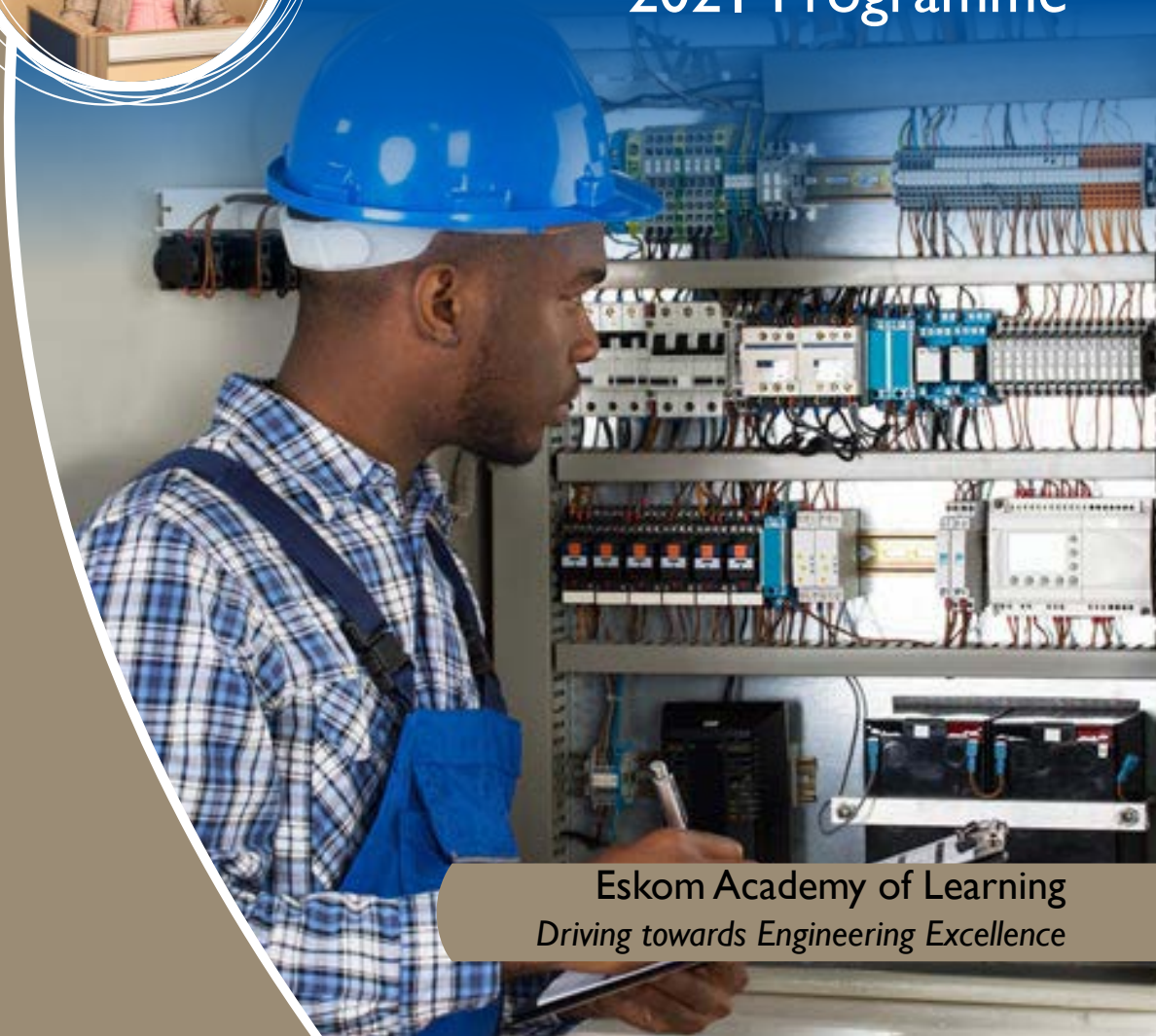
Eskom

Eskom Power Plant Engineering Institute

EPPEI

2021 Programme



Eskom Academy of Learning

Driving towards Engineering Excellence

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Foreword

Welcome to another edition of the EPPEI Programme Book, the last for the second phase of EPPEI.

As we all know, Eskom is still struggling to deal with the many technical challenges we face and in order to meet and overcome these challenges, Eskom Guardians need to be adequately capacitated so that they can adapt to the changing energy landscape, by acquiring relevant specialised technical skills and competencies through the EPPEI programme. With the acquired skills and competencies, the Eskom workforce will be better equipped to bring about the change required to turn around the organisation's technical performance in the specific critical areas and implement the Just Energy Transition pathway we have embarked on.

The Eskom Power Plant Engineering institute (EPPEI) is a partnership that was established in 2012 between Eskom and six universities, to improve the technical skills and knowledge of the electric power industry and, more specifically, Eskom's workforce. Close collaboration between industry and universities, including universities of technology, through specialisation centres in EPPEI has brought about significant benefit to the organisation since research and study towards postgraduate qualifications focus on Eskom-specific technical challenges. Not only were Eskom capacitated with specialist knowledge but also other engineers and technicians working in the wider power industry.

Recently a ninth Specialisation Centre was added, the Specialisation Centre in Engineering Management hosted by the University of Johannesburg. In this SC the focus will be on the project management of large infrastructure and maintenance projects to equip Eskom engineers to ensure these projects are executed on time, within the allowed budgets, reaching all the technical objectives.

Currently there are 149 students enrolled on the EPPEI programme 71 from Eskom, all of whom are working closely with Eskom industrial mentors and academic supervisors on Eskom-specific technical challenges. To date 310 students graduated, 49 with PhDs and 226 with masters, of these students 171 were Eskom employees.

In this Programme Book you will read about the current students who joined the EPPEI programme in 2021 and their projects. We look forward to their graduation as well as the outcome of the operational and applied research that will be implemented in the organisation.

Enjoy!

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2 EPPEI Eskom management team

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5 Asset Management Report & Completed project summaries

Since the inception of the EPPEI programme in 2012 a total of 38 masters degree research projects lead by the University of Pretoria and Tshwane University of Technology, have been completed by the Asset Management Specialisation Centre. During the early years, most of the attention was focused around problems related to the structural integrity of Eskom physical assets such as steam turbines.

A large number of student research projects were focused on resolving problems related to various aspects of steam turbine structural integrity. These projects included the development of probabilistic methods to account for uncertainties in material properties, damping, stress cycle histories, in the prediction of Eskom steam turbine blade fatigue life. Another example of the early work was the development of practical finite element modelling approaches to understand the torsional behaviour of turbo-generator trains. The focus of this research gradually converged towards the development of techniques which can be used to infer the levels of steam turbine blade vibration from measurements of the blade tip time of arrival at a particular point on a turbine casing. These techniques are commonly known as blade tip timing techniques.

This research lead to the development of a number of novel concepts which could be applied to conduct practical online condition monitoring of turbine blade vibration. Because of the potential impact of using such techniques for optimised operation of turbines that have exceeded design life, Eskom RT&D subsequently initiated a large project to implement these techniques for rotating blade health monitoring. This is a multiyear project which is led by Eskom RT&D in association with the centre at the University of Pretoria. Current EPPEI research aims to take these concepts even further and focus on prediction of blade remaining useful life, i.e. extending the diagnostic capability that was developed to a prognostic capability.

Since 2015 the range of activities of the specialisation centre expanded considerably with a much broader focus on asset life cycle management. An interesting example of this work is a project which developed novel techniques to measure maintenance productivity at Eskom. By applying rigorous statistical tests to empirical data from Eskom, the validity of measuring maintenance productivity as a strategic performance indicator was established and a relationship was found between strategy and productivity. It was shown that the relative ease of measurement and broad application of these metrics could be exploited by senior management engaged with strategic decisions.

Recently, Risk Based Inspection (RBI) became a very important focus area in the centre, as a a preventive maintenance strategy that combines prediction of the expected failure time based on statistical methods, with condition monitoring to prevent potential equipment failures. Various RBI implementation studies have been conducted at Eskom to investigate the efficiency and effectiveness of RBI implementation, and it is believed that this will have significant impact in Eskom in the future.

In another recent project a framework for the assessment of asset operational readiness (AOR) for new build power plant was proposed. The study developed AOR assessment tools, qualitative survey tools and scoring systems. It is anticipated that this will enable stage wise assessment of each component for individualized performance rating.

Asset Management: Completed Project

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Latent analysis of unsupervised latent variable models in fault diagnostics of rotating machinery such as mills, motors, generators, and gearboxes under stationary and time-varying operating conditions

Project summary:
In this work, latent variable models (LVMs) were used to capture a probabilistic representation of an asset in a healthy state. LVMs were used to detect deviations in the asset due to faults, and under a temporal preservation approach proposed in this work, it was shown that LVMs are well suited to performing fault diagnosis in vibration-based condition monitoring.

Project detail:
In this work, unsupervised latent variable models negate the requirement for asset fault data. These models operate by learning the representation of healthy data and utilise health indicators to track deviance from this representation. A variety of latent variable models are compared, namely: principal component analysis, variational auto-encoders and generative adversarial network-based methods. This research investigated the relationship between time-series data and latent variable model design under the sensible notion of data interpretation, the influence of model complexity on result performance on different datasets and shows that the latent manifold, when untangled and traversed in a sensible manner, is indicative of damage.

Three latent health indicators are proposed in this work and utilised in conjunction with a proposed temporal preservation approach. The performance is compared over the different models. It was found that these latent health indicators can augment standard health indicators and benefit model performance by extending LVMs into all facets of fault diagnostics, i) fault detection, ii) fault isolation, and iii) fault trending. This allows one to compare the performance of different latent variable models, an approach that has not been realised in previous work as the interpretation of the latent manifold and the manifold response to anomalous instances had not been explored. If all aspects of a latent variable model are systematically investigated and compared, different models can be analysed on a consistent platform.

Brian Ellis (PhD)
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Hybrid methods for determining the remaining useful life of turbomachine rotor blades

Project summary:

Hybrid methods for diagnosis and prognosis of mechanical components such as low pressure steam turbine blades have the potential of improving the accuracy and precision of remaining useful life predictions when historical fault data are scarce.

Project detail:

Fatigue crack propagation is one of the most common reasons for rotor blade failure in turbomachines. The vibration characteristics of a blade changes as it develops a fatigue crack. By measuring the vibration of these blades (using blade tip timing or stain gauge techniques), it is possible to identify the condition and predict the remaining useful life (RUL) of the blade.

The most recent developments in vibration-based condition monitoring techniques use physics-based models or data-driven methods to estimate when these blades will fail. However, there is no single ideal approach for predicting a component's RUL from its vibration characteristics. Different model types can lead to inaccurate or uncertain RUL predictions especially when the amount of representative failure data is limited.

The goal of hybrid methods is to combine physics-based models with data-driven methods. Hybrid methods for diagnosis and prognosis of mechanical components have the potential of improving the accuracy and precision of RUL estimation, especially when the historical fault data is scarce. This project focuses on the limitations and improvements of a hybrid approach for turbomachine rotor blades.

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Centrifugal compressor stage defects identification

Project summary:
This study addresses the stage performance prediction of an IGCC when only the compressor's overall performance characteristic, in conjunction with the impeller diameters and tip speeds, are known. The study is limited to IGCCs used in the coal-fired power generation industry of South Africa.

Project detail:
A stage stacking procedure was developed in contrast to the traditional stage stacking procedure. This procedure does not require a known operating point on each stage's performance curve, it assesses the relative stage performance at the compressor's surge flow rate. For this study the maximum pressure ratio of each stage is acquired through the application of similarity principles while a simplified 1-dimensional impeller analysis model is used to assess relative impeller head coefficients. The modelling process was developed based on performance and design data for IGCCs obtained from a compressor manufacturer. Performance data of four IGCCs, consisting of 13 stages, were obtained, including the design data for ten impellers.

The four IGCCs for which data were obtained, the stage-discharge pressure and isentropic efficiency curves were calculated using the developed model. The maximum variation between the III measured and calculated pressure and isentropic efficiency curves equalled 8.20% and 10.84%, respectively. The prediction accuracy of the developed modelling procedure is similar to map-based models found in literature and is considered adequate for identifying an underperforming stage. Thus, the developed model could serve as a valuable conditioning monitoring tool for site-based compressor owners.

Gregory Jansen van Vuuren (MEng)
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Extracting blade condition information from the pressure field around a turbine blade

Project summary:

Turbine stages are exposed to a variety of excitation sources in the power industry. This study is centred on investigating blade vibration and its relationship with the flow field through a steam turbine which is largely applicable to the power industry.

Project detail:

The resulting forced vibration excitation of the blades may occur near a blade's natural frequency. Blade vibration is an inevitable, inherent characteristic of turbines as the rotor blades travel through the trailing wakes of the upstream stator blades. Blade vibration can be worsened by other mechanisms such as pitting, corrosion fatigue and stress corrosion cracking commonly experienced in the power industry.

Measuring turbine blade vibration allows for condition monitoring of the blades for damage. This is often coupled with finite element models of the blades or with computational fluid dynamic models of the flow field around the blades. These numerical methods, although well-established, lack the complexity of the true multi-physics phenomena within a turbine. As the blade vibration measurement techniques essentially capture blade vibration that is the result of fluid-structure interaction (FSI), blade vibration should be modelled as a coupled problem, but this is usually computationally expensive. A rudimentary yet fundamental numerical model of a turbine stage is thus required to model the fluid structure interaction while minimising computational costs and retaining accuracy.

Asset Management: Completed Project

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Automated learning rates in machine learning for dynamic mini-batch sub-sampled losses

Project summary:
Gradient-only Line Searches (GOLS) are developed to resolve learning rates during neural network training as is often required for data dependent models in asset management applications. We find GOLS to be competitive with tuned constant learning rates without the need for hyperparameter tuning.

Project detail:
Learning rate schedule parameters remain some of the most sensitive hyperparameters in machine learning, in particular when mini-batch sub-sampling is considered. Mini-batch sub-sampling (MBSS) can be conducted in a number of ways, each with their own implications on the smoothness and continuity of the underlying loss function. In this study, dynamic MBSS, often applied in approximate optimization, is considered for neural network training, where the mini-batch is updated for every function and gradient evaluation of the loss function.

The implication is that the sampling error between mini-batches changes abruptly, resulting in non-smooth and discontinuous loss functions. This study proposes an approach to automatically resolve learning rates for dynamic MBSS loss functions using gradient-only line searches (GOLS). A systematic study is performed, which investigates the characteristics and the influence of training algorithms, neural network architectures and activation functions on the ability of GOLS to resolve learning rates. Matlab and PyTorch 1.0 implementations of GOLS are available for both practical training of neural networks as well as a research tool to investigate dynamic MBSS loss functions.

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Towards a deep reinforcement learning based approach for real-time maintenance decision making and resources allocation for prognostic and health management application. This approach is relevant to multiple Eskom applications.

Project summary:

Industrial operational environments are stochastic and can have complex system dynamics which introduce multiple levels of uncertainty. In this dissertation, the applicability of using a Multi-Agent Deep Reinforcement Learning based approach for decision making is investigated to determine the optimal maintenance scheduling policy in a fleet of assets where there are maintenance resource constraints.

Project detail:

This study considered the underlying system dynamics of maintenance capacity, as well as the health state of individual assets, a near optimal decision making policy found the increase equipment availability while also maximizing maintenance capacity. The implemented solution is compared to a run-to-failure corrective maintenance strategy, a constant interval preventive maintenance strategy and a condition based predictive maintenance strategy.

The proposed approach outperformed traditional maintenance strategies across several asset and operational maintenance performance metrics. It is concluded that Deep Reinforcement Learning based decision making for asset health management and resource allocation is more effective than human based decision making.

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Prevention maintenance optimization in a capital-constrained environment

Project summary:
Historically, preventive maintenance was regarded as a secondary business process that adds additional, albeit necessary, costs to production activities. This study research aims to develop an overall preventative maintenance optimization methodology concerning a budget for a specific plant that can be used in a decision process for an organization.

Project detail:
Historically, prevention maintenance was regarded as a secondary business process that adds additional, albeit necessary, costs to production activities. Recently this perception has changed, and more time and effort have been directed into attempts to optimize maintenance strategies within the context of sustainably achieving the business goals of organizations.

Due to the recognition of the importance of maintenance from an organizational perspective, a number of different maintenance-related approaches have been developed. These approaches include reliability centred maintenance, business-centred maintenance, total productive maintenance and life cycle costing. Common to all these approaches are techniques to optimize the maintenance strategies using material models.

The study focusses on data-driven optimization models that consider costs and the reliability performance of equipment. The practical implementation of these optimizing maintenance models presents two main challenges. Different models based on analysing the historical failure data of the system or component are considered in order to optimize the maintenance strategies to be applied to these two types of individual systems. A major limitation of these maintenance optimization models is that they all require failure data for their implementation, which is not always obtainable.

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Towards a hybrid approach for diagnostics and prognostics of planetary gearboxes

Project summary:
This project addresses several challenges related to prognostics methods for gearboxes that utilize a combination of physics-based and data-driven models. Combining these two types of model is an important step towards the development of digital twins that could be used to address problems related to issues such as gearbox failures in air cooled condenser gearboxes.

Project detail:
The reliable operation of gearboxes is critical for the sustained operation of many machines used in industry.

Hybrid diagnostics and prognostics methods aim to exploit the advantages of both physics-based and data-driven models. These methods have unique advantages that give them the potential for addressing the many challenges associated with the condition monitoring of planetary gearboxes.

In this project, a hybrid framework for diagnostics and prognostics of planetary gearboxes is developed. The proposed framework aims to diagnose and predict the root crack length in a planet gear tooth from accelerometer measurements. To do this, physics-based and data-driven models are developed and integrated into health-state estimation and health state prediction phases. Models developed include finite element models for estimating time-varying mesh stiffness, a lumped mass model for simulating the vibration response and the Paris crack growth law for remaining useful life prediction.

The application of the proposed framework on experimental and simulated gearbox data revealed specific challenges that need to be overcome before hybrid diagnostics and prognostics of gearboxes can be implemented in practice.

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Investigation into the efficiency and effectiveness of risk based inspection (RBI)

Project summary:

This study evaluates the efficiency of RBI implementation, costs for executing scopes of work prior to RBI implementation were compared to RBI scopes Pre-Outage and Post-Outage scopes execution costs on two power stations that were identified as the most advanced in the RBI implementation roll-out plans.

Project detail:

A proposed framework was developed for RBI implementation improvement methods. The results showed that RBI is generally a cost effective process when the prior RBI scope execution cost was compared to RBI scope execution cost. RBI could reduce the maintenance costs through scope optimisation and downtime reduction. The RBI implementation process was found deficient for the specific instances, based on the audit findings and bow-tie risk assessment conducted in the case study. The most significant improvement areas identified included, ensuring that RBI scopes are uploaded into the Computerised Maintenance Management System and there is only one consolidated final inspection scope submitted to Outage Department and tracked for tasks completion during the outage.

This study revealed that the case studied organisation is currently not efficient in implementing RBI, and could benefit significantly if they improve through executing the RBI maintenance inspection scopes as planned. The conducted interviews, recurring audit findings, and lessons learnt analysis demonstrated that the organisation is not effective, as it was successful in meeting only one from a total of six RBI implementation objectives. Extending the inspection frequencies to 72 months and beyond for some low risk components through RBI implementation was the only RBI objective in which the organisation met successfully.

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Informative frequency band selection for performing envelope analysis under fluctuating operating conditions in the presence of strong noise and deterministic components

Project summary:
Under varying speed and load conditions it is difficult to isolate bearing damage. Therefore, this research is aimed at identifying features of a vibration signal that are robust against varying speed and load and which would be suitable for implementation in applications such as coal mill gearbox bearings.

Project detail:
Effective incipient fault detection requires a method that can separate fault signatures under constant and time-varying operating conditions. Identification and optimal selection of the informative frequency band which contains fault information is the focus area of the research in this article. Many automatic band selection techniques exist and have proven effective under constant speed and load conditions. However, it has been shown that these techniques occasionally identify frequency bands that contain non-damage related information, especially under fluctuating operating conditions and at low damage levels.

With this research, a new methodology is proposed which makes use of popular informative frequency band selection techniques, such as the Fast Kurtogram amongst others, to effectively identify damage under constant and fluctuating speed and load conditions.

A key step in this methodology, the NICogram, requires healthy historical data, which is used to identify frequency bands that contain novel information in unclassified signals. The methodology uses multiple signals to identify whether a component is damaged or not through a probabilistic approach. It is shown that the method performs much better than the conventional informative frequency band identification methods on synthetic and experimental data.

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Asset operational readiness assessment of new build power plant equipment

Project summary:
This research aims to propose the best-practice AOR framework for meg-projects in the power generation industry. The survey shows that AOR implementation follows the Project Life Cycle Management (PLCM) principles, from conceptual and pre-feasibility phases to commissioning and operation phases.

Project detail:
The survey considers methodologies and techniques, which aids to enhance AOR framework development such as Root Cause Analysis (RCA) exercises. The study has provided an opportunity to develop an AOR theoretical framework refinement methodology, inclusive of RCA, AOR assessment tools, qualitative survey tool, and scoring systems. The AOR best practice framework and refinement methodology application to a real mega project case study, with historical data, enables a stage wise assessment of each component for individualized performance rating. This provides an identification of the areas that require refinement to have an improved AOR framework as outcome.

The research outcome shows that there are implications for inadequate development and implementation of items in the proposed framework. The implications range from rework during manufacturing and construction, poor product quality delivery, poor performance post commissioning, and overall cost overruns. In addition, the study provides evidence that implementation of the AOR framework aids a project to realize its potential and yield positive results, which ultimately benefits an organization in terms of quality product delivery, cost reduction, and optimal Operations and Maintenance of the established asset.

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A focused approach to RBI for boilers, the associated generic failure frequencies and damage factors and how it is applied

Project summary:
This study focusses on applying risk-based processes to create a relative risk ranking model for boilers by focussing on the corrosion fatigue mechanism of boiler tubes. Corrosion fatigue analysis as a failure mechanism, consists of the interaction between corrosion and fatigue, an in-depth study of the underlying mechanisms was conducted.

Project detail:
The increased energy demand within South Africa has led to continued periods of load shedding. This has had an adverse impact on the industry, quality of life and the economy as a whole. These activities have progressed from a predominantly time-based (prescriptive) approach towards a risk-based approach.

This study used the following generally accepted standards like BS EN 16991:2018 and API RP 580 give a comprehensive outline of the basic elements for developing, implementing and maintaining a risk-based inspection program. API RP 581 takes this outline one step further and contains the quantitative methods that support the minimum guidelines presented by API RP 580. None of these models are however directly applicable to predicting the failure of boiler equipment due to the mechanism of corrosion fatigue pressurized.

A systematic methodology to evaluate the risk associated with specific failure mechanisms in boilers, such as corrosion fatigue, does not exist or is not readily available. A comprehensive risk-based predictive model, using aspects of the abovementioned standards and guides, was developed to demonstrate the predictability of corrosion fatigue in sub-critical boilers. Weightings were assigned to contributory causes to corrosion fatigue, which then allocated relative risk ranks to certain segments within a boiler. Operators and owners of boilers can derive benefit from this model by focusing inspection, maintenance and alteration activities on those equipment locations with the highest relative risk score.

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Impact of coal quality on equipment lifetime at coal-fired power stations

Project summary:
While the impact lower quality coal has on cycle efficiency is understood, the influence it has on equipment reliability and lifetime is often not understood. The present study aims to investigate the impact of varying and deteriorating coal quality on the life-time and reliability of equipment in coal power stations.

Project detail:
The influence of coal calorific value and ash content has on air-heater element erosion was evaluated. This was accomplished by establishing a correlation between calorific value and ash content of coal from a specific colliery; this was then used to calculate the mass of fly ash and flue gas produced when burning enough coal to satisfy the boiler load. An erosion model was then used along with historical coal quality and air heater erosion history to develop and fit a model for full boiler load.

The model was verified against data not used during the development of the model, and a seemingly good prediction was made when compared to the measured result. The calorific value of the coal in the model was varied for a hypothetical situation; this indicated that as calorific value decreases the erosion of air heater elements increases. The influence abrasiveness index has on mill liners was also investigated as part of this study. Historical liner ultrasonic thickness and coal abrasiveness index results were used to fit a mathematical formula.

6 Emissions Control Report & Completed project summaries

The EPPEI Specialisation Centre (SC) for Emissions Control was established to assist Eskom in meeting the current and future environmental regulations with respect to particulate and gaseous emissions. To this end, the SC is involved in the quantification of pollutant emissions from Eskom power plants, the assessment of the impacts of the emissions on human health and the environment, and research and development on the technologies used to reduce these emissions to regulatory acceptable levels.

In terms of emissions quantification and the impact thereof the EC SC has worked closely with Eskom over the past years to establish a sound scientific understanding of the aforementioned. Through a series of activities that have included dispersion modelling, emissions calculations, emissions measurement, and field observations of ambient and indoor air quality and advanced source apportionment studies, the contribution of power station emissions on the Highveld have been quantified. Impacts from other important sources, especially the emissions resulting from the domestic burning of solid fuel in dense low-income settlements have also been quantified.

Currently Eskom is not able to meet all the Minimum Emissions Standards, and in addition to research on improving the emissions abatement units, emissions offset alternatives have also been investigated and interventions proposed through high quality observations and modelling. The EC SC has been actively pursuing research on one such offset intervention, namely the development of cost-effective, thermally efficient dwellings that can replace the current informal dwellings. Additionally, a novel low-emissions, semi-continuous coal stove that can be integrated into the thermally efficient dwellings has also been designed and is currently being tested. Apart from the abovementioned activities, the EC SC has also worked on modelling the distribution of mercury emissions from power stations and assessed the relative effectiveness of abatement technologies on these emissions.

In terms of research on emissions abatement technologies, the SC has developed a detailed, 3-D numerical model of the Kusile wet flue gas desulphurisation (WFGD) absorber. The model was validated using plant data provided by Steinmüller Engineering GmbH. The validated model can be used by the process engineers to simulate a range of plant conditions, which can greatly assist in process optimisation, troubleshooting, and diagnostic testing. The EC SC has also developed a process model for reducing WFGD water consumption through flue gas heat recovery, and in collaboration with Steinmüller Engineering GmbH., the model was validated against their proprietary WFGD Design Program. Using the model, water savings of roughly 30 % is predicted to be possible with the implementation of different flue gas heat recovery options. Such water savings would make WFGD water consumption comparable to that of conventional semi-dry FGD systems, which is also being studied within the SC. For example, the SC has also rendered support to Eskom on the design of the riser of a circulating fluidised bed (CFB) absorber of a pilot-scale semi-dry FGD system. The SC has also established world-class laboratory facilities that includes a resistivity measurement apparatus to characterise fly ash resistivity, which is a key factor that determines electrostatic precipitator (ESP) performance. Other laboratory facilities include a laboratory-scale ESP, fabric filter plant (FFP), and semi-dry flue gas desulphurisation (FGD) units, i.e. a laboratory-scale spray dry scrubber and circulating fluidised bed (CFB) riser. Apart from being used in research, the equipment can also be used for demonstration and training purposes.

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The Influence of SO_3 conditioning on the resistivity of selected South African fly-ashes

Project summary:

SO_3 flue gas conditioning influences the resistivity of fly-ash particles from coal combustion. Resistivity testing was conducted to log the influence of various SO_3 concentrations at various temperatures on the resistivity of fly-ashes.

Project detail:

Particulate emission legislation implies a particulate emission limit of 50 mg/Nm_3 (10% O_2, dry basis) for all new and existing power stations. Fly ash resistivity is key factor in ESP design and performance with South African ashes generally having highly resistive ash compared to e.g. American ashes.

The study experimentally quantified the relation between SO_3 ambient concentration and fly ash resistivity for industrially generated fly ashes. Industrially sampled South African fly ashes were tested in a laboratory test rig consisting of a temperature controlled oven, humidifiers, SO_3 injection system and a range of flow controllers.

It was found that the injection of SO_3 at ambient concentrations of between 10 and 20 ppm and constant moisture concentrations yielded a reduction of the resistivity.

Evaluation against the standard Bickelhaupt model for resistivity prediction showed a significant deviation from the experimental results, primarily over-predicting the resistivities. The differences were attributed to the elemental composition, where South African ashes show considerably lower levels of alkali metals and more specifically sodium. Modifications to the model were proposed to describe the South African ashes more accurately.

7 Energy Efficiency Report & Completed project summaries

Rising energy demand and the imminent threat of climate change are critical issues in society. Many energy conversion processes are a result of thermofluid systems to provide electricity, heating and cooling. The EPPEI Specialisation Centre in Energy Efficiency (EE) have expertise in modelling these systems. Such models can be used to improve the efficiency of existing plant and enable condition-based maintenance.

Models are built using tools available in industry. Tools such as CFD, the one-dimensional network approach or a combination thereof are used for modelling thermofluid systems. Cutting edge advanced analytics techniques such as machine learning and AI are used for data driven model order reduction. The combination of these capabilities enables the development of accurate and computationally inexpensive numerical tools applicable to industry needs. This work supports the recommendation by Professor Tshilidzi Marwala who urged South Africa not just to be users but also be builders of 4IR technologies. EE have been actively developing skills in this area. Results of these projects were presented to the Generation Process Engineering Steering Committee (GPESC). Implementation is supported by Pravin Moodley, Yashveer Maharajh and Alton Marx from Generation Asset Management.

EE started a partnership with Vaal University of Technology (VUT) in 2017. Ms Lethu Vilakazi is a full-time employee at VUT and enrolled for master's on a part-time basis in January 2017 under Professors Alfayo Alugongo and Pieter Rousseau. Her project enabled her to gain exposure to the power industry through her project which required her to perform an uncertainty analysis on measurements taken at Lethabo Power Station. She was guided by Charlene Govinden who mentored Lethu and enabled access to plant data for model validation. Lethu has enrolled for a PhD at UJ and participating in OMEP training through the foundation physics course.

In 2018 a project was initiated to investigate how the configuring burner swirl can improve heat uptake in the furnace at Lethabo Power Station. Several follow up investigations have been conducted at Lethabo, specifically the investigation of the impact of low load operation on radiant superheaters. This work is now being applied to other boilers in Eskom through task force projects supporting the modelling group within Generation Asset Management.

A master's project by Preetha Sewlall (Senior Engineer – Duvha Power Station) has been shown to be important for Eskom's water management. The approach adopted in this thesis was to learn from the existing Eskom Excel water management tools and develop a standard mathematical model that could be structured in EtaPRO calculation templates. These templates were to be structured such that they function as process components to develop water balances at a power station. It was concluded that it is possible to develop process models within the EtaPRO software from well-defined mathematical models to address the performance monitoring concerns on water systems within Eskom. The methodology is currently being rolled out within Eskom on EtaPro. These projects would have normally been conducted by external consultants. The research-based training approach has enabled Eskom engineers to lead strategic projects in Eskom. EE continue to support Eskom through participation in the GPESC, Boiler Process Care Group as well as the Process Engineering and Energy Efficiency Care Group.

Energy Efficiency: Completed Project

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Impact on heat rate and subsequent emissions due to varying operation of coal fired power plants

Project summary:

The project presents a novel approach for predicting the part load thermal performance of different coal fired power plants to enable more accurate emissions calculation in energy mix modelling.

Project detail:

Energy mix modellers often use a constant emissions factor/heat rate model when trying to show the emissions reduction benefits of integrating renewable power generation system on the grid. This approach could be misleading. Akpan developed a novel and simple Variable Turbine Cycle Heat Rate (V-TCHR) model for predicting the part load thermal performance of different Coal Fired Power Plant (CFPP) architectures. His model will enable more accurate CO_2 emissions impact studies for electrical networks with a substantial renewable generation. The research started with the development and validation methodologies for setting up representative CFPP process models using the VirtualPlant software. The thermal performance of 192 process models were investigated at various part load conditions. The observations drawn from the data led to the development of the V-TCHR model. He applied the V-TCHR model in a CO_2 emissions impact study of four different hypothetical power system networks. His results show the applicability of the V TCHR model in energy mix modelling, and how one could under-estimate the CO2 emissions by 2-9% if variable heat rate is not incorporated into the study.

Energy Efficiency: Completed Project

Dr Gary de Klerk (PhD)
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A methodology to investigate the cause of quenching in once-through tower type power plant boilers

Project summary:
A new methodology was developed to determine the root cause of quenching in large once-through power plant boilers. By understanding the causes and preventing the occurrence of quenching, the life of thick-walled high temperature components can be conserved.

Project detail:
The research focused on unwanted quenching that can occur in large utility boilers after shut-down. Quenching results in high stresses when the hot superheater and main steam piping system are unintentionally exposed to water. Thick sectioned components are prone to thermal fatigue cracking as a result of the through-wall temperature gradients. A new methodology was developed to determine the root cause of quenching and it was applied to successfully identify a previously unknown siphon effect that caused many damaging quench events at a power plant. The methodology includes a heat transfer model of the boiler that identifies condensation in the superheater, and a liquid tracking model that estimates the level of liquid in the superheater. The models were verified by comparison with real plant data. The temperature gradients in main steam piping undergoing quenching were measured and the resulting thermal stresses were evaluated. The results show that quenching causes significant stresses which can be avoided. The research provides tools to investigate quenching and to determine through-wall temperature gradients for calculating the fatigue life consumption of high temperature boiler components.

Energy Efficiency: Completed Project

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Development of a modelling methodology and condition monitoring platform for air-cooled condensers

Project summary:
The project aimed to develop a process modelling methodology to investigate the performance of air-cooled condensers. A condition monitoring platform was also developed using machine learning and simulation data.

Project detail:
The study focused on modelling a utility-scale ACC system at steady-state conditions applying a 1D network modelling approach with a component-level discretization. This approach allowed for each ACC cell to be modelled individually, accounting for steam duct supply behaviour, and for off-design conditions to be investigated. The process modelling methodology was used to determine ACC performance for a wide range of operating conditions, including ambient air temperature, wind effects, and steam-side mass flow rates. The process model was validated to site data and was used to predict ACC performance at off-design conditions, such as hot air recirculation and wind effects.

Simulation data generated by the process model was then used to develop a surrogate machine learning-based condition monitoring tool, allowing for near-real-time predictions of performance for a wide range of operating conditions. The machine learning model was also validated, and 93.5% of backpressure predictions were within 6% of the site data. The tool highlighted the potential of machine learning-driven forecasting tools, reducing computation time from 20 minutes to a few seconds while retaining relative accuracy.

Energy Efficiency: Completed Project

Heeran Heerlall (MSc)
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Power station thermal efficiency performance method evaluation

Project summary:
Eskom's thermal efficiency models we evaluated for model, systematic, temporal and baseline performance data uncertainty. The study has yielded: recommendations to improve the method, identified the critical parameters for accuracy improvement , and the optimal time resolution that the program should be run on.

Project detail:
A 3600 MWe wet-cooled power plant situated in Mpumalanga was selected to study the impact of uncertainties on the STEP model outputs. The STEP program was reviewed against industry standards. The STEP calculation sequence was modelled on MathCad® for verification and then coded in Python® to effect the sequential perturbations for: the systematic, temporal, and combined uncertainty propagation. Erroneous baseline performance data were identified through: large deviation from the direct and indirect methods, and thermodynamic modeling using EtaPro Virtual Plant®.

Energy Efficiency: Completed Project

Andani Siavhe (MEng)
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Numerical investigation of a large air-cooled steam condenser

Project summary:
Computational Fluid Dynamics (CFD) was used to the performance of an air-cooled condenser under advere windy conditions.

Project detail:
Using an open-source CFD framework, OpenFOAM, a large ACC with 30 fan units was modelled under adverse windy conditions. Physical measures for improving the ACC's performance were investigated. It was found that using B2a-fans is the most effective way of improving the performance of an ACC serviced by A-fans. It was also concluded that open-source CFD tools can be used for such industry scale problems.

Willem van der Meer (PhD)
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A thermofluid network based methodology for integrated simulation of heat transfer and combustion in a pulverized coal-fired furnace

Project summary:
A thermofluid network-based methodology was proposed for a pulverized fuel furnace that combined the zonal method with a one-dimensional burnout model for the heat generation. The model was shown to compare well with real plant measurements at different load conditions for sensitivity studies involving coal quality, particle size distribution, furnace fouling and burner operating modes as well as demonstrating co-simulation with a steam-side process model in Flownex® for steady-state and dynamic simulations.

Project detail:
Coal-fired power plant boilers consist of several complex subsystems that all need to work together to ensure plant availability, efficiency and safety, while limiting emissions. A thermofluid network-based methodology was proposed for a pulverized fuel furnace that combined the zonal method with a one-dimensional burnout model for the heat generation, together with characteristic flow maps for the mass transfer. The approach provided a computationally efficient model that captures the three-dimensional radiation effects, flue gas exit temperature profile, carbon burnout and O_2 and CO_2 concentrations, while integrating with the steam side process model for steady-state or dynamic simulations.

The model was first validated by comparing it with empirical data and other numerical models applied to the IFRF single-burner furnace. The full scale furnace model was then calibrated and validated via detailed CFD results for a wall-fired furnace operating at full load. The model was shown to scale well to other load conditions and real plant measurements. Consistent results were obtained for sensitivity studies involving coal quality, particle size distribution, furnace fouling and burner operating modes. The ability to do co-simulation with a steam-side process model in Flownex® was successfully demonstrated for steady-state and dynamic simulations.

Energy Efficiency: Completed Project

Lethukuthula N Vilakazi (MTech)
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Identification and analysis of steam temperature maldistribution in superheater tubes via measured and derived parameters

Project summary:
A final superheater of a 620 MW coal-fired power plant unit was analysed based on real plant measurements taken during steady state operation at 100, 80 and 65 percent of the current boiler capacity. An MEB methodology was implemented to determine parameters that are not measured in the plant.

Project detail:
The MEB was validated by comparing results with measured plant data. The comparison provided a difference that is less than 2%. Identification of the measurement uncertainties provided confidence on each measurement.

Uncertainties of parameters derived using the MEB methodology was achieved by uncertainty propagation through the MEB model.

The extent of temperature maldistribution was determined based on the measured outside tube metal temperatures. The results from the thermocouple measurements on the steam pipes connected to the final super heater inlet and outlet manifold headers show that there is temperature maldistribution between the inlet headers of the four legs.

There is also significant maldistribution at the outlet headers resulting in noticeable local temperature gradients. It can also be concluded that the low load of 65 percent resulted in the highest temperature maldistribution compared to the higher loads, of 100 and 80 percent. Super heater tube metal temperatures are exposed to high temperatures at low loads which may lead to tube leaks.

8 High Voltage DC Report & Completed project summaries

Line design – The research in this area included high temperature conductors, vibration and stranding. At present the Lines course is being developed which will update the previous work and enable engineers in Eskom to be trained in the latest techniques. This enables the use of new high temperature conductor types to be considered and optimisation techniques to be employed. Savings in R'm can be maintained with improved techniques.

Insulator enhancement – Graphene, a 2D nanomaterial, has been successfully produced for the improvement of next generation epoxy insulators and coatings exhibiting hydrophobic, electrical and thermal properties. Application research, testing and production are next steps.

Smart Technologies – This enables the reduction of SAIDI in distribution networks by using smart devices. The research enables the deployment and evaluation of various devices that can be used on the network. The skills developed enable a better understanding of the nature of SAIDI as well as how certain smart devices can be used to improve the overall SAIDI value.

HVDC research – The advent of inverter based resources such as wind farms increase the use of VSC's and HVDC systems. The research in this area enables better understanding of the effect of these devices on the system. This knowledge is critical to the operation of the network as well as protection of the network. SMES and superconducting devices – the application of the DSMES allows for modelling and understanding of the application of dip mitigation on the distribution networks. The development of a superconducting reactor allows for understanding of the modular development of a reactor which is far smaller and depicts low to zero losses on the distribution system. Skills developed cover the nature and application of superconductors which can be used to benefit the grid into the future.

Application of DG and EV on the grid – The research undertaken in this regard is critical to understand the implication of distributed generation as well as the advent of electric vehicles on the grid. The skills and modelling developed assists planners in analysing the network and application of DG and EV.

Efficient lighting impact – The modelling and harmonic pollution of efficient lighting is necessary to understand the effect of these devices on the network. Certain faults due to these effects need to understood and modelled.

Natural ester oils for transformers – There are a great number of benefits from using ester oils. They are less flammable and developed from renewable crops and not fossil fuels. The application and testing as well as impact on transformer design is necessary to understand prior to implementation of this oil and development of standards.

Lightning performance on high voltage networks – The understanding of reduced footing resistance on lightning performance is critical in line and substation design. Skills developed in the modelling and design of earth mats and tower footing is critical in compiling standards and guidelines for implementation.

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The design and application of a superconducting series reactor towards its use as a fault current mitigating device on distribution power networks

Project summary:

This PhD project explored the potential of Superconductivity in mitigating some of the challenges experienced in Power Systems. It specifically focused on the design and construction of a superconducting series reactor (SSR) to be used as a possible fault current mitigation device.

Project detail:

The SSR was developed as an alternative to a SFCL (Superconducting Fault Current Limiter) as a fault current mitigation device as it was postulated that it could achieve the desired fault current reduction, at a reduced cost. It would also be more energy efficient than the traditionally employed air core reactor. A desktop SSR was designed, constructed and tested, and found to be comparable with an equivalent copper reactor in the limitation of fault current but in a manner that was more energy efficient. The SSR also has the potential for a significantly reduced physical footprint in the substation yard.

The progress and results of this project has been reported in 3 Journal Publications including one in the IEEE Transactions on Applied Superconductivity. It has also been discussed and presented at various International (CERN, USA) and National conferences (Cigre, PowerGen Africa, SAUPEC) where it was well received. The employee has already been requested by Eskom senior management to respond to international companies who have asked Eskom to consider usage of their devices on our network.

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Electric Vehicle Parking Management System (EV/PMS)

Project summary:

EV/PMS is a smart AI powered system that involves parking and charging management of electric vehicles. Modern and future smart parking and charging design practices for EVs are discussed, modeled and simulated using MATLAB. The results are presented and discussed in detail including parking management and maintenance, power scheduling and control for driven and autonomous EVs.

Project detail:

The modern and future of electric vehicles is smart and IA powered to be fully autonomous, from journey scheduling, self-driving, parking and charging. In this thesis, journey scheduling is discussed and how/why it is important for parking reservation and power scheduling for charging. Practical smart parking and charging requirements for EVs are discussed in detail. Grid-Tie renewable energy for parking spaces is explored, modeled and simulated. Load based dynamic tariff scheme is discussed and used for modeling. The EV/PMS system is discussed (including existing and proposed/future systems), modeled and simulated using MATLAB to visualize and assist decision making for the system design. The importance of smart parking and AI assisted system is explored and discussed in detail, since this is what makes EV systems usually smarter than conventional/combustion vehicles. The simulation results are presented and discussed. Recommendations for further work required are outlined and explained in detail.

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Stability of the grid incorporating multi terminal HVDC: A case study of a South African network

Project summary:

The project carried out made use of a line commutated converter (LCC) multiterminal high voltage direct current (MTDC) system for the improvement of Eskom AC Transmission network. The converter control architecture and modelling are emphasized and explained.

Project detail:

The effective short circuits ratio (ESCR) of the interconnecting AC lines determines the effectiveness of any HVDC system in an AC network. Considering the ESCR of South Africa AC networks, this completed project gave a performance analysis of Eskom transmission network when incorporated with a MTDC system. The transient stability, small signal stability of the network was improved when a MTDC system was used to interconnect the 765kV transmission corridor.

9 Renewable Energy Report & Completed project summaries

The EPPEI Specialisation Centre for Renewable Energy (SC-RE) at Stellenbosch University was established in 2012, and has since been key to establishing Stellenbosch as the foremost university in South Africa in the area of renewable energy and power system research, education and training.

During the first phase of EPPEI up to end 2016, the SC-RE focussed on renewable technologies like wind generation and concentrating solar power (CSP), aimed at supporting the Eskom Sere wind farm and the World Bank loan CSP plant that Eskom was planning at that stage.

By the time that phase II of EPPEI commenced in 2017, renewables on the Eskom grid were increasing significantly leading to multiple integration challenges. The SC-RE's focus therefore shifted to supporting Eskom in these challenges, with our focus shifting from renewable technologies towards the field of power system simulations and studies.

Within this field, several contributions deserve to be highlighted:

Mitigating the impacts of photo-voltaic (PV) generation on distribution grids
A study in partnership with Eskom, City of Cape Town and UCT quantified the impacts of small-scale embedded generation (SSEG), specifically PV, on distribution feeders and transformers. The study and continuing related research activity inform pro-active grid-interface standards and SSEG hosting capacity regulations like NRS097-2. As SSEG continues to increase in future, such standards and regulations will mitigate costly impacts including premature transformer failures, and feeder and transformer upgrades due to SSEG. Avoided costs to Eskom due to this SC-RE contribution represents percentages points of future transformer failure replacement and distribution upgrade costs.

Improved system operator forecasting accuracy based on South African conditions
The share of variable renewable energy generators like wind and solar in the South African power system is increasing fast. Accurate operational timeframe forecasting is critical to ensure continued system reliability and least cost generation. SC-RE's work in forecasting high speed wind cut-out events and in classifying wind power variability according to atmospheric states has the potential to significantly improve the quality of forecasts available to the Eskom system operator. This in turn will reduce the allocation and use of operating reserves. Avoided costs to Eskom due to increase forecasting accuracy can represents several percentage points of future ancillary services costs.

Adapting Eskom's business model to the renewable energy-based utility death spiral threat
Increasing erosion of utility revenue due to residential and commercial embedded generation (EG) has been termed the "utility death spiral", and is a threat faced by utilities world-wide, including Eskom. Research, models and tools developed by SC-RE, in partnership with Eskom RT&D, quantify the potential future uptake of EG in South Africa as well as the potential financial impact on Eskom, and continues to inform a pro-active Eskom response to the utility death spiral threat. Through this work the SC-RE directly contributes to the future sustainability of Eskom's business model.

Brandon Peterson (PhD)
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A discriminative approach to harmonic emission assessment

Project summary:

Developing a methodology to fairly evaluate harmonic emission for grid code compliance at renewable power plants.

Project detail:

Harmonic emission assessment methods using 10 minute RMS values is limited in that it may not accurately and fairly evaluate the harmonic distortions that are emitted from a Renewable Power Plants (RPP). RPP's should only account for the harmonic emission that they emit onto the network. Direction of harmonic emission has historically been a challenge and this research is aimed at developing a pragmatic solution to this engineering problem.

A novel approach in the application of aggregated harmonic phasor measurements has been proven to accurately and fairly account for harmonic emission from RPP's. The developed assessment technique has shown that harmonic emission is dynamic depending on the network topology as well as the location of other non-linear loads relative to the point of evaluation.

The developed harmonic emission technique was field tested at large scale RPP's sites on both MV and HV levels and it showed that using aggregated harmonic phasor measurements yielded the true performance of RPP plants as opposed to RMS values. The aggregation process reduced the volume of data to be processed when compared to true phasor measurements, which led to longer measurement periods resulting in better harmonic emission assessments.

Renewable Energy: Completed Project

Agnes Ramokone (MEng Electrical)
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Load and energy profile development using occupancy and interactions or activities in residential buildings

Project summary:

An artificial intelligence proficient predictive based-model for households' load profile development, to assist and enhance energy planner's activities and electrification scheme implementation and upgrade.

Project detail:

An adept model to address and improve demand prediction accuracy while minimizing errors associated with conventional mathematical tools that are based on assumptions or use of fixed conditions. The significance of occupants' activities, occupancy presence, and income categories to improve the energy load prediction was demonstrated. Furthermore, neglect associated with volatility and nonlinearity in energy consumption (usage) patterns in residential buildings due to various factors such as occupants' presence and activities in non-AI-based systems (conventional models – deterministic, stochastic etc.) was addressed.
A comparative study was also conducted with respect to other AI-model based systems which did not apply occupants' activities, occupancy presence, or income as part of its variables to evaluate their performance. The developed ANN-based model outperformed other models.

This is expected to assist energy practitioners in terms of load and supply issue especially during the peak period's interval. Furthermore, the cost of electrification implementation / upgrade that are mostly routed around ADMD will be reduced or restricted.

Renewable Energy: Completed Project

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A comprehensive methodology for impact assessment studies of energy storage systems on low voltage distribution feeders

Project summary:

This research investigates the technical impacts of energy storage systems (ESSs) on low voltage (LV) residential feeders.

Project detail:

Traditional power systems were not designed to accommodate the loads presented by newly introduced ESS (EVs, BESS, hybrid PV, UPS) technologies. Therefore, impact assessment studies focused on investigating the nature, scope, and severity of the technical impact of these technologies on distribution networks are important. This work has proposed a comprehensive stochastic-probabilistic methodology for assessing the technical impact of ESS technologies on radial LV feeders, with capabilities of uncertainty propagation, simulation of unknown future scenarios of ESS penetration, demonstration of an extensive range of feeder performance interpretable using design risk factors and determining the hosting capacity of a particular network to various ESS technologies. This proposed methodology can be used to inform EV uptake policies under various operation restrictions, to identify possible future network upgrades and reinforcements, and to aid network planners in component selection and sizing. This work is particularly important for network planners, DNO and policymakers in understanding the extent of technical issues associated with ESS penetration and equipping them with the necessary information for setting design standards, component selection, infrastructure upgrade recommendations and the formulation of relevant penetration and ESS uptake regulations.

Renewable Energy: Completed Project

Khanyisa Shirinda (MEng Electrical)
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Optimal management of small grid connected PV with ground water pump hydro energy storage for farming in arid areas

Project summary:

An investigative project based on controlling and optimizing the daily operation of a farm operated renewable energy microgrid, with the aim of minimizing the use of grid electricity.

Project detail:

This research work was inspired by the current state of the electrical energy in our country, such as random electricity blackouts. Therefore, the study aimed to demonstrate the technical and economic feasibility of the grid connected renewable energy microgrid for farms using underground pumped hydro storage (PHS) technology. A high demand season (winter) was used as the worst-case scenario and specific TOU tariffs for that season have been considered during the analysis of the model. The model ensured effective flow of power by utilizing the renewable energy power as a priority, when meeting the load demand. Then, the grid power was used when the electricity price is cheaper (off-peak) or to supplement the unmet load during high demand season. The simulation results of the proposed system revealed that, using the developed model to optimally manage the power generated by the PV and the PHS. The cost of the electricity may be reduced by at least 62% after 7 years of the 30 years planned to run the project. The project's further research may be to eliminate the unused/ excess renewable energy generated during low demand season (summer) as well as fit other geographical locations which may have different input parameters and may change the configuration of the proposed system.

Anthea Solomon (MEng)
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Wideband modelling and parameter estimation of capacitor voltage transformers using a pseudo-random impulse sequence

Project summary:

The research project involved:
(i) the development of a methodology for monitoring and detecting internal capacitor voltage transformer (CVT) failures, using parameter estimation techniques and waveform pattern recognition, and
(ii) the development and implementation of a methodology for the application of a Pseudo-Random Impulse Sequence (PRIS) perturbation current source for on-site measurement of CVT frequency responses, and CVT model parameter estimation.

Project detail:

A new method using waveform pattern recognition for the detection of internal capacitor voltage transformer failures experienced during network transients, energization, de-energization and steady state conditions was examined and discussed in this research. This can be a useful tool in the Eskom business that would minimize time spent on fault finding, and limit the impact on surrounding plant if imminent failures are identified and attended to early enough. In addition, it can prompt timeous replacement of the equipment before severe failures occur, considering long lead times regarding procurement processes and unavailability of strategic spares. The approach is based on evidence collection, where analog voltage recordings, are critically appraised and used as a tool for failure detection and condition monitoring.

Most of the circuit parameters of CVTs are propriety and not available to the end user. The development of a parameter estimation technique for CVTs was explored as a means of obtaining these circuit parameters, as well as detecting internal failures. A novel parameter estimation approach using of a pseudo-random perturbation signal (PRIS) was introduced for the application of measured time domain signals. The proposed parameter estimation methodology, yielded satisfactory results as it accurately estimated the CVT design parameters, which can in turn be used for utility applications.

Three novel contributions were made in this research.

Renewable Energy: Completed Project

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Impact assessment of high penetration of rooftop PV in municipal electrical networks

Project summary:

The proliferation of intermittent energy sources, such as Photovoltaic Distributed Generators (PVDGs), subject the existing distribution networks to technical challenges and more so at high penetration levels. This research proposed an approach for quantifying technical impacts resulting from high penetration of rooftop PV into the existing LV distribution networks.

Project detail:

Despite limits prescribed for PV connection on MV/LV distribution networks in NRS 097-2, customer owned rooftop PV systems may not always conform. The uncertainty associated with PVDG uptake is a concern to distribution network operator, which deterministic load flow (DLF) do not accommodate.

This project proposed impact assessment framework based on Monte-Carlo simulation based probabilistic load flow (PLF). Beta Probabilistic Density Function (PDF) is implemented to represent input variables such as loads, PVDG power and locations. Simulations are conducted on DIgSILENT PowerFactory for a selected iterations. Cape Town urban residential network was used as a case study for the implementation of the impact assessment framework. The study focused on system performance parameters, such as voltage magnitude, equipment thermal loading and voltage unbalance factor (VUF) and were evaluated in relation to the NRS048 compliance.

Results showed that thermal limit serves as a limiting factor for the system hosting capacity, due to electrically short feeder characteristic of urban residential network. Statistical representation of output system parameters allow for an increased hosting capacity to be considered by the network planner based on their permissible violation risk.

10 Combustion Engineering Report

The Specialization Centre for Combustion Engineering has engaged in a brought spectrum of projects around the boiler and auxiliary plant. Each project was selected to address technical challenges for which a solution could provide potential benefits to Eskom.

Prediction of coal moisture in raw coal stockpiles: A model to predict the residual surface moisture content was developed based on experimental work, considering the size fractions of coal in a coal stockpile. It is now used in Eskom Primary Energy Division for coal moisture estimation. It will also be valuable for guiding coal contracts with suppliers in the future and ensuring that Eskom receives the quality of coal that it paid for. Development of a condition monitoring philosophy for a pulverised fuel vertical spindle mill: This project showed the possibility of implementing a mill condition monitoring philosophy which could have a significant financial impact on the milling plant of the fleet by shifting from outage based to condition based maintenance. The project demonstrated that condition-based monitoring could be achieved using existing measurement methods.

Measurement and prediction of coal flow rates in pulverised fuel pipes: The work led to an improvement in the PF flow measurement standard that was subsequently implemented and is currently used as an Eskom guideline. The work was based on extensive on-site testing and provided a critical review of the pulverised fuel flow testing methods used in Eskom.

Solid Particle Erosion of Ductile and Brittle Materials at Coal Fired Power Plants: The results of the study are being used to select erosion resistant material for PF boilers to reduce wear related maintenance costs. Development and design of mill de-sander for SA coal applications: The project led to design upgrade of desander technology that lead to an improvement in the PF classification process which will reduce boiler wear and reduce SO3 emissions by selectively extracting silica sand particles and pyrites.

Effect of biocides and bio dispersants on condenser tube fouling and thermal performance: The result of the project is currently implemented at Kriel Power Station and will improve the heat transfer characteristics of their condensers and subsequently improve the entire cycle efficiency. It also led to further work to improve the effectiveness of the use of a novel chemical treatment, to abate the formation of bio-fouling.

Dense phase pneumatic conveying of fly ash: The results of this project are being used to optimise the air consumption for the dense phase conveying system at Medupi by the researcher who is senior engineer at the auxiliary plant at Medupi. This will lead in substantial reduction in compressed air consumption.

Prevention of Dew Point Related Air Heater Fouling: This project resulted in the development of a modelling tool for Eskom that will be used to analyse air heater performance and the occurrence of dew point. The tool can be used for quad sector designs which are installed at Medupi and Kusile. Investigation work is already on the way to look at possible modifications that will lead to preventing air heater fouling caused by dew point occurrence. The tool has been validated using extensive measurements at Matimba Power Station.

Combustion Engineering Report *continued...*

Total air flow measurement using a multi whole Pitot tube: This current project will improve the total air flow measurement as required by the FFFR guidelines which is important for ensuring boiler safety and efficiency.

Evaluation of the quality of gypsum produced at coal fired power stations versus the market requirements in South Africa: The results of this project helps Eskom in the commercialization of Gypsum product from the Kusile plant.

The combustion engineering specialization center at Wits has contributed significantly to building a community of highly skilled industrial specialists within Eskom. Many of the MSc graduates have taken on key and positions in Eskom that have positively impacted Eskom's technology and engineering decisions. This has helped to fill the existing gap of SMEs within Eskom for which costly international and local engineering consultants were otherwise required.

Landry Mbangu Katende (MEng)
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Application of Mass and Energy Balances (MEB) to determine coal, air required and flue gas flow rates in a power plant

Project summary:
The primary objective of this study was to determine the heat rate of the power plant using the measurements of critical parameters and MEB calculations. The MEB method was used to determine coal, air, and flue gas mass flow rates and the plant's heat rate. Furthermore, CFD was used for airflow visualization and optimization in the secondary air system.

Project detail:
The MEB method was used to establish a coherent set of input and output data for the boiler, as well as to troubleshoot the existing data of the coal-fired power plant. The MEB, which primarily focused on the calculation of coal, air and flue gas mass flow rates, was studied in detail, and expanded to allow reliable results. The entire MEB method was applied with actual plant data extracted from the plant's operating control system, and the MEB results were further analyzed with the plant's C-Schedule to determine performing as per technical specifications. The plant's coal consumption and heat rate results were calculated by means of a Mathcad model that was developed using boiler MEB methodology.

11 High Voltage AC Report

The HVAC Specialisation Centre continues to provide a good Return on Investment (ROI) by training Eskom staff via conducting Eskom-focused research towards postgraduate degrees and by providing courses such as a course on high-voltage corona that was presented to Eskom staff in 2019. Other courses are being planned for 2020/21.

Power system projects have included tackling inter-area oscillations between the Koeberg power station generators and the generators at the Mpumalanga power stations and well as the effect of the recently installed wind farms in the Western Cape on the optimum settings for the Power System Stabilizers at Koeberg power station. Another project in this area involved an investigation into methods for increasing the amount of power that can be transferred along a transmission line corridor. Another project involved the real-time estimation of the amount of inertia on the Eskom network – this is becoming increasingly important with the integration of renewables that do not contribute inertia and thereby making the network more difficult to control.

An insulation coordination project involved investigating the possibility of increasing the nominal voltages of Eskom substations (e.g. from 88 kV to 132 kV) without the expense of replacing the busbar structures. The Eskom student who conducted this research presented his results at the prestigious Cigre General Meeting in Paris where he was awarded a Best Paper Prize.

In the asset management area, a project involved an investigation into methods for monitoring the condition of vacuum circuit breakers and an investigation into rotor thermal instability failures at Eskom power stations. Another project involved the detection of vibration sparking in stator bars at Eskom power stations which can lead to early insulation failure. Another project involved the optical monitoring of pollution on transformer bushings.

In the smart grids area, a project involved an investigation into improved monitoring of small distribution transformers. Another project involved designing suitable tariffs when both PV and EV are present at the distribution level. Another project involved automation of the response to faults specifically at the distribution level – a technique known as Fault Location, Isolation and Service Restoration (FLISR).

The HVAC SC also participates in Eskom SCOT committees in addressing Eskom electrical equipment issues. A PGDip degree that was initiated by the HVAC SC has been remarkably successful in attracting a large number of enthusiastic students (26 in 2020). The course content has benefitted greatly from feedback from Eskom SMEs and is providing training on the evolving power system (especially with the future integration of a large amount of renewable energy sources and smart grids).

Filipe Fernandes (MSc)
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Optical monitoring of pollution on MV transformer bushings

Project summary:

This research aims to optically monitor the dry pollution level on transformer bushings and determine the possible leakage current should the dry polluted surface be critically wetted. The research involves the implementation of an image capturing system with appropriate image processing.

Project detail:

Preliminary image capture of four artificial levels of salt deposit pollution: clean, light, medium and heavy was successfully achieved. The percentage level of surface pollution was found using image binary thresholding. A Reflectance Transformation Imaging (RTI) array was designed and implemented. It facilitated the virtual reconstruction of the imaged surface, yielding 26 different processed images. 20 trials were conducted, each with a measured leakage current and Equivalent Salt Deposit Density (ESDD) measurement. A loose exponential relation was found between ESDD and leakage current. Each trial had a minimum of 250 dry surface images associated with it. A regression model, transfer learning convolutional neural network (CNN) was implemented based upon the AlexNet image classification CNN. The regression model was trained using 70 % of the image data acquired in the trials and validated on the remainder. Several iterations of the CNN were tested with varying data organisation in order to ascertain the highest level of accuracy. The final CNN had a relative RMSE of 0.3 mA for a predictive range of 0.1 mA to 10 mA.

12 Materials & Mechanics Report

The EPPEI Materials and Mechanics specialisation centre was established within the UCT Centre for Materials Engineering in 2012 to focus primarily on the high temperature behaviour of engineering materials, with emphasis on materials utilised in power generation.

The specialisation centre was founded on four main goals, namely (i) supervision of Eskom engineers registered for higher research degrees where projects are focused on solving Eskom challenges, (ii) development and presentation of short training courses in materials technology, (iii) establishment of partnership with developing university in order to grow materials and mechanics expertise, and (iv) enable technology transfer to industry where appropriate.

In particular, the research focus was directed at investigating and understanding the influence of service operating environments on the performance of materials with a view to being able to (a) better predict the life of engineering materials and components in power generating plant, (b) optimize the selection of materials for plant construction, (c) improve manufacturing technologies including welding and (d) improve the reliability in monitoring material and component integrity.

To achieve this, we recognised that training and research includes elements of physical metallurgy and metallography, structural integrity, high temperature behaviour (including creep), environmental degradation (including corrosion), welding metallurgy and processes, materials modelling, and non-destructive evaluation (NDE).

In order to address the goals outlined above, not only now and in the recent past but also in the future, we have fostered the growth of a very strong materials science and mechanics capability that extends across three universities, namely UCT, Nelson Mandela University and Stellenbosch University. The academic lead and primary materials testing capability is situated in the UCT Centre for Materials Engineering which is led by Professor Robert Knutsen. The main capability in materials characterisation has been established through the EPPEI-supported appointment of Dr Johan Westraadt in the Centre for High Resolution Transmission Electron Microscopy at the Nelson Mandela University. Partnership with Associate Professor Thorsten Becker at Stellenbosch University completes the picture by providing strong support in fracture mechanics and mechanical property assessment.

Together we have worked with Eskom, particularly the Research Technology and Development (RTD) division, to develop expertise in assessing, characterising and understanding materials damage. Through this collaboration we have successfully supervised Eskom engineers and non-Eskom students towards achieving masters and doctorate degrees, and in doing so, our knowledge and capability to provide ongoing support to Eskom has expanded. Additional collaboration with the University of the Witwatersrand and the University of Pretoria, particularly with respect to welding technology, has further strengthened our local capability to support Eskom.

Materials & Mechanics Report *continued...*

Research highlights during EPPEI I and II include assessment of the weldability of service aged steam pipe, development of a complex model to simulate oxidation of nuclear grade stainless steel in a primary water reactor, optimisation of heat treatment to prevent stress corrosion cracking occurrence in turbine blades, method development for full field strain measurement during accelerated creep testing, and microstructural damage characterisation of service aged turbine rotor steels. The latter project has not only contributed to extensive savings by avoiding replacements incorrectly judged by the OEM, but it has also resulted in the ongoing development of rigorous protocols to assess material damage condition using advanced electron microscopy techniques. Our ability to link microstructure characterisation and mechanical property measurement in understanding material property and damage evolution during service contributes substantially to improving risk-based inspection practices and the ability to support Eskom in meeting challenges to ensure long term sustainable and affordable electricity supply in South Africa.

Mapula Matjee (MSc)
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Investigation of the stress corrosion cracking resistance of SAF2205 and AISI304 weldments for the marine environment application

Project summary:
The suitability of SAF2205 duplex stainless steel as a replacement for AISI 304 for large storage tank application was investigated. The SAF 2205 steel out-performed the AISI304 steel and consequently is the preferred material of choice.

Project detail:
Large storage tanks are constructed on site from plate which is welded to form multiple panels that constitute the tank walls. The welding operation introduces residual stress that cannot be relieved by post-weld heat treatment. Consequently, it is critical that the metal is able to resist the onset of stress corrosion cracking during service, particularly in environments at or near the sea. Welded plate sections for SAF2205 duplex stainless steel and AISI304 austenitic stainless steel were subjected to long-term salt-spray testing under controlled conditions which included the imposition of stress to simulate the weld geometry. In addition, pre-stressed samples were subjected to the Strauss test (copper sulphate + sulfuric acid) to determine susceptibility to embrittlement. Evaluation of the degree of corrosion attack and embrittlement demonstrated best results for the SAF2205 duplex stainless steel.

13 New project submissions

The following students are currently studying through EPPEI. These are summaries of their research topics.

Emissions Control: New Project

Bilha Jepchumba Chepkonga (MSc)
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Use of industrial brine sludge waste (IBSW) in semidry flue gas desulpherisation

The IBSW is used to prepare hydrated lime to be used in a spray dry scrubber. Effect of additives on sorbent utilization is also investigated.

Applicability to Eskom

Hydrated lime used as a sorbent by Eskom is expensive thus alternative sources of the sorbent is desirable. In this project, hydrated lime is obtained from IBSW by chemical processes.

Emissions Control: New Project

Tshiamo Geneke (MEng)
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Effect of alkaline activator composition on the geopolymer properties produced from South African power station fly ash

Eskom produces ~36 million tons of ash annually, of which 90% is fly ash and only 7% of the ash is valorised; much lower than the global average of ~55%. Geopolymer production from fly ash, as a Portland cement substitute, presents an opportunity to upcycle this underutilised resource.

Applicability to Eskom

Fly is a hazardous pollutant produced from electricity generation from coal. Geopolymers will minimise the storage of fly ash and indirectly, due to it being a cement replacement, potentially decrease emissions associated with cement production.

Emissions Control: New Project

Marcus Keulder (MEng)
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Kinetics of hydrated lime sulphation for semi-dry flue gas desulphurisation in a circulating fluidised bed

The kinetics for the reaction between sulphur dioxide and hydrated lime are determined in a micro-scale laboratory reactor. The reaction is of importance as it can be used in circulating fluidised bed reactors to reduce sulphur dioxide in flue gas.

Applicability to Eskom

Eskom needs to reduce the toxic components present in the flue gas emitted by their power stations during the generation of electricity to comply with South Africa's minimum emission standards. The implementation of circulating fluidised bed (CFB) reactors will reduce the amounts of sulphur dioxide emitted by power stations. Kinetics for the reaction between sulphur dioxide and hydrated lime are necessary for the successful design of a CFB reactor.

Emissions Control: New Project

Robert Someo Makomere (MSc)
Email: rsomeo@yahoo.com

The use of cellulose nanocrystals to support $Ca(OH)_2$ nanoparticles-diatomite matrix in low temperature dry flue gas desulphurization

A modified nano-sorbent activated by diatomite additive to help improve sorbent utilization.

Applicability to Eskom

Help reduce O&M costs when controlling emissions from coal power plants.

Emissions Control: New Project

Coenraad Wilhelmus Meyer (Winroe) (MEng)
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Coal pellets as an alternative fuel for a semi-continuous coal stove

This study aims to determine the thermal and emissions performance of coal pellets with different properties, to identify how these properties influence the combustion thereof in a semi-continuous coal stove.

Applicability to Eskom

The improved semi-continuous coal stove is proved to deliver significantly lower emission levels than when compared to a domestic coal stove. Therefore, it is plausible that the large-scale implementation of the semi-continuous coal stove in rural settlements can significantly reduce household pollution and provide an alternative means of domestic energy generation. This study can consequently be used by Eskom as an offset program to aid in the reduction of South African air pollution.

Emissions Control: New Project

Phumudzo Mudau (MSc)
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Emissions quantification of firewood use in winter season: A case study for Mangondi village in Limpopo province, South Africa

This study seeks to quantify the emissions of firewood combustion from Mangondi village in Vhembe district, in Limpopo Province South Africa.

Applicability to Eskom

Fuelwood is an alternative source of renewable energy. However, Greenhouse gases (CH_4, CO_2) and criteria pollutants (SO_4, NO_X, PM2.5 & PM 10) are usually measured as the main gaseous pollutants caused by the consumption of wood. Therefore, quantification of emissions released from fuelwood use in rural settings is necessary.

Emissions Control: New Project

Ntsitlola Felicity Nthatisi (PhD)
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Modeling of the combustion of pellets in a semi-continuous stove using CFD

Investigates the use of coal pellets as alternative solid fuel for household use.

Applicability to Eskom

Repurposing of coal fines and reduction of environment pollution while emphasizing green coal energy.

Emissions Control: New Project

Cornelius Janse Odendaal (MEng)
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The modelling of circulating fluidised bed processes for carbon dioxide capture

Provide an advance mathematical model for the optimal design of a circulating fluidised bed for carbon dioxide capture from a multi component flue gas.

Applicability to Eskom

This project can lead to a full industrial scale CFBR at the Eskom power stations. This will help reduce the CO2 emissions from these plants, resulting in less carbon tax and a cleaner source of energy.

Emissions Control: New Project

Cara Prinsloo (MEng)
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Hydrodynamics inside a laboratory-scale semi-dry flue gas desulphurisation riser

The hydrodynamics of hydrated lime inside a CFB-riser is being studied using experimental measurements (using an iso-kinetic sampler), CFD modelling techniques and factorial design analysis. The experimental measurements and the CFD models include a wide range of solids feed rates, superficial gas velocities and riser height settings.

Applicability to Eskom

This is an initial study of a semi-dry FGD system which has shown promise in the area of SO2 removal. From this study, the investigation will become more in depth and valuable information on the practicality of such a system will be brought to light.

Emissions Control: New Project

Michael Roberts (MSc)
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Development of a test section for the evaluation of dilute gas-particle flow measurement devices

A test section is designed for the purpose of training Eskom personnel in the use of Pulverized Coal (PC) measuring devices. The test section fits into a facility that generates a two-phase gas-particle stream - called a PC Test Loop. Computational Fluid Dynamics (CFD) was used to design the test section, practical measurement were conducted using iso-kinetic and laser-based measuring devices and finally the measured and computed results were compared.

Applicability to Eskom

The measurement of pulverized coal flow on a coal-fired power station is a very important and integral part of operating a plant successfully. Training of employees and the evaluation or calibration of measuring devices are therefor in constant demand. Access to this off-site PC Test Loop facility allows easy access and a controlled environment in which to conduct training and to perform further research on the use of measuring gas-particle devices.

Emissions Control: New Project

Lerato Tshisi (MSc)
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Modelling ambient vehicle emissions in Zamdela using AERMOD

Studies indicate that vehicle emissions are a problem of inquiry however, there has been insufficient research so far to better understand fundamentals to consistently monitor on-road transport emissions. Therefore, this study aims to assess the impact of vehicle emissions by developing and emissions inventory and modelling the spatial distribution of vehicle emissions.

Applicability to Eskom

Vehicles are an important source of ambient Particulate Matter (PM) in Zamdela. Consistent monitoring of on-road emissions is needed as much it is being done for industries and other ground level sources.

Energy Efficiency: New Project

Alton Marx (PhD)
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Deep neural networks applied to the analysis of thermal power plant load losses

Develop power plant load loss fault diagnosis and root cause analysis deep learning models that assign the proportion of load loss associated with a plant area, system, and/or equipment faults in near real-time.

Develop power plant load loss fault propagation and load loss forecasting deep learning models for various time intervals.

Applicability to Eskom

Identifying what portion of load loss is associated with which plant area, system and/or equipment faults play a critical part in thermal power plant operation and maintenance strategies.

Energy Efficiency: New Project

Michael Ross (MSc)
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Dynamic modelling of steam turbines

The project saw the development of a paired turbine modelling methodology to predict the internal clearances of conventional steam turbines during transient operations. The project showed that a paired modelling approach allows one to accurately predict the thermal and structural behaviour of these turbines during a full cold start up procedure.

Applicability to Eskom

The development of such a model is significant given the accuracy of the analysis possible given limited geometric inputs from turbine OEMs, allowing engineers at Eskom to perform similar analysis on current and future turbine units. The results of this research with ultimately lead to a greater understanding of steam turbine clearance behaviour during transient operations and inform clearance installation during unit shut down, leading to potential efficiency gains across Eskom's fleet.

Renewable Energy: New Project

Leigh Bongers (MSc)
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Imbalance forecasting for dynamic operating reserve dimensioning for renewable energy aligned power systems

With mounting concerns about the impact of the increasing variability and uncertainty that is associated with increase in renewable energy generation, implementing a dynamic operating reserve dimensioning methodology can prove beneficial to procure operating reserves more efficiently on a shorter time horizon while maintaining system reliability. Using a data driven approach, the system imbalance can be forecast as a metric to allow more accurate and efficient reserve dimensioning based on expected requirements for reserve capacity.

Applicability to Eskom

Many transmission system operators, like Eskom, still use traditional, static reserve dimensioning methodologies where variable renewable energy generation variability and uncertainty is not part of their design considerations, because reserve requirements were dominated by forced outage risk, the characteristics of which do not change significantly with time. Moving towards a dynamic methodology requires a dimensioning metric that was not used before. Having a metric for forecast system imbalance that is calculated and regularly updated using updated system conditions and relevant variable renewable energy generation data, means an informed reserve dimensioning decision can be made for more efficient and reliable reserve dimensioning of the Eskom grid to ensure supply and demand are balanced more closely.

Renewable Energy: New Project

Francois du Plessis (MEng Electrical)
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Characterization of non-linear inverter behavior in renewable energy power plants

An increasing number of IPPs featuring inverter-based technologies are connecting to the grid. Methods are needed to characterize the harmonic emissions of these inverters and develop accurate modelling techniques.

Applicability to Eskom

- Understanding the effects of IPPs on the grid from a power quality perspective
- Determining the contributor to a certain harmonic (grid or IPP) – compliance assessment
- Understanding existing harmonic models specified by international standards (IEC)

Renewable Energy: New Project

Nande Fose (MEng)
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Application of an IEC 61850-90-5 standard for predictive dynamic stability system

As power systems have become more complex worldwide and are running closer to their operational limits, the introduction of WAMPAC systems has become important in order to better manage the grid, to improve the efficiency of system use, to ensure the security of supplies. We are approaching an era where all metering devices will be time-synchronized and capable of providing accurate, high precision time tags as part of any measurement. IEC 61850-90-5 standard is used to investigate the Predictive dynamic stability maintaining system using Phasor Management Units (PMU) for an out of step condition in a transmission ring network.

Applicability to Eskom

Enhancement of the grid stability through IEC 61850 communication standard based protection would be of great benefit. Synchronizing Generators of the two parties i.e. Eskom and IPP's can be quite complex and needs not to be taken lightly as this would result in major power outages so implementation of such IEC 61850-90-5 standard based predictive dynamic stability system would maintain a smart constant generating grid owing to its fast detection and fault isolation when an out-of-step condition is detected thereby improving key performance system indexes are that put in place to govern Eskom's energy supply and failure for utilities to meet the targets comes with a fine so in essence Eskom's revenue will also be increased.

Renewable Energy: New Project

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Design and Performance Investigation of a Low-Cost Flux Reversal Machines for Direct-Drive Wind Generator

The electrical machines that are mostly used in wind energy generation are costly, particularly the permanent magnet synchronous generators. These machines have a good energy yield, but developing a non-permanent magnet substitute that has a justifiable energy yield and is direct-drive driven would be economical in the sense that, gearbox maintenance costs and rare earth element based permanent magnets used would be eliminated.

Applicability to Eskom

As a major energy provider, Eskom needs to diversify it's energy mix from the dominant use of coal based energy generation to a renewable source like wind. Therefore, the use of wind turbines that are driven by a cost-effective electrical machines should be a viable benefit for the utility in providing cost-effective energy.

Renewable Energy: New Project

Johannes Lambrechts (MEng)
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The measurement of supraharmonics in power networks

To research the current measurement standards and research what is needed to do a correct measurement of supraharmonics on a LV network.

Applicability to Eskom

Research is tied to Eskom RT&D project: "Power Quality in the future grid". The research will contribute to the decision making or NRS084 and will provide DX solutions with the knowledge of supraharmonic measurements.

Renewable Energy: New Project

Daniello Mouton (MEng)
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Incorporating short-term constraints into long-term power system planning

This paper presents an approach of incorporating short-term operational constraints into a long-term planning model. The results will highlight the importance of considering operational constraints and the key role that flexibility plays in power system operation. By neglecting short-term operational constraints in the long-term planning of a power system, it can lead to higher system cost, lower performance, and curtailment of VREs.

Applicability to Eskom

The latest integrated Resource Plan (IRP) proposes that wind and PV contributes 33% of total installed capacity in South Africa by 2030. With this penetration level, there will be increasing need for power system flexibility in the South African grid. It is therefore important to evaluate and understand the degree to which the existing grid is flexible or inflexible to ensure optimal planning for flexibility in future electricity generation mix of the country.

Renewable Energy: New Project

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Techno-economic and environmental analysis of municipal solid waste for electricity generation: A case study

The study is to analyzes the technical possibility, economic viability, and environmental impact of possible Waste-to-Energy technologies.

Applicability to Eskom

This will assist Eskom to enhance energy security in an efficient and sustainable manner to promote carbon mitigation in Southern African.

Renewable Energy: New Project

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Managing the impacts of distributed generation on low voltage distribution networks using autonomous inverters

Rooftop solar PV systems give rise to various technical impacts on low voltage distribution networks. This research focuses on how effective inverter-based reactive power control and voltage regulation functions can be on South African low voltage distribution networks to accommodate increased PV penetration levels without compromising the quality of supply to all customers.

Applicability to Eskom

As the largest distribution network operator on South Africa it is important for Eskom to be able to uphold an acceptable quality of supply whilst providing nondiscriminatory grid access to customers who want to generate their own energy. This research may provide a technical background to working groups and other researchers as to how effective inverter-based reactive power control and voltage regulation can manage the impacts of distributed generation.

Renewable Energy: New Project

Jason Waugh (MEng)
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Establishment of a pre-payment-meterbased Dx capacity enhancement program, based on a retrofitable loRa based network

A quantitative analysis on how, through the establishment of a retrofitable LoRa-based Netowkr, smart functionality on historic pre-paid meters can be activated as part of a smart Demand Side Management Program.

Applicability to Eskom

With the current grid constraints experienced by Eskom, a program based on an innovative network technology combined with a mass deployment ready management system will introduce an alternative mechanism to load curtailment.

Renewable Energy: New Project

Ria Xavier (MEng)
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The coordination of smart inverters and opportunities for South Africa

This project investigates the benefits of coordinated smart inverter control with regards to voltage regulation with high PV penetration levels.

Applicability to Eskom

This project includes a review of smart inverter control techniques applied internationality in contexts of high RE penetrations and provides recommendations for South Africa's advancement in terms of grid-code and smart inverter regulations.

Renewable Energy: New Project

Andrew Hlupo (MSc)
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Validation and application of the small punch test for toughness measurement of steels

This research project seeks to provide a concise and repeatable approach in using the small punch test method in material mechanical property analysis. The small punch test method findings will be correlated to conventional mechanical test methods and digital-to-image correlation will be adopted in this project to reliably detect crack initiation and propagation, improving the validity of the results.

Applicability to Eskom

The small punch test, being an NDT, will ensure that minimal material will be required for testing to obtain the mechanical properties and life of power plant components. Maintenance can be carried out and the condition of the components can be assessed without prolonged downtime, allowing Eskom and the power sector to supply power consistently whilst monitoring its plant components without disturbance of operations.

Renewable Energy: New Project

Tinashe Jambo (MSc)
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Influence of Post Weld Heat Treatments (PWHT) on high temperature tensile behavior of P91 Weldments

Grade 91 steel was developed for improved strength at high operating temperatures resulting in improved power plant efficiency. In the case of pipe applications, the steel is referred to as P91. Since its adoption, premature failures of weldments have been reported and this study focuses on using the detection of localised strain during high temperature cross-weld tensile testing to determine the influence of variable PWHT on service performance. P91 steel is of special interest due to its deployment in the Eskom Kusile and Medupi power plants in South Africa.

Applicability to Eskom

This research gives insight into the implications of deviations in PWHT practice for P91 pipe installations. The understanding of changing tensile behaviour across weldments as result of PWHT procedure contributes to understanding the metallurgical risk associated with deviations in PWHT field practices.

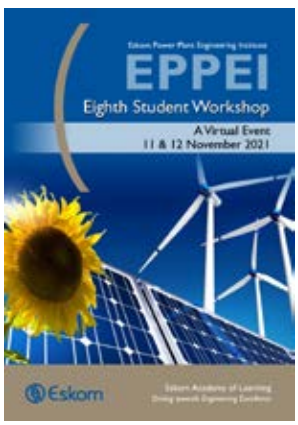
14 EPPEI Student Workshop 2021

This year marked our second successful virtual format of the 8th Annual EPPEI Student Workshop, on 11 & 12 November. It was well-attended by both University academics and Eskom staff. A huge thank you must go out to the HVDC Team at UKZN for organising a well-run and all-round successful event!

The students presented their work once again in presentation form, and they all did a phenomenal job. One student winner was selected for each session, based on four criteria: quality of their slides, fluency of speaking, explanation of theory and results, and lastly for their ability to answer questions from the audience. The names of the winners per session are:

- **Session 2 (Smart Grid):** Mashangu Xivambu, with project titled "Technological Interventions to maximise benefits in electrification programme"
- **Session 3 (Renewable Energy):** Aroon Sukhnandan with project titled "Voltage Stability Challenges on a Highly Compensated Utility-Scale System: A Case Study"
- **Session 4 (Materials):** Hlanganani Nyembe with project titled "Microstructural evaluation of ex-service 1CrMoV turbine rotor steels"
- **Session 5 (Asset Management):** Anisha Ulassi with project titled "Investigation of the uncertainty of wall thickness testing of boiler tubes with fly ash erosion degradation"
- **Session 7 (Digital Twins & Emission Control):** Willem van Schalkwyk with project titled "Discrimination between Nearby and Direct Lightning Strikes to a Long Operational Medium Voltage line to Assist in the Determination of the Basic Insulation Level (BIL)"
- **Session 8 (Energy Efficiency, Materials & Combustion):** Lindsay Westraadt with project titled "Machine learning structure-property models for low carbon steels"

We wish to thank all the students, panel members, speakers and guest speakers for their participation in the workshop. We hope that it was enjoyed by all who attended, and we look forward to hosting a physical event again in the future!



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