Journal of Electrical Engineering and Automation (ISSN: 2582-3051)
www.irojournals.com/iroeea/

Power Electronic Solution for Dust Emission from Thermal Power Plant

V. Pavithra[1], P. Karpagavalli[2]

[1]PG Scholar, Department of EEE, GCE Salem, India
[2]Professor, Department of EEE, GCE Salem, India

E-mail: [1]pavithravenkateshan@gmail.com, [2]karpagamgce@gmail.com

Abstract

In thermal power stations, flue gases are let to the atmospheric air through the chimney. This exhaust gas contains some toxic elements like Suspended Particle Matter (SPM), SOX, NOX, Mercury etc. It causes air pollution in the atmosphere and affects the human beings and aquatic lives. The allowable limit of this flue gas dust emission to the atmosphere is about 50 mg/m3. In order to separate this dust particle from the flue gas, Electrostatic Precipitators (ESP) are used to collect those unwanted suspended particles before passing them to chimney. ESP requires high efficiency to extract those dust and hence, High-Frequency High Voltage (HFHV) power supply is applied to increase the efficiency of the collecting electrode of the electrostatic precipitator. The HFHV power supply provides a significant reduction in the size and weight of the complete ESP installation.

Keywords: Electrostatic precipitator, dust emission, flue gas, HFHV, rapping

1. Introduction

The Suspended Particle matters in the flue gases from the thermal power stations are more toxic and which when mixed with the atmospheric air. The permissible limit of the dust emission to the atmosphere is about 50 mg/m3 [1][5]. For the separation suspended matters from the flue gas Electrostatic Precipitators are used before passing dust emission to chimney [4]. The highly efficient ESP's are used for increasing the Collection efficiency of the flue gases to separate the dust particles.[3] The Efficiency of the Electrostatic Precipitator can be increased by modifying the internal design of ESP and also by interchanging the power electronic component of the power circuit of Electrostatic Precipitator [2][3].

DOI: https://doi.org/10.36548/jeea.2022.2.006
Received: 28.05.2022, received in revised form: 29.06.2022, accepted: 12.07.2022, published: 22.07.2022

2. Proposed System

The modern Power Electronics with IGBT switching devices offer dynamic performance. DC voltage of about 400V is given as the input to the inverter section as depicted in fig. 1. The switching frequency of about 10 KHz is applied to the IGBT switches. In the Inverter DC voltage is converted to AC voltage with high switching frequency of about 10 KHz. The AC voltage of about 400V is obtained and given as the input to the high-power transformer. Power transformer increases the voltage level to 70 KV. Finally, the high voltage from transformer is converted to DC through rectifier section and then this voltage is given as input to the Electrostatic Precipitator.

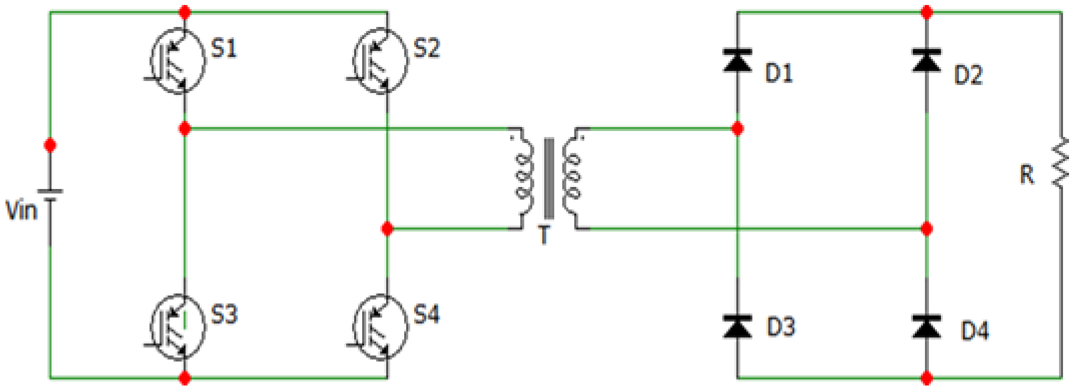

Figure 1. Power Circuit of the proposed converter

2.1 Electrostatic Precipitator

An Electrostatic Precipitator (ESP) shown in fig.2 is used to segregate suspended matters from flue gas by applying high voltage to the electrodes. Due to ionization, the particles get ionized and attracted to the collecting electrode having opposite charge. Electrostatic precipitators operate on the principle of the attraction of a charged particle by an oppositely charged collector.

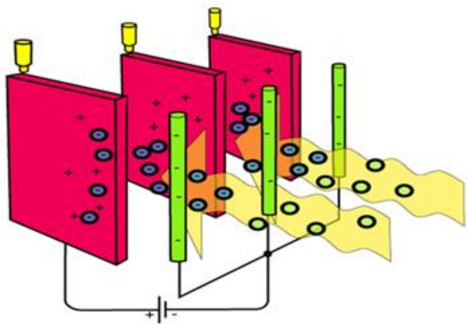

Figure 2. Electrostatic Precipitator

2.1.1 Operation of Electrostatic Precipitator

Electrostatic Precipitators collect the unwanted suspended particles from the flue gases before passing them to chimney. The High-Frequency High Voltage (HFHV) power supply is applied to increase the efficiency of the collecting electrode of the electrostatic precipitator. This flue gases are passed through the electrodes placed in the ESP in the horizontal direction. The electrodes are placed in the range of about 300 mm to 500 mm. The DC voltage of about 70KV is applied to the negative electrode while the positive electrode is grounded. The negative electrodes undergo ionization and produce large number of ions due to the corona effect. Due to high ionization of dust particles, the negative charge on the particles is increased and they move to the positive electrode. The negative electrode is called the emission plate, while the positive electrode is called the collecting plate. The collecting electrodes are periodically shaken off, i.e. rapped. The rapping process is done by means of the spinning hammers which produce the mechanical vibration periodically to remove the detaching dust layer deposited on the electrode. The ash can be collected from the V-shaped hoppers, located below the ESP chamber. The dust and ashes are further segregated by means of water or pressurized air. Bypassing through the sequence of the serially connected sections, the precipitation efficiency reaches 99.9%.

2.2 Modeling of Electrostatic Precipitator

2.2.1 Particle Charging

The Corona discharge is produced as a result of particle charging.

$$q_f(t) = \frac{q_s t}{t + r_f}$$

where, q_s = $Saturation\ charge$

t = $exposure\ time$

r_f = $field\ charging\ time\ constant$

2.2.2 Particle Collection

The velocity of the collecting particle can be calculated by coulomb force which is given by,

ISSN: 2582-3051

$$F = qE$$

where, $F = coulomb$ force (N)

$E = Electric$ fie(V/m)

$q = positive\ charge$Collection Efficiency

The Efficiency of the Electrostatic precipitator can be obtained by,

$$\eta = 1 - \exp(\frac{A_c U_t}{Q})$$

where, $A_c = Total\ collecting\ electrode\ area$

$Q = Gas\ volumetric$ flow $rate$

a) Designing of Needle plate Electrostatic Precipitator

Particle Collection

$$F = qE$$

where, $E = 10^5$

$q = 3 * 10^{-16}$

$F = (10^5)*(3 * 10^{-16})$

$F = 3 * 10^{-11}$ N

Collection Efficiency

$$\eta = 1 - \exp(\frac{A_c C_c}{Q})$$

where, Collection area of ESP, A_c = 145.7449 m^2

Cunizham correction factor, C_c = 1.168

Gas flow rate, Q =363.1 m^3

$\eta = 1 - \exp(\frac{145.7449 * 1.168}{363.1})$ = 37

$$\eta = 37\%$$

b) Designing of Tubular Electrostatic Precipitator

Particle Collection

$$F = qE$$

where, $E = 10^5$

$q = 3 * 10^{-16}$

$F = (10^5)*(3 * 10^{-16})$

$F = 3 * 10^{-11}$ N

Collection Efficiency

$$\eta = 1 - \exp(\frac{A_c C_c}{Q})$$

where, Collection area of ESP, A_c = 422.66 m^2

Cunizham correction factor, C_c = 1.168

Gas flow rate, Q =363.1 m^3

$\eta = 1 - \exp(\frac{422.66*1.168}{363.1})$ = 74.82

$$\eta = 75\%$$

3. Simulation Results

Simulation of the proposed system is performed as shown in fig. 3. Overall operation of the proposed system is analyzed using MATLAB Simulink.

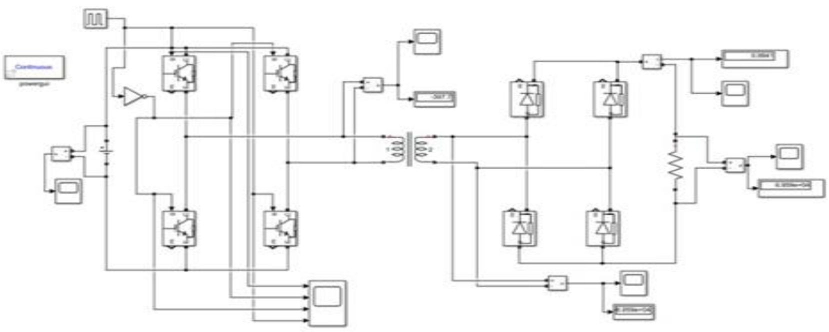

Figure 3. Simulation Diagram of the proposed system

The input waveform for the proposed inverter is DC supply with 400V as shown in the fig. 4. The gate pulse for the proposed inverter having four IGBT is shown in fig. 5.

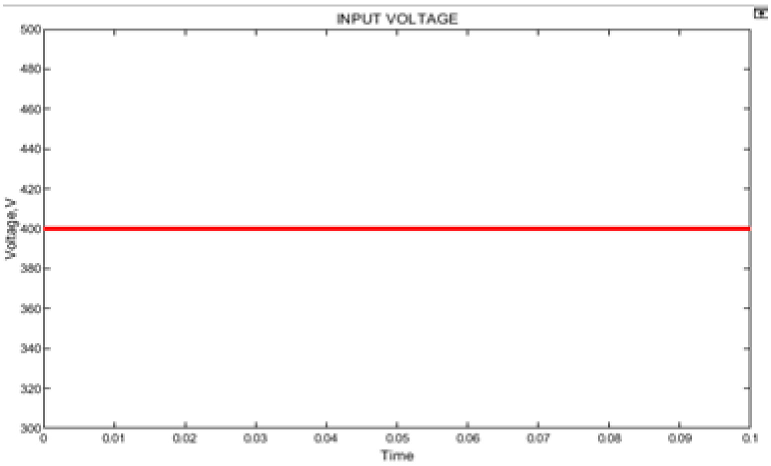

Figure 4. Input Voltage of the inverter

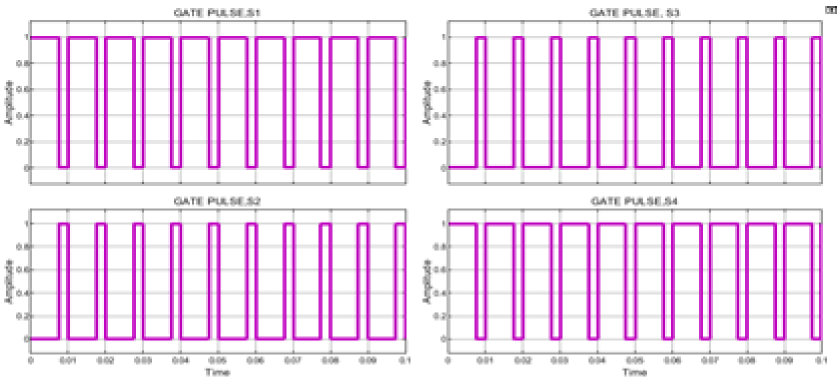

Figure 5. Gate Pulse of the IGBT in the inverter

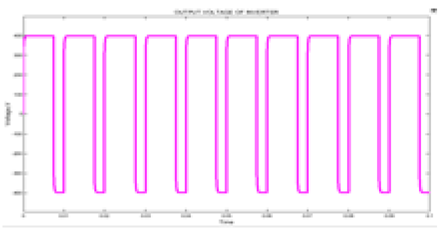

Figure 6. Output Voltage of the Inverter

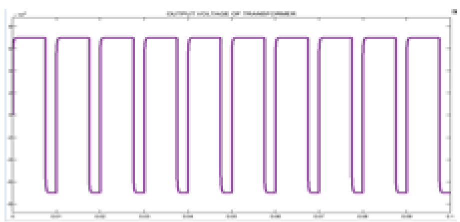

Figure 7. Output Voltage of the Transformer

The switches S1 & S3 have same PWM pulses. The switches S2 & S4 have same inverted PWM pulses with 2 microsecond dead time. The output voltage of the proposed inverter and transformer for IGBT switches are shown in fig. 6 and fig. 7 respectively. The Output Voltage & Output Current of the proposed Electrostatic Precipitator for IGBT switches are shown in fig. 8 and fig. 9.

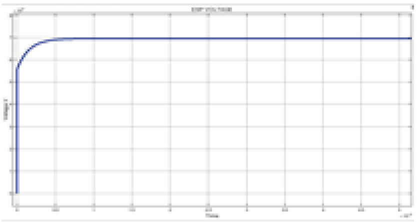

Figure 8. Output Voltage of the ESP

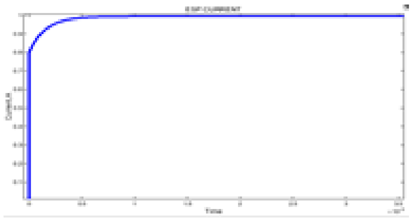

Figure 9. Output Current of ESP

Table 1. Comparison of the existing & proposed System

Parameters	Existing system	Proposed system
Ripple Voltage	1.7 KV (MOSFET)	0.16 KV (IGBT)
Ripple Current	0.25 mA (MOSFET)	0.024 mA (IGBT)
Collection Area of ESP per pass	145.7449 m^2 (Needle Plate ESP)	422.66 m^2 (Tubular ESP)
Collection Area of ESP two pass	291.4898 m^2 (Needle Plate ESP)	845.32 m^2 (Tubular ESP)
Collection Efficiency	37% (Needle Plate ESP)	75% (Tubular ESP)

Table 2. Simulation results of the proposed system

Parameters	Value
Input voltage of the Inverter	400 V
Output voltage of the Inverter	400 V
Input voltage of Transformer	400 V
Output voltage of Transformer	70 KV
Input voltage of Rectifier	70 KV
Output voltage of Rectifier	70 KV
Output current of Rectifier	1000 mA
Output power of Rectifier	70 KW
Switching Frequency	10KHz

The high voltage from Transformer is converted to DC through Rectifier. The obtained output voltage of Rectifier is 70 KV and output current of Rectifier is about 1000mA. The output power of the Rectifier is 70 KW which is illustrated in Table 2.

4. Conclusion

The dust emission from the flue gas is minimized by applying the HFHV to the ESP of the thermal plant. By increasing the supply voltage to the Precipitator, the collecting efficiency of the ESP is also increased simultaneously. The voltage of the proposed system is 70 KV and the current is about 1000 mA. The power of the system is 70 KW. The HFHV power supply provides a significant reduction in the size and weight of the complete ESP installation. In the proposed system, the control strategy and unipolar sinusoidal PWM techniques are simulated by using MATLAB/Simulink. In the designing of ESP instead of using Needle plate type ESP, the collection efficiency of ESP can be increased by using Tubular ESP. Efficiency of Tubular ESP is nearly about 75% which is more than the Needle plate type ESP whose efficiency is only 37%. Comparing to conventional SCR based technology, the average corona power can be increased significantly by using IGBT based power supply to improve the precipitator efficiency. The desired objective ripple current and ripple voltage are also reduced. Additionally, during flashovers, the fast current control of IGBT power inverter improves precipitator performance since the fast voltage recovery increases the precipitator voltage. Due to the exact voltage control of IGBT inverter, a smooth DC voltage can be generated, and is more economical.

References

[1] N. Grass: 150kV/300kW High Voltage Supply with IGBT Inverter for Large Industrial Electrostatic Precipitator, 42nd IAS Annual Meeting of the 2007 IEEE Industry Applications Conference, New Orleans, LA, USA, Sept. 2007, pp. 808 – 811.

[2] J.C. Fothergill, P.W. Devine, P.W. Lefley: A Novel Prototype Design for a Transformer for High Voltage, High Frequency, High Power Use, IEEE Transaction on Power Delivery,Vol. 16, No. 1, Jan. 2001. pp. 89 – 98.

[3] N. Grass, W. Hartmann, M. Klockner: Application of Different Types of High-voltage Supplies on Industrial Electrostatic Precipitators, IEEE Transaction on IndustryApplications, Vol. 40, No. 6, Nov/Dec. 2004, pp. 1513 – 1520.

[4] N. Grass: Fuzzy Logic-optimising IGBT Inverter for Electrostatic Precipitators, 34th Annual Meeting of the IEEE-IAS, Vol. 4, Phoenix, AZ, USA, Oct. 1999, pp. 2457 – 2462.

[5] L.M. Dumitran, P. Atten, D. Blanchard, P. Notingher: Drift Velocity of Fine Particles Estimated from Fractional Efficiency Measurements in a Laboratory-scaled Electrostatic Precipitator, IEEE Transaction on Industry Applications, Vol. 38, No. 3, May/June 2002, pp.852 – 857.

Author’s biography

V. Pavithra received the B.E. degree in Electrical and Electronics Engineering from Excel College of Technology, Pallakapalaym , Namakkal, Tamil Nadu in 2010. She is currently pursuing the M.E. degree with the Department of Electrical and Electronics Engineering, Government College of Engineering –Salem under Anna University, Chennai, Tamil Nadu. Her main field of interest is Power Electronics & Drives.

P. Karpagavalli received the M.E degree in Electrical and Electronics Engineering and the Ph.D. degree Anna University, Chennai, India. She is currently Professor (CAS) at the Department of Electrical and Electronics Engineering, Government College of Engineering – Salem, Chennai, Tamil Nadu, India. Her area of research includes power Electronics, AC and DC Drives, Power systems and Renewable Energy Sources.