NATIONAL ENERGY REGULATOR OF SOUTH AFRICA
INDEPENDENT TECHNICAL AUDIT OF ESKOM TRANSMISSION DIVISION

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1 BACKGROUND

“The National Energy Regulator (NERSA) is the regulatory authority established in terms of the National Energy Regulator Act, 2004 (Act No. 40 of 2004) with the mandate to undertake the functions of the Gas Regulator as set out in the Gas Act of 2001, the Petroleum Pipelines Regulatory Authority as set out in the Petroleum Pipelines Act of 2003 and the I Electricity Regulation.

As part of regulating the electricity industry, NERSA is mandated to ensure that Eskom Holdings complies with the National Transmission license and Grid Code, amongst other regulations prescribed by the regulatory authority.

The regulatory objectives as stated in the NERSA compliance monitoring transmission framework are:

- To establish a monitoring process that facilitates the measurement of compliance to license conditions.
- Ensure that all non-compliances are identified; corrective measures are instituted to rectify these non-compliances, monitored and followed through.
- Ensure that the transmission system is reliable and power transmission is sustainable during times of an increase in power consumption.
- Ensure that customers and regulatory requirements are met through high reliability, and that outages or possible outages are not as a result of negligence or carelessness.”

In continuously working on achieving these objectives, NERSA appointed an audit team comprising:

- Africon (lead consultant),
- EirGrid Plc (Transmission System Operator of the Republic of Ireland),
- Enzani Technologies (Local BEE consultant),

to assess Eskom Transmission’s compliance to the Grid Code and Transmission License requirements.

This report covers the auditor’s findings and recommendations resulting from the above mentioned audit.
2 PURPOSE OF THE AUDIT

The objectives of the audit, was:

- To perform a general assessment of the level of compliance of ESKOM Transmission to the licence conditions and Grid Code conditions pertaining to the “National Transmission Company” with regards to the roles as System Operator, Transmission Service Provider and Transmission System Planner.

- To determine the status and effectiveness of the ESKOM Transmission maintenance strategy, expansion plans and philosophies.

- To determine the execution and success of the ESKOM Transmission maintenance plan.

- To determine the effectiveness of the ESKOM Transmission refurbishment and expansion plans.

- To determine the effectiveness of operation of the interconnected power system.

- To assess the emergency preparedness of the ESKOM Transmission System.

3 CONTEXT OF THE AUDIT

The audit focused on all the technical business units of ESKOM transmission as per the license conditions, and focused on ESKOM Transmission’s role as:

- System Operator,

- Transmission System Planner,

- Transmission Network Service Provider.

This audit was conducted in an Independent manner, to ensure objectivity and improvement of service delivery in general, and assessed:

- The condition of the Transmission Networks

- The state of execution of ESKOM’s Transmission Maintenance and refurbishment programmes,

- The level of readiness to deal with shortcomings in the transmission network.

The scope of work of the assignment was to:

- Verify the status and effectiveness of the maintenance strategy, philosophies and the execution of the maintenance plan,

- Verify the utilisation of maintenance budget and determine problematic areas if they exist,

- Verify the quality of maintenance and operating activities (specifically adherence to OEM requirements and potential for errors of judgment),
- Determine asset status and condition of the grid and substations,
- Verify the adequacy of recording of maintenance and operating activities,
- Verify the accuracy of the quality of supply and outage reporting systems,
- Determine the adequacy of the process to identify and prioritise capital spending,
- Determine the adequacy of the process of investigating incidents,
- Verify the implementation of the recommendations arising out of the incident investigation reports,
- Determine the adequacy of the project supervision,
- Verification of the appropriateness of dealing with network outages, including response times,
- Determine the actual expenditure for maintenance, refurbishment and expansion in the last five financial years,
- A review of operational training and effectiveness in implementing emergency preparedness plans,
- A review of the implementation of system technologies that would provide operators with an early warning of impending system disturbances and recommended remedial actions,
- Develop a barometer to determine the generic level of compliance to license conditions for use by NERSA. The model shall be populated with the relevant Transmission data, and
- Visit at least 20 of Eskom Transmission substations that are representative of all areas, age and type of equipment in the country excluding those that are customer specific.

4 APPROACH

The objectivity of the audit process was a key priority throughout, and was achieved by assembling an audit team consisting of Africon professionals experienced in and knowledgeable of the South African electricity sector and EirGrid, with international experience in the field of System Operation and Transmission Planning. The third party to this team was Enzani Technologies who participated with the purpose to build skills and capacity in the local engineering field.

One of the key objectives of this audit was that the results of the audit should have national benefits to the electricity industry.

The audit was conducted by using a single team for the project, with experienced subject matter experts leading each business unit to be audited.

A specialist team focused on licence and grid code compliance matters.

Additional to these teams, we would have a team of specialist advisors available as head office support to the field teams on an ad-hoc basis. They would carry out analysis in support of the field teams if required.
The audit was conducted by means of a series of workshops with Eskom transmission, focusing on business matters, and two site teams assessing the transmission plant by means of a set of assessment checklists.

The auditors focused on the processes, procedures and systems in support of the above functions at the time of the audit and on the delivery of key outputs. It was verified which processes, procedures and systems were in place, are they implemented, and if these ensure compliance to the Grid Code and Licence, and what this level of compliance is.

The approach of the auditors was to focus on the Eskom Transmission business areas, to obtain an objective view, and highlight “big picture” issues which need to be addressed, rather than just a “box-ticking” exercise.

A comprehensive audit report was compiled at the end of the audit, focusing on each of the areas described above.

Provision was made for capturing Eskom Transmission’s comments on these reports.

During the audit, the auditors took cognisance of the economic and socio political environment in which Eskom Transmission must operate.

These include aspects such as:

- The inherent growth in electricity demand together with initiatives such as ASGISA and rural electrification are driving a need for substantial investment in new generation capacity and in additional transmission to connect the new generation and serve the growing load.

- At the same time, there is a need for increased investment in replacement or refurbishment of existing transmission assets.

- A competitive wholesale electricity market has not yet been established, but transparency now will facilitate the ultimate establishment of such a market in Southern Africa with all its benefits.

- There is a risk of delays and obstacles to the delivery of transmission projects: obtaining uncontested Records of Decision (RODs), manufacturing and construction constraints, engineering skills issues,

- Growth in demand and delays in completing necessary reinforcements combine to make it difficult to schedule outages with knock-on effects on both maintenance and construction.

- There are significant Human Resources constraints in Eskom Transmission due to the age and experience profile of the staff and the falling life expectancy in South Africa.

### 4.1 Introduction to the Eskom Transmission Grid

Eskom Transmission plans, operates, expands and maintains the transmission grid supply infrastructure in South Africa.

This grid currently comprises approximately 27,000km of high voltage transmission lines and 150 high voltage substations.
This grid interconnects the main centres around the country, and transports electricity from the coal fired power stations concentrated mainly in the Northern and Central regions of the country. It also transports electricity from the hydro power stations, gas stations and pumped storage generators. The transmission Grid also interconnects South Africa to neighbouring countries: Namibia, Botswana, Zimbabwe, Lesotho, Swaziland and Mozambique. Eskom Transmission is also responsible for operating the South African portion of the 533kV HVDC link from Cahora Bassa in Mozambique to Apollo in the Central region.

The network operations and maintenance of the 132kV, 275kV, 400kV and 765kV voltage levels are segregated into seven grid boundaries.

Figure 1: Map of the Eskom Transmission Grid

The supply network continues to face a number of challenges as the demand for electricity in South Africa increases. When the growth in demand reaches levels where the electricity generation is increasingly outweighed by the demand, firm supply and availability of alternative routing in supply becomes problematic.

One of these challenges is the supply of electricity to the Western region as this is one of the most critical areas in the network, namely the electricity supply backbone from the Northern grid in Mpumalanga, through the Free State Region, into the Western
Region. This region has one main power station (Koeberg nuclear power station) which, under normal conditions, serves about 50% of the demand in the Western grid and the rest is supplied by the above mentioned supply backbone.

In the event of a planned maintenance outage of one of the two Koeberg units, the rest of the backbone carries about 75% of the load, while the usage of the peaking generation (Gariep, Van der Kloof Hydropower Stations and Palmiet Pumped Storage Power Station) are used to supplement the rest of the demand on the grid.

4.2 The Growing Demand for Electricity on the South African Electricity Industry

The predicted electricity growth rate of South Africa is on average between 6 – 12%. This would have an impact on the entire electricity supply industry which includes Eskom and the Municipalities.

The figure below illustrates the compound effect of various growth rates over a period of twelve years.

![Load Growth](image)

Figure 2: impact of different load growth values over twelve years

This implies that for an electricity growth rate of 12% per year, the complete electrical system (generation, transmission lines and substations) should be increased twofold in 5 – 6 years. A growth rate of 6% results in a 50% additional capacity (i.e. 50% more generation, substations and lines) required in 7 years, where 100% additional capacity would be required in 12 years.

The aforementioned argument does not take into account the actual load factors of the electricity networks, which could result in lower levels of capacity increase requirements. Full consideration of the actual network load profiles will require a dynamic and complex study, which did not form part of the scope of this audit. The auditors merely used the aforementioned arguments to raise awareness of the implication of load growth, especially if refurbishment requirements are also taken into consideration.
The electricity supply industry usually strives to match the supply to the demand, which could impose severe pressure on the existing electrical equipment suppliers, as these suppliers are currently running at maximum production capacity. Delivery periods of the equipment could be seriously effected.

An additional fact to consider is that the Eskom Transmission 275kV equipment is approximately 30 years old. A large number of circuit breakers and instrument transformers are therefore due for refurbishment and replacement.

Aged equipment requires more frequent maintenance. Old protection schemes are not as fast as modern schemes, and could result in decrease of QOS due to increase in system demands.

Care should also be taken to execute the required network expansion refurbishment and maintenance a manner which does not result in “Availability of Supply” problems.
5 AUDIT FINDINGS AND RECOMMENDATIONS

The main findings and recommendations of the auditors are summarised as follows:

5.1 Transmission System Planning

The primary function of effective transmission planning is to identify the transmission asset investment requirements necessary to ensure that the load can be supplied with appropriate reliability and at minimum overall cost to the electricity consumer.

The audit found that the approved processes and procedures required for effective transmission planning are in place, thus facilitating compliance with the relevant Transmission Licence and Grid Code provisions. In carrying out its system planning tasks, the Eskom Transmission planning function is guided by and applies these procedures.

However, the auditors would like to highlight the following major concerns in this area:

- The continuing growth in electricity demand in South Africa, together with the development of new generation to supply the growing demand means that major investment in the transmission system is required. Whilst the plans for such investment have been prepared and approved, the implementation of the investment is a major challenge. It will be important that Eskom Transmission and NERSA monitor closely progress in the delivery of the major reinforcement projects.

- The criteria for network investment are set out in Section 7 of the Network Code. Compliance with Section 7 is outside the scope of this audit. However, compliance with the provisions of Section 7 tends to delay investment in the strengthening of the transmission system. Section 7 and its application to the major transmission corridors should be reviewed.

- To ensure joint optimisation of investment taking account of needs driven by ageing and needs driven by expansion requirements, it is important that there is communication with regard to expansion and refurbishment requirements at the earliest possible stage. A formal process to make Transmission Planning aware of refurbishment needs, and to take future system requirements into account in developing refurbishment strategies, should be developed and introduced.

- With regard to applications for connection to the transmission system, there are processes in place to manage and track the processing of applications and to carry out all the necessary associated analysis. The processing of some applications is not completed within the timescales set out in the Network Code. However, it appears that the processing does meet the requirements of the applicants (demand customers applying through KSACS and distribution customers - Eskom and municipalities).

- With regard to provision of information, Transmission Planning is in compliance with Licence and Grid Code requirements.

- To carry out all its functions in compliance with the requirements of the Licence and Grid Code, Transmission Planning must have sufficient staff with the necessary skills, expertise and experience. At present, there are relatively few staff members in Transmission Planning with more than five years experience.
Therefore it is essential that Eskom Transmission implement appropriate staff recruitment, training, development and retention measures. Eskom Transmission is fully aware of this challenge and is developing business-unit wide policies to address it.

5.2 System Operations

The conclusion of the auditors is that the System Operator is in overall compliance with the Grid Code. One non-conformance issue was identified: commissioning, is not carried out in full compliance with Section 13 of the System Operation Code.

- The Emergency Preparedness Plans (EPPs) are well developed and are excellent guidelines for efficient substation restoration. Operation Thekgo will lead to some communications protocols issues within the documents. The Life Cycle guideline requires correct signing-off. There will be a requirement to bring all EPPs into their life cycle. The Auditors recommend that one drills per annum in each Grid, including at least one night drill, be scheduled starting in the financial year 2007/8. Until these items are completed, Eskom Transmission is only in partial compliance with Section 8 of the System Operation Code (Emergency and Contingency Planning).

- There is a need to develop a comprehensive Blackstart plan for the complete Grid. The draft plan presented needs more development. There is a need to carryout at least one live System test every year, as required by the Grid Code. Until these items are completed, Eskom Transmission is only in partial compliance with the Grid Code chapter 8 (Emergency and contingency planning).

- Load shedding is a very well developed defensive scheme making full use of voluntary and mandatory load shedding. The Gentleman’s Agreement for restoration of voluntary shed load should be put on a formal footing. Until this item is completed, Eskom Transmission is only in partial compliance with Section 8 of the System Operation Code (Emergency and Contingency Planning).

- Automatic Frequency Restoration (AFR) schemes should be evaluated for mandatory load shed customers.

- A Prolonged Energy Capacity Deficit Plan, for rota load shedding, should be developed. Until this item is completed, Eskom Transmission is only in partial compliance with Section 8 of the System Operation Code (Emergency and Contingency Planning). This could fall under the umbrella of Operation Thekgo.

- The System Operator will require support from NERSA in developing and approving a System Operation Reliability Standard. This work is in progress.

- Eskom Transmission and the System Operator recognise the challenge represented, especially in the South African context, of developing and retaining skills. For the System Operator there is a need to increase expertise in the generation knowledge to deal with Grid Code issues. The reasons for poor staff motivation should be explored by a staff survey.

- The process for induction and training for all staff is well developed. The certification of operators ensures quality control. Consideration should be given to the reduction of the recertification timescale from three to two years. The large block of regular refresher training could be better focused at developing plans and procedures.

- The System Operator recognises that the introduction of the new Energy Management System in the National Control Centre (TEMSE) is a major challenge. To maximise the benefits offered by the new tools there will be a need for extensive training. This training should be carefully monitored and
extra training offered, if required. There is a need to develop a certification programme for TEMSE certification. The tools demonstrated in the NCC were state-of-the-art and well understood and supported.

- Fault and system event reporting and investigation are well developed. There is sound reporting and excellent follow up and auditing. Some procedures were noted as being out-of-date. Some review of responsibilities and reporting will be driven by the outcomes of Operation Thekgo.

- The volume of exemptions and derogations from the Grid Code should be of concern to a prudent System Operator, these include:
  - Generation scheduling;
  - Transmission scheduling co-ordination;
  - Excitation systems for generators;
  - Reactive capability for generators;
  - Generator islanding capabilities and testing thereof;
  - Voltage control and Quality of Supply (QOS).

### 5.3 Network Service Provider

The auditors found the network services processes, procedures and systems generally in compliance with the Grid Code.

The auditors did however identify the risk areas listed below, which, if not attended to in time, could increase and eventually result in non-compliances and associated network failures:

- Skills shortages due to the ever aging skills base, and the limited number of new skills.

- Impact of the refurbishment backlog, compounded by the planned grid expansion, on the existing resources both within and outside Eskom Transmission.

- There also seems to be limited integration between the compiling of the refurbishment and expansion planning process.

- The ever increasing network fault levels could eventually result in some of the substations, especially the older ones, not complying with the new fault levels. If the busbars and earthmat designs are not re-evaluated and re-designed where necessary, risk of catastrophic failures and personnel safety will increase.

The recommendations for the above listed findings can be summarised as follows:

- Focused initiatives to retain skilled staff.

- Programmes and initiatives for “shadowing” experienced staff or succession planning and dedicated programmes to develop and broaden new skills base.

- A more comprehensive planning process, which not only focuses on funds, but also includes aspects such as resources, contractors, availability of maintenance equipment, and plant and equipment lead and delivery times. This process should focus on reducing duplication of efforts (plant refurbished only to be replaced a few years later) and ensuring priority corridors are getting the
necessary attention to ensure that quality and availability of supply targets are kept and improved upon.

- The review of network substation busbar and earthmat fault capacity as part of the annual network fault review process.

### 5.4 Grid Condition

Although the auditors found the transmission grid to be in a good condition and well maintained, a number of risk areas were identified, which if not attended to in time, could increase and eventually result in non-compliances and associated network failures.

These can be summarised as:

- The aging technical skills base, impacts of the refurbishment backlog compounded by the planned grid expansion.

- The aging of the major equipment such as transformers, circuit breakers and instrument transformers could, if not attended to by means of a well focused approach, present a risk to ensure “Quality of Supply” and “Availability of Supply”.

- The levels of the transformer dissolved gasses in oil can present a risk of transformer failure if not monitored and managed by Eskom Transmission.

- The substation yard stone and earthing of security fences present a risk to personnel safety.

- The corrosion of equipment at some coastal areas presents a risk if not managed proactively.

The summarised recommendations for the above are:

- To embark on initiatives to ensure a successful process of transfer of skills and training of personnel, with the full support from NERSA and the Government.

- To implement an asset management or life cycle management approach to the replacement, maintenance or refurbishment of equipment. This asset management process must be fully integrated with the load growth demands of the system, and must include track record of similar equipment, experience with similar equipment, common solutions.

- To fit all transformers older than 20 years and with a capacity larger than 200MVA be fitted with “Dry Keep” and gas analyzers, to closely monitor their condition, hence try and limit numbers of untimely transformer failures.

- To embark on a comprehensive transformer asset management process, which includes:
  - Sampling transformer oil on a regular basis.
  - Keeping a single database where all oil gasses of the grid transformers are analysed and monitored on a national basis.
  - Establishing an accurate trending analysis of each transformer oil gases.
• Implementing a national initiative to flag transformers which have gasses above the acceptable limits.

• Implement processes and procedures to co-ordinate and manage corrective action and replacement, thereby preventing degrading QOS due to transformer failures.
  
  o To adopt a consistent approach for the earthing of substation fences and gates, and ensure that the yard stone is at minimum levels to ensure safety of personnel.

5.5 Grid Code Compliance

In determining the overall compliance to the Grid Code, the auditors found that:

  o The System Operator, a Business Unit within the Transmission Division of Eskom (Eskom Transmission), is effectively administering the application of the Grid Code for users of the power system;

  o Eskom Transmission is identifying and administering the appropriate changes to the Grid Code, subject to the approval of NERSA;

  o There are processes in place within Eskom Transmission that facilitate compliance with the Transmission Licence (hereafter referred to as the “Licence”) and the Grid Code; and

  o These processes appear to be generally adequate to ensure compliance and are implemented appropriately, but are in need of improvement in some areas.

The auditors identified the following issues/recommendations:

  o Eskom Transmission should ensure that all relevant Grid Code documentation is made available to NERSA in a timely fashion for publication.

  o Eskom Transmission should prepare and provide NERSA with a list of all data and documentation that should be included on the Grid Code website. If data or documents are currently not published, provide these to NERSA, whether or not they have been previously provided.

  o Eskom Transmission should ensure that the membership lists of the expert teams as established under the Grid Code Advisory Committee (GCAC) are compiled and subsequently published on the Grid Code website. Alternatively the relevance of this requirement could be discussed with NERSA and/or the GCAC.

  o Eskom Transmission should ensure that the required number of GCAC meetings is held each year.

  o The Governance Code could be modified to allow for discretion on the number of annual GCAC meetings with the agreement of the GCAC members.

  o The auditors consider that in place of the cross divisional Eskom Expert Team meeting, it would be beneficial to hold a Eskom Transmission meeting, allowing representatives from the relevant functions of Eskom Transmission to meet to
discuss and debate Grid Code exemption and amendment requests in order to put forward an Eskom Transmission view to the GCAC.

- As the information required for a thorough investigation of some exemption requests may be somewhat confidential in nature to either the applicant or the applicant’s equipment supplier or service provider, the current process of reviewing and discussing of individual Grid Code exemptions at the GCAC meetings may need to be reviewed when the industry is fully deregulated. Parties may be reluctant to disclose commercially sensitive information if it is known that the whole industry will be privy to it, especially as the minutes of GCAC meetings are published.

- Due to the significant quantity of “legacy” exemption requests (from plant and equipment that was in service prior to the introduction of the Grid Code) that require to be processed, additional Eskom Transmission resources may need to be made available to ensure their timely processing. An action plan be which would identify where compliance could be achieved, what would be involved and how long it would take to achieve this would be of benefit.

- The Grid Code Compliance Matrix should be further developed to include if compliance to each Grid Code section has been achieved, and if not what the status is, including a link to any other relevant documentation associated with or related to this non-compliance.

- Eskom Transmission should ensure that GCAC meeting agenda items are circulated within the required time.

- The Governance Code could be amended to allow for additional agenda items to be added at short notice, but only with the agreement of all GCAC members.

- No evidence was provided to demonstrate that Eskom Transmission gives sufficient notice of the relevant NERSA Board meeting to an exemption or amendment applicant. It is recommended that sufficient notice be given.

- Eskom Transmission should extend its Grid Code assessment on a sample of the Transmission Grids to all Grids and to all areas of Eskom Transmission.

- Where non-compliances are identified in the above mentioned assessments, exemptions should be sought by Eskom Transmission from NERSA for the time required to achieve compliance. Regular updates should be provided to NERSA.

- No evidence was provided to demonstrate that Eskom Transmission keeps a log of all Incident Reports (IRs) both received and communicated to customers as required by the Grid Code. It is recommended that this log is kept.

- No evidence was provided to demonstrate that Eskom Transmission reports annually to NERSA on the number of live and closed out non-conformance reports (NCRs) for each customer category, and the number of disputes resolved. It is recommended that this reporting is done.

- The optional requirement in the Grid Code for a service provider to issue an IR or a NCR in the Grid Code is currently not compulsory. It is recommended that it be made compulsory in order to formalise this process.
6 CONCLUSION

The auditors found that Eskom Transmission complies in general with the Grid Code and Transmission Licence.

There are however risks and “gaps” identified in the various business areas, which would need attention in future to enable Eskom Transmission to remain in compliance, whilst embracing the present and future challenges facing the organisation.