CHAPTER FOUR

SIMULATION AND RESULTS

4.1 Introduction

In this thesis the case study is simplified of electrostatic precipitator of Garri 4 station thermal power generation. In this chapter all equations of mathematical model are simulated to obtain the collection efficiency of ESP. The data that used recorded in appendix B .MATLAB codes are developed to implement this study and obtain the results.

4.2 Electric Field Simulation

To have full general idea about the mechanism of ESP electric fields firstly, must represent the electric fields of positive charge and negative charge. as shown in figure 4.1 and figure 4.2, respectively.

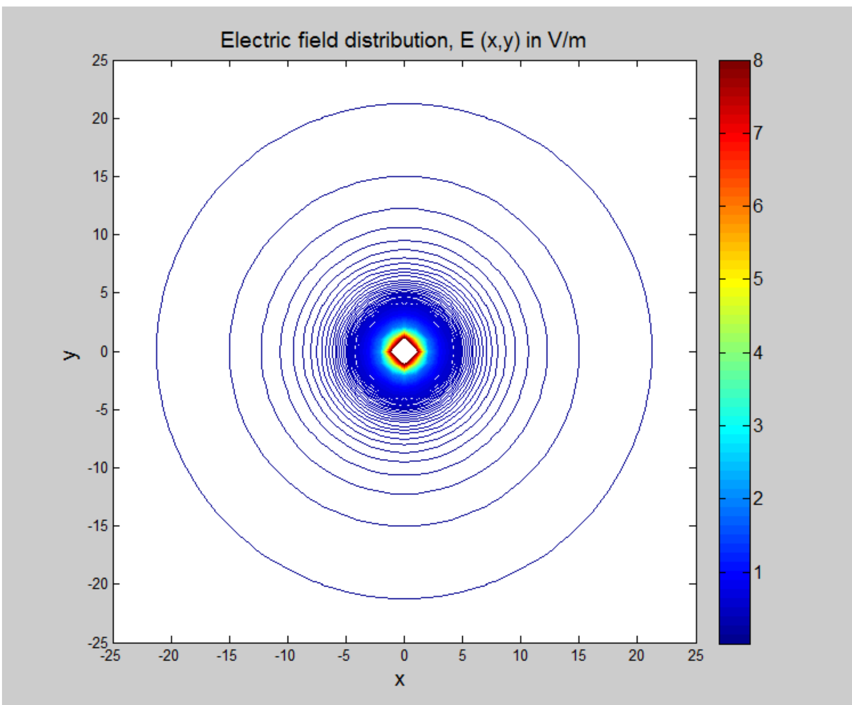

Figure 4.1 : electric field distribution for positive charge

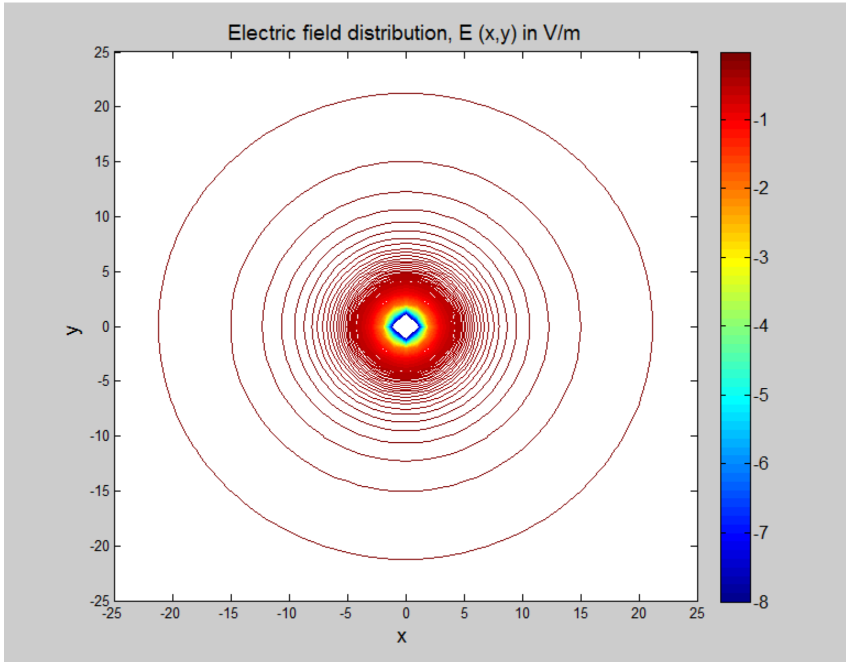

Figure 4.2: electric field distribution for negative charge

4.3 Accuracy Of Charge Simulation Technique

The accuracy of charge simulation technique is checked by investigating how the boundary conditions are satisfied in cases of one and multi-discharge wires (one, three discharge wires) as shown in Figure 4.3. It found that the maximum percentage error of the calculated surface potential of discharge wires did not exceed 10^{-6} and the maximum percentage error of the calculated surface potential of collecting plates did not exceed 3×10^{-3} (Theoretically, the potential at any point along the collecting plates should be zero) irrespective of the number of discharge wires and ESP geometry (wire radius r_c, wire-to-wire spacing d and wire-to-plate spacing H of ESP). Figure 4.4 shows as electrostatic field distribution for one discharge wire with charge Q= 1×10^{-9}C to investigation if boundary conditions are satisfy. Electrostatic field distribution increase more than the first case that is will be clear in figure 4.5 when used mult-discharge wires(three discharge wires).

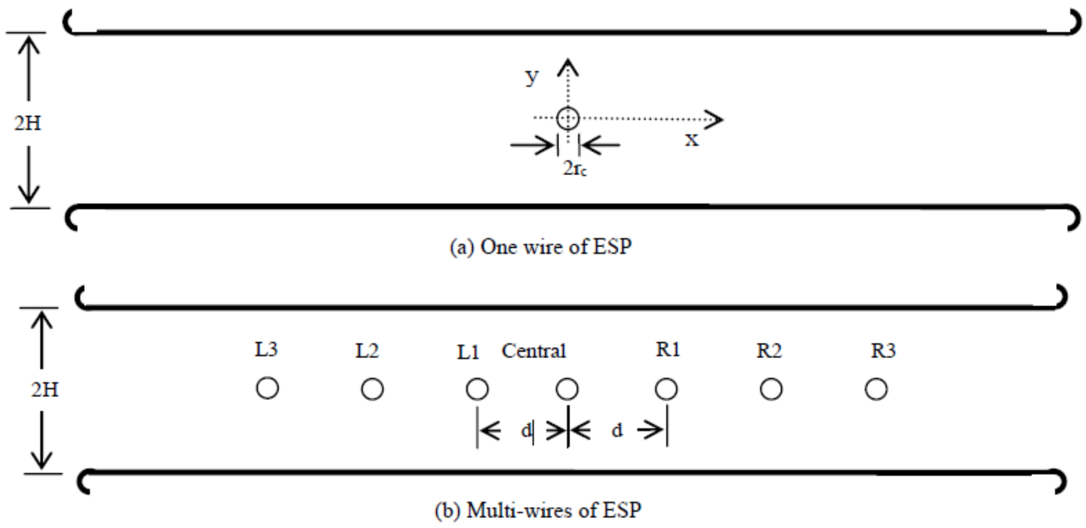

Figure 4.3: Configuration of wire-duct ESP

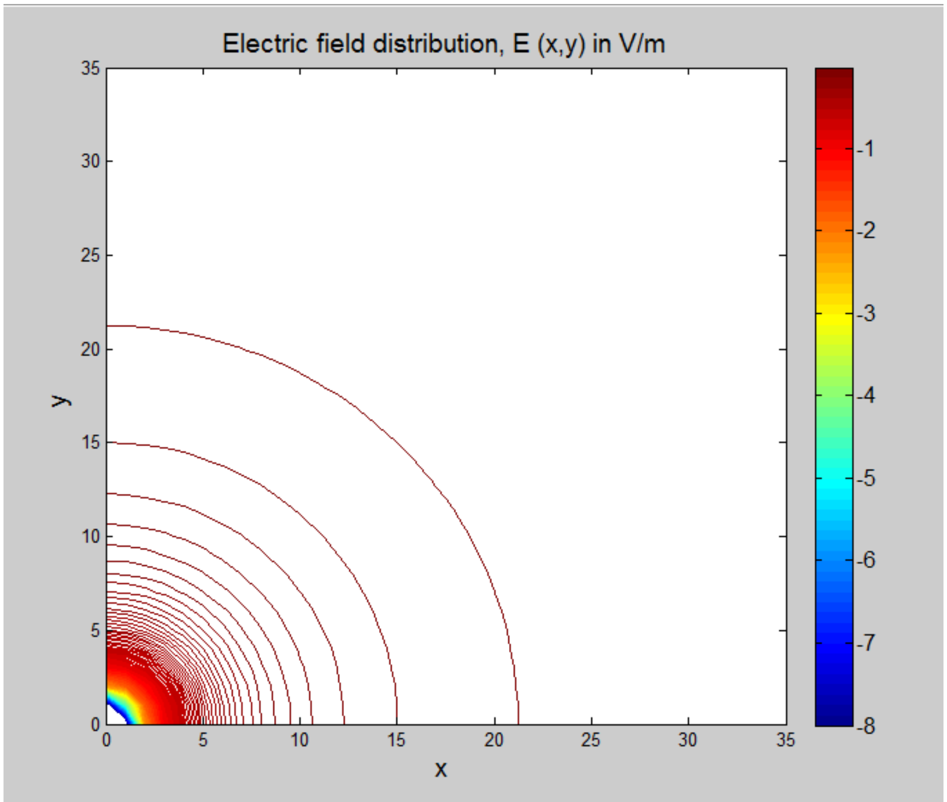

Figure 4.4: Electric field distribution for one quarter of wire duct ESP

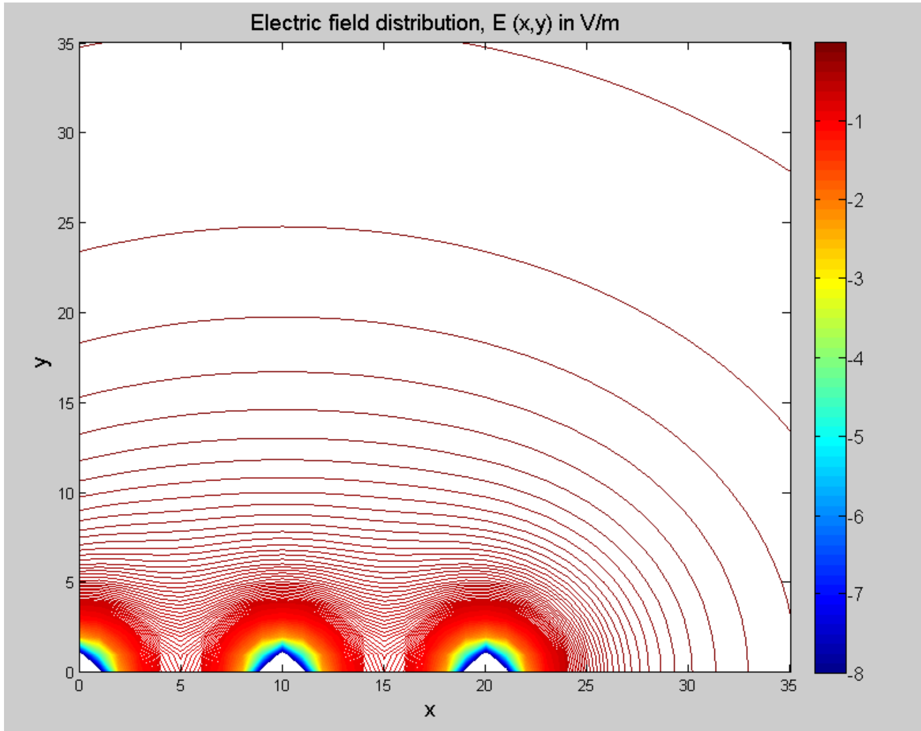

Figure 4.5: Electric field distribution and boundary points for three wires

4.4 Electrostatic Field Along ESP Axis

The electrostatic field intensity along the ESP Y-axis starting from the surface of the central discharge wire up to collecting plate. It is quit clear that the electrostatic fields intensity in Figures 4.6 to 4.8 are increase with number of wires discharge as shown in Table 4.1.

Table 4.1: Electrostatic field for one, two and three wires

No. of Wires	Electrostatic Field V/m
One Wire	$9*10^4$
Two Wires	$2.306*10^5$
Three Wires	$4.806*10^5$

On the other hand, Figure 4.6 to 4.8 shows the decrease of the electrostatic field intensity along the vertical axis of symmetry (y-axis) for applied voltage of 5kV (less than the onset voltage).

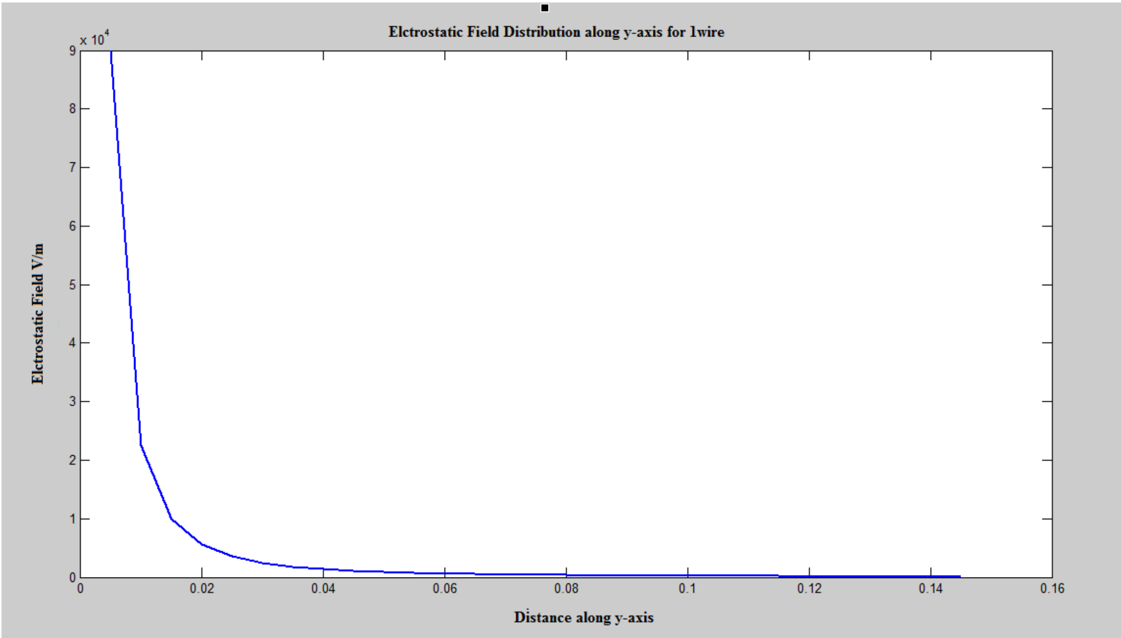

Figure 4.6: Electrostatic Field Distribution along y-axis for an applied voltage of 5kV

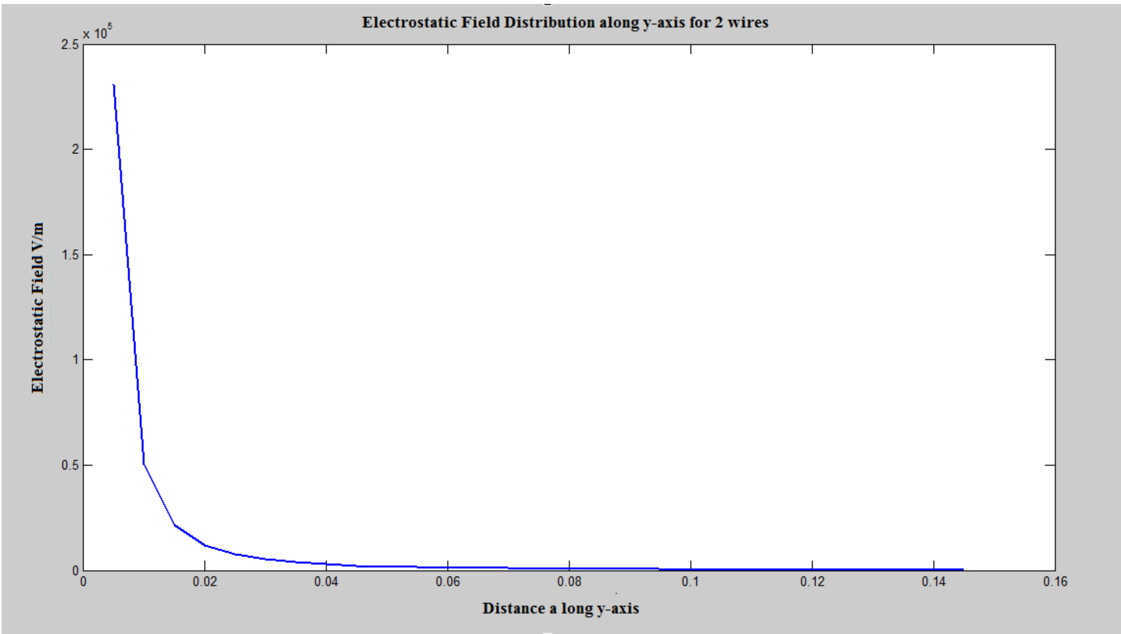

Figure 4.7: Electrostatic field distribution along y-axis for ESPs with two-wires at an applied voltage of 5kV.

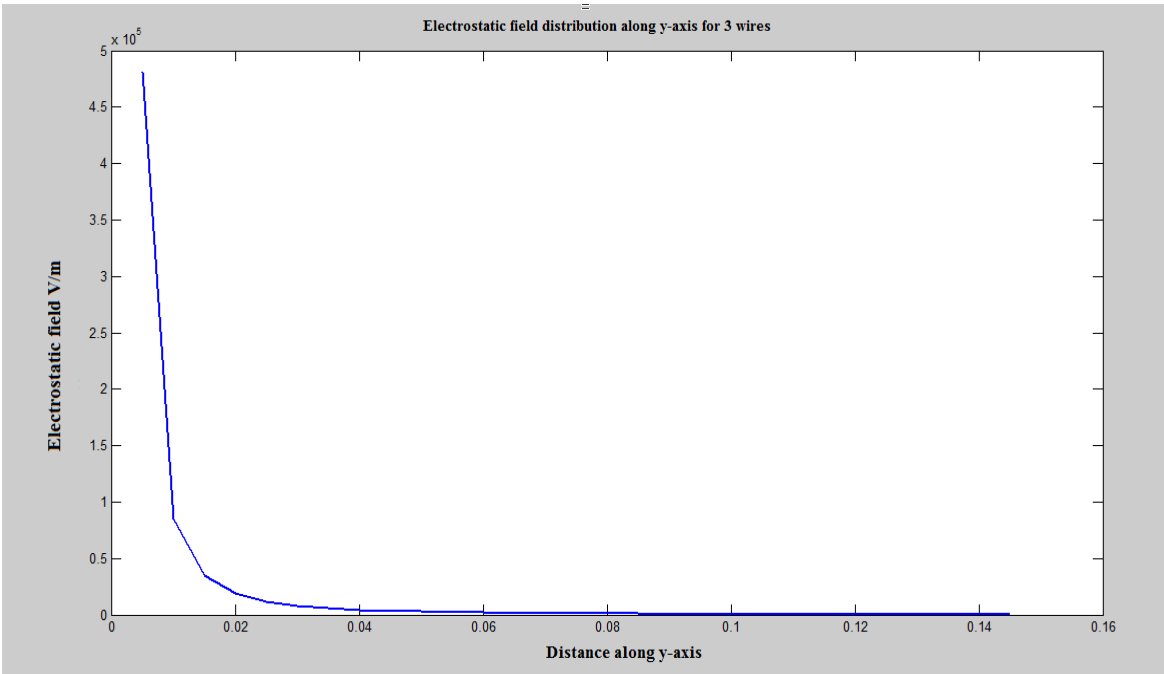

Figure 4.8: Electrostatic field distribution along y-axis for ESPs with three-wires at an applied voltage of 5kV.

4.5 Electrostatic Field Along ESP axis

For ESPs with one, three discharge wires. It is clear that the field near the central discharge wire in case of one-discharge wire ESP is higher than that for ESP with multi-wires. This is simply explained by the shielding effect imposed on the central wire due to other wires, Figure 4.9 and Figure 4.10. On the other hand, the field near the collecting plate for one wire ESP is smaller than that for ESP with multi-wires, Figure 4.8 and Figure 4.9.

This conforms to the fact that the voltage applied to the discharge wires is the same, so the line integral of the field value from the central wire surface up to the collecting plate should be the same whatever the number of discharge wires.

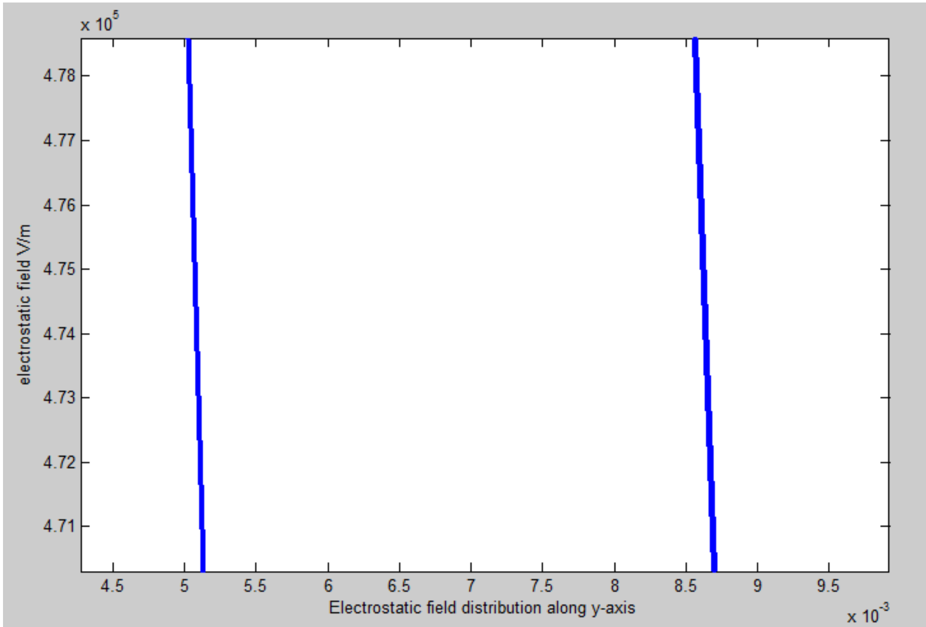

Figure 4.9 Electrostatic field distribution along y-axis near the central discharge wire for ESPs three -wires at an applied voltage of 5kV.

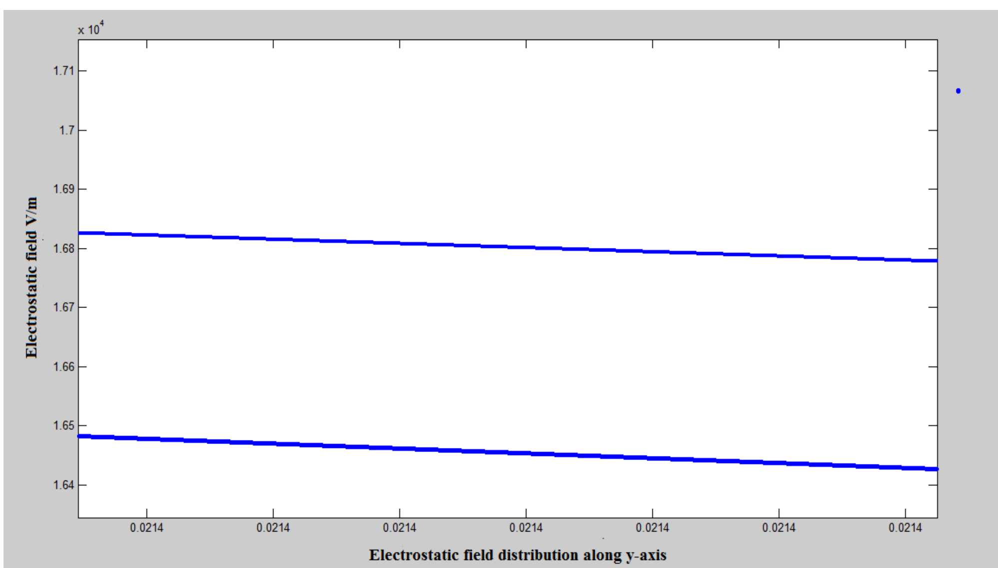

Figure 4.10 Electrostatic field distribution along y-axis near the collecting plate for ESPs with three -wires at an applied voltage of 5kV.

4.6 ESP Behavior and Efficiency

In study of ESP behavior it is important that know the relation between efficiency and voltage, that will be clear as follow:

4.6.1 Simple Calculation For Collection Efficiency at 30kv

For inlet condition ,the V_{std} is calculation based on Equation (3.28) using the parameters values as shown in Table 4.2

Table 4.2 :the parameter value of inlet condition

parameters	value
V_m	34.8cu.ft
ΔH	1.385
T_m	96.49F
P_{bar}	29.94
Y	1.006
T_{std}	68F
p_{std}	29.92 in of Hg

$$V_{std} = \frac{34.8 * 1.006 * 68 * \left(29.94 + \frac{1.385}{13.6}\right)}{96.49 * 29.92} = 24.77\ cu.ft$$

Differential filter weight = m_n=1.236 g

Then using Equation (3.29), the concentration at the inlet calculated as :

$$Conc_{inlet} = \frac{m_n}{V_{std}} = \frac{1.236}{24.77} = 0.0499\ g/ft^3$$

similarly for outlet conditions , the V_{std} is calculated based on the Equation (3.28) the parameter values as shown in Table 4.3 , the remain parameter values the same as shown in Table 4.2 .

Table 4.3 :the parameter value of outlet condition

parameters	value
V_m	43.716cu.ft
ΔH	1.982
T_m	88.56F
Y	1.002

$$V_{std} = \frac{43.716 * 1.002 * 68 * \left(29.94 + \frac{1.982}{13.6}\right)}{88.56 * 29.92} = 33.82\ cu.ft$$

Then using Equation (3.29), the concentration at the outlet calculated as :

Differential filter weight = m_n=0.2742 g

$Conc_{outlet} = \frac{m_n}{V_{std}} = \frac{0.2742}{33.82} = 0.0081\ \ g/ft^3$

finally the actual collection efficiency

$$\eta = \frac{Conc_{inlet} - Conc_{outlet}}{Conc_{inlet}}$$

$\eta = \left(\frac{0.0499-0.0081}{0.0499}\right) = 0.8375$ = 83.75%

4.6.2 Modeling Precipitator Behavior

Table 4.4 represent the collection efficiency with different applied voltage, it found that capture efficiency is function of voltage and it is increased when applied voltage increased. The collection efficiency of particulates also increases. Figure 4.11 and Figure 4.12 shown the impact of changing applied voltage on collection efficiency, it found that the collection efficiency reaches a value of 99.9%, at the voltage of 52kv. Hence, a voltage of 52kv or higher is required to achieve a collection efficiency of 99.9%.

Table 4.4: Collection efficiency with different applied voltage

No	Applied Voltage kV	Efficiency
1	20	77.26%
2	25	89.88%
3	30	96.30%
4	35	98.87%
5	40	99.72%
6	45	99.94%
7	50	99.989%

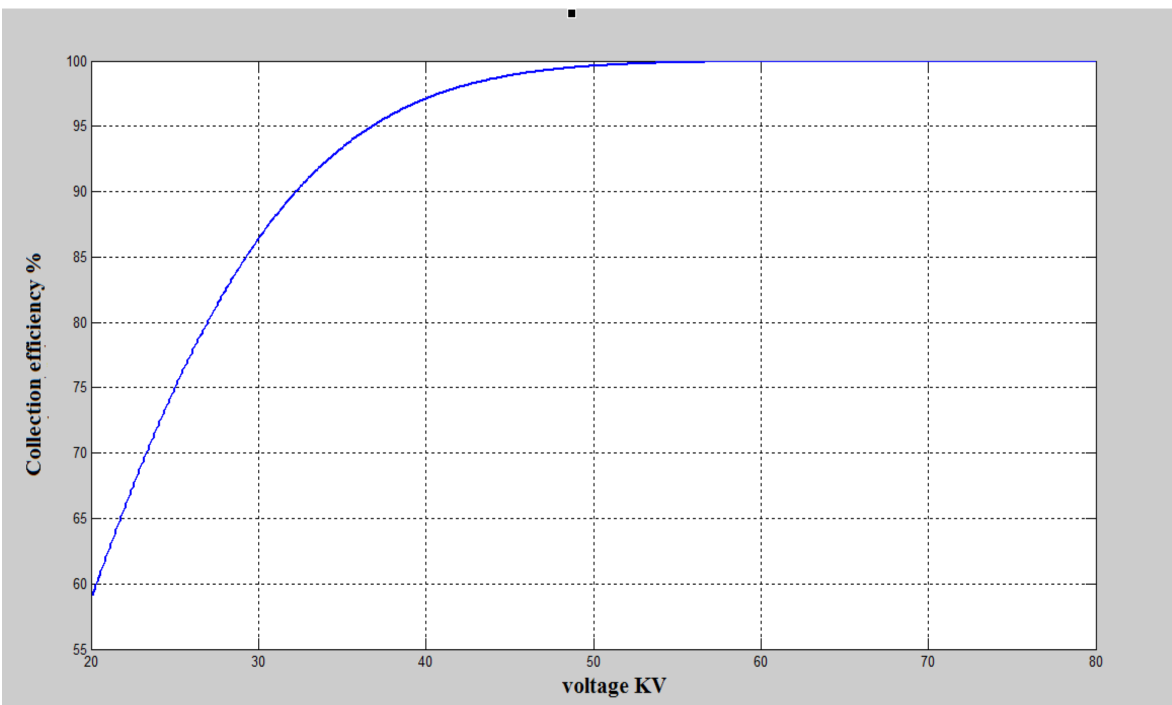

Figure 4.11: Curve for collection efficiency vs voltage

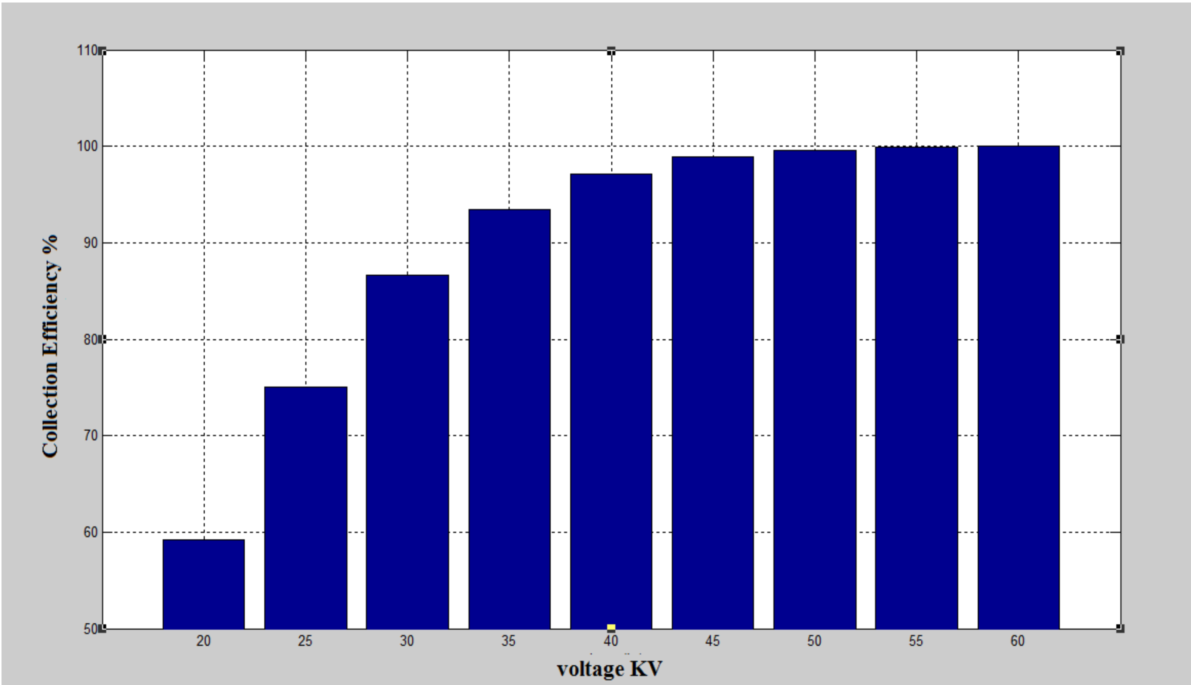

Figure 4.12: collection efficiency in different voltage

4.7 Impact of ESP Parameters Variation In Collection Efficiency

Mainly applied voltage have a major in collection efficiency, but there are other factor can also influence in collection efficiency as follows:

4.7.1 Temperature

Table 4.5 shows, the variation in collection efficiency when taken low temperature (70C^o) and high temperature (150C^o) with different value of applied voltage. It is clear that temperature had little impact on collection efficiency.

Table 4.5: Collection efficiency in different temperature and voltage

No	Voltage KV	efficiency in temperature		
		109C^o	70C^o	150C^o
1	20	59.1730%	59.1716%	59.1744%
2	25	74.9886%	74.9872%	74.9899%

3	30	86.4069%	86.4058%	86.4079%
4	35	93.3877%	93.3870%	93.3884%
5	40	97.1210%	97.1207%	97.1214%
6	45	98.8781%	98.8779%	98.8783%
7	50	99.6087%	99.6086%	99.6087%
8	55	99.8837%	99.8778%	99.8779%
9	60	99.9659%	99.9658%	99.9659%

4.7.2 Distance between plates

Table 4.6 shows the variation in collection efficiency when taken small distance between plates (9cm) and larg distance between plates (14cm) with different value of applied voltage. It is clear that the distance between plates have large impact on collection efficiency.

Table 4.6: Collection efficiency in different temperature distance between plates and different voltage

Voltage KV	9cm	12cm	14cm
20	77.2557%	59.1730%	45.1016%
25	89.8822%	74.9886%	60.4541%
30	96.3075%	86.4069%	73.7079%
35	98.8781%	93.3877%	83.7700%
40	99.7162%	97.1210%	90.6980%
45	99.9402%	98.8781%	95.0500%
50	99.9895%	99.6087%	97.5543%
55	99.9985%	99.8837%	98.8781%
60	99.9998%	99.9659%	99.5221%