SMART SUBSTATIONS FOR SMART GRIDS: PIONEERING DIGITAL PROTECTION IN NAMIBIA

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Abstract

Namibia has taken a pioneering step in grid modernization with the commissioning of the Sekelduin Digital Substation, the country's first facility to fully integrate IEC 61850 digital protection and control systems. Developed by NamPower as part of its strategic supply upgrade in the Erongo region, the substation employs a hybrid protection architecture that combines conventional hard-wired systems with process bus technologies. This paper details the design and implementation of Protection, Automation, and Control (PAC) systems at Sekelduin, highlighting its feeder, transformer, and busbar protection schemes, redundancy strategy, and fibre-based communication infrastructure. By leveraging digitalisation while ensuring compatibility with legacy assets, Sekelduin sets a benchmark for transition toward intelligent grid systems.

Figure 1: PAC panels ready for FAT

1. Introduction: Digital Transformation in African Utilities

African utilities are under increasing pressure to improve efficiency, reliability, and sustainability while managing aging assets. Digital substations, built on IEC 61850 standards, offer interoperability, reduced wiring, predictive maintenance, and enhanced cybersecurity. Namibia's Sekelduin Substation near Swakopmund represents a milestone as the nation's first digital facility, combining process bus technologies with conventional systems. This hybrid approach preserves investment in legacy infrastructure while positioning NamPower for future renewable integration and intelligent grid operations.

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2. Project Overview: Sekelduin Substation and Strategic Objectives

The Sekelduin Substation is a **132/66/33 kV indoor switching station** supplied from Kuiseb Substation, 35 km away. It forms part of NamPower's Erongo region upgrade to support mining, industry, tourism, and residential expansion. Key elements include: - **Transformers**: one 60 MVA (132/66/22 kV) and one 20 MVA (132/33 kV).

- **Switchgear**: compact Mixed Technology Switchgear (MTS) for 132 & 66 kV, and gas-insulated fixed-pattern metal-clad switchgear for 33 kV.
- **Environmental Design**: housed indoors to withstand corrosive coastal and desert conditions.

Strategic objectives: - Enhance grid reliability and resilience.

- Enable renewable integration and scalability.
- Reduce maintenance costs via digital diagnostics.
- Mitigate copper theft through fibre-optic communication.

Figure 2: Compact switchgear and PAC panels in preparation for SAT

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3. Design Philosophy: Hybrid Architecture and IEC 61850 Integration

NamPower adopted a **hybrid protection model**:

- **Main protection**: fully digital IEC 61850 Edition 2 implementation with process bus, sampled values (SV), and GOOSE messaging.
- **Backup protection**: hybrid solution with hard-wired CT/VT connections, GOOSE messaging, and station bus integration.
- **Redundancy**: dual PRP (Parallel Redundancy Protocol) fibre-optic networks (LAN A and LAN B).

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his design ensures interoperability, future scalability, and resilience while maintaining backward compatibility with legacy assets such as conventional CTs, VTs, and Siemens 7SD610 relays at Kuiseb.

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4. Protection, Automation, and Control (PAC) System Implementation

The PAC system integrates Intelligent Electronic Devices (IEDs), Process Interface Units (PIUs), Intelligent Merging Units (IMUs), and Relay Panels into a coherent protection and control system. Key schemes include:

a) **HV Feeder Protection (132 & 66 kV)**
   - **Main IED**: line differential + impedance with FO tele-protection.
   - Functions: overcurrent, earth fault, frequency, power swing blocking, travelling wave fault location, synchrophasors.
   - **Backup IED**: earth fault, overcurrent, CB failure, auto-reclose.

b) **MV Feeder Protection (33 kV)**
   - Per-bay Main IEDs with differential, overcurrent, and earth fault functions.
   - **Centralized backup**: buszone protection for all bays, overcurrent, and earth fault.
   - Additional functions: synchrophasors, vector shift, autoreclose.

c) **Transformer Protection**
   - **20 MVA (132/33 kV)**: differential, restricted earth fault, AVR functionality, backup overcurrent/earth fault.
   - **60 MVA (132/66/22 kV)**: dual Main1/Main2 differential, restricted earth fault, AVR, synchrophasors, cross-tripping.

d) **Busbar Protection (33, 66, 132 kV)**
   - Low-impedance differential with two-out-of-two logic (main + check zone).
   - Backup functionality embedded within centralized schemes.

e) **Bay Control Functionality (BCF)**
   - Synchronism check, interlocking, command sequencing, alarm grouping, local HMI.
   - IEDs provide local mimic displays with event logging.

f) **Substation Automation System (SAS)**
   - Dual redundant networks with routers, managed switches, and PRP Red Boxes.
   - SIHMI and Station Gateway provide SCADA, automation, and inter-centre communication.

5. Infrastructure and Technology: Switchgear and Communication Networks

- **Relay Panels**: house main and centralized protection IEDs in control room.
- **Local Control Cubicles (LCCs)**: at switchgear, housing backup IEDs, PIUs, and IMUs.
- **Process Bus**: digitizes CT/VT signals for protection and control.
- **Auxiliary Supplies**: dual AC (230 V) and DC (110 V) redundant schemes feeding IEDs, breakers, and control circuits.
- **Fibre-optic Cabling**: segregated, overhead in control rooms, ducted in yard; eliminates theft and interference.

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6. Operational Advantages: Predictive Maintenance and Remote Diagnostics

Digitalisation transforms operations:

- **Condition-based maintenance**: devices continuously monitored.
- **Remote diagnostics**: via SIHMI and Station Management Computer (SMC).
- **Time synchronisation**: PTP IEEE 1588 ensures event correlation across devices.

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7. System Redundancy and Legacy Compatibility

Sekelduin ensures continuity via dual-path architecture:

- Digital sampled values + hardwired CT/VTs.
- PRP redundant LANs A/B.

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8. Conclusion: Toward Intelligent Grid Systems in Namibia

The Sekelduin Digital Substation marks Namibia's entry into the era of intelligent grids. By combining **digital IEC 61850 process bus technologies with conventional fallback protection**, NamPower has delivered a future-proof, secure, and reliable energy node. The project sets a model for utilities across Africa, proving that legacy infrastructure can coexist with digital innovation while ensuring resilience, cost savings, and readiness for renewable integration.