Short Term Power Forecasting: State of Research & Development in South Africa and proposed way forward

CSIR Energy Centre

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September 2017
Objectives

1. CSIR Background

2. Overview of electricity market in South Africa

3. Short Term Load Forecasting (STLF) Research and Development in South Africa

4. Future vision for Short Term Forecasting in South Africa (Load and Variable Resource)

5. Conclusion
CSIR Background
"The objects of the CSIR are, through directed and particularly multi-disciplinary research and technological innovation, to foster, in the national interest and in fields which in its opinion should receive preference, industrial and scientific development, either by itself or in co-operation with principals from the private or public sectors, and thereby to contribute to the improvement of the quality of life of the people of the Republic, and to perform any other functions that may be assigned to the CSIR by or under this Act."

(Scientific Research Council Act 46 of 1988, amended by Act 71 of 1990)
The CSIR at a glance

The CSIR’s Executive Authority is the Minister of the Department of Science and Technology

**In numbers:**

- **71yrs**
  - 1945 - 2016

- **2 668**
  - Total staff

- **1 980**
  - Total in SET base

- **350**
  - SET base with PhD

- **R2.4 bn**
  - Total operating income

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Cape Town

Stellenbosch

Pretoria

Johannesburg

Durban

Port Elizabeth
CSIR Energy Centre team as of 17 August 2017

Interns
- Enoch
- Thapelo
- Bridget
- Salome
- Siphelele

SET Base (37)
- Functional Support (1)
- Seconded (4)
Area of interest to us in green

Energy Demand
- Demand Assessment in End-use Sectors
- Demand Forecasting (short-term, long-term, spatially)
- Supply Forecasting (short-term, spatially)
- Conventional Energy Technologies Market Intelligence

Energy Supply
- Resource Assessment (solar & wind)
- Renewable Energy Technologies (solar, wind, biogas, hydro, HPs, biofuels)

Energy Storage
- Batteries (design and integration)
- Hydrogen (production, storage and integration)
- Heat Storage
- Storage System Integration (P2eMobility, P2pumping)

Energy Systems
- Energy Planning
- Grid Planning (Transmission and Distribution)
- Micro Grids (including island grids)
- Smart Grids (observability and controllability)
- Energy-System Operation

Energy Markets and Policy
- Energy Economics
- Energy Markets (local, regional, global)
- Energy Regulation
- Energy Trading
- Energy Statistics

Energy Industry
- Energy Economics
- Energy Markets (local, regional, global)
- Energy Regulation
- Energy Trading
- Energy Statistics

Energy-Autonomous Campus Programme
- EAC Energy Demand
- EAC Energy Supply
- EAC Energy Storage
- EAC Grid Design
- EAC Operations (control and visualisation)

Administrative Support Functions

Research Support Functions
The CSIR current capacity and projects

Wind & Solar Resource Assessment
- Using in-house tools and WindPro/PV Syst®
- Installation of Solar PV and possible Wind generators

Wind Atlas of South Africa (WASA)
- Infrastructure
- Data collection and quality assurance
- Data interpretation and Analysis

PV / Wind Aggregation Study
- Aggregating of wind and solar resource
- Development of capacity factor maps
- Development of relative LCOE maps

Technology development
- Development of technology (process, product, service)

Power System Analysis
- Scenario development
- Energy mix scenarios
- IRP Inputs

Energy Autonomous Campus
- Virtual power plant
- Test facility for Short term variable resource forecasting model

Driving the development of Embedded Generation National Standard
- SANS 10142-3
- NRS 097

Strategic basic & applied research
- Generation of new knowledge and application of existing knowledge
Energy Supply has four areas following a value chain

Research focus areas of the research group Energy Supply

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</thead>
<tbody>
<tr>
<td>1</td>
<td>Resource Assessment</td>
<td>Quantification of the available resource (solar and wind), new profession of Energy Meteorologists; biomass and hydro assessment together with NRE</td>
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<td>2</td>
<td>Renewable Energy Technologies (solar, wind, biomass, hydro, ambient heat)</td>
<td>Technology performance, testing and verification, technology System Integration, technology-specific research</td>
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<td>3</td>
<td>Supply Forecasting</td>
<td>Solar and wind forecasting (week-ahead, day-ahead, intra-day), new profession of Energy Meteorologists; long-term forecasting together with NRE</td>
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<td>4</td>
<td>Conventional Energy Technologies Market Intelligence</td>
<td>Track the global market development for all conventional energy technologies. It is envisaged that we will in future provide the Power Generation Technology Data as input for the Integrated Resource Plan (IRP).</td>
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Overview of electricity market in South Africa
Eskom supplies lion’s share of Africa’s electricity

Generation:

- Eskom supplies 96% of South Africa’s electricity and more than 45% of Africa’s electricity
- 14 coal fired power stations with a total installed capacity of 39.3 GW or 84% of the total generation capacity
- Nuclear generation capacity comprises 1.9 GW ~4 %
- Diesel supplied gas turbine generation capacity comprises 2.4 GW ~5%
- Renewable energy incl. pumped storage and imports is responsible for ~7 %
- Power consumption per capita 4300 kWh per capita per annum
South African Transmission grid is well developed

Transmission & Distribution:

- Highly developed AC transmission grid 220kV – 765kV
- Highly developed AC sub-transmission (33kV – 132kV) and distribution grid 400V – 33kV
- Large DC import from regional hydro (Cahora Bassa 500kV)
- Development governed by 10 year Transmission Development Plan and 20 year Strategic Plan
Future growth of SAPP faces challenges

Markets:
- Most advanced in Sub-Saharan Africa
- Part of the Southern African Power Pool (SAPP):
  - 12 Southern African Countries – Population 230 Million
  - Created in August 1995 to optimise use of all regional power
- SAPP Regional Power Trading Framework established by SAPP members
- Trade surplus electricity on a day ahead basis
- Future Surplus power:
  - DRC – Grand Inga
  - Mozambique - Gas reserves and Cahora Bassa hydro
The Integrated Resource Plan (IRP) is the expansion plan for the South African power system.

In its most recent version, the IRP 2010 plans a doubling of power-generation capacity from 2010 to 2030.

A draft IRP has been released in November 2016:

**Guiding Policy for Future Generation Installations in South Africa**

### Installed Capacity

<table>
<thead>
<tr>
<th>Year</th>
<th>Peaking</th>
<th>Other Storage</th>
<th>CSP</th>
<th>Biomass/Gas</th>
<th>Wind</th>
<th>Solar PV</th>
<th>Coal</th>
<th>Nuclear</th>
<th>Coal (new)</th>
<th>Nuclear (new)</th>
<th>Gas</th>
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<tr>
<td>2016</td>
<td>50</td>
<td>112</td>
<td>9</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>17</td>
<td>30</td>
<td>30</td>
<td>20</td>
<td>10</td>
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<tr>
<td>2030</td>
<td>82</td>
<td>72</td>
<td>6</td>
<td>2</td>
<td>6</td>
<td>2</td>
<td>8</td>
<td>14</td>
<td>14</td>
<td>10</td>
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<tr>
<td>2040</td>
<td>109</td>
<td>22</td>
<td>8</td>
<td>1</td>
<td>8</td>
<td>2</td>
<td>15</td>
<td>8</td>
<td>8</td>
<td>15</td>
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<tr>
<td>2050</td>
<td>136</td>
<td>14</td>
<td>8</td>
<td>1</td>
<td>8</td>
<td>2</td>
<td>15</td>
<td>8</td>
<td>8</td>
<td>15</td>
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**Sources:** CSIR analysis
From 2013 to 2016, 3.1 GW of wind, solar PV and CSP commissioned
Short Term Load Forecasting (STLF) Research and Development in South Africa

Intra Day / Day Ahead
Short Term Load Forecasting in SA has come a long way

- **Pre 1998**: Short Term Load Forecasting Model Developed by Eskom
- **1998**: Recurrent neural networks for short-term load forecasting
- **2008**: Development of models for short-term load forecasting using artificial neural networks
- **2010**: Daily peak electricity load forecasting in South Africa using a regression approach
- **2013**: An assessment of the Short Term Wind Energy Forecasting Potential in South Africa
- **2016**: A comparison of regression algorithms for wind speed forecasting at Alexander Bay

**Ph1:** System Adequacy & Reserve Margin Study
**Ph2:** Operational Variable Resource Prediction
Conclusions of research conducted to date

1. No real focus on variable resource power forecasting for operations
2. Statistically based – no work done on physical (weather) power prediction
3. Does not take into account meteorological anomalies present in South Africa
4. Not a priority to develop local capacity in variable resource power forecasting since it can be procured *
5. It is necessary to now start building this capacity in SA

Why is local development of short term power forecasting capacity relevant?

1. Skills development and localisation:
   • Government Skills Development Act (31) implemented in 2003 has the aim of developing and localising the skills of the South African workforce to a world class level

2. Local topography and weather anomalies:
   • e.g. Western SA anomalies in boundary layer jet performance showing a strong presence during daytime hours; escarpment resulting in unique weather structures; diverse and complex weather systems

3. Unique power system:
   • Extreme distances between load and generation centres
   • Generally cannot rely on other local power systems to provide stability and this must be provided ‘in-house’

4. Impact of accurate variable resource forecasts:
   • Study by IEEE in 2016 evaluated 270 different energy mix scenarios and quantified the value of wind power forecasting improvements showed annual cost savings up to 5.8% by improving accuracy
Future vision for Short Term Forecasting in South Africa (Load and Variable Resource)
What have we established and where to next?

South Africa has existing capacity in Short Term Load Forecasting.

South Africa has strong ties with international expertise.

Unique Power System which requires bespoke solutions.

Future Generation Landscape showing higher % variable resource.

What does the road-map look like to capitalise on this strong base?
Existing Eskom STLF Model

\[ Y_i = \alpha + \gamma X_{1i} + \delta X_{2i} + \theta X_{3i} + \zeta X_{4i} + \eta X_{5i} + \eta X_{6i} + \varepsilon \]

Where:

- \( Y_i \) = Hour \( i \) forecast, \( i = 1,2,\ldots, 168 \)
- \( X_{1i} \) = Day type and seasonality
- \( X_{2i} \) = Weather variable
- \( X_{3i} \) = Public events
- \( X_{4i} \) = Holidays
- \( X_{5i} \) = Anomalies
- \( X_{6i} \) = Change in profile

Increasing significance since this term includes the IPP’s contribution

Now need to establish relationship between existing load forecasting methodology and variable resource forecasting
Global best practice

Figure 1: The various forecasting approaches can be classified according to the type of input (SCADA indicates data available on-line). All models involving Meteo Forecasts have a horizon determined by the NWP model, typically 48 hours.

1. SCADA
2. METEO FORECASTS
3. TERRAIN

- **Model**

**Forecasts of WP production**

- **Figure 1:** The various forecasting approaches can be classified according to the type of input (SCADA indicates data available on-line). All models involving Meteo Forecasts have a horizon determined by the NWP model, typically 48 hours.

1. Short-term statistical approaches using only SCADA as input (horizons: <6 hours).
2. Physical or statistical approaches. Good performance for >3 hours.

Giebel et al. The State of the Art in Short-Term Prediction of Wind Power Literature Overview, 2nd Edition
What has been done for countries similar to SA

Australian modified ANEMOS System used by AEMO for pre-dispatch variable resource short term forecasting

What type of forecast do we need?
- Individual generator forecasts
- National Electricity Market (NEM) Wide forecast
- Region forecasts
- Uncertainty forecasts
Proposed variable resource system operator model

(NWP = Numerical Weather Prediction)

NWP e.g. ECMWF

NWP e.g. METFR

NWP e.g. METOF

(VRPP = Variable Resource Power Prediction)

Include IPP Power forecasts and actual production data

Initial State

Combination Module

Benchmarking

Final VRPP

Final VRPP

SA Research Team Generated VRPP

Procured VRPP 1

Procured VRPP 2

Procured VRPP 3

Procured VRPP 4
Proposed variable resource system operator model

Include IPP Power forecasts

Final VRPP

Combination Module

Procured VRPP 1

Procured VRPP 2

Procured VRPP 3

Procured VRPP 4

SA Research Team Generated VRPP

NWP e.g. ECMWF

NWP e.g. METFR

NWP e.g. METOF

End State
Conclusion
Conclusion

1. The future Generation Landscape will show a higher % variable resource in the Energy mix

2. South Africa has a unique Power System which requires bespoke solutions

3. South Africa has existing local capacity in Short Term Load Forecasting

4. South Africa has strong ties with international expertise in Short Term Variable Resource Forecasting

5. South Africa needs to further develop the local short term load forecasting capability by focusing on incorporating short term variable resource forecasting
Note: “Thank you” in all official languages of the Republic of South Africa