A review of preventative maintenance on South African electricity sector.

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Regardless of the overhaul outages planned with the aim of preventing failures on the energy plants in South Africa, it is witnessed not to be effective based on the production ratio outcomes. The production ratio as per the South African power enterprise is 80:10:10. The ratio is based on 80 % availability, a fixed 10% planned maintenance and 10 % unplanned maintenance. Consequently, the concept of preventative maintenance has become a buzz phrase amongst scholars and industry practitioners, even though, preventative maintenance is attaining a higher level of significance in well developed countries, such as America and China due to its ability to smoothening the energy sector. In Africa, particularly in South Africa the integration and adoption of the concept of preventative maintenance is phasing challenges. To date, over the past decades several studies have been led to investigate the benefit of preventative maintenance implementation in the energy sector at global level. However, very few investigative studies concerning the implementation and adoption of preventative maintenance in the South African energy generation sources have been conducted, hence the overall objective of this paper is to fill this gap by means of critically analyzing studies that were conducted or developed in the field of preventive maintenance over the past two decades. The outcome of the analysis of the existing literature on preventative maintenance clearly illustrates that there are flaws in the current body of knowledge related to a lack of sufficient studies in the context of South African electricity sector.

Keywords
Energy Sector, maintenance strategies, boilers

1.0 Introduction

Maintenance management strategies are categorised into planned and unplanned activities. Planned activities comprise of proactive and reactive approach, and unplanned activities are repairs and replacements. In summary of above discussion, proactive activities are scheduled replacements, predicted maintenance and planned discard. And, reactive activities are failure finding tasks, recalibration and redesign (Wang et al. 2006). Selection of maintenance management strategy is depended on the operational system, resources and skills acquired within an organisation. Some of the strategies that can be deployed is Reliability Centred Maintenance (RCM), Total Productive Maintenance (TPM) and Mixed Management Strategies. Organisations that seek benefit of a reduction in plant failure apply TPM or RCM because of proper condition maintenance of the technical plant resulting in production continuity. Although TPM appeared favoured in industry for its strategy deployed involving the plant operators in the day-to-day maintenance activity. Importantly, the quality and availability of the plant spares have a huge impact in the plant's ability to meet production requirement. It is norm practice to regulate maintenance spare parts as much as possible. It is crucial as it means that we can minimize the number of maintenance spares that are stored as inventory and thus minimize the overall cost and eliminates the worry of slow-moving stock levels that tend to deteriorate with a long shelf life.

Preventive maintenance can be defined as activities executed on a planned, periodic, and specific plan to keep equipment in its original working state through the process of inspection and refurbishment (Dhillon and Liu 2006; Wang et al. 2010). These execution of activities is conducted aimed at minimizing breakdowns and wear rate. Other objectives include the maintenance of the condition and reliability of the plant, minimize production interruptions caused by breakdowns and to crucially keep a good momentum of production. Preventative maintenance is planned or scheduled maintenance (Endrenyi et al. 2001; Wang et al. 2010; Stadnicka et al. 2014). It is argued to be the best maintenance strategy employed in most organization across industries, praised for optimum management of equipment failure and the management of the risks of the plant unavailability. However, it is also argued to be a strategy reducing plant reliability and promoting plant failure, deployed by maintenance routines which could be ineffective due to the costs in the long term and the existence of the impossibility of the plant's life being extended. Nevertheless, the employment of this maintenance strategy should be in accordance to the condition of the plant.

2.0 Critical analysis of the current literature

The objective of this section is to assess current literature on energy. To begin with, the critical assessments was conducted, the ICISI of Science database was used with "maintenance of power plants" as key words. The time frame was between 1997 and 2017. The search focused on pure reviewed articles published in English fulling in certain research areas. The search resulted in 289 documents that were critically assessed by means of title and abstract with the purpose of creating additional boundaries and eliminating incorrect or unrelated entries (screening phase). Throughout this phase, groups of inclusion and segregation standards were established, against which individually every single journal article was evaluated. Precisely, articles assessed are those which concentrate on maintenance of power plants. It should be highlighted that studies that did not meet these requirements were not considered. At this point, the results generated were 141 studies focusing on maintenance in power plants. These studies were labelled on the basis on a set of standards, for instances in this paper the studies were selected based on the citation. To this end, the table below illustrates the fifteen best studies in the field of power plant maintenance, that were critical

Table 1. Gap analysis of current literature

Authors	Country of study	Source of energy	Methodology	Plant Focus
Laing et al (2010)	Germany	Renewable	Qualitative	N/A
Keatley et al (2013)	Ireland	Thermal	Quantitative	Generator
Khelif et al (2012)	Algeria	Fossil Fuel	Quantitative	Overall Power Plant
Chang et al (2012)	PR China	Nuclear	Qualitative	N/A
Dorji and Ghomashchi (2014)	Australia	Renewable	Qualitative	Turbine
Sullivan et al (2013	Austria	Fossil Fuel	Qualitative	Overall Power Plant
Feng et al (2010)	PR China	Fossil Fuel	Quantitative Qualitative	Generator
Frangopol (2011)	United States of America	N/A	Qualitative	N/A
Kumar and Maiti (2012)	India	N/A	Qualitative	N/A
Castro et al (2014)	South Africa	Fossil Fuel	Quantitative	Engine
Boukelia and Mecibah (2013)	Algeria	Thermal	Qualitative	Overall Power Plant
Foong et al (2008)	Australia	Renewable	Quantitative	Overall Power Plant
Brewer and Canady (1999)	United States of America	Nuclear	Quantitative	Overall Power Plant

Wang et al (2006)	PR China	Thermal	Qualitative	Overall Power Plant
Ohunakin et al (2006)	Nigeria	Renewable	Qualitative	Overall Power Plant

As per above table, (Laing, et al., 2010) in this paper discusses aspects in the renewable energy sector of Germany indicating a reduction in levelized energy expenses with a modular storing integration of 2–3%. This paper furthermore illustrates results to qualify theories in a life cycle assessment, a contrast of an AndaSol-I type solar thermal power plant with the unique two-tank molten salt storage and with a “hypothetical” concrete storage demonstrates a benefit of the concrete storage technology regarding environmental effects. The environmental effects of the proposed concrete based AndaSol-I reduced by 7%, considering 1 kW h of solar electricity distributed to the grid. Concerning only the production of the power plant, the emissions reduced by 9.5%.

As per above table, (Keatley, et al., 2013)compiled a paper on large thermal generating units in Ireland, which were mainly designed to counterattack creep damage caused by base load technique throughout an operative service life of further than 40 years. These thermal units are over operated to meet the demand which result in accelerated rates of life consumption due to the instigation of fatigue related damage methods that these units were not designed to withstand. The authors highlight on the outcomes of studies in Ireland to relate fatigue-life ingesting (quantified in total lifetime starts) and damage build up (quantified in annual maintenance expenses) to produce a model which can be utilised to forecast lifetime hot, warm and cold per-start expenditure for a distinctive base load unit in a variety of market and wind-penetration situations.

As per above table (Khelif, et al., 2012)illustrate that these days levelized electricity expenditure of diesel power plants in the southern of Algeria is comparatively higher due to its low efficiency compared to other current plants whereby high maintenance and operations expenses and many other complications to operate with fossil fuel due to its waterless area. This study examines the probability of hybridization of the diesel power plant with a photovoltaic (PV) method whereby the performances of each part have been simulated. The simulation outcomes sanction that the hybrid configuration is truly achievable even though the levelized electricity price is very sensible to fossil fired fuel expenditures.

As per above table, (Dorji & Ghomashchi, 2014)have carried out a study on turbine failure on an Australian renewable power plant that not only increases the plant down time and causes income loss, it poses a serious danger to the life of operational and maintenance personnel in instances where the power house in underground specifically. This article draws an overview of four hydro-turbine failure modes constructed on a widespread literature review also qualifying of field observations at the Tala Hydropower Plant. Furthermore, the report makes available information about diverse turbine parts that are more expected to be liable to breakdown under the four-outlined hydro-turbine failure modes. It also tries to clarify some recommended methods to avert and mitigate against these failure modes.

As per above table, (Sullivan, et al., 2013)paper compiled based on Austria’s fossil fuel powered power plants, presents a method for integrating metrics for electric-sector reliability into a universal Integrated Assessment Model (ISM). Utilizing load, resource accessibility, and system report data with high temporal resolution, the authors designed a set of reduced-form constraints that lead investment and practice decisions among power plants in IIASA’s MESSAGE model. The examination observes how such reliability metrics influence modelled system build-out, as well as in scenarios with greenhouse gas (GHG) limits.

As per above table, (Chang, et al., 2012)compiled a study on the People’s Republic of China’s grid of which falls under distribution energy life cycle by presenting a smart grid that provides technology for optimising nuclear generated electricity distribution systems by distributed and computer-based remote sensing, control and automation and two-way communications. In this paper, the authors propose an innovative method for the smart grid to grip uncertainties rising from condition monitoring and maintenance of power stations. Three scenarios are studied in this paper, which illustrate the capability of the proposed approach for conducting operational variations taking place in an offshore substation with controllable computational difficulty.

As per above table, (Feng, et al., 2010)propose an iterative generator maintenance scheduling (GMS) system in China's power markets, bearing in mind the influence of unexpected unit failures. It is constructed on the diverse objectives of power generators and the independent system operator (ISO) as well as the variable availability of power units. In the paper, it is described that the system operating costs is made up of three terms of cost, reliability, production and maintenance. The last two costs are analysed by the system probabilistic production simulation with the equivalent energy function (EEF) technique. In conclusion, a 21-unit system is used to illustrate the proposed GMS issue.

As per above table, (Frangopol, 2010)compiled a study in the civil infrastructure field to address the deteriorating levels of performance and safety especially in the United States of America. The primary aim of this paper is to illustrate recent achievements in the life-cycle performance evaluation, maintenance, management, optimisation and monitoring of civil structural systems under doubt to qualify data for this study.

As per above table, (Kumar & Maiti, 2012)put together a study that addresses the issues of maintenance policy selection for an industrial unit in India. The proposed maintenance policy criteria consider risk of equipment and cost of the maintenance thereof. Fuzzy analytic network process (FANP) is deployed, to deal with fuzzy variables and the preferred maintenance strategy is determined using the analysis. This was on a chemical plant' unit after which a methodology was selected for thirteen different equipment on the one unit.

As per above table, (Castro, et al., 2014) presents a continuous-time model developed for long-term maintenance scheduling of a gas engine power station with parallel units. The study attempts to address the mean time to repair with less expenses to repair and challenges of constant minimum and flexible maximum power demands in South Africa. Through the resolution of a real-life problem, the authors illustrate that the projected formulations are quite effective computationally, while obtaining valuable intuitions about the system.

As per above table (Boukelia & Mecibah, 2013)conducted a study addressing the increasing demand in energy and the relatively developing environmental issues caused by fossil fuels, in Algeria, while renewable energy offering better opportunities. This paper describes and operating principles of the parabolic trough power stations, in addition an appraisal of considerations on the valuations for concentrating solar power potential of Algeria. The examination demonstrates the competitive practicality of these plants. In conclusion, an outline is given on the parabolic trough power plant projects growth in the country, including the first integrated solar combined cycle plant, adding to the three hybrid power plants that are anticipated for completion in 2018.

As per above table (Foong, et al., 2006)Compiled a study on common practice in the hydropower generation to either cut the maintenance period or to postpone maintenance tasks, when there is probable energy not served based on present water levels and prediction of storage inflows. It is vital that a maintenance scheduling optimizer can integrate the options of decreasing the maintenance duration and or postponing maintenance tasks in the search for practical maintenance schedules. This article illustrates an optimised ant colony optimization-power plant maintenance scheduling optimization (ACO-PPMSO) design that deliberates such options in the optimization progression is presented. Furthermore, a search strategy is presented to boost the forcefulness of the algorithm that was tested on five hydropower stations in Australia, whereby it was proven to can allow decreasing the duration of maintenance in the circumstance of predictable demand shortfalls.

As per above table, (Brewer & Canady, 1999)in this study describes the result of assessing the probabilistic risk group at the Duke Power Company in the United States that renders support for the maintenance rule by performing tasks eight listed tasks that are not typically linked to the initial employment of the rule. The described maintenance rule should be kept constant with the existing design and operation of the plant. This study concludes that support of the maintenance rule will be one of the vital roles of the probabilistic safety assessment (PSA) group for the remaining life of the plant.

As per above table, (Wanga, et al., 2006)conducted a study aimed at evaluating various maintenance approaches for different equipment. In this paper they illustrate that a supreme maintenance strategy combination is necessary for increasing reliability and availability of production plants without increasing expenditure. The selection of maintenance strategies is a typical multiple criteria decision-making (MCDM) problem. To address the indeterminate judgment of deciders, a fuzzy alteration of the analytic hierarchy process (AHP) technique is utilised as an evaluation instrument, where indefinite and rough judgments of deciders are interpreted into fuzzy numbers. A definite example of choice of maintenance approaches in a power plant with the application of the proposed fuzzy AHP approach is given, illustrating that the predictive maintenance approach is the most appropriate for boilers. This paper furthermore presents a case study on the fuzzy AHP technique proposed, as a simple and effective instrument for tackling the unknown and imprecision related to multiple criteria decision-making problems, which possibly prove valuable for plant maintenance managers to outline the best maintenance strategy for each equipment.

As per above table, (Ohunakin, et al., 2011) in this paper, appraises small hydropower (SHP) growth and scrutinizes Nigeria’s renewable energy current situation with respect to the developed policies and Energy Power Sector Reform (EPSR) Act 2005. Besides government efforts to diversify and encourage privatising energy sources to promote renewable energy growth, there remains challenges against the development strategy. After a qualifying data on the current situation, it is concluded that government must incorporate subsidies, feed-in-tariffs, and framework for Price Purchase Agreements (PPA) into the policies to further promote renewable energy and attract both indigenous and foreign investments for quick adoption and rapid expansion of SHP technologies.

Conclusion

To date, over the past decades several studies have been led to investigate the benefit of preventative maintenance implementation in the energy sector at global level. However, very few investigative studies concerning the implementation and adoption of preventative maintenance in the South African energy generation sources have been conducted, hence the overall objective of this paper was to fill this gap by means of critically analyzing studies that were conducted or developed in the field of preventive maintenance over the past two decades. The outcome of the analysis of the existing literature on preventative maintenance clearly illustrates that there are flaws in the current body of knowledge related to a lack of studies based in South African electricity generating sources.

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