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Policy discussion for sustainable integrated electricity expansion in South Africa

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ABSTRACT

Emerging reports have shown that despite Eskom's continued investment in increasing electricity supply capacity to grid connected and off-grid households, there has been a steady decline in electricity consumption (kWh/month/individual) and household income (ZAR/month). This paper presents an integrated electricity expansion model (IEEM) for South Africa that seeks to incorporate demand side management (DSM) in providing a roadmap for improving and increasing energy (electricity) access that is sustainable, viable, ethically compliant and cost effective. In modelling IEEM, a modified genetic algorithm (MGA) would be utilized in simulating the dispatch of DSM loads (residential houses only) across the country. This paper advances traditional grid expansion planning by presenting smart policy discussions on the usefulness of IEEM in reducing associated network losses, enhancing utilization of local energy sources and minimizing expansion and plant operations costs. This paper also discusses the impact of the IEEM on the quality of life (QoL) of households and quality of service (QoS) of the utility. Electricity consumption data have been adopted from the existing literature and appropriately modified.

1. Introduction

According to the Transmission Development Plan (TDP) (Eskom, 2015), Eskom is expected to step up the construction of additional electricity supply capacity from 2017. The accelerated efforts by Eskom are sequel to the energy crisis that has plagued South Africa since 2008; originally leading to massive blackouts, load shedding and huge economic losses (Kohler, 2014; Shezi, 2015). While about 3516 MW is expected to be lost from the grid due to deteriorating and decommissioning of ageing power plants between 2021 and 2024, about 19,000 MW is expected to be added to the grid capacity through new builds and capacity expansion between 2017 and 2024 (Eskom, 2015). Table 1 (Eskom, 2015) presents the planned decommissioning between 2021 and 2024 while Table 2 (Eskom, 2015) and 3 (Eskom, 2015) present the planned supply capacity increment between 2017 and 2024. Within, Table 2 shows the Medupi and Kusile coal-fired and Ingula pumped storage power stations as key developments to meet peak demand. The power plants in Table 2 all feed into the national grid.

Further, additional costs are expected to arise given the need to increase the transmission network capacity and the requirement to build additional transmission and distribution stations in order to wheel power to homes and industry sites. It is expected that the bulk of the costs for expansion will be borne by the electricity consumers in form of increased electricity bills while further support will come from loans from the government and commercial creditors (BusinessReport, 2018). The population growth predictions shown in Table 4 (Eskom, 2015) present a growing trend in electricity demand forecasts. An assumed consequence of the increasing population, increasing energy needs and increasing industrialization is the need for Eskom to continue to boost generation capacity to always match projected demand. Yet this idea is at variance with a global trend, where demand side management (DSM) initiatives are being implemented in order to reduce the need for new builds and efficiently utilize existing technologies to meet current demand. This is due, largely, to the huge costs involved in building power stations and the long timespan between construction the synchronization of power plant outputs (Ofgem, 2015).

Fig. 1 presents the conventional electricity expansion plan currently being exploited by Eskom. During the process of executing electricity expansion, Eskom models electricity demand increases considering diverse factors (Gross Domestic Product (GDP), inflation, previous electricity demand growth, government policies etc.) to come up with various growth patterns considering multiple variants (shown in Table 4).

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Nomenclature

DLC	Direct Load Control
DP1, DP2, DP3	Dynamic pricing tariff options
FBAE	Free Basic Alternative Energy
FBE	Free basic Electricity
k,z	Indices of buses
MGA	Modified Genetic Algorithm
QoL	Quality of Life
QoS	Quality of Service
REPs	Renewable Energy Projects
SHS	Solar Home System(s)
T	24 h duration or 96 time slots
t	time slot of 15 min interval
TOU	Time of Use pricing tariff option

1.1. *Prevailing problems associated with South Africa's electricity expansion plan*

The demerits of the conventional electricity expansion plan of South Africa are as follows:

- There is the possibility of a supply glut (surplus) due to over-compensation of supply capacity. Such an instance was witnessed in the 1990's and led to the mothballing of the Komati, Camden and Grootvlei power stations (Monyei and Adewumi, 2017).
- There is the possibility of a supply deficit owing to either demand exceeding projections or policy inconsistencies that mitigate against the development of new builds to shore up supply capacity. Such an instance was witnessed in 2008, when supply could not meet peak demand leading to massive load shedding and blackouts (Kohler, 2014; Shezi, 2015).
- Low utilization of renewable energy resources. Despite considerable increase in renewable energy projects (REPs), the lack of control over end user load dispatch (flexible DSM loads) by Eskom prevents them from fully utilizing the potentials of REPs due to their stochasticity. System operation and planning is thus done using base load stations (coal and nuclear) whose capacities and performances can be evaluated exactly.
- The loss of loads and blackouts remain a possibility. In instances of peak demand, the inability of Eskom to quickly dispatch end user loads without financial penalties means the possibility of load shedding becomes high.
- Electricity billing could be excessive. According to Eskom (2017), between 2008 and 2013, electricity price cumulatively rose by about 114% which was at variance with declining electricity prices prior to 2008/09. The sharp increase in electricity price (which was to enable Eskom raise future revenue to cover for new builds) was met with increasing public resistance (Eskom, 2017). Eskom has thus consistently argued for further increases in electricity prices to enable it to bridge its revenue shortfall (R35 billion in 2014/15).

1.2. *Major contributions of this research*

The aim of this paper is to study and show the impact of an electricity expansion model (that integrates all aspects of the electricity grid) on peak demand reduction, expansion costs reduction, capacity utilization maximization, maximization of earnings (for the supply side), minimization of electricity costs (consumption/utilization side) and network loss reduction. This is consequent on the fact that in addressing the issues associated with the conventional system of electricity expansion planning in South Africa, there is the need for an electricity expansion plan that is capable of:

- Isolating consumers from extreme price fluctuation due to the utility's billing system that attempts to recoup investments on new builds.
- Utilizing REPs effectively. Rather than expending huge sums building large-scale storage facilities for wind and solar projects, end user loads could be dispatched during times of wind/solar availability. While we acknowledge the role of battery energy storage in stabilizing the electric grid and enabling the integration of REPs (Hu et al., 2017), we however draw caution from DiOrio et al. (2015) who offer that *it is necessary to evaluate the utility rate structure, and determine whether the addition of battery storage can be leveraged to reduce costs enough to justify the upfront capital expenditure and replacement costs*. This is important in ensuring that consumers do not become unnecessarily over-burdened with huge electricity bills.
- Efficiently utilizing installed supply capacity. With adequate knowledge of demand schedules and operational control of a fraction of end users loads, the utility is able to optimally dispatch generation sources and allocate end user loads such that dispatched supply capacity is efficiently utilized. This is necessary to prevent energy wastage, reduce emissions and operations losses.
- Minimizing network losses.[1] With advanced knowledge of demand growth profiles across the provinces, it becomes possible to evaluate the associated costs (economic, losses) and benefits of situating a generation source closer to a demand hub[2] or extending the transmission network from the generation hub[3] to the demand hub. While it might be economical to locate power plants close to primary fuel sources, there is the possibility of incurring high economic costs and he network losses through evacuating power from the generation site to load centres. Balancing the location of generation sources to minimize economic costs and network losses becomes important.
- Minimizing expansion. The ability to predict demand growth and evaluate operational DSM (by which we mean flexible loads whose operation hours can be influenced externally) capacity provides the utility company with an avenue to explore varied energy supply mix options, including REPs. This may minimize the utility's expansion of supply capacity, inherently improving efficiency and reducing expansion costs.

Table 1
2021–2024 Planned power plant decommissioning Eskom (2015).

	Camden		Hendrina		Arnot	
Year	Unit	MW	Unit	MW	Unit	MW
2021	6	− 160	4	− 190		
2022	7	− 170	3	− 190		
	8	− 180	5	− 180		
2023	5	− 180	2	− 190	3	− 380
	4	− 185			2	− 380
	3	− 185	1	− 190	1	− 376
2024	2	− 190				
	1	− 190				

[1] According to Eskom (2015), total technical energy losses for the 2014/15 financial year was estimated at 8.79%. While transmission losses (estimated at 2.53%) are mainly associated with power evacuation and increase with distance, distribution losses (estimated at 6.78%) are influenced by factors such as network design, network topology, load distribution and network operations.

[2] We define a demand hub to be a cluster of provinces with cumulative demand exceeding 15% of the total demand for South Africa.

[3] By generation hub we mean a cluster of power plants with generation capacity exceeding 30% of total generation capacity of South Africa. An example of such is the Mpumalanga Power Pool (MPP).