DEMAND FORECASTING FOR NETWORK CAPACITY PLANNING IN ELECTRICAL UTILITIES – A REVIEW OF EXISTING METHODS CONSIDERING THE EVOLVING TECHNOLOGIES OF THE ENERGY ARENA

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ABSTRACT

Planning for sufficient energy resources in a country is of paramount importance to ensure sustainable development of the economy and prosperity of its citizens. In South Africa the national utility, Eskom, is tasked to create a balance between the electricity demand and the supply thereof. Forecasting the electricity load on the networks to supply the country demand becomes an important task to ensure that capacity planning does not constrain potential growth, and neither does it construct overinvestment to compromise feasibility of implementation. The landscape of energy utilization is currently experiencing rapid evolution in technology and poses significant challenges to the way the electricity demand forecast needs to be done. Technology is evolving to provide more efficient, cost effective and reliable alternative energy sources than the conventional methods used in the past. Improved electricity efficiency and user behavior plays a significant role in future electricity demand requirements. This paper provides a comparative literature review on current forecasting methodologies to provide insight to which of these methods can be utilized in the future. A set of requirements is concluded on to identify the most relevant and effective forecasting methodologies to improve accuracy on forecasting electricity demand into the technology advanced future.

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1. INTRODUCTION: AN EVOLVING POWER SECTOR

The turn of the millennium indicated the start of a new era in which the fundamentals of the power sector began to change. For most of the past century the electric utilities of the world was mostly stable, fairly predictable and commonly operated in a vertically integrated supply chain. Supply of electricity requirements was mostly operated by conventional power stations (mostly coal fired, gas or hydro generation plants) which was then transferred through a high voltage transmission grid to a distribution substations where it is transformed to lower voltage distribution networks for residential and industrial uses. The utilities had mostly predictable load growth and therefor predictable sales which was governed and periodically adjusted to keep utilities reasonably profitable. A significant change in technology within the power sector changed the stable state of the power sector. New technologies for generation of electricity, especially on the customer side of the value chain started to emerge. The term 'prosumer' was derived from the original word customer, which indicates a customer that can use energy and simultaneously play an active participant in the market by supplying energy back into the networks [1]. This changes the configuration of the network operations significantly.

Throughout the ages, industrialisation brought technological leaps and this led to paradigm shifts which today is referred to as "industrial revolutions". This took us from mechanisation (the 1st industrial revolution), to the extensive use of electricity (the 2nd industrial revolution), then the widespread digitalization (the 3rd industrial revolution), and then the latest revolutionary changes in technology advancement brought us to a new fundamental paradigm. With terms such as the "Internet of things", revolutionary energy generation and advanced digitalisation of industries and "smart" technologies, it brings us to the 4th industrial revolution that is now looming [2].

The world economic forum in collaboration with Bain and Company did an excessive study on the future of technologies influencing the grid. They argue that the fourth industrial revolution builds on the legacy of the digitalisation of the third industrialisation where multiple technologies are combined to takes us to a paradigm shift in economy, business, society and the individual. This paradigm shift involves transformation of entire systems and in particular also within the electricity landscape where the scope of the power sector is becoming more complex than ever before, with rapidly changing technologies in power generation and storage thereof, emerging innovative business models and shifting regulatory landscapes. It is imperative to support a reliable, economically competitive and environmentally sustainable electricity system as a corner stone for a modern society into the future [3].

In the book, Future of Utilities and Utilities of the future [1], it was highlighted that there is a growing concern as to which end of the scale the electric power sector would tilt. Some experts is of the opinion that the utilities as they are known currently is at a death spiral form where there is no escape which can bring the end of utilities as they are currently known. Specialists on the other side of the spectrum are of the opinion that the world is at the start of a new evolution and that the many challenges the sector face should be embraced. A revolutionary future is envisaged even though significant changes is required within the power sectors' network operations, business models, how it is regulated and its culture. A recent study by Accenture indicated that by 2025 the annual revenues of US utilities may potentially be $48 billion lower than they would have been otherwise due to the rapid growth of distributed energy generation sources and gains in energy efficiency. The same study indicates demand of the grid to lower by 15% relative to current status quo. European utilities are likely to experience the same, coupled with a current decline in conventional demand growth. Other studies concluded that the rapidly falling prices of Photo Voltage (PV) technologies will ensure an increase in uptake of this technology in both commercial, industrial, agriculture and domestic use. It is further projected that globally fossil fuels might be dominated greatly by renewable energy generation by 2050 [1].

The U.S Energy Information Administration (EIA) publishes a yearly International Energy Outlook Overview with global energy predictions up to 2050. The EIA classifies the world countries into Organization for Economic Cooperation and Development (OECD) members and non-members (non-OECD). According to EIA the non-OEC countries indicate a stronger demand growth in energy needs as these countries show strong economic growth, increased access to marketed energy and quickly growing populations (these include African countries, China, India, Brazil to name a few). These countries face challenges with both forecasting the growing demand and engineering systems around evolutionary new technologies. On the other side of the equation is the OECD countries (OECD Europe, Canada, United States, Japan, Australia and New Zealand amongst the top players) where energy demand is on a decline or a slower growth due to increase in energy efficiencies. The going concern on these networks is changing of structures and regulation to include new technologies and systems, rather than plan for demand growth [4].

These facts are all an indication that renewable and alternative energy sources is showing great possibility in changing the conventional power delivery methods, and possibly the demand on the utility electricity grid. Taking all these fundamental paradigm shifts and increasing technological evolution in consideration, the question emanates - how does this influence the design of the current utilities?

Increasingly, utilities will be facing challenges with network designs evolving into decentralised from centralised, on how customers will be connected to the grid, whether they will be customers or prosumers, and how these structures would be governed and regulated to still provide a resilient and profitable organisation. This is all aspects that form the future scenarios of how we can design electricity grids going forward. However for the foreseeable future a prominent, and very important function is still needed as the starting point of all these aforementioned planning activities: forecasting the network demand. Such a demand forecast is complex and increasingly difficult to formulate taking the amount of uncertainties and external factors such as technological advancement, political stability, population growth of the country and governing structures of the power sector into account.

Form a local perspective the focus then moves to the South African utility, Eskom Holdings SOC Ltd. (Eskom). The forecasting of the electricity demand as a fundamental input to the network capacity planning processes should be defined and refined to obtain the most suitable method(s) for forecasting the future. Such methods is needed to forecast electricity demand to create equilibrium between generation sources and the national demand within the electricity supply chain. A supply chain once vertically integrated and now finding a notion towards horizontal integration. These forecast needs to serve as input to network development plans that will enable necessary infrastructure development for economic growth empowerment.

This article provides a brief literature review on forecasting techniques available for long term demand forecast to assist in determining the most suitable approach in forecasting future demand, taking in consideration the range of external factors created by advanced technology development and changing of energy sources from conventional to alternative sources. The study aims to enable Transmission network capacity forecasters in Eskom to provide more accurate and appropriate forecasting for adequate network development plans.

2. BACKGROUND ON FORECASTING DEMAND FOR THE SOUTH AFRICAN ELECTRICITY GRID

2.1 Current Transmission Demand Forecasting in Eskom

Eskom is the current custodian and main contributor to South Africa's base electricity load and plays a fundamental role in meeting South Africa's energy requirements. Eskom currently supplies 97% of the country's demand and therefor as the principal transmission and distribution licensee in South Africa, Eskom is responsible for developing and maintaining the country's transmission and distribution infrastructure as well as South Africa's interconnections with the Southern African Power Pool. The transmission grid planning forecast is produced as input to the Transmission Development Plan (TDP), which essentially contributes to the capacity planning of the transmission networks in order to fulfil the vision set by the National Development Plan (NDP) for the energy sector of South Africa. The NDP is a governmental document that sets growth targets for all South African sectors. The NDP's main aim is to eliminate poverty, reduce inequality and grow the South African economy. The current edition is aimed at growth targets to be achieved by year 2030 [5].

Transmission network studies require long term forecasts with at least a ten year horizon, however a twenty-year plus horizon is preferred. A Transmission demand forecast has the purpose to identify future load growths and highlight possible network constraints in need of expansion [6]. Taking in consideration that the energy sector is undergoing a paradigm shift, it is imperative that the forecasting needs to adapt to provide accurate results.

The system in which Eskom operates its production can currently be classified as a balanced vertically integrated supply chain as most of its production comes from owned subsidiaries. This gives Eskom the competitive advantage of currently being the monopoly energy provider to Southern Africa. However, capacity constraints from 2007 coupled with economic downturn created cause for panic. Alternative energy sources and advanced technologies in renewable generation become a prominent trigger to the formation of a horizontally integrated supply chain going into the future, in order to sustain market share and competitive advantage. Eskom facilitates a renewable integration programme where independent power producers (IPP's) can receive licences and generate power to use and sell back on to the national grid [6].

It is imperative that any forecast is done within the right context given the purpose it should serve. Within Eskom, a number of forecasts exist, each driven to satisfy a specific business need. However, it is important that although different forecasts serve different purposes and business needs, such forecasts should be aligned and managed from a holistic perspective to not only achieve the overall objectives of the utility, but to also adhere to the electricity demand of a country, and in specific, align to the goals set, in the case of South African utility Eskom, these goals were set by government in the NDP [5].

The Eskom transmission demand forecast is currently done by using a top down approach where South Africa's total electricity demand is taken into account within a mathematical model and balancing algorithm. Methodologies are continuously updated to forecast the demand. The methodology currently consists of both quantitative and qualitative forecasting techniques with the S-curve methodology applied predominantly. The methodology used in Eskom was developed by Dr DF Payne in 2004 and is continuously researched and improved to suit the growing complexity of the energy utility operations [7].

Figure 2-1 gives a brief overview on the current forecast process followed in the Eskom transmission demand forecast process. A top down approach is followed where national load is disaggregated to the transmission (Tx) station points within the networks. Spatial demand areas are translated to load capacity needs per Main Transmission Substation (MTS) for capacity design engineering purposes. A supply and demand model is used to better understand future expected demand growths in the complex and highly uncertain environment. A mathematical model is then used to solve a non-linear programming problem when allocating loads to substation nodes. The demand per forecast area is validated by evaluating relevant market intelligence and external information such as economic analysis and other growth factors [7]. Bottom up forecast validation is then done with alignment that is done on distribution forecasts and interaction with the distribution operating areas. This interaction is facilitated by use of the Geo Spatial Forecasting (GLF) forecasting tool used by the distribution forecasters for the bottom up forecast

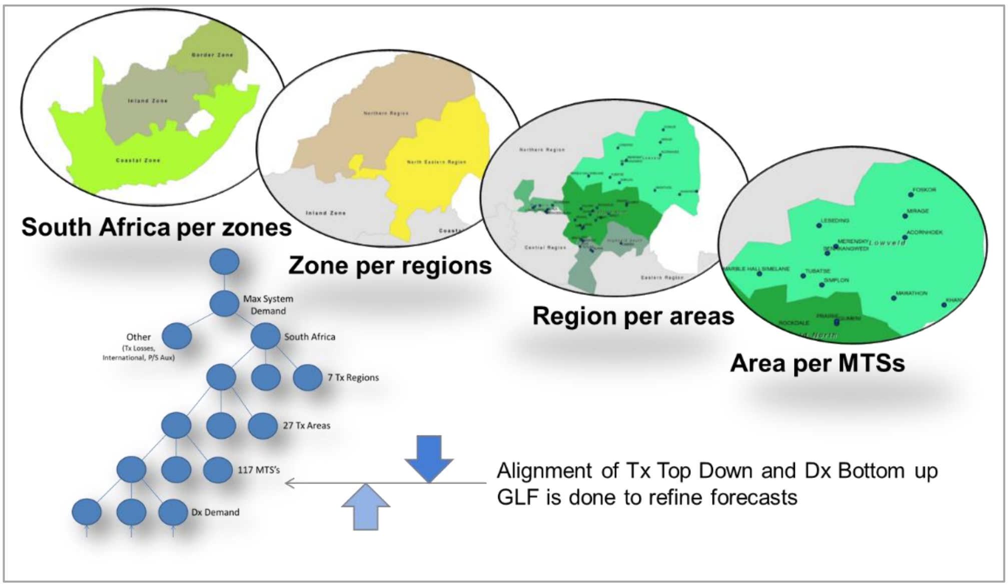

Figure 2-1: Current top down methodology for Eskom Transmission Demand Forecast

A schematic design was derived to show the context of the current Eskom supply chain, and can be seen in figure 2-2. Prior to 2008 the Eskom system was a closed supply chain vertically integrated with only the conventional coal, nuclear, single hydro plant and selected co-generation from key customers. Additional to this the Direct Current (DC) line built from Caborra-bassa was also accounted for within the supply system.

The national grid is split into distribution networks (Dx) ranging from 22kV to 132kV networks, which is then connected to the larger transmission networks (Tx), designed for 257kV to 765kV lines to transport power over larger distances.

Figure 2-2 is a schematical representation of the network conectivity landscape until recent changes in generation resources and adding of the independent power producers programme (IPP) to the national grid. The diagram shows the simplistic verticaly integrated supply chain. Generation supply (mostly conventional) is connected to the grids, which is in turn connected to the national demand. This is a fairly uncomplicated and linear landscape for which forecasting was fairly predictable by using trends of the past and qualitative and quantitative approaches to determine the forecast.

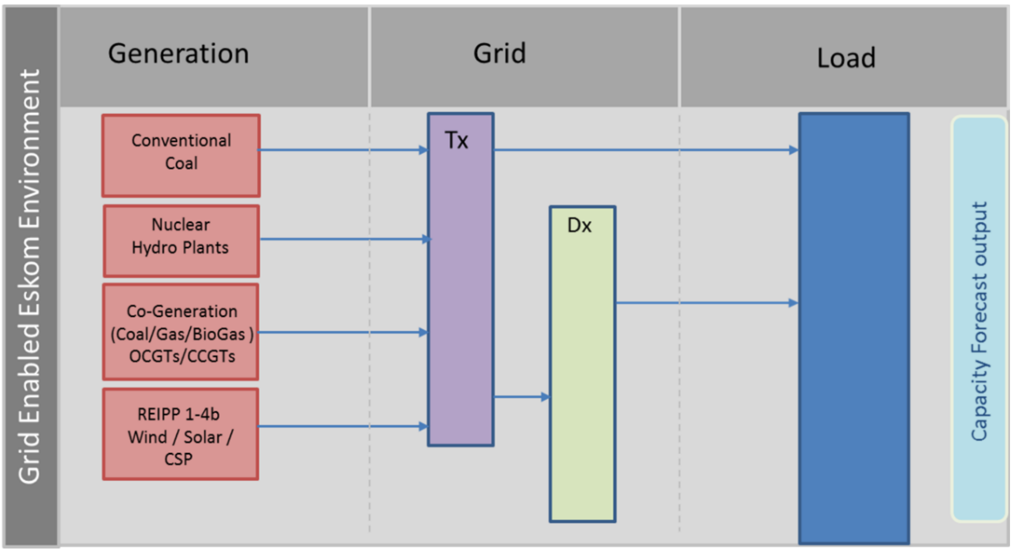

Figure 2-2 : Network connectivity diagram indicating the vertically integrated supply chain without unconventional a generation source

2.2 Future considerations within the Transmission Demand Forecasting in Eskom

In his article, 'Gridlocked', Hedden [8] investigates the future scenarios of the South African Grid. He discussed the loadshedding South Africans experienced between 2008 and 2014 , and argues that this was seen as an electricity crises at the time. A significant amount of pressure was put on the South African Department of Energy (DoE) to search for ways to increase generation capacity and implement demand side management programmes to reduce annual load usage. New coal-fired station power plants are in construction, and oil and gas are explored as a possible energy source. New Independent power suppliers (IPP's) are contributing towards energy supplies. This is currently increasing the blurring of the line between consumers to prosumers. Hedden therfor states that the electricity sector in South Africa is changing exponentially with the influence of renewable energy, IPP's and small-scale embedded generation (SSEG).

When considering a smarter grid scenario into the future, Hedden [8] forecasts that there will be a need for the grid to enable renewable and embedded generation sources in such a manner that the benefits is distributed by all users of the grid. A higher penetration of renewable energy benefits will increase economic growth and sustainability.

Such a scenario implicates that the future of the Eskom grid will increasingly include current initiatives such as the renewable programs (REIPP), gas (for both combustion power stations and residential and industrial use), micro and privately owned grids, self-generation, electric vehicles and more alternative energy sources.

It can be argued that the future forecasting scope of grid capacity demand forecasting might change, considering the impact of self-generation or off grid capabilities provided by alternative energy sources (such as gas) and alternative generation of energy (such as renewables). The network connection landscape is then expanded with a section that can be either connected to the grid on temporary basis or be deflected and functiononing totally off-grid. The alternating users will typically make use of PV technology or wind turbines for energy generation, however if the source (such as wind or sun) is unavailable beyond the current storage capability of the generator. These customers would return to the utility for energy needs and should therefor still be accounted for in the base load predictions. Currently most of the official generation sources feeds back into the national grid and can be seen as an import or supply onto the system.

As technology evolves and electricity tarriffs increases, customers are moving increasingly towards grid deflection where they utilise generation technologies in order to function independently from the utility grid. It becomes evident then that a certain portion of the load of the country is not supplied by the local grid, and is seen as self-sufficient and a form of grid deflection can be seen. Currently this is a very small portion of the national load, however this is fast changing when taking in consideration that the 4th industrial revolution is at our front door and the technologies that it brings changes. The advanced technological improvements and the sustainability thereoff will have an impact on the proportion of grid serviced load and the customer differentiation that will cause future load forecasting to look substantially different. Figure 2-3 gives a representation of the network conectivity landscape taking self generation, grid deflection and unconventional generation sources in consideration. The figure shows where there is posibility for excess generation to be evacuated through the utility grid and therefor changes the capacity forecasting scope, as indicated by the arrows following back into the grids. When this is the case, the forecaster should now take in consideration not only the spatial load to be supplied, but also the excess generation to be evacuated through the grid. The excess generation that needs to be evacuated will require capacity on the networks, and therefor needs to be included intor the capacity forecast per transformer.

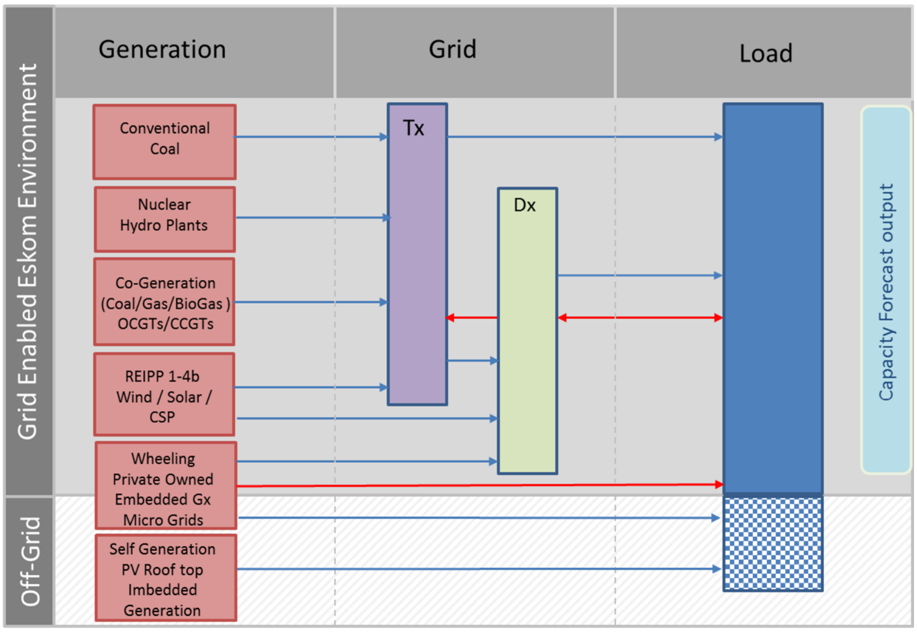

Figure 2-3: Network connectivity diagram indicating a horizontally integrated supply chain with unconventional generation sources included.

Figure 2-4 gives a schematic prediction on the author's sentiment on how the forecasting scope for national grid capacity development might differ from the current moving into the future. The perception is that currently there is a portion of customers fully relient on the national grid, a portion that is seen as variable and can be selfsuffiecient at certain times of the day, however they return as soon as ther generation reliability decreases. Then lastly there is a small portion currently off grid. It is foreseen that in future these segments will change in proportion to one another, however it is still unpredictable to what extend they will change. This creates further uncertainty with the forecast of capacity for utility planning purposed.

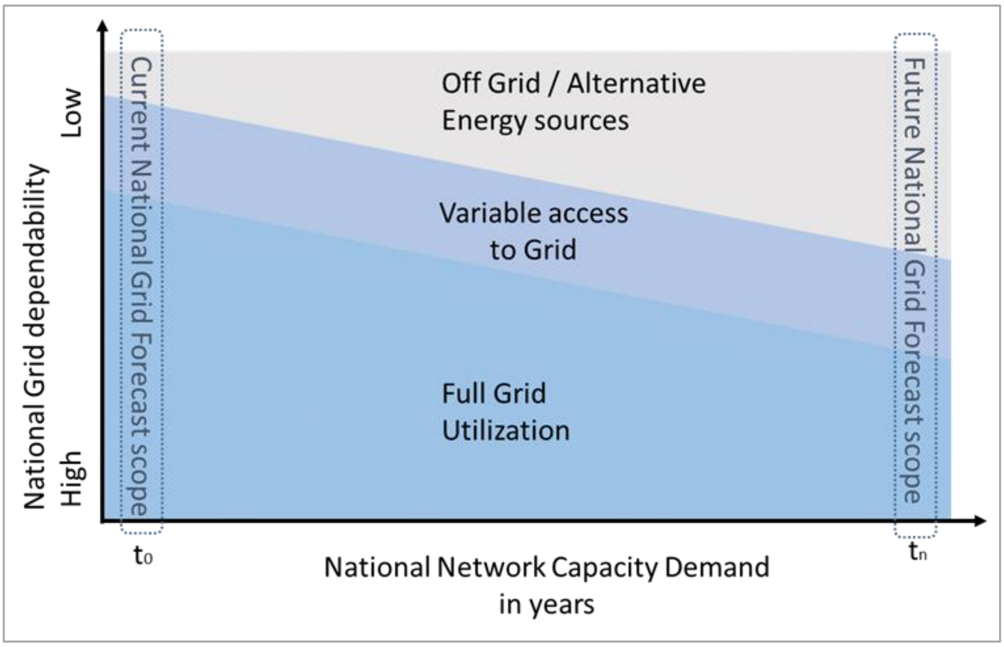

Figure 2-4: Schematic prediction on the forecasting scope into the future

Kessides, Bogetic and Maurer [9] identifies a number of current and forthcoming issues in the South African electricity sector where they highlight the difference in location of load centres and future generation sources. It can be argued that once the alternative energy sources reaches mature levels of production, it might have the need to feed back into the national grid in order to "sell" energy supply to the national utility. If we consider the South African generation landscape, where conventional power supply is currently located in the north of the country (close to the current load centres), and most renewable energy natural resources such as wind and sun is most prevalent to be set up in the south of the country (far from the major load centres), a need for transportation, import and evacuation of generation becomes a great grid planning consideration [9].

Figure 2-5 shows that both demand drivers and generation sources can have an impact on the grid demand forecast going into the future. First of all it is the spatial area load that needs to be forecasted, then secondary effects on the required grid capacity caused by excess generation should be considered.

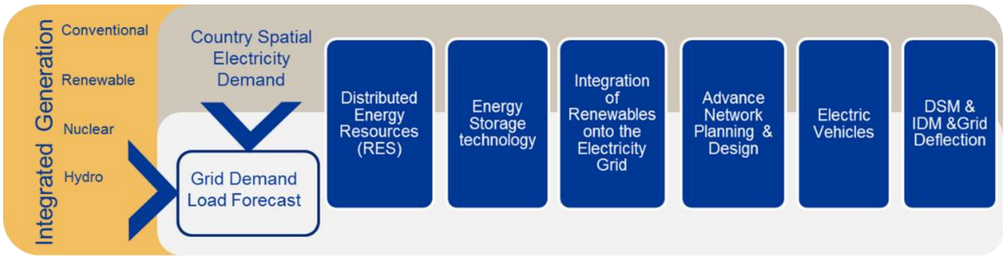

Figure 2-5: Identified possible influencing factors to the Grid Demand Forecast

There is a great need to evaluate the current available forecasting methodologies and accompanying forecasting techniques to ensure optimal forecasting for the growing complexities of the power sector. The following section will give a brief overview on available technologies.

3. A LITTERATURE REVIEW ON FORECASTING METHODOLOGIES

3.1 Demand Forecasting Defined

Dr Hans Levenbach [10] has devoted his career into finding appropriate demand forecasting practices to facilitate demand planning within any supply and demand domain. In his book Change & Chance embraced, he defines demand forecasting as a process with the main objective to predict future events or conditions. He further explains that forecasting attempts to predict change in the presence of uncertainty. He argues that there is much more surrounding forecasting than using past trends to predict the future. This could be agreed to if the changes within the power sector is evaluated. The future will certainly change from the past conventional power sector. The challenge is to distinguish what combination of techniques is available in literature to combine into a framework for the technological advanced future. Care should be taken to distinguish which areas of the past can still be utilized qualitatively to apply to similar growth areas into the future [10].

3.2 Forecasting electricity demand

Similar to most manufacturing industries where supply and demand needs to be balanced, the power sector can be related to a supply and demand model. In a load forecasting case study done by Hong, and Shahidehpour [11] they express an opinion that electric utilities run the power grid, to deliver energy. It is in simple terms the business of turning electrons into electricity for consumption by the user, a simple demand and supply problem. In the current electrical industry, energy cannot be massively stored with the technologies at hand. Therefor electricity cannot be considered as a product that can be stored on a shelf and sold for future use, it is rather a product that is sold at real time and the supply and demand should be balanced every operating moment. This increases the complexity of forecasting the product and ensuring adequate demand can be met at all times.

With the future in mind, it can then be argued that with technological advancement electricity storage might influence how the demand and supply will be balanced. It can be agreed that the power system planning of electricity demand and supply is seen as a non-linear system with a number of influencing factors and role players rather than a simple linear system with inputs and outputs. Hong further reasons that load forecasting is used through all segments of the electric power industry, including generation, transmission and distribution network planning, and in the sales and revenue planning arena. He stresses the importance of load forecasting, as inaccurate load forecasts might result in financial burden [11].

3.3 Evaluation of forecasting methods and techniques available

When deciding on which forecasting methods and techniques to use, the forecaster should take care to analyze what is the purpose and goal of the forecast and what data is available. Chambers, Mullick and Smith [13] published a paper on how to select the right forecasting technique. They substantiated that the forecaster's selection of a method depends on many factors such as the context of the forecast, the relevance and availability of data, the accuracy of the forecast, the time period for which the forecast should be applied and timelines for analysis. Chambers *et al.* [13].

From a selection of articles on forecasting techniques, it can be reasoned that forecasting techniques can be grouped into eras of development. The first group of techniques can be grouped into "Pre-Personal Computer" area which pertains strongly to techniques used mainly before the 1980's. As the computer industry ramped up and the personal use of computers became more accessible, a new set of forecasting techniques was launched, these where technological advanced and computer driven to allow increased processing capability. Spatial forecasting techniques was also introduced in this era of intelligent methods. Thirdly the latest group of methods can be classified as strategic or smart grid era techniques leading us to intelligent and scenario based forecasting technique.

Hong *et al.* [11] explains the word "technique" as a group of models that fall in the same family, such as Multiple Linear Regression (MLR) models and Artificial Neural Networks (ANN). A forecasting technique is explained by Levenbach as a simplified representation of a real world situation [10]. On the contrary, "methodology / methods" represents the general solution framework that can be implemented with multiple techniques [11]. Figure 3-1 shows a summary of the technique categories identified.

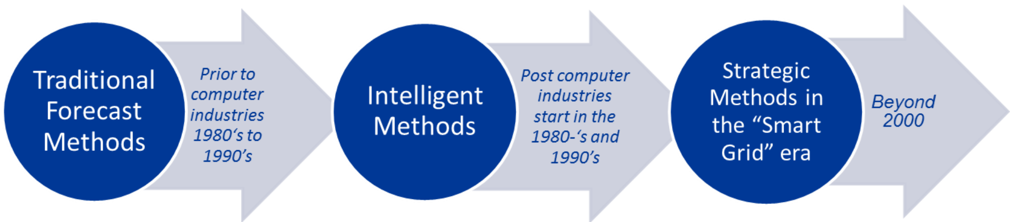

Figure 3-1: Forecast Techniques grouping according to era

The forecasting techniques found in literature will now be discussed and grouped accordingly. Various literature sources were sourced. Sioshansi [1], Levenbach [10], Hong *et al.* [11], Chambers *et al.* [13], Lempert [14].

3.4 Traditional Forecast Methods (Prior to computer industries 1980's to 1990's)

The very first energy forecast was done when Thomas Edison provided streetlamps to Pearl Street Station in New York in 1882. Hong highlighted that equation was simple, and the amount of lights was counted to calculate the demand to meet. Following the development of the energy implementation in more than streetlights, Hong describes that engineers had to make use of tables and figures to calculate forecasts as no statistical packages where invented yet [11].

The traditional forecast methods are grouped by Chambers et al. [13]as three basic types – Quantitative and qualitative techniques, time series analysis and projection, and causal models. Each of these has a number of techniques relating to the set of models. Some of these models used no computer processing, whilst others were at the very start of computer involvement.

3.4.1 Quantitative and Qualitative Methods

Quantitative techniques is mostly suited for short term forecasts where rigorous data analysis is done mostly by statistical and deterministic approaches. Regression methods and statistical analysis is often used where good current data is available. Chambers *et al.* [13].

Qualitative methods are more often used where there is not much data available and the expert opinion needs to be applied. This method is sub divided by Chambers *et al.* [13] into the following forecasting techniques:

3.4.1.1 Delphi Method

With this method a panel of experts is used to analyze and interrogate information. This is often done by questionnaires, interviews or by panel discussion. This method has a fair to good reputation on forecasting accuracy for both short and long term forecasting. It is typically applied to forecasts of long-range and new-product sales, as well as forecasts of margins. Chambers *et al.* [13]

3.4.1.2 Market Research

This technique includes the systematic and formal process to test hypothesis about real markets. This technique is excellent for use in short term and fair to good for use in long term forecasting. In this technique Chambers *et al.* describes that a considerable amount of market data is needed. Chambers *et al.* [13]

3.4.1.3 Panel Consensus

This is one of the most widely practiced qualitative method. This technique assumes that a panel of experts can derive at a better forecast than one person. Panel members is free to contribute their opinion on the forecast. A disadvantage of this technique is that the forecast is often influenced by social factors and my not reflect a true consensus. This is not a good method for long term forecasting according to Chambers *et al.* [13]

3.4.1.4 Visionary Forecast

This technique relates to the Delphi ad Panel Consensus techniques, however is rather based on personal visions and judgment. It is therefore not a very reliable forecasting technique and is not widely used for either short or long term forecasting. Chambers *et al.* [13]

3.4.1.5 Historical Analogy

This is a comparative analysis that uses past trends to introduce similar growth patterns into the future. This is not a strong technique to use for short term forecasting, however it is fair for use in long term forecasting. It is often used for new product forecasts. Chambers *et al.* [13]

3.4.2 Time Series

Levenbach [10] defines a time series as a set of historic data which is chronologically ordered such as energy consumed per hour for an extended period. The following techniques can be summarized under time series models.

3.4.2.1 Moving Average

Chambers *et al.* [13] describes moving average as a time series where each point of a moving average is the arrhythmic or weighted average of a number of consecutive points in the series. A number of data points is selected in order to eliminate effects of seasonal or irregularity. It is a very poor technique to use for long term forecasting. Chambers *et al.* [13]

3.4.2.2 Exponential smoothing

This technique is proven to be similar to the moving average by Chambers *et al.* except that more recent data points are allocated more weight. Descriptively the forecast is the same as the past, with some proportions of the past error. There is many variations of exponential smoothing according to Chambers *et al.* [13]

3.4.2.3 Box-Jenkins

Box-Jenkins technique is explained as a mathematical model that is fitted to a time series and is optimal in the sense that it assigns smaller errors to history than any other model. This is one of the most accurate traditional statistical routines and is excellent for short term forecasting, however it is very poor for the use in long term forecasting. Chambers *et al.* [13]

3.4.2.4 Trend Projections

This technique is one of the very first used and fits a trend line to a mathematical equation and then projects it into the future by means of the used equation. There are a few different types of these trends such as polynomial, logarithmic, and so on. This is a good technique to use in long term forecasting. Chambers *et al.* [13]

3.4.3 Causal Methods

Chambers *et al.* argues that causal models takes into account everything known about the forecasting system and utilizes information such as sudden events that could have influenced the data. They further argue that causal models are the best for predicting long term forecasts. Chambers *et al.* [13]

3.4.3.1 Regression Models

It is stated that these techniques relate strongly to sales and other economic variables. This technique estimates an equation using the least squares techniques. Relationships are primarily analyzed statistically and quantitative conclusions can be made. This is very good for short term forecasting however it is unsuitable for the use in long term forecasting. Chambers *et al.* [13]

3.4.3.2 Econometric Models

Ghods and Kalantar [15] describes the econometric approach as one that combines economic theory and statistical techniques for forecasting electricity demand. The approach approximates the relationship between energy consumption and factors influencing consumption. Ghods *et al.* [15]. It allows for multiple interdependent regression equations that describes the economic and profit activity. If excellent data is available this can be a good technique to use in long term forecasting.

3.4.3.3 Input-Output Models

Chambers *et al.* [13] describes these models as techniques used to describe the flow of a process where input parameters are transformed to certain outputs. These models can be enhanced to create economic input–output models where this technique is combined with the econometric models. This is argued as an excellent technique for long term forecasting.

3.4.3.4 Life-Cycle Analysis

This is explained by Chambers *et al.* as an analysis and forecasting done for a new product development growth rates based on S-curve techniques. This is a good technology for both long and short term forecasting [13].

3.5 Intelligent Methods (Post computer industries start in the 1980-‘s and 1990’s)

Hong states that computer applications started to ramp up after the 1980’s and a significant amount of research was placed into computer based techniques as well as spatial load forecasting. This introduced the concepts of load forecasting regarding where the load was coming, when it will be anticipated and how much load growth is anticipated.

3.5.1 Trending, Simulation and Hybrid methods

Trending methods use mathematical functions to fit the past load growth to the future load growth. Hong *et al.* [11] explains that this technique is mostly applied by using polynomial regression where the load is transferred to a function of trend and cycle. He further explains that simulation methods can also be excellent for long term use and is a technique that attempts to model the load growth patterns at play. Furthermore Hong *et al.* [11] explains how Hybrid models can be created to combine both trending and simulation to further accuracy on the forecast.

3.5.2 Artificial Intelligence

Hong *et al.*[11] explains that artificial intelligence models are based on artificial intelligent techniques such as Artificial Neural Networks (ANN), fuzzy logic, and black-box models to name a few.
Hong *et al.*[11] elucidates that ANNs have been extensively used for load forecasting since the 1990’s. ANN is a soft computing technique that does not require the forecaster to explicitly model an underlying physical system. The system is enabled to learn from historical data. Mapping can be established between the input variables and the electricity demand, which can then be adopted for prediction.

Fuzzy logic is used for short term forecasting and can be used for network forecasting, and not ideal for long term forecasting as summarized by Suganthi and Samuel [16]. They further explain that neural networks can be used successfully to model electrical networks and the associated load points [16].

3.6 Future Strategic Methods in the "Smart Grid" era

Hong explains how the power sector is going through a grid-modernization process where technologies are changing and network planning needs new consideration. New forecast areas such as Demand-response and Renewable-Generation forecasting will need to be investigated going into the future. Hong [12].

The great amount of uncertainty in the future power sector leads us to the following forecasting techniques.

3.6.1 Systems Thinking and Complex Theory

Stoker and Fick [17] delivered a paper which analyses the current situation in respect of South Africa's electricity situation and asks the question if Systems Thinking, more specifically as it pertains to the theory of Complex Adaptive Systems, would make a contribution to improved Electrical Energy decision making. The authors concludes that the mental framework which Systems Thinking provides, and specifically the theory which explains the behavior of Complex Adaptive Systems, could make a positive contribution towards achieving quicker coherence in respect of South Africa's future Electricity System. Stoker *et al.* [17]

3.6.2 Scenario Planning

Amer, Dai and Jetter [18] produced a review on scenario planning. They highlight that the use of scenario planning techniques is very useful in an era where uncertainty, innovation and change are prominent. They reason that scenario planning stimulates strategic thinking and helps to overcome thinking limitations by allowing multiple outcomes. They further argue that scenario planning is a valuable tool that can assist organizations to prepare for possible eventualities and make them more flexible and innovative. Creating different scenarios delivers an overall view of the environment and highlights the interactions among several trends and events in the future. They reason that scenarios can generally be used for any time frame, however it is most useful in long term forecasts. It has been proven that at corporate level scenario planning approaches was more popular and agile in larger companies and generally used for forecasting horizons of 10 years or more. Amer *et al.*[18].

3.6.3 Practical applications of strategic methods in literature

A few examples is available where scenario planning techniques was used in the power sector and Eskom specific. Hedden [8] produced three scenarios in his article 'Gridlocked' where he took South Africa from now to 2050 with his scenarios. He differentiated the three scenarios as the 'Current path scenario' where Eskom stays at the monopoly of the energy market, then he introduces the 'Efficient Grid scenario' in this scenario optimization of the grid is considered with investment in electricity generating capacity and ensuring efficiency of network operations. He then concludes with a 'Smart Grid scenario' where network efficiency and generation capacity is accompanied by integrated energy and grid planning to include renewables and decentralized electricity sources.

Another strategist in scenario planning is Cilliers [19] who investigated scenarios into the year 2035 with his article on South African futures. Cilliers [19] takes political circumstances in consideration and then proposes three scenarios. The first is a very successful Scenario called 'Mandela Magic' that alludes to a GDP growth rate of 5.1% pa. His second scenario is more to the conservative side, however still produces a 3.8% pa growth. And then he conclude with a lower scenario where he argues that the political instability South Africa is constantly experiencing will lead to a scenario called 'Nation Divided', with a nominal growth rate of 2.6% pa. Cilliers [19].

4. FACTORS INFLUENCING A DEMAND FORECAST

Other than the methods for creating forecasts, there is a number of factors external to the forecasting parameters that has an influence on the forecast. Some of these factors can be listed:

4.1 Technology and innovation

Musango and Brent [20] produced a study on technology in society. They argue that technology assessment is not new, however it is more relevant than ever in todays' energy market. They acknowledge that technology innovation is seen as a competitive advantage. They conclude that energy analysis tools is needed and should be researched further to enable the governing structures to identify and incorporate technological change into their plans. Musango [20].
In McKinsey's Quarterly report, Nyquist [21] reason that technology outliers should be monitored in order for the business to expect change and effectively deal with the change it might bring [21].

4.2 Energy efficiency

Energy efficiency is described by Hedden [8] as a parameter that is not necessarily linear to capacity requirement. He states that an increase in efficiency can lead to a decrease in cost which then in turn lowers the energy intensity. However, due to lower costs, demand usage can in fact go up. Energy efficiency and the change it can bring should be monitored closely.

4.3 Battery Storage

Mills, Barbose and Seel [22] produced a study on how to plan for distributed disruption, with the focus on incorporating solar into utility planning. They argue that the rapid growth of photovoltaic will continue to grow and that this will have critical implications for utility planning processes. They further explain how the storage component on this technology can affect the size and type of future infrastructure needed. This can have an immense effect on how we need to forecast and plan for future networks. As affordability of storage increases and technology advances, the effect will become apparent. Mills *et al.* [22].

4.4 Regulatory changes and economic stance

The world economic forum did a comprehensive study on finding operating models for the future. [4] They specify that governance is an important role player in how we drive change and agility. They state that Governance refers to the organizational accountabilities and the critical decisions that needs to take place by putting economic favorable models in place.
Cilliers [19] argues in his article that the heart of the economic failures lay at the inability of government, labor and business to chore around common growth visions. It is therefore inherently important that regulatory institutions and government work together to create a coherent vision for development of the power sector to enhance economic growth. He highlights how historical political climates in the different years where causes for failures and successes alike. Cilliers [19].

5. THE FUTURE OF FORECASTING IN A GROWING UTILITY

This article highlights the amount of uncertainty currently experienced in the power sector. There is a definite need to create a process for choosing, evaluating and executing the most accurate combination of techniques and tools available, whilst taking the ever changing environment into account.

A few forecasting models is available in literature to apply. These needs to be researched further and the applicability should be linked to the above mentioned techniques.

Suganthi *et al.* [16] elaborates on some energy models for demand forecasting, and one prominent model used is the LEAP model. The long-range Energy Alternatives Planning system was developed by the Stockholm environmental Institute and is a bottom up forecasting model. This is not ideal for the National Demand forecast that takes a top down approach from national perspective to transmission network points [16].

The initial review of the current electricity supply chain and the future challenges with advanced technology led to a set of initial research questions:

1. How will the demand forecast for capacity planning be influenced going into the new Power System Paradigm with the effects of Distributed Energy Resources and advanced technologies?
2. Which forecast techniques of the past is still applicable and agile enough to apply?
3. How can new complex thinking and current forecasting techniques be combined to guide forecasters to improve accuracy in the uncertain future?
4. What will the impact of unconventional generation be on the spatial forecast models, when considering evacuation of power from one area to another?

A set of requirements was identified and it is suggested that a model be designed to create a unique modelling approach for forecasting into the future. These aspects should be researched further and combined into a final forecasting framework for implementing within the current demand forecasting process:

1. Determine all possible influencing factors which can have an impact on the demand forecast, such as demand response and sustainable renewable generation forecasts.
2. Group impacting factors to be tracked and continuously revised for inclusion into forecast.
3. Evaluate advanced implementation models on long term electricity forecasting available from literature, aid in selection of the most suitable needs.
4. Combine available techniques and models to create custom framework to aid in building forecast scenarios. Framework suggesting optimal forecasting technique for identified forecast should be:
    a. Structured and include method selection criteria to facilitate forecasting.
    b. Should include methodology on incorporating renewable and decentralized generation sources into grid forecast.
5. Investigate tools to use for user interface to facilitate in combining different results to provide the forecaster with a holistic view of the influencing factors for the forecast.
6. Combine selected techniques with future scenarios to enable agile and robust forecast fitted to the scenario framework Add next – structured literature review to be done on application of techniques and models in long term energy forecasting

6. CONCLUSION

As the preceding discussions advocate, it is imminently clear that the electrical power sector is experiencing a paradigm shift and undergoing rapid change. It is important that the forecasting processes, models and techniques available is used optimally to ensure accuracy of the forecast as input to the planning of the electrical grid. A brief comparative evaluation was done on available and applicable techniques to gain better understanding in the type of models available from literature. Literature showed a strong notion towards strategic thinking and implementation of scenarios based forecasting. There is a need to further research and create a cohesive methodology that will be translated into a framework that optimally combines the most appropriate techniques for forecasting the demand of a determined scenario. The scenarios will be mostly dependent on the technology deployment, energy efficiencies and data available for use of the appropriate technique. It is suggested that an in-depth study is done to create a long term forecasting framework for demand forecasting of the electrical networks in South Africa.

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