Optimization of coal ash collection efficiency for Electrostatic Precipitators

(Optimisation du Rendement de Captation des cendres cHarbons pour les Installations de DEpoussiérage Electrostatique)

An helpful on site tool for ESP operation
ORCHIDEE has been
coko-developed by

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ORCHIDEE makes possible to simulate the complete operating conditions of the plant from the coal field to the stack.
ORCHIDEE: an help to optimize …
… the plant performances.

Particles emissions

- Coal quality
- Coal blending
- Flue gas velocity distribution
- Electrical power supplies
- Renovation
- Combustion parameters
What is ORCHIDEE

ORCHIDEE is a simulation tool devoted to the optimization of the environmental performances of a thermal plant, fired with coal or other fuels. It evaluates the performances of the electrostatic precipitators, once the operating conditions of the plant are given. This evaluation is based on physical models of the combustion conditions and of the electrostatic precipitation processes.

ORCHIDEE is a software package realized in two distinct modules:
- A user-friendly interface to enter the data and to display the results
- A simulation module which contains the numerical models of physical processes

ORCHIDEE is a French acronym which means « Optimization of the ash collection efficiency in plants with electrostatic precipitators ».

ORCHIDEE can be installed in the plant control room and give real time simulations, answer to questions of the type “what happens if ..”, and support the plant Manager to take operation decisions.
How to compute the dust emissions

To estimate the performances of the electrofilter, ORCHIDEE is based on a self-consistent description of the physical phenomena of the electrostatic precipitation. This approach makes possible to follow in detail the overall operation of an electrostatic precipitator, independently from the performance data given by ESP manufacturers.

However, the simulation cost, in terms of calculation time, is relatively high. For this reason, the basic calculations are carried out for each configuration only in the stage of plant calibration. The calibration is based on a number of parametric calculations and is relatively long (several hours).

The calibration phase gives the coefficients of a multidimensional interpolation formula. This formula makes possible a rapid estimate the ESP efficiency and an almost instantaneous calculation of dust emission. It requires obviously specific correlation coefficients for each electrofilter.
Data inputs are:

• The physico-chemical analysis of coals: HHV/LHV, moisture, ash content, organic matter (C, H, O, N, S), mineral matters (major elements of ashes).
• The power load and the energy efficiency of the unit
• The combustion conditions: O2 rate in the economizer and in the stack, bottom ash rate, unburnt carbon rate, gas temperature in the electrofilter, atmospheric temperature and relative humidity
• The geometry of the electrofilter: field number, casing number, geometry of the emissive wires and the collecting plates.
• The electric parameters of the electrofilter: the number of T/R sets per field, the voltage (or the current) at the secondary of the T/R sets
• The velocity distribution of the flue gas at the inlet section of each casing.
• It is possible to study coal blends (up to 4 coals), and to take into account supporting oil admixture.
What ORCHIDEE can do?

A) ESP normal operating conditions

ORCHIDEE can calculate:

• the balance of the combustion inlet: coal, air, oil admixture

• the balance of the flue gas: flow rate and composition at the boiler outlet

• characteristics of the fly ash: concentration, size distribution, and electrical resistivity

• the captation efficiency of the electrostatic precipitator

• the dust characteristics at the stack: concentration and size distribution
What ORCHIDEE can do?

B) ESP abnormal operating conditions

ORCHIDEE can calculate:

- The effect on efficiency of cut wires on efficiency and voltage-current characteristics
- The effect of deposits on plates and electrodes on efficiency and voltage-current characteristics
- The effect of insulation leakage on efficiency and voltage-current characteristics
- The effect of flue gas distribution inside the ESP
What ORCHIDEE can do?

C) The effect of rapping sequences and gas conditioning

ORCHIDEE can calculate:

• The effect of different rapping sequences of the collecting plates and emissive wire

• SO3 injection effect on resistivity and by that on efficiency
**What ORCHIDEE cannot do?**

**ORCHIDEE** is an off-line simulation tool, i.e. it is not connected to the control system of the power plant.

It is not possible in the present version to simulate ESP with pulsed energization. *Intermittent or semipulse?*

**ORCHIDEE** takes into account but does not include the calculation of a detailed velocity distribution of the flue gas in the electrofilter (flow modeling).

It simulates the operating characteristics of the plant under stationary conditions; therefore, it is not possible to simulate the transient states of the electrofilter (unit starting).
### Model organization

<table>
<thead>
<tr>
<th>1 – Gas flow</th>
<th>2 – Electrical field</th>
<th>3 – Particle migration</th>
<th>4 - Collection efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Data structure</strong></td>
<td><strong>Laplacian Field</strong></td>
<td><strong>Ion Migration</strong></td>
<td><strong>Particle Collection</strong></td>
</tr>
<tr>
<td><strong>Gas Flow: 3D Fluid-Dynamic</strong></td>
<td><strong>Electric Field</strong></td>
<td><strong>Particle Charging</strong></td>
<td><strong>Rapping Reentrainment</strong></td>
</tr>
<tr>
<td><strong>Gas Flow: 2D Fluid-Dynamic</strong></td>
<td><strong>time loop</strong></td>
<td><strong>Particle Migration</strong></td>
<td><strong>Process Efficiency</strong></td>
</tr>
<tr>
<td><strong>Back Corona</strong></td>
<td><strong>Glow Corona</strong></td>
<td><strong>Space Charge Distribution</strong></td>
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<td><strong>Streamer Corona</strong></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td><strong>Breakdown</strong></td>
</tr>
</tbody>
</table>
General structure of ORCHIDEE

The user interface of ORCHIDEE was designed with the "traditional" functionalities of menus and clicking buttons.

A tools bar, always accessible, makes possible to navigate between different screens.

The first 4 buttons are the usual functions:

- New configuration
- Open a configuration
- Save a configuration
- Result printing

The following buttons correspond to the operational ORCHIDEE screens:

- Main screen
- Fuel screen
- Unit screen
- ESP operation screen
- ESP geometry screen
- ESP power supply screen
- ESP rapping screen
- ESP velocity distribution screen
- ESP detailed particle captation
Coal blend and SO3 injection

- % of coal blending:
  - 30 % Coal 1
  - 30 % Coal 2
  - 40 % Coal 3

- Resistivity of blend: 1.1E+08 Ohm.cm

- Temperature: 135 °C

- Injection de SO3: 10 ppm
Geometry screen

- Active zone
  - N° of the field: 1
  - Nb of rows: 20
  - Nb of plates: 6

- Plate
  - Type: Sigma
  - Length: 2.9m
  - Row: 11.2m
  - Height: 12.3m

- Wire
  - Type: "wire" (not specified)
  - Length: 467mm
  - Row: 400mm
  - Height: 113mm

Warning: These data are relatives to 1 casing.
**Rapping screen**

![Rapping screen with fields and data](image-url)

<table>
<thead>
<tr>
<th>FIELD 1</th>
<th>FIELD 2</th>
<th>FIELD 3</th>
<th>FIELD 4</th>
<th>FIELD 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time for whole tour with contration(s)</td>
<td>225</td>
<td>Time for whole tour with contration(s)</td>
<td>225</td>
<td>Time for whole tour with contration(s)</td>
</tr>
<tr>
<td>Degree between hammer(s)</td>
<td>18</td>
<td>Degree between hammer(s)</td>
<td>18</td>
<td>Degree between hammer(s)</td>
</tr>
<tr>
<td>Time On</td>
<td>15</td>
<td>Time On</td>
<td>15</td>
<td>Time On</td>
</tr>
<tr>
<td>Time Off</td>
<td>15</td>
<td>Time Off</td>
<td>30</td>
<td>Time Off</td>
</tr>
<tr>
<td>Time between rapping (s)</td>
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<td>Time between rapping (s)</td>
<td>675</td>
<td>Time between rapping (s)</td>
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<tr>
<td>No min. of sync. rapping/caring</td>
<td>1</td>
<td>No min. of sync. rapping/caring</td>
<td>2</td>
<td>No min. of sync. rapping/caring</td>
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<td>15</td>
<td>Time On</td>
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<tr>
<td>Time Off</td>
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<td>Time Off</td>
<td>75</td>
<td>Time Off</td>
</tr>
<tr>
<td>Time between rapping (s)</td>
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<td>Time between rapping (s)</td>
<td>1350</td>
<td>Time between rapping (s)</td>
</tr>
<tr>
<td>No min. of sync. rapping/caring</td>
<td>2</td>
<td>No min. of sync. rapping/caring</td>
<td>2</td>
<td>No min. of sync. rapping/caring</td>
</tr>
</tbody>
</table>
Power Supply
Voltage current characteristics

Curves current/tension

Intensity in A

Voltage in kV

Field 1
Extrapolation
Field 2
Extrapolation
Field 3
Extrapolation
Field 4
Extrapolation
Field 5
Extrapolation

Curve current/tension for 1 TR
Back-corona alarm
<table>
<thead>
<tr>
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<tr>
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<tr>
<td>Time between rapping (s)</td>
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<td>2</td>
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<td>2</td>
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**Rapping screen**
Field Faults

- Defect du champ
  - Encrassement Fils
  - Encrassement Plaques
  - Fuite Isolateurs
  - Fils coupés

- Epaisseur file: 5 mm
- Epaisseur plaques: 20 mm
- Fuite
  - Faible
  - Moyenne
  - Importante
- Fils coupés: 5 %
Faults on UI characteristic

Voltage/current characteristics

Current in A

Voltage in kV

Field 4

Field reference 4

Current/voltage for 1 T/R
Back-corona on UI characteristic

![Graph showing voltage-current characteristics with fields labeled as Field 4 and Field reference 4.](image-url)
ESP detailed balance

Particle diameter range in μm

- < 1.7
- 1.7-4.0
- 4.0-10.0
- 10.0-28.5
- > 28.5

Concentration in mg/Nm³
Back-corona effect and warning
How to use the results

It is possible to run simulations by varying in the following data:

• Power plant load
• Fuel: choice of different coals, blend of several coals, support oil
• Conditions of combustion: modification of the of air excess (O2 rate after the economiser), temperature of the gas in the electrofilter, stray air entry (O2 rate in the stack).
• Electrofilter: electric sections out-service, variation of the power supply voltages, modification of the velocity distribution.

To test more significant modifications such as the addition of a field to the electrofilter or the replacement of the internals, it is necessary to modify the unit structure and to calibrate again ORCHIDEE using several complete calculations.

In any case the simulation results make possible to select the best conditions for plant operation and maintenance, and to adapt these conditions in real time to the evolution of the plant external constraints (power load, failures, coal supply, etc.)