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# Development of NPP Safety Requirements into Kenya's Grid Codes

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## Abstract

For Kenya to connect a nuclear power plant (NPP) to the electrical grid, major safety requirements have to be met. These requirements are documented in the grid codes. As presently drafted, Kenya's grid codes do not contain any NPP requirements. Through case studies of selected grid codes, this paper will study frequency, voltage and fault ride through requirements for NPP connection and operation, and offer recommendation of how these requirements can be incorporated in the Kenya's grid codes.

***Key Words:*** *Grid codes, safety requirements, frequency, voltage*

## 1. Introduction

According to Kenya's Least Cost Power Development Plan (LCPDP) study period 2013-2033, the first NPP of 1,000MWe is expected to be connected to the grid in 2024. The interface between NPP and an electrical grid has relevance to each other in terms of nuclear safety, national infrastructure and commercial aspects. The key issues are the particular requirements of the NPP with regard to nuclear safety and a reliable electrical supply.

NPPs like other power plants have to qualify for grid operating parameter capability (e.g. frequency, voltage capability parameters). Careful attention must be paid to the design and operation of the electrical grid system and the interface between the NPPs and the grid, in order to avoid events that might challenge the safety of the nuclear plant.

In Kenya, the electricity industry is regulated by the state owned National Control Centre, which is under Kenya Power and Lighting Company (KPLC). Kenya's grid has a limited, voltage and frequency limits are exceeded in many occasions and blackouts of major parts of the grid are common.

The Kenya's grid codes, as presently drafted, implicitly assume that generators connecting to the transmission system are synchronous generators that have a controllable prime mover (can perform load following). NPP, now being connected to this transmission system, may not fit this model. It is notable that Kenya's grid codes do not include requirements relating to nuclear power generating plant. The grid codes therefore need to be updated so that they set out clearly the connection and operation requirements for these new types of generator.

## 2. Grid Codes

### *2.1. Importance of Grid Codes*

Grid codes are basically the rules to be followed when connecting generators to the grid. The grid codes within a transmission region are issued by the Transmission System Operator (TSO), for that region, with the purpose to ensure system stability. Since the purpose with the grid codes is to sustain system stability, the grid codes will depend on system needs. The grid codes contain power quality requirements as well as system stability requirements [1].

The manner in which the transmission system is operated can affect safe operating limits of the NPP [2]. Nuclear power reactors require robust and diverse sources of reliable electrical power supply during all modes of operation to meet fundamental safety functions. Grid codes must therefore take into consideration this important need for NPPs.

Grid codes act as a standard document for all the entities interacting in power systems as shown in Figure 1. It is the responsibility of the TSO to check whether the codes are being obeyed at every level or not. They address all significant concerns related to the grid.

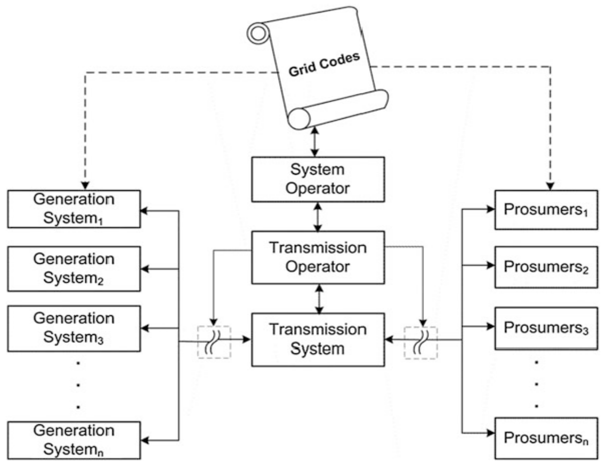


**Figure 1: importance of grid codes [9].**

*2.2. Classification of Grid Codes*

Grid codes are categorized into planning, operating, connecting data communication and balancing codes. This paper covers important aspects of connecting and operating codes as illustrated in Figure 2.

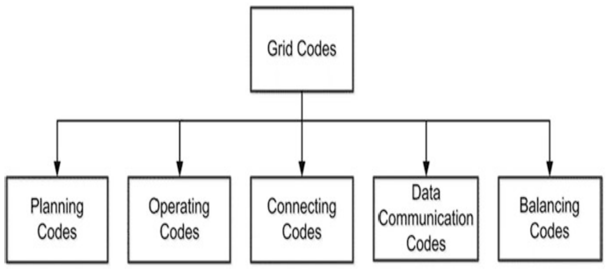


**Figure 2: Classification of Grid Codes [3].**

## 3. IAEA Grid Codes Requirements and Recommendations

International Atomic Energy Agency (IAEA) safety standards require that "The functionality of items important to safety at the nuclear power plant shall not be compromised by disturbances in the electrical power grid, including anticipated variations in the voltage and frequency of the grid supply." Further requirement is that, "Items important to safety for a nuclear power plant shall be designed in accordance with the relevant national and international codes and standards [4]."

The IAEA safety standards recommend that [5]:

- Grid codes should recognize the specific features and design requirements of nuclear power plants,
- The off-site power system should satisfy the nuclear safety criteria established in national and international standards, the grid code and electrical design criteria (as imposed by national electrical codes), and
- In accordance with national legislation, national grid codes or bilateral agreements between each transmission system operator and each power generating facility, a power generating facility should be designed in such a way that it supports highly reliable grid system operation.

## 4. NPP Connection to Grid and Operation requirements

Reliable electrical power is needed for most or all safety functions in the NPP. The safety systems of the NPP are designed for continuous operation with limited variations in voltage and frequency from the nominal values. Hence voltage and frequency of the electricity supply must also be controlled within a defined narrow range. This is often guaranteed in grid codes.

The electrical grid has been demonstrated to be the most reliable source of power for safety systems in the NPP. A stable and reliable grid would be one where voltage and frequency are controlled within pre-defined limits and disconnections are infrequent events. Generating units are required to meet certain technical performance requirements which are published in the grid codes. Figure 3 below shows required voltage and frequency ranges for NPP operation.

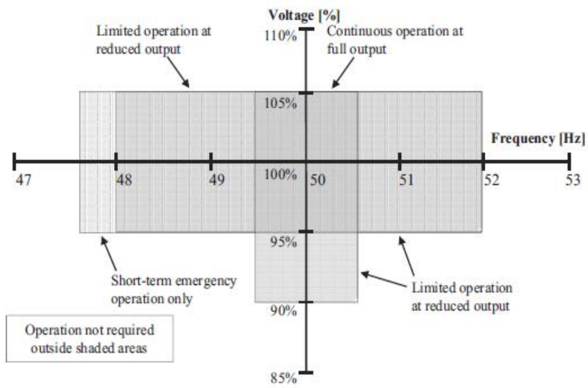


**Figure 3: Required voltage and frequency ranges for NPP operation [6]**

In addition, generating units should have 'fault ride-through' capability, so it will remain in operation (not trip) for defined transient events on the transmission system [6].

Frequency fluctuations set up transients in the NPP. If the frequency fluctuations extend beyond the normal dead band (100 mHz) of the governors, a disturbance is created in the NPP – change in steam flow into the turbine. Consequently, Flow of primary coolant in the NPP is affected and consequently the pump speed. Abnormal frequency variations above a certain magnitude will lead to isolation of the NPP.

Overvoltage may lead to damage to equipment, under-voltage may lead to tripping of auxiliaries, causing tripping of the NPP. Unfavorable voltage conditions at the NPP will affect the start-up of large motors and delay start-up of the NPP after the trip.

## 5. Kenya's Grid Codes and Grid Situation

Kenya's grid codes require that [7]:

- "The minimum steady state voltage magnitude on the transmission network will be 90% of nominal voltage and the maximum steady state voltage magnitude will be 110% of nominal voltage."
- "Plant shall not be required to operate in a sustained manner outside the range of the normal operating frequency excursion band but should remain in service for short-term operation in the range of 45.0 Hz to 52 Hz."
- "Short-time variations (of several minutes duration) within 5% of the intended values shall be considered in the design of plant by Code Participants."

Apart from the above three requirements, Kenya's grid codes have no other technical requirements to generating plants regarding frequency, voltage and fault ride through, NPP requirements are not included either.

Kenya's grid load flow simulation has shown that with a 600MWe NPP integrated to the Kenya's grid, under voltage violations to below 0.89PU would be experienced at the NPP switchyard bus due to suppressed generation (a very unacceptable situation with regard to NPP safety) [10].

## 6. Case Study

NPPs must be able to run at rated voltage plus a specified voltage range. The voltage range depends on the level of the voltage on the transmission system, which is 400kV, 220kV and 132kV nominal voltages in Kenya.

Comparison of different Germany and UK grid codes with operating NPPs show permitted voltage ranges shown in Table 1. These two grids are designed according to IEC standards which are applicable in Kenya. They serve as a reasonable comparison during the development of frequency and voltage safety requirements in Kenya's grid codes.

**Table 1: Germany and UK nominal voltage comparison**

| **Country** | **Germany** | | **UK** | |
|---|---|---|---|---|
| kV / Mode | Nominal Voltage | Voltage range | Nominal Voltage | Voltage range |
| Continuous | 400kV | -8% to 10% | 400kV | -10% to 5% |
| | 220kV | -13% to 12% | 275kV | ±10% |
| | 110kV | -13% to 12% | 132kV | ±10% |
| Limited time period | X | | 400kV | -±10% |
| | | | 275kV | ±10% |
| | | | 132kV | ±10% |

Table 2 shows specified voltage ranges are the most restraining requirements for these grids:

**Table 2: specified voltage range for continuous and limited time grid operation [1].**

| **Specified voltage range** | | | |
|---|---|---|---|
| Nominal voltages | Continuous voltage range | Limited time period | |
| | | 15 minutes | 1 hour |
| 400kV | -13% to 10% | -13% to 20% | -13% to 20% |
| 275kV | ±10% | -10% to -15% and 10% to15% | X |
| 220kV | -13% to 12% | % | X |
| 150kV | -3% to 13% | -3% to -10% and 10% to 20% | -3% to -10% and 10% to 20% |
| 132kV | ±10% | -10% to -20% and 10% to 20% | 10% to 18% |
| 110kV | -13% to 12% | X | X |

Normal NPP operation should be possible within the specified Voltage and frequency range and time limit as shown in Table 2 and 3.

Germany's grid codes does not allow operation for any frequency below 47.5Hz or above 51.5Hz but this is allowed for a limited time period in the UK grid codes and generic grid operation frequency requirements.

**Table 3: Germany, UK and Generic frequency range requirements for electrical grids [8].**

| Frequency range requirement | | | |
|---|---|---|---|
| Frequency (Hz) | Germany | UK | Generic requirement |
| 52.0 – 53.0 | X | X | 3 minutes |
| 51.5 – 52.0 | X | Continuous operation | Continuous operation |
| 51.0 – 51.5 | Continuous operation | Continuous operation | Continuous operation |
| 50.5 – 51.0 | Continuous operation | Continuous operation | Continuous operation |
| 49.5 – 50.5 | Continuous operation | Continuous operation | Continuous operation |
| 49.5 -47.5 | Continuous operation | Continuous operation | Continuous operation |
| 47.5 – 47.0 | X | 20 Sec | 20 Sec |
| > 47.0 | X | 20 Sec | 20 Sec |

## 7. Recommendations and Conclusion

Voltage and frequency excursions in Kenya’s grid are notably frequently outside the generic requirement and the values observed by the German and UK grid codes. Kenya’s grid codes require continuous operation for ±10% of nominal voltage and 45.0 to 52Hz on the grid which poses safety issues for an NPP.

Considering stringent NPP connection to grid and operational safety requirements, and the importance of the TSO to NPP safety, more elaborate requirements need to be documented in the Kenya’s grid codes. UK and Germany have a history of meeting high standards of nuclear safety and it is therefore recommended that format like the one in Table 1 to 3 should be adopted. Kenya’s Grid code considering NPP should have:

- Strict rules for voltage variation, that is, -5% to +10% of the nominal voltage
- Strict rules for frequency variation, that is, 48Hz to 52Hz of the nominal frequencyand
- Effective protection system to address fault ride through, to maintain supply to the plant.

## ACKNOWLEDGEMENTS

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