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SAWEA
South African Wind Energy Association

21 - 23 OCTOBER 2025
8:00 am – 5:00 pm

CAPE TOWN, SA
CTICC 2

2025 PRESENTATION

Short-Term Wind Forecasting Model using LSTM Framework

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22nd October 2025

SPEAKER **OVERVIEW**

Christopher Marz

Council for Scientific and Industrial Research

Researcher

PRESENTATION **OVERVIEW**

01 • History of AI

02 • Why AI works

03 • Three keys of AI

04 • Application of AI: Wind Forecasting Modelling

SLIDE AI Timeline 1950 – 1970: Early Publications, Research and Discoveries

Alan Turing's publication on whether "machines can think". Pioneered the test of a machine's ability to mimic intelligence

Term "Artificial Intelligence" is coined at Dartmouth Workshop in a paper: Darthmouth Proposal

Frank Rosenblatt introduces the first type of artificial neuron called a perceptron capable of supervised learning for binary classification.

First multilayer perceptron model was created by Alexey Ivaknenko and Valentin Lapa.

Stochastic Gradient Descent used to train multilayer perceptrons by Shun'ichi Amari.

Marvin Minsky and Seymour Papert publish **Perceptrons**. Describes limitations of feedforward neural networks. The publishing of the book seen as the start of the first AI Winter. Lack of funding and confidence followed.

SLIDE AI Timeline 1970 – 1999: Continued Publications, Improvements and Theorems

Backpropagation training method is published by Seppo Linnainmaa. Essential for neural network training. Originally called automatic differentiation.

Neural Networks are more widely used with Backpropagation training

Universal Approximation Theorem: proved that multilayer feedforward networks are universal approximators.

Gerry Tesauro wrote a Backgammon program capable of competing against the world's best. The program used reinforcement learning.

Deep Blue chess machine beats then world champion Garry Kasparov
Long Short-Term Memory (LSTM) first published by Sepp Hochreiter and Juergen Schmidhuber

SLIDE AI Timeline 2000 – 2023 : Means of Application, Landmark Research, Rapid Adoption

Introduction of Recommender Systems for marketing and media use

LSTM model first to win pattern recognition contests (handwriting)

Image recognition using Deep Learning takes off. Pivotal moment. AlexNet model developed by Alex Krizhevsky wins with half as many errors as the model in second place. Uses GPUs to train AlexNet.

Deep Learning is improved by the development of residual neural network (ResNet). Its structure is widely adopted.

Landmark paper published by researchers at Google introduced Transformers architecture. Paper Attention Is All You Need. Led to LLMs and generative pre-trained transformers.

OpenAI debuts ChatGPT (30 Nov 2022). It spurs discussion around AI's impact on society. By 2023, it had over 100 million users just 2 months after launch becoming the fastest growing consumer application to date.

SLIDE **Why AI works**

A function is just a defined relationship that maps inputs to outputs. So neural networks ‘capture’ that relationship by proven mathematical approximation methods.

SLIDE **Three Keys to AI**

Data

- The information/features used to extract relationship between input and desired output.

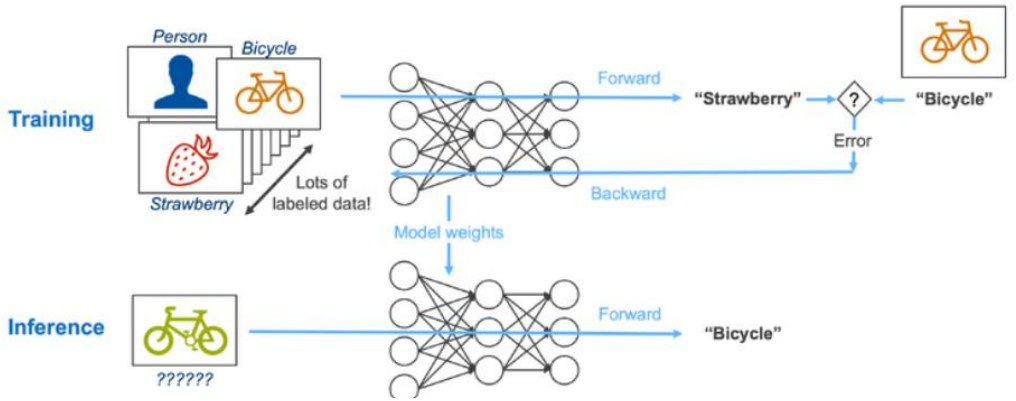
Model framework

- The framework trained to extract the underlines patterns and relationship within the data in order to generate an output.

Method of Evaluated Correctness

- Comparing model output to expected output.
- Learning is done using a repeated passes (epochs) and early stopping callback mechanisms to prevent overfitting.

- Ultimately, it is transforming an input into a numerical representation in order to determine relationships in the data using some form of mathematic metric and related to a desired output.



SLIDE **Aim and Model framework**

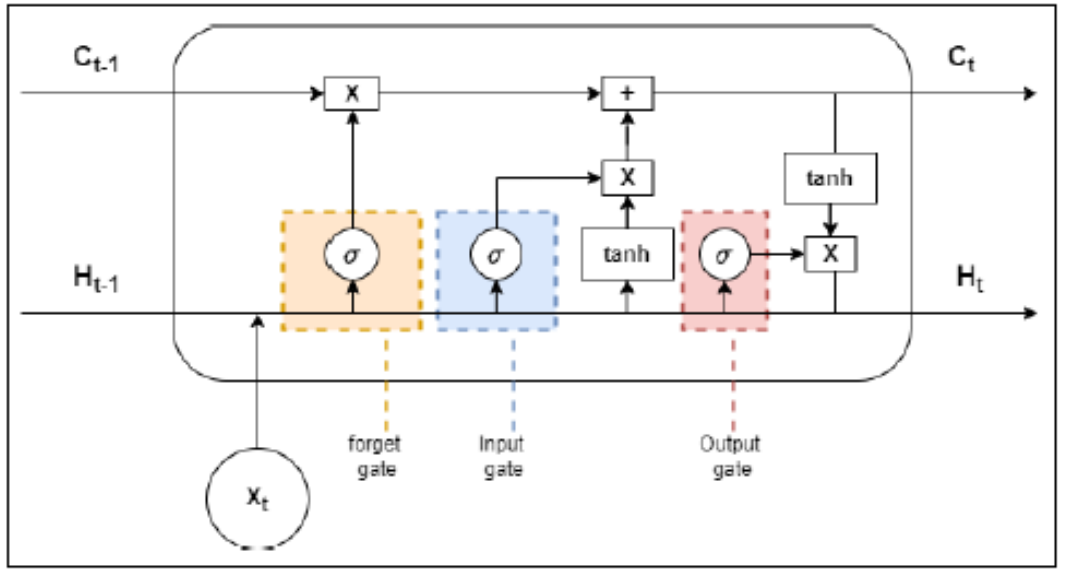
Aim

Develop model framework trained to forecast wind power an hour ahead using wind speed time series data.

Model Framework

- Stacked Long Short-Term Memory framework.
- LSTM is a type of Recurrent Neural Network.

LSTM unit



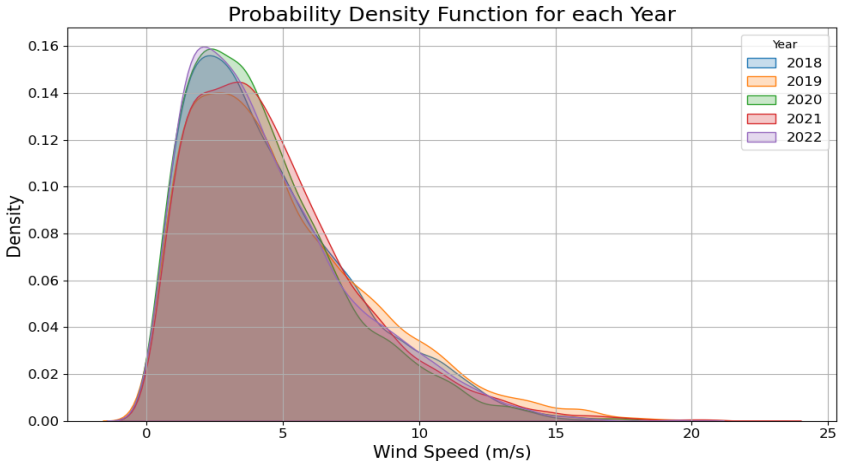
Why LSTM

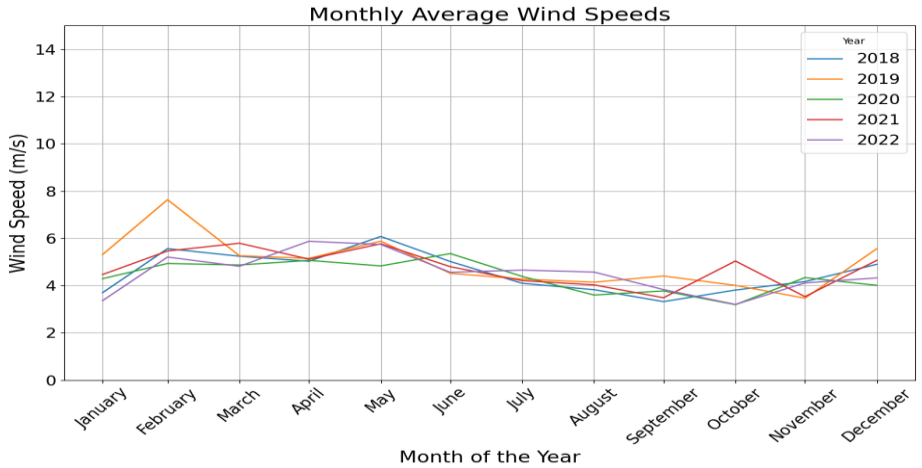
- RNNs have the capability to be trained using sequential data
- Prevents Vanishing Gradient Problem. Backpropagation cannot work properly.
- Three gates: Input, forget and output gate.

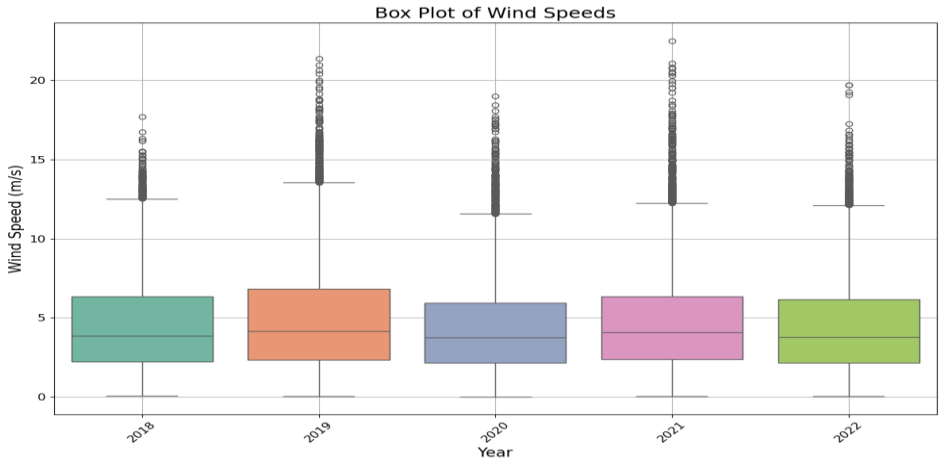
SLIDE **Methodology**

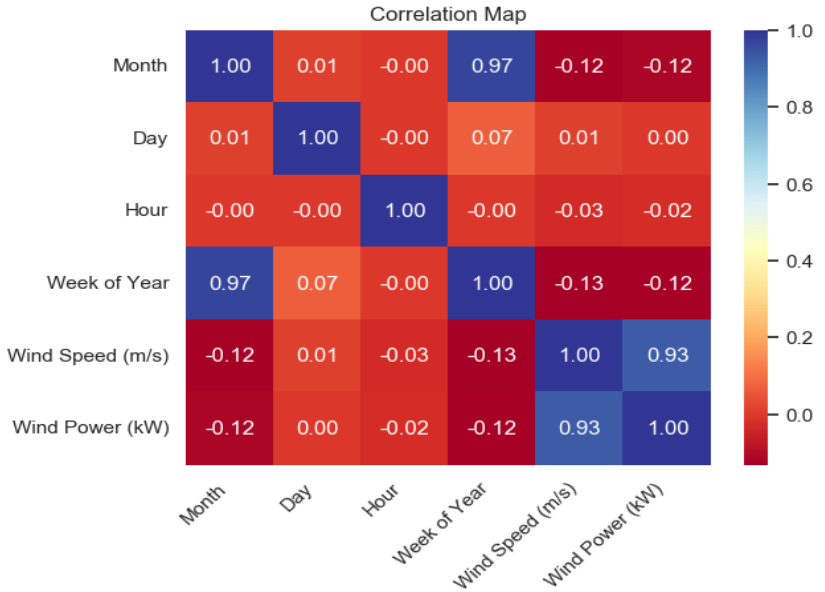
- **Get data**: obtain labelled data for model,
  - Metrological Time series from 2007-2012 from NREL
  - Wind turbine data
- **Processing data**: remove/edit/adjust data to prepare it for it to be used to train/test
  - Data Feature Engineering and sequencing
- **Split into train and test subsets**: the data is split into two subsets. Training is used to train the model such as the model can predict a particular outcome.
- **Train and build model**: using the training dataset, train the model
- **Test model with test subset**: testing subset inputted into the model
- **Evaluate model performance**: after testing the model, it outputs predictions and these data accuracy must be evaluated against the labelled data from the testing data using a performance metric (e.g. MSE, RMSE)
- **Model deployment**: if evaluation is satisfactory, the model may be deployed

SLIDE **Screening Input Data**



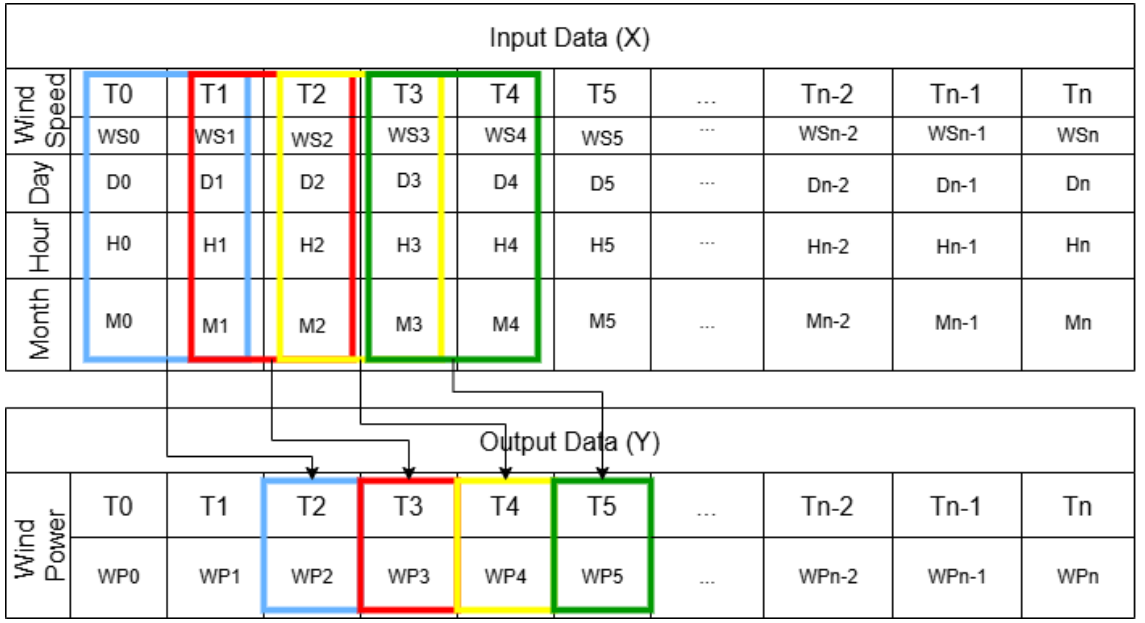




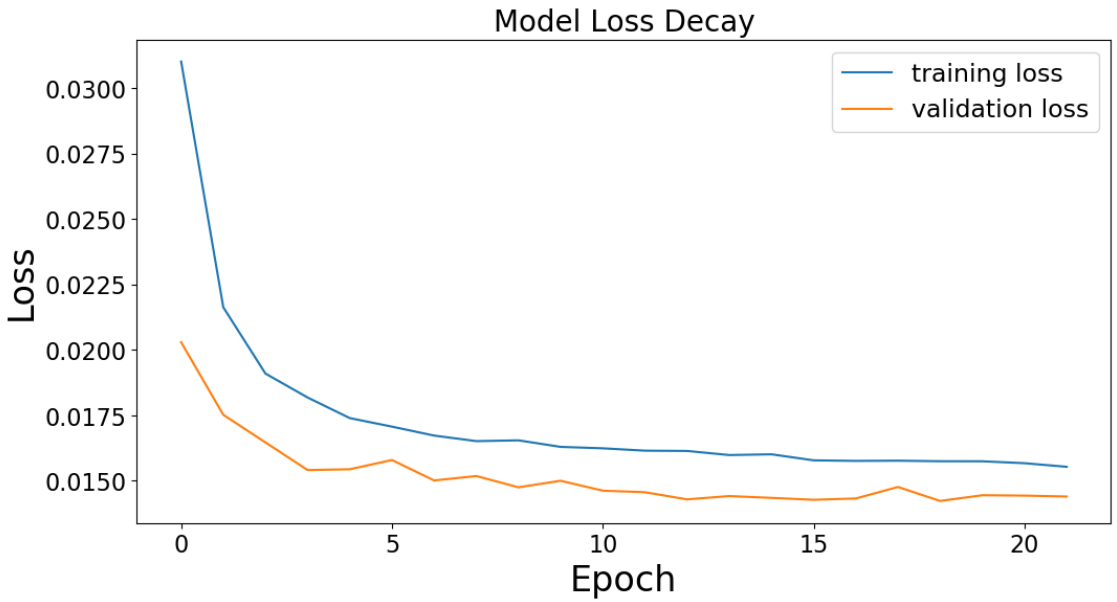


SLIDE **Data Sequencing Procedure**

- Data sequencing involves preparing the training input and output data such that the temporal alignment is correct.
- The model operates as sequence-to-sequence model. Therefore, each output sequence requires a corresponding input sequence.
- The input time series data is sequenced into 24 hour increments to match with the next hour's wind power.
- 24 input time data to 1 output of wind power.

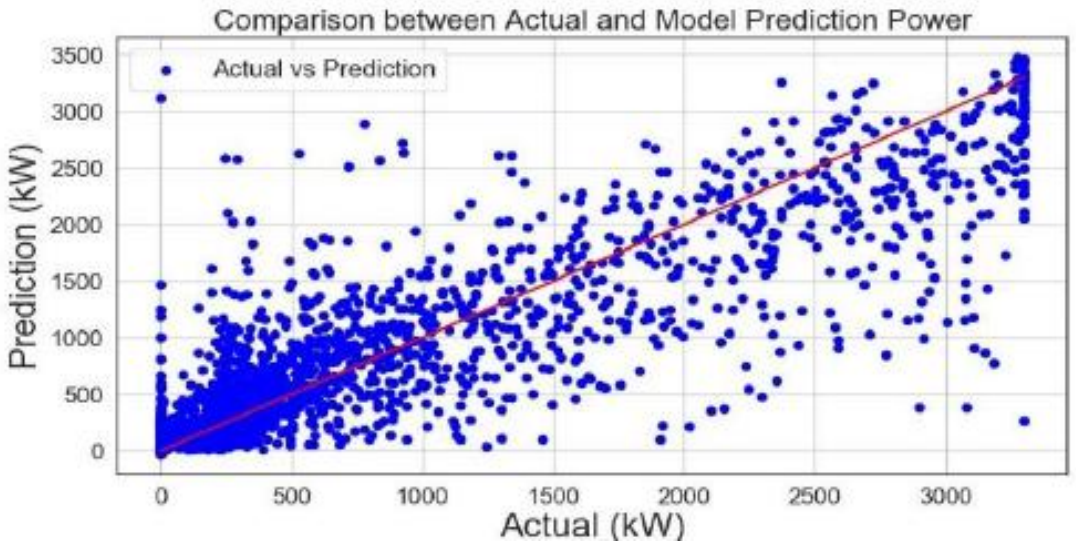


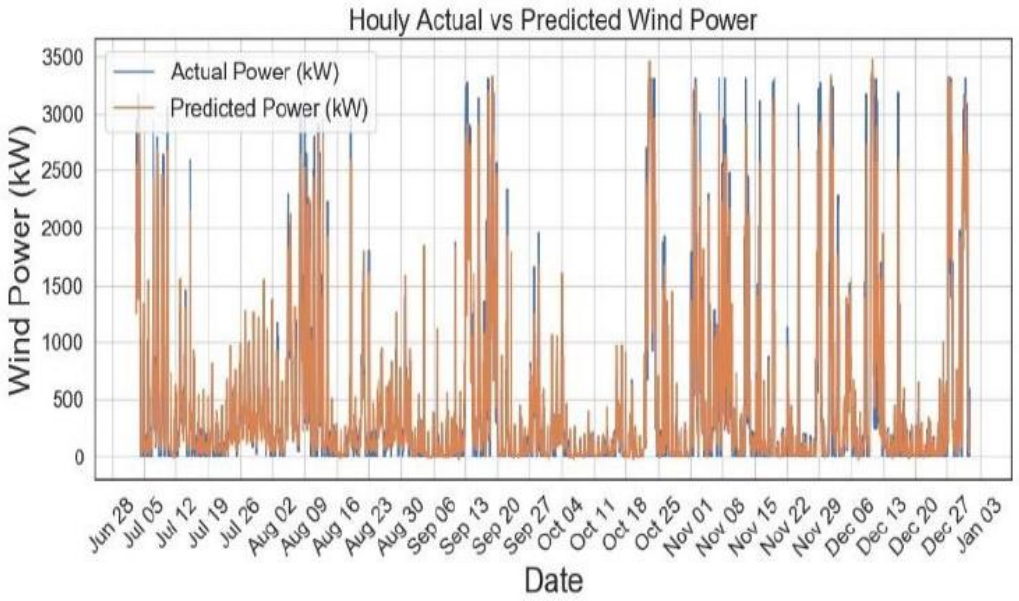
SLIDE **Results**



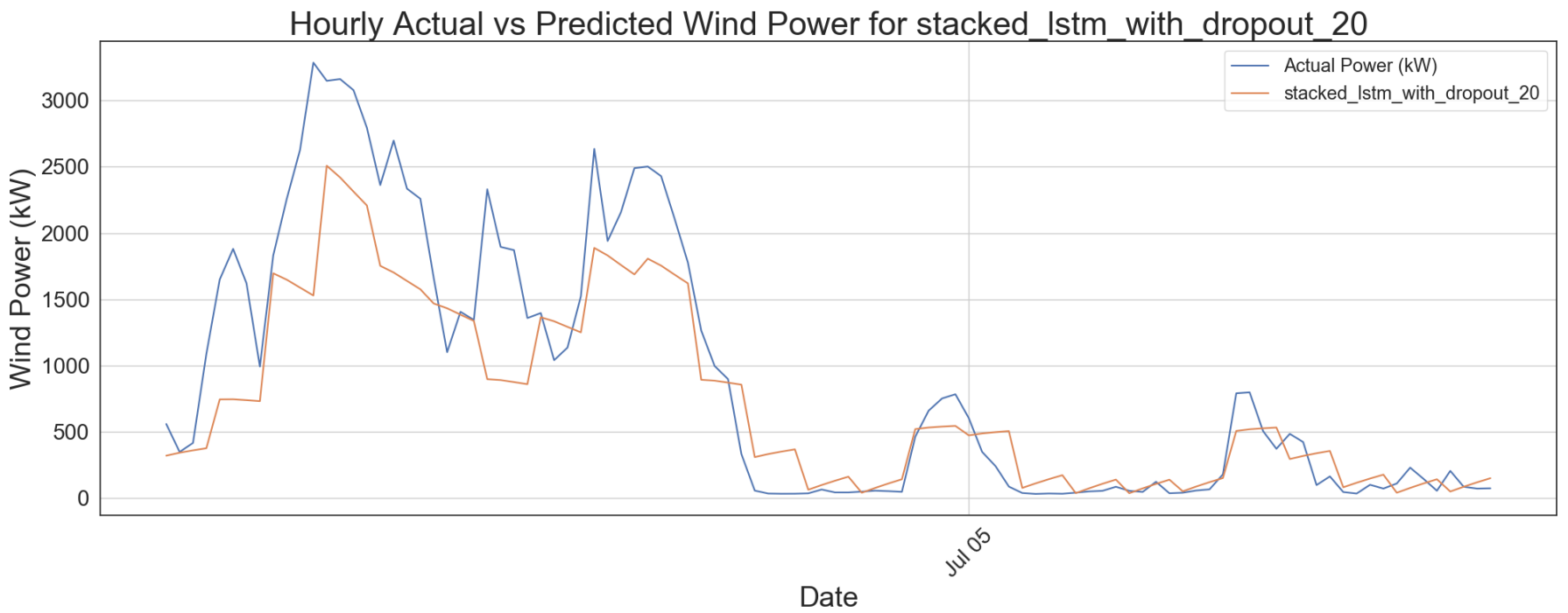
Metric	Formula	Score	Measured in
Mean Absolute Error (MAE)	$\frac{1}{n}\sum_{i=1}^{n}(y_i - \hat{y}_i)$	172.85	kW
Root Mean Squared Error (RSME)	$\sqrt{\frac{1}{n}\sum_{i=1}^{n}(y_i - \hat{y}_i)^2}$	333.13	kW
R2-Score	$1 - \frac{\sum_{i=1}^{n}(y_i - \hat{y}_i)^2}{\sum_{i=1}^{n}(y_i - \bar{y})^2}$	0.8103	
NRMSE	$\frac{RSME}{\sigma}$	43.21	%
NMAE	$\frac{RMAE}{\sigma}$	22.42	%

SLIDE **Results**

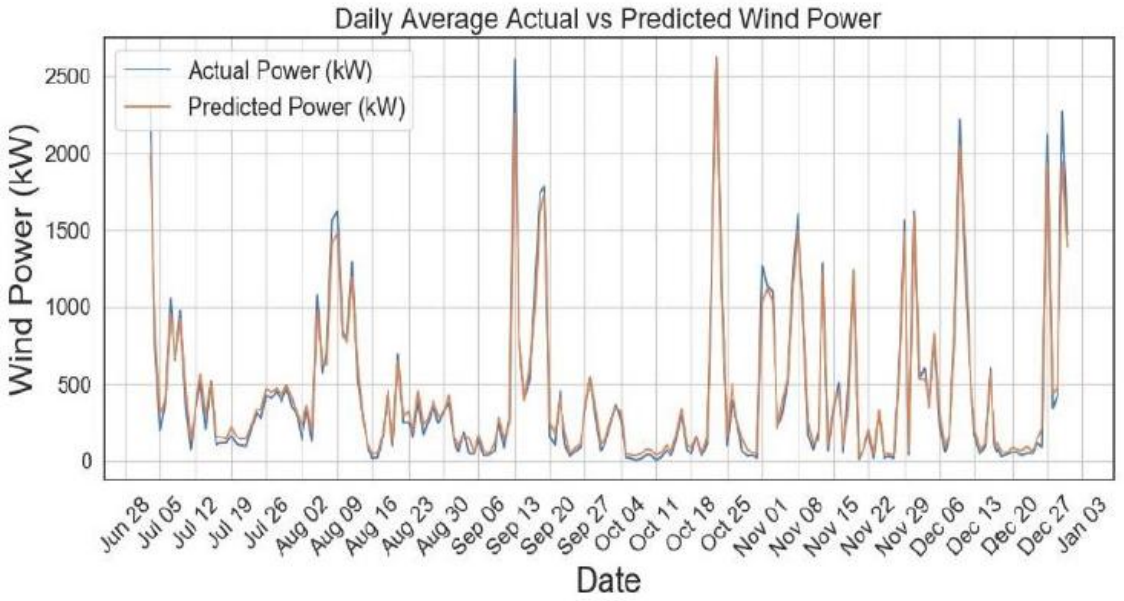


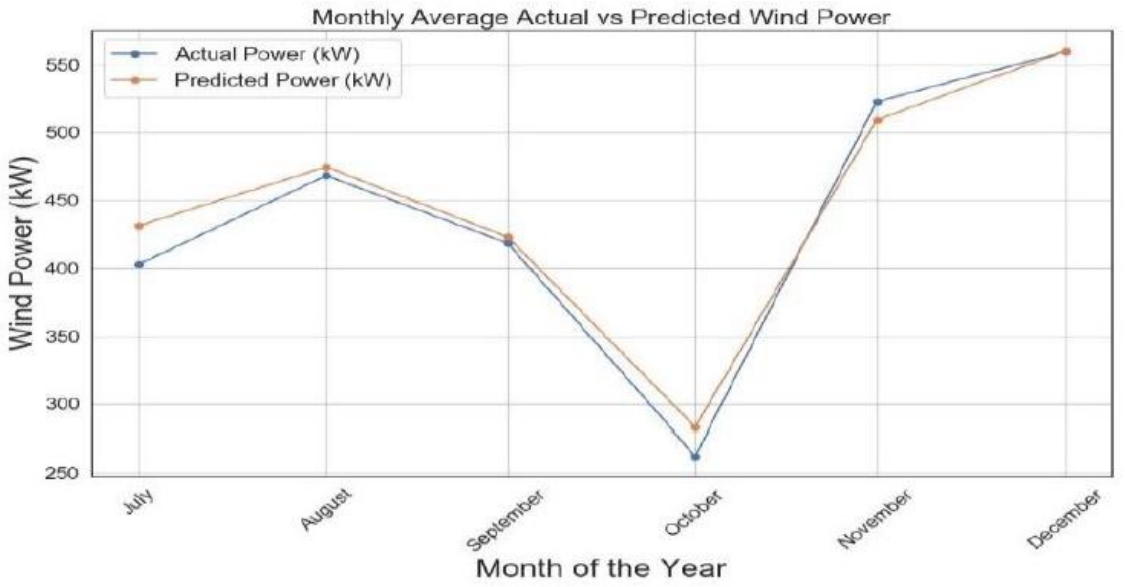


Zoomed Time series comparison



SLIDE **Results**





SLIDE **Conclusions**

- the stacked-LSTM model performed relatively well when predicting an hour ahead.
- NMAE and NRMSE metrics indicate that error values are 50% less variable when comparing to the standard deviation of the actual test data.
- Highly correlated input and labelled data meant that model was able to capture the related variance between both yielding a R2-Score greater than 0.8.
- Model can be applied to other forecasting applications.
- Further improvement are being implemented to increase accuracy e.g. using SVR.

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THANK YOU FOR LISTENING!

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