**TECHNICAL SUPPORT FOR CONTINUED SUPPORT ON REGIONAL MARKET FRAMEWORK IMPLEMENTATION TO THE REGIONAL ELECTRICITY REGULATORS ASSOCIATION OF SOUTHERN AFRICA (RERA)**

Grid Code Framework

for Interconnectors

**Prepared for:** **Prepared by:**

Office of Energy Programs Deloitte Financial Advisory Services, LLP

Bureau of Energy Resources 1919 N. Lynn Street

U.S. Department of State Arlington, VA 22209

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Acronyms

|  |  |
| --- | --- |
| BPA | Blanket Purchase Agreement |
| DOS | U.S. Department of State |
| ENR | Bureau of Energy Resources |
| IDMT | Inverse Definite Minimum Time |
| IEC | International Electrotechnical Commission |
| kA | Kilo Ampere (1000 ampere) |
| kV | Kilo Volt (1000 volt) |
| ms | Milli Second |
| RERA | Regional Electricity Regulators Association |
| SADC | Southern African Development Community |
| SAPP | Southern African Power Pool |
| TSO | Transmission System Operator |

# Overview

Work under *Technical Support for Continued Support on Regional Market Framework Implementation to the Regional Electricity Regulators Association of Southern Africa (RERA)* is funded by the United States Department of State (DOS) through the Bureau of Energy Resources (ENR) Power Sector Program (PSP). This work will continue support to RERA, as well as three selected pilot countries – Zambia, Namibia, and Botswana – to develop tools and procedures identified by the Market & Investment Framework (MIF) and the Framework Roadmap. The primary objective is to make further progress with specific generation and transmission projects, as identified by the Southern Africa Power Pool (SAPP) and RERA and to increase SAPP membership and participation in the regional electricity market.

In support of this objective, this document provides a Grid Code Framework for Interconnectors based on existing country-specific codes and SAPP operating guidelines. This Framework identifies possible improvements and addresses gaps in order to advance the process of creating a harmonized grid code for cross-border interconnectors amongst Southern African Development Community (SADC) countries, critical for the provision of effective and transparent access to transmission systems across borders and coordinated planning of interconnector capacities.

This Framework provides the minimum technical requirements for interconnectors to support the reliability and security of the integrated power system. Following standard language for grid codes, the text utilizes the passive voice.

During the course of this project, the Deloitte Team conducted a sustained effort to secure a non-disclosure agreement (NDA) with SAPP (through RERA), in order to obtain the SAPP Operating Guidelines as well as other critical information regarding the internal protocols and procedures used by the SAPP Coordination Center (SAPP CC). However, the Deloitte Team was unable to secure the required NDA after repeated attempts. As a result, this Grid Code Framework for Interconnectors – particularly the sections pertaining to Connection Code, Data Exchange Code, Operations Code, and Outage Coordination – was developed drawing from international leading practices for cross-border interconnectors, feedback provided by pilot country counterparts, and the following list of documents:

* The Namibian Grid Code, Electricity Control Board of Namibia;
* The Zambian Grid Code, Electricity Act, Government of Zambia;
* The South African Grid Code; and
* ENTSOE Network Codes.

## Scope

This Framework is intended only for cross-border interconnectors and shall be applicable to the following entities that may own a cross-border interconnector:

* Transmission System Operators (TSOs) and Transmission National Service Providers;
* Regional Operators and independent Transmission National Service Providers;
* International Power Traders; and
* Generation or end-use customers with cross-border interconnections.

## Definitions

“Interconnector” refers to a high-voltage electrical connection between two countries, either through an overhead transmission line, a cable, or transformer.

“Transmission System Operator” (TSO) refers to an entity that conducts generation dispatch, outage management, and reliability coordination.

## Requirements Not Bound By This Code

This Framework shall not apply to elements that are not directly connected to another country’s transmission system, unless a cross-border impact is demonstrated by the affected TSO.

# network code

The Network Code provides the minimum technical requirements for equipment that constitutes an interconnector, in order to maintain the reliability of interconnected systems.

## Equipment Design Standards

Primary substation equipment and transmission lines shall comply with the relevant International Electrotechnical Commission (IEC) Standards. Application shall cater to requirements of local law and be determined by or in consultation with the country’s TSO. The entities that own substations and transmission lines shall develop and maintain applicable standards for substation equipment and transmission lines, details of which shall be supplied to the other entities that are part of the interconnector upon request.

Each entity that is part of the interconnector shall provide documentary proof that their connection equipment complies with all relevant standards, both by design and testing.

Insulation coordination studies shall be performed for all interconnectors. Based on such studies, proper surge protections shall be provided at both ends of an interconnector.

## Clearances

The safety clearances for substation equipment and transmission lines shall comply with the relevant National Electrical Safety Code.

## Substation Arrangements

The standard substation arrangement shall be based on providing one busbar zone for every main transformer / line normally supplying that busbar. Section 9 describes the system reliability criteria to which the interconnector must adhere.

A double busbar with a circuit breaker bypass facility configuration or a breaker-and-half configuration shall be used on all interconnectors above 132 kV.

## Earthing and Surge Protection

The interconnector substations shall ensure adequacy of all earthing installations to provide for the following:

* Safety of personnel and the public;
* Correct operation of all protection systems; and
* Agreed design and performance levels.

Earthing isolators shall be provided at the substations where the fault level is designed for 20 kA and above.

Substations shall be provided with adequate protection to limit lightning surges to protect substation equipment.

## Tele-control

A stakeholder such as a local TSO or a Power Marketer may be permitted to maintain tele-control equipment in the substation yards or buildings to perform monitoring of its own equipment and other equipment as agreed with the relevant parties.

# protection requirementS

## Fault Levels

The fault levels at the interconnector substations shall be maintained at the same value agreed during the design stage. If fault levels are increased by more than 2% at an interconnecting substation, due to network upgrade or addition of new generators, the affected entity shall inform the other entity of the increase in fault level. Additionally, a joint impact assessment shall be carried out to determine possible solutions to mitigate the fault level increase.

## Circuit Breaker Operating Times

Maximum permitted high-voltage circuit breaker tripping and fault clearance times depend on system conditions, as defined by the respective TSO. Guidelines for fault clearing times, including circuit breaker operating times, are as follows:

* 80 ms for 400 kV and above;
* 100 ms for 220 kV and below 400 kV; and
* 120 ms for below 220 kV.

All circuit breakers associated with an interconnector shall be equipped with synch-check relays.

## Interconnector Line Protection

Interconnector lines shall be protected by two equivalent protection systems: Main 1 and Main 2. These systems shall be fully segregated in secondary circuits.

An additional earth fault protection shall be incorporated in the main protection relays or installed separately to alleviate possible deficiencies of distance relays in the detection of high-resistance faults.

Non-directional over current and earth fault protection functions shall be installed either separately or as an integral part of the main protection relay to provide backup.

The protection relays shall provide reliable protection against all possible short circuits and remote or local backup for busbar faults that are not cleared, as well as those that are not set to provide overload tripping. Where specifically required, feeder protection may be set to provide remote backup for other faults as agreed upon with other participants.

## Automatic Re-Closing

The interconnector lines shall be provided with automatic re-closing facilities. The settings for automatic re-closing shall be selected jointly by both interconnected transmission systems and the settings shall consider transient stability, secondary arcing duration, and environmental constraints.

## Power Swing Blocking

Distance relays on the interconnector lines shall be equipped with power swing blocking facilities. These facilities shall block unwanted operations of distance relays during power swing conditions, in accordance with SAPP Operating Guidelines.

## Tele-protection Requirements

Distance protection systems shall facilitate instantaneous tripping for faults anywhere on the protected line by making use of tele-protection facilities.

## Transformer and Reactor Protection

Transformer and reactor protection schemes shall be designed to provide the following minimum protection functions:

* Faults within the tank;
* Faults on connections;
* Overheating; and
* Faults external to transformer or reactor.

The following relay applications shall be used in the transformer and reactor protection:

* IDMT earth fault on both windings;
* IDMT and instantaneous over current relays on all windings;
* Current differential;
* High impedance restricted earth fault;
* Thermal overload; and
* Buchholtz alarm and trip.

## Shunt Capacitor Protection

All capacitors shall be equipped with sequence switching relays to limit inrush current during capacitor bank energization. Inrush reactors and damping resistors shall also be employed to limit inrush current.

The following protection functions shall be provided for all shunt capacitor configurations:

* Unbalanced protection with alarm and trip stages;
* Overcurrent protection with instantaneous and definite time elements;
* Earth fault protection with instantaneous and definite time function;
* Overload protection with IDMT characteristics;
* Overvoltage with definite time; and
* Circuit breaker close inhibit for 300 seconds after de-energization.

## Out-of-Step Protection

The purpose of out-of-step protection is to separate the two interconnected systems in a situation where the two systems fall out of synch due to a major disturbance in one system. In such situations, system separation is desirable in order to safeguard the security of the power system from any effects of the disturbance. The transmission companies shall perform coordinated studies to define the functionalities and settings.

# metering code

## Metering Code Overview

The metering point shall be located at each end of the interconnector or at a location mutually agreed by the interconnecting countries.

The transmission service providers of interconnecting countries may request an independent audit of metering installations. The requesting participant shall be responsible for any costs related to the audit.

The type, installation, operation and testing of metering equipment at each metering point shall comply with the relevant country’s metering specifications.

## Metering Requirements

The metering code shall contain the following elements:

* Each metering point shall be provided with main and check metering;
* Meters shall be capable of measuring both active and reactive energy;
* Meters shall be capable of measuring active and reactive energy flows in both directions;
* Meters shall be configured to store/record metering data in half hourly integration periods. Storage/recording must utilize non-volatile memory which can be maintained without external power;
* Meters or recorders shall be capable of storing data in memory for 40 days or more;
* Data stored in either a meter or recorder shall be remotely and locally retrievable;
* A telecommunications medium shall be connected to the meter / recorder where possible;
* The accuracy of meters shall be in accordance with the relevant country’s metering specifications;
* In the event of a metering installation being used for purposes other than metering data, such use shall not in any way obstruct metering data collection and accuracy requirements; and
* No secondary user shall interfere with the voltage transformer or current transformer circuitry.

## Data Validation

Data validation shall be carried out in accordance with the relevant country’s metering specifications in the event of the following scenarios:

* Inability to electronically access the meters;
* An emergency bypass or other scheme having no metering system; or
* Unavailability of metering data.

Data validation can include any of the following:

* Manual download of meter data;
* Estimation or substitution subject to mutual agreement between the affected parties;
* Profiling;
* Reading of the meters at scheduled intervals; and
* Estimation in a mutually agreed method.

## Meter Verification

Meter verifications shall be conducted in accordance with the relevant country’s metering code and meter readings shall be compared with the metering data base at least once a year.

## Metering Database

The network operator that owns the meters shall create, maintain and administer a metering database containing (in addition to meter measurement data) the following information for the previous 5 years at minimum:

* Name and unique identifier of each metering installation;
* The date on which each metering installation was commissioned;
* The connecting parties at each metering installation;
* Maintenance history schedules for each metering installation;
* Fault history of each metering installation; and
* Commissioning documents for all metering installations.

## Metering Database Inconsistencies

In the event that testing reveals that data in the metering database is inconsistent with the data in the meter, the party that owns the meters shall inform all affected participants, and corrections shall be made to the official metering data.

## Access to Metering Data

Metering data shall be accessed through a central database that stores all interconnector energy flows.

## Confidentiality

Metering data and passwords are confidential information and shall be treated as such at all times.

# interconNECTOR connection code

Any generator or load interconnection shall follow the relevant country’s Generator Interconnection Codes. Connecting a generator or a load to an interconnector shall not affect the interconnector’s originally approved rating and its power transfer capability. A joint impact assessment study shall be conducted by the countries associated with the interconnector before an approval for a generator or load interconnection is granted.

# data exchange code

The objective of the Data Exchange Code is to define the obligations of the parties involved with regard to exchange of information in order to operate a safe and reliable interconnector. Each entity on both sides of an interconnector shall exchange the following information:

* Substation single line diagrams;
* Substation equipment specifications;
* Substation protection philosophy and settings;
* Communication protocols;
* Transmission line design details; and
* System planning models.

The entities shall mutually agree on the format for provision of data.

# interconnector operations code

Interconnectors shall be operated per the relevant TSO and SAPP’s Operating Guidelines. The entities that are part of an interconnector shall cooperate with the TSOs in providing required information, such as maintenance schedule, in timely manner for reliable interconnected system operation.

TSOs will make all reasonable endeavors to maintain operation of a cross-border interconnectors unless it becomes evident that continued interconnected operation would jeopardize the system or damage equipment.

An interconnector may request that a TSO takes any available action to increase or decrease the active energy transfer by the way of emergency assistance. The TSO shall meet such requests provided it has the capability to do so without jeopardizing network integrity.

The TSO is responsible for restoring an interconnector after an interruption.

# maintenance outage coordination

It is the responsibility of an interconnector to request an outage from the TSO for planned maintenance, repairs, auditing, testing, or commissioning.

The TSO shall be responsible for sanctioning or refusing an outage, and for issuing the relevant operating instructions.

The TSO shall ensure the interconnector has contingency plans before it grants an outage.

The Maintenance Outage scheduling process shall be carried out in accordance with SAPP Operating Guidelines.

# planning and project development coordination

The two transmission companies involved in operation of the interconnector shall conduct joint planning studies, as well as coordinate project design, construction, and commissioning activities.

The planning process shall be divided into major activities, as follows:

* Identification of the project objective;
* Formulation of alternative options to meet the objective;
* Study of these options to ensure compliance with agreed technical limits, and justifiable reliability and quality of supply standards;
* Cost of these options;
* Determination of a preferred option; and
* Request for approval of the preferred option and project initiation.

During the planning and project development phases, the two transmission companies shall exchange information as described in Section 6.

# NEXT STEPS

This document should serve as the initial framework leading to development of a comprehensive grid code for cross border interconnectors across the SADC. As discussed at the outset of this document, the cooperation and participation of the SAPP Coordination Center will be essential in further updating and refining this framework. With the long-term objective of developing the SADC’s power sector, incentivizing investment, and reaching full electrification in all Member States, establishing a harmonized grid code across the region, similar to the one implemented in Europe’s ENTSO-e system, is a critical step. Such harmonization will improve the overall reliability of the Southern African interconnected system in addition to providing transparency to transmission project developers.