Study of a Direct Conversion of Wind Energy into Electricity

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What is Wind Energy?

• The wind is a form of solar energy
• Irregular but with a strong potential
• Wind turbine converts wind energy into electricity

• What are the Wind turbine limits?
  ➢ Cut-out speed (usually 25 m/s)
  ➢ Noise pollution
  ➢ High cost + High maintenance

How to solve these issues?
Current Wind Turbines

State of the Art | Principle | Particle Production | Prototype | Results and Perspectives

Wind turbine farm in Saint-Félix-Lauragais Haute Garonne (2011)

Floating vertical axis wind turbine VERTIWIND Project

Offshore wind turbine farm in Denmark Siemens, 2013

Wind Kinetic Energy

Mechanical Energy

Electrical Energy

Rotating Blades

Electrical Generator

11/05/2016

PHENIICS Doctoral School Day 2016
What about a Bladeless system?

State of the Art | Principle | Particle Production | Prototype | Results and Perspectives

Wind Kinetic Energy

Mechanical Energy

Electrical Energy
What about a Bladeless system?

Wind | Kinetic Energy

Direct Conversion

Mechanical Energy

Electrical Energy

Wind against an Electric Field

Prototype from Delft University
How does this work?

**State of the Art | Principle | Particle Production | Prototype | Results and Perspectives**

1. Particle attracted by the negative electrode
   - Particle direction in the field
   - Collector potential $V_x$ rises $\Rightarrow ||\vec{E}||$ rises
   - Works as long as $||\vec{F}_{wind}|| > ||\vec{F}_E||$

2. If we add the Wind drag force in the opposite direction of the Electric force
   - Particle direction
   - Collector

3. Collector potential $V_x$ rises $\Rightarrow ||\vec{E}||$ rises
   - Works as long as $||\vec{F}_{wind}|| > ||\vec{F}_E||$
   - Loss of the charged particle

4. U-turn of the particle if $||\vec{F}_{wind}|| < ||\vec{F}_E||$
   - Collector
   - Collector potential $V_x$ rises $\Rightarrow ||\vec{E}||$ rises
How would it look like?

System with a collector

Isolated system without a collector
How can you obtain charged particles?

What do we need?

- **Efficient** creation of charged particles with **suitable properties**
- Liquid particles → no need for recycling
- Production of a **large number** of particles at **very low energy consumption**
How can you obtain charged particles?

What do we need?

- **Efficient** creation of charged particles with suitable properties
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**EHDA** (Electro-Hydro-Dynamic Atomization)

**EHDA Principle**

- Liquid
- Capillary
- Plate
- HV

**An EHDA example**
From Cloupeau “Research on Wind Energy Conversion”

**Charged droplets created at the apex**
From DBV technologie
What are the limitations?

- Reducing the ion mobility \( \mu = f(q, d) \)
- Controlling the particle size: \textit{monodisperse} particles or a \textit{stable sized distribution}
- For liquid particles \( \rightarrow \) the \textit{Rayleigh limit}

\[ q_{\text{max}} = 2\pi \sqrt{2\gamma \varepsilon_0 \cdot d^3} \]

- \textit{Evaporation} of liquid during flight \( \rightarrow \) decrease of the particle size
- Collisions between charged and neutral particles in air \( \rightarrow \) fragmentation / neutralization

\( \rightarrow \) Ensure better coupling between particles and the wind
\( \rightarrow \) Multi-Injectors system
Electrospray Experiments

State of the Art | Principle | **Particle Production** | Prototype | Results and Perspectives

Charged particles emitted from a cone

*Glass capillary with a metallic wire inside*
Electrospray Experiments

State of the Art | Principle | Particle Production | Prototype | Results and Perspectives

1. Charged particles emitted from a cone

Glass capillary with a metallic wire inside

Grounded target

Grounded target
Electrospray Experiments

State of the Art | Principle | Particle Production | Prototype | Results and Perspectives

Charged particles emitted from a cone

Glass capillary with a metallic wire inside
Electrospray Experiments

State of the Art | Principle | Particle Production | Prototype | Results and Perspectives

Charged particles emitted from a cone

Glass capillary with a metallic wire inside

1

Grounded target

2

Grounded target

3

Grounded target

4

Grounded target
Prototype Design

State of the Art | Principle | Particle Production | Prototype | Results and Perspectives

- Liquid Tank
- Capillary
- PUMP
- Extraction Electrode
- Collector isolated from the ground
- Energy Collector
- Collector
Prototype Design

State of the Art | Principle | Particle Production | Prototype | Results and Perspectives

Liquid Tank

Capillary

PUMP

Extraction Electrode

Collector isolated from the ground

E_{extraction}

Energy Collector

11/05/2016

PHENICS Doctoral School Day 2016
Some Results: The EWICON Project

State of the Art | Principle | Particle Production | Prototype | Results and Perspectives

Outputs of the Electrostatic Wind Energy Converter project led at Delft University

= Power Supplies HV + Pump
= $\frac{P_{\text{out}}}{P_{\text{in}} + P_{\text{max wind}}}$

<table>
<thead>
<tr>
<th>Number of Electrospray Nozzles</th>
<th>$P_{\text{in}}$</th>
<th>$P_{\text{max Wind}}$</th>
<th>$P_{\text{in}} + P_{\text{max Wind}}$</th>
<th>$P_{\text{out}}$</th>
<th>Wind Conversion Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1 mW</td>
<td>264 mW</td>
<td>265 mW</td>
<td>3.1 mW</td>
<td>1.17 %</td>
</tr>
<tr>
<td>6</td>
<td>1.5 mW</td>
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$P_{\text{out}} > P_{\text{in}}$
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$P_{out} > P_{in}$

$P_{max\ Wind} >> P_{out}$

= Power Supplies HV + Pump

= $P_{out}/(P_{in} + P_{max\ Wind})$

LOW YIELD!
Next Steps

<table>
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<th>To be improved</th>
<th>How?</th>
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<td>Increasing the wind conversion yield</td>
<td>Decreasing the ion mobility</td>
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<tr>
<td>Removing the interaction between the injector nozzles</td>
<td>Designing better shielding Studying extraction simulations</td>
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A new prototype is being designed to improve these points
Other possibilities

State of the Art | Principle | Particle Production | Prototype | Results and Perspectives

Van de Graaff Generator

Wind Energy Convertor

A new kind of Van de Graaff!

Pelletron Generator from NEC (ANDROMEDE Project)
The Dream Team!

THANK YOU!
The Dream Team!

THANK YOU!
For a given wind speed $V_{\text{collector}}(V)$

- Transient State
  - $||\overrightarrow{F_{\text{wind}}}|| < ||\overrightarrow{F_{E}}||$

- Steady State
  - $||\overrightarrow{F_{\text{wind}}}|| = ||\overrightarrow{F_{E}}||$
  - $||\overrightarrow{F_{\text{wind}}}|| > ||\overrightarrow{F_{E}}||$