times when supply is higher than demand and the excess of generation should be curtailed or stored. Load curtailment has been a standard practice in Germany for over a decade.

The challenges facing electricity system operation with increasing variable renewable energy supply can be summarised as follows:

- Generation forecasting becomes more complex and uncertain,
- System ramping requirements to enable intermittent electricity generation from variable renewable energy increase significantly,
- Energy balancing becomes more challenging as system stability and voltage management are more difficult to achieve,
- Sophisticated procedures are required to manage surplus supply from renewables during standard periods, including curtailment and other constraints, and
- High-speed shutdown requirements.

Some flexibility can be provided by dispatchable thermal generation, energy storage, demand side response, distributed energy resources (e.g., rooftop solar), electric vehicle-to-grid technology, hydrogen fuel and interconnectors with other countries. Other solutions include Time of Use rates, underground compressed air, offshore wind and wave technology and other emerging technologies.

In order to prepare the grid for periods with 100% renewable energy supply (as is the goal in Australia) the network must be extended and strengthened along with the establishment of generation resources; technical requirements must be redefined; operational tools and processes must be enhanced and regulatory and market reforms must be designed and implemented to support effective and efficient planning and operations. Digitisation of operations and markets is a prerequisite.

Grids in the future will need long-term storage solutions to address extended periods with minimal wind/solar production and will need renewable resources to provide essential grid services. Storage will be needed to provide ancillary services, intra-hour and multiple-hour ramping needs. In addition, markets for imbalance services can assist in enhancing grid reliability and integrating renewable energy resources.

In order to achieve the system operational capability required for higher variable renewable energy shares in the next decade(s) research must be undertaken and operational policies must be developed. Appropriate operational standards and system services will be required, based on enhanced integrated control centre technological development and tools to enable the system to be operated efficiently, effectively, and safely.

In addition, significant investment is required to reinforce the transmission network and to develop smart solutions such as ‘SmartWires’ and vehicle-to-grid technology to maximise network capabilities.