Neural Network Based Sensorless Maximum Wind Energy Control with Compensated Power Coefficient

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### Current Mechanical Sensorless Peak Power Tracking Control

<table>
<thead>
<tr>
<th>Advantage</th>
<th>Power Coefficient Polynomial</th>
<th>Power mapping with 2-D Look-up Table</th>
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<tbody>
<tr>
<td>Reduce the cost and improve the reliability of the system by removing a number of anemometers</td>
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<table>
<thead>
<tr>
<th>Disadvantage</th>
<th>complex and time-consuming real time calculation</th>
<th>1. Trade off between accuracy and memory space</th>
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<tbody>
<tr>
<td></td>
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<td>2. Sub-optimum solution, control delay and slow searching mechanism</td>
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## Proposed work

<table>
<thead>
<tr>
<th>Task 1</th>
<th>ANN based wind speed estimator</th>
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<td>Task 2</td>
<td>ANN based power tracking control algorithms to compensate the potential drift of wind turbine power coefficient curve</td>
</tr>
<tr>
<td>Advantages</td>
<td>Simple, highly precise, fast real-time calculation</td>
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</tbody>
</table>
Variable Wind Speed System

(a) PMSG wind Generator

(b) SCIG wind Generator
Analysis of Wind Turbine Maximum Power

\[ P_m = \frac{1}{2} \rho \Lambda C_p(\lambda) V_w^3 \]
\[ \lambda = \frac{r_m \omega_r}{V_w} \]

- \( P_m \): output mechanical power of the wind turbine,
- \( \rho \): air density,
- \( \Lambda \): tip speed ratio,
- \( C_p \): the power coefficient,
- \( r_m \): radius of the rotor,
- \( \Lambda \): wind turbine rotor swept area,
- \( V_w \): wind velocity,
- \( \omega_r \): rotor speed of the turbine

\[ P_{t_{\text{max}}} = K_1 V_w^3, \quad K_1 = 0.5 \rho \Lambda C_{p_{\text{max}}} \]
\[ \omega_{r^*} = K_2 V_w, \quad K_2 = \lambda_{opt}/r_m \]
Wind velocity estimation by ANN (I)

\[ P_m = \frac{1}{2} \rho \Lambda C_p (\lambda) V_w^3 \]

\( P_m \), \( \omega_r \), \( V_w \), ANN
Wind velocity estimation by ANN (II)

\[ W1 = \begin{bmatrix} 16.9416 & -0.32662 \\ -1.1305 & -0.98684 \\ 0.016079 & -0.098342 \\ -0.0047199 & -0.01391 \\ -0.00047781 & -0.018374 \end{bmatrix} \]

\[ W2 = \begin{bmatrix} 0.010461 & -0.0072528 & 0.74866 & -199.9214 & -4.444 \end{bmatrix} \]

\[ B1 = \begin{bmatrix} -1491.0553 \\ 151.7459 \\ 2.213 \\ -1.9241 \\ 1.7676 \end{bmatrix} \]

\[ B2 = \begin{bmatrix} -188.9384 \end{bmatrix} \]
Peak Control strategy with compensation of power coefficient drift
Derivation of Pseudo-power curve

(a) Increasing wind velocity
(b)
Peak Control strategy with compensation of power coefficient drift
Simulation Study of PMSG Wind Generator

Diagram showing the components of a PMSG wind generator system, including the turbine, PMSG, diode rectifier, IGBT inverter, DSP, and 3-phase load.
SCIG Wind Generator

Diagram showing the components of a SCIG wind generator:
- Turbine
- CIG
- IGBT Rectifier
- IGBT Inverter
- RTDS
- dSpace
- ANN estimator
- Current Controller
- Vector Rotation

Symbols and variables:
- Wind
- IGBT Rectifier
- IGBT Inverter
- RTDS
- dSpace
- ANN estimator
- Current Controller
- Vector Rotation
- $V_b, V_c$
- $I_b, I_c$
- $I_a^*, I_b^*, I_c^*$
- $I_{ds}^*$
- $I_{qs}^*$
- $\sin$, $\cos$
Experimental Setup
Experimental Results

- Actual wind speed
- Estimated wind speed

Graph showing:
- Time (s) vs. Actual Wind Speed
- Time (s) vs. Estimated Wind Speed

Graphs showing:
- Tip speed ratio
- Desired and actual Turbine power (kW)
- Generator Power (kW)
Conclusion

• A maximum mechanical power of the wind turbine can be well tracked at both dynamic and steady states;
• A neural network based wind velocity estimator is developed to provide fast and accurate velocity information to avoid using anemometers;
• A neural network based scheme is presented to compensate the potential drift of wind turbine power coefficient curve without extra sensors A maximum mechanical power of the wind turbine can be well tracked at both dynamic and steady states;
• The simulation study and experimental results of PMSG wind generator and SCIG wind generator proves the validity of the method.