PRECIPITATION OF FINE PARTICLES CONSIDERING UNCERTAIN DUST PROPERTIES

István KISS, Tamás IVÁNCSY, István BERTA
Budapest University of Technology and Economics
Department of Electric Power Engineering
1521 Budapest, Hungary
e-mail addresses:
kiss@ntb.bme.hu, ivancsy@hivolt.ntb.bme.hu, berta@ntb.bme.hu

Abstract

It is well-known, that dust properties have a strong influence on the process of the precipitation. Some of the main relationships between the precipitation efficiency and the parameters of dust, like specific resistance, permittivity, particle size etc. have also been published [1].

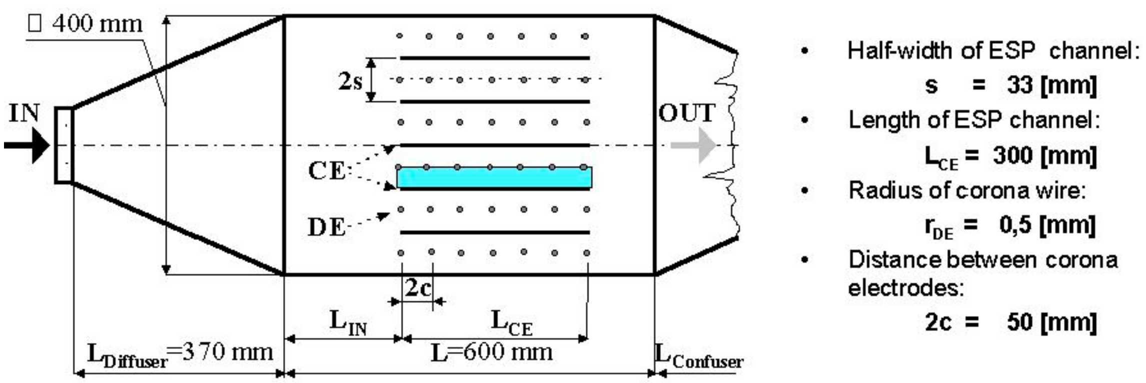
There are several uncertainties in the determination of these parameters. Some parameters can not be properly determined, some properties cannot be measured continuously, and some of them are changing during the operation of ESP, etc. Because of the uncertainty of these factors the reliability of ESP models can decrease with decreasing accuracy of the input data.

The most important aim of our investigations was to determine the effect of the variation of the dust parameters on the precipitation. The degrees of these dependencies have been investigated and presented in the paper. Based on the new results, it is possible to estimate what accuracy is necessary in case of different parameters to obtain reliable ESP models.

1. Introduction

For the investigation of ESP's performance in case of fine particles, we used a model precipitator illustrated in Fig. 1. The subject of analysis was one half channel of the model electrostatic precipitator. To obtain information about the performance of the numerical model, velocity profile measurements with a LASER-Doppler Anemometer (LDA) were carried out using oil fog as the input of the precipitator. The measurement results were presented in [*1], these results provided the control values for our model. The applied voltage was 20 kV at air speed of 1 m/s.

As a first step, our original model [4] was used to analyse the particle trajectories, then a fuzzy logic based expert system was created to demonstrate the taking of non-ideal effects into consideration.



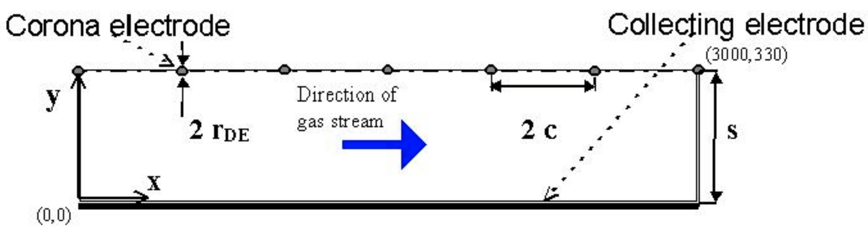


Fig. 1.

2. The applied ESP model

Fig. 2 illustrates the applied computational model. The model consists of two parts, an electrical field computational module and a flow field computational one. The modules are working in a time-loop, the results of electrical field computation module are transferred to the flow field computation module, it modifies the dust concentration distribution and gives it back to the electric field calculation module.

The electrical field computation module requires the applied supply voltage, the geometrical data, the dust properties and the dust concentration as input parameters. The determination of ionic charge density, the corona current injected into the analysed half cannel is calculated according to Peek's law [5]. Knowing the actual ionic space charge density and the actual electric field intensity distribution, the charge of particles can be determined according to the field charging and diffusion charging model. (In our case at fine particles the second one is dominant.) Based on that the Coulomb-force acting on the particles and the drift velocity due to the electric field can be determined and the result can be transferred to the flow field computation module.

The flow field is determined by a turbulent diffusion model, using step-forward method to calculate velocity distribution, dust concentration and particle trajectories. After a certain number of calculation steps the change of the computed results became less, than a required value, thus the accuracy is supposed to be appropriate and the iteration process stops. Based on the particle trajectories it is possible to determine the collection efficiency.

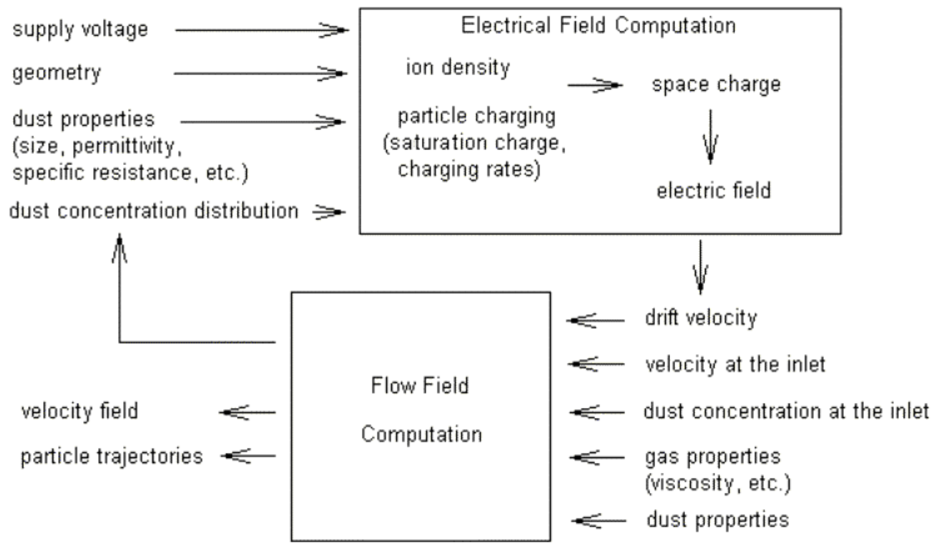


Fig. 2.

3. Taking the uncertainty of dust parameters into consideration

During the numerical analysis three data connecting to the dust were changed, assuming, that they change durig the operation of an ESP unit. Base-values for the incoming dust concentration, particle diameter and relative permittivity were set to 10 g/cm^3, 1 µm and 5 respectively. The efficiency of precipitation was examined near the target values; we supposed that the changes of these parameters during the operation of the electrostatic precipitator remain between the following maximal and minimal values:

- 5 g/cm^3 and 15 g/cm^3 for the incoming dust concentration
- 0.5 µm and 2 µm for the particle diameter
- 1.5 and 15 for relative permittivity.

Fig. 3 represents the calculation results for the target values. Making the same computational process for the different combinations of data it is possible to use them in generating a knowledge base about the influence of the change of parameters. The method is based on fuzzy logic and is presented in the next chapter.

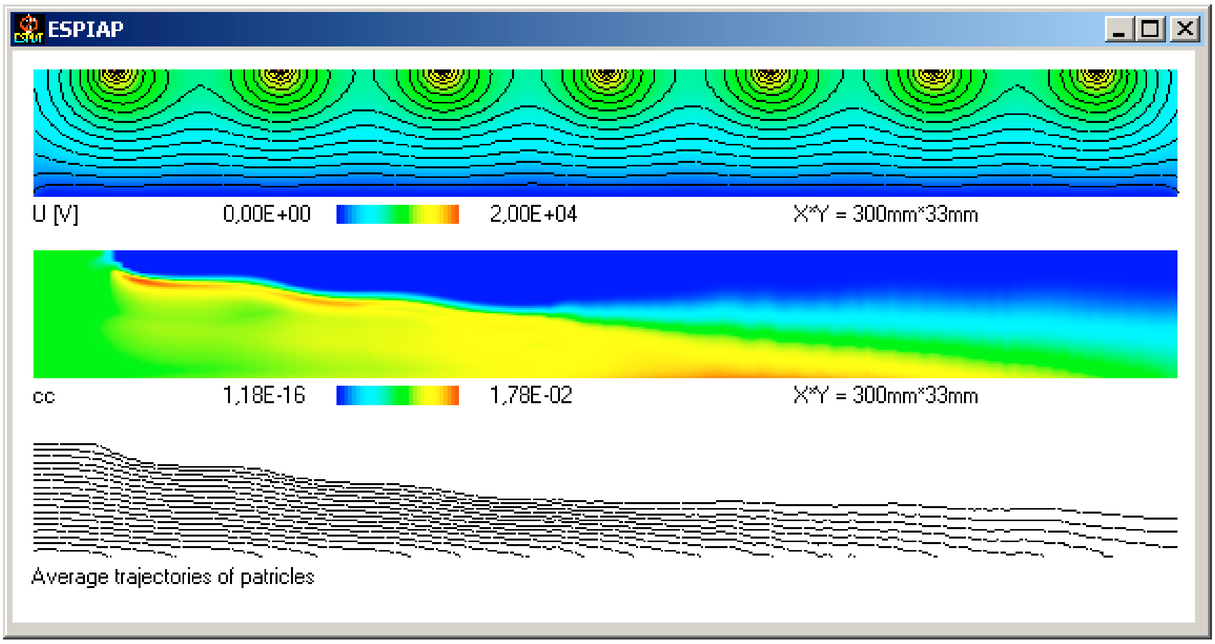


Fig. 3.

4. Usage of fuzzy logic in the ESP model

The usage of fuzzy logic in ESP analysis is illustrated in Fig. 4.a. An analyser module operating based on fuzzy logic is added to the "conventional" ESP model. The starting parameters of the calculation (boundary conditions, geometric and material data, etc.) are denoted by a_1...a_n, while the computed quantities are signed by b_1...b_m. A part of these data are the input parameters of the fuzzy analyser, which fuzzyfies (classifies) them. The fuzzyfication means an assignment between the actual value of the input parameters and a number between 0 and 1 based on the membership functions.

Beside values a_i some parameters (f_1...f_k), are not taken into consideration in the ESP model, but they are useful inputs for the fuzzy analyser. The outputs of the fuzzy analyser denoted by o_1...o_h give the modified values of outputs b_1...b_m.

The knowledge base in the analyser gives the connection between the inputs and the outputs of the model. Knowing the fuzzyfied value of the input parameter and using the rule base, a fuzzy value between 0 and 1 can be assigned to the output.

The whole process is illustrated in Fig. 4b. The actual value of parameter a_i is denoted by x. Its value determines membership values μ_S and μ_M for membership functions S and M. The rule-base gives the connection between membership functions of the input and output, so it is possible to obtain, which membership function are involved in the process. Finally output value y can be obtained by one of the defuzzyfication methods, like Center of Gravity (COG) in our case.

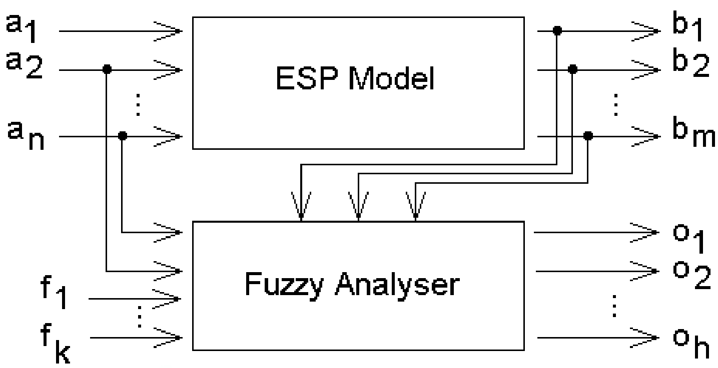
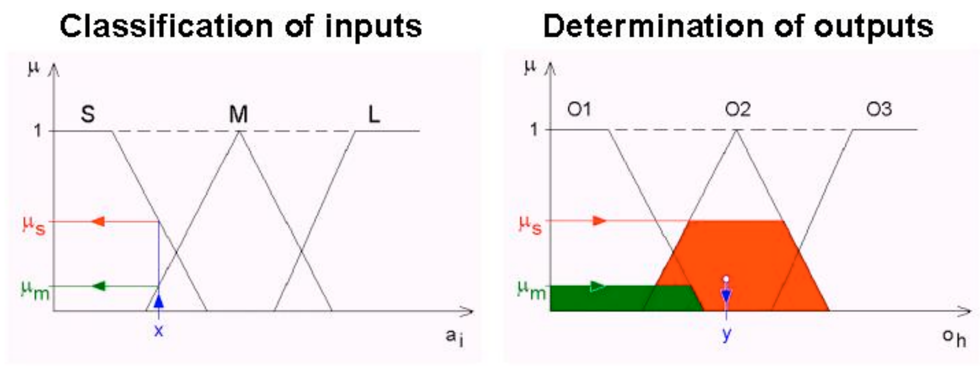


Fig. 4.a



Rule base

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if a_i **is** S **then** o_h **is** O2

if a_i **is** M **then** o_h **is** O1

if (a_i **is** L) **and** (a_{i+1} **is** M) **then** o_h **is** O3

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Fig. 4.b

5. Results of computation

Based on the model calculations, membership functions were defined for each dust property, named "below the target value", "near the target value" and "above the target value". The output value was a number between zero and one meaning how near the target value is to the result produced by the numerical model.

Fig. 5. shows the surface diagrams of computational results. Each diagram contains a vertical axis and two horizontal ones. Vertical axis express the degree, that the given parameter combination will results in a collection efficiency value that is very close to the target value. (Target value is the collection efficiency calculated for the previously described dust parameters.)

Each vertical axis represents a physical property of the dust entering into the electrostatic precipitator. As it can be seen there are two properties used as variables in the diagrams, the third (missing) one is a constant, namely the target value of the quantity.

The three-dimensional surfaces have their maximum near the target values. It can be seen, that increasing deviation in the input parameters will increase the difference from the target value, but there is a certain territory, where the computational results connecting to not exact parameters have acceptable reliability.

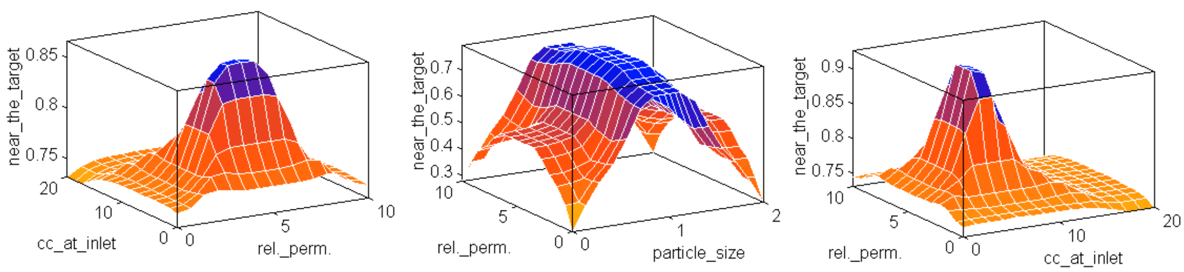

Fig. 5.

6. Conclusions

By the help of a fuzzy logic based expert system it is possible to determine the effect of the variation of the dust parameters on the precipitation. The degree of the dependency of model reliability in case of changing parameters can be expressed as a multidimensional function. Based on the results, it is possible to estimate what accuracy is necessary in case of determining different parameters to obtain reliable modelling results.

References

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