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Novel Based Electro Static Precipitator For Various Applications.

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Abstract: *A New designed Discharge electrode with high frequency or Three phase transformer is controlled by power electronic devices such as IGBTS are used to improve power consumption & performance of E.S.P. The distillery sector is polluting industries in India & world. These units generate large volume of dark brown colored waste water, which is known as "spent wash". Liquid wastes from breweries and distilleries possess a characteristically high pollution and have continued to pose a critical problem of environmental pollution in India and many countries.*
Keywords: *Electrostaticprecipitator,Spentwash,Distillerycomponent(key words)*

I. Introduction

New designed Discharge electrode with High frequency transformer or Three-phase transformer electrostatic precipitator (ESP) has been developed for control of submicron particles which are very harmful and Hazardous to the environment generated in exhaust gas. In new designing E.S.P process is very much sophisticated to control the NOx, SOx, and Mercury along with CO, CO2, O2 and N2.

Because of new designing very fine particles could be agglomerated and captured effectively in the ESP. The electrical supplied voltage, dust loading and the gas flow velocity at the ESP were considered while the supplied voltage of the pre-charger was varied from minimum level to maximum level of voltage in KV with respect to current in **ma**. The overall collection efficiency increased with the supplied voltage while the dust loading and gas velocity did not give strong effect. A model to predict the overall collection efficiency at various operating conditions could be evaluated from the experimental data and it has improved from 99.87% to 99.98%.

Features of New Discharge - Electrode :
Best corona generation properties among various types of Rigid Electrode.
Mechanically stable electrodes for optimum rapping vibration transmission and effective dislodgement.
Light weight, ease of shipping site. Long life.

II. Designing Aspects

Three phase full converter conduction, High frequency transformer Design

MECHANICAL	ELECTRICAL
4-D Electrode	High frequency Transformer
	Three phase Transformer
	IGBT Converter
	Thyristor
	Diode full bridge rectifier

THREE PHASE IGBT CONVERTER

The waveforms of the input voltages, the conduction angles of I.G.B.T'S and the output voltage of one phase, for firing delay angles (a) of (a) and (b) are shown. For 0°= a = 60° (∏/6), immediately before triggering of IGBT 1, two IGBTS (5 & 6) conduct. Once IGBT 1 is triggered, three IGBT (1, 5 & 6) conduct. As stated earlier, a IGBT turns off, when the current through it goes to zero. The conditions alternate between two and three conducting IGBTS.

At any time only two IGBTS conduct for 60°.= a = 90°. Although two IGBTS conduct at any time for 90° = a = 150° , there are periods, when no IGBTS are on. For a =150°, there is no period for which two IGBTS are on, and the output voltage becomes zero at a=150°(5∏/6). The range of delay angle is 0°=a=150°.

To derive an expression for the average output voltage of **three phase full converter** with high load assuming continuous and constant load current. The output load voltage consists of 6 voltage pulses over a period of 2∏ radians, hence the average output voltage is calculated as

At ωt=(∏/6 +α) , IGBT is already conducting when the IGBT is turned on by applying the gating signal to the gate of . During the time period ωt=(∏/6 +α) to (∏/2 +α), IGBTS and conduct together and the line to line supply voltage appears across the load.

At ωt=(∏/2 +α), the IGBT-2 is triggered and IGBT6 is reverse biased immediately and *IGBT6* turns off due to natural commutation. During the time period ωt=(∏/ +α) *to* (5∏/6 +α), IGBT-1 and IGBT-2 conduct together and the line to line supply voltage appears across the load.The *IGBTS* are numbered in the circuit diagram corresponding to the order in which they are triggered. The trigger sequence (firing sequence) of the *IGBTS* is 12, 23, 34, 45, 56, 61, 12, 23, and so on. The figure shows the waveforms of three phase input supply voltages, output voltage, the IGBTS current through $IGBT_1$ and $IGBT_4$, the supply current through the line ‘a’.

We define three line neutral voltages (3 phase voltages) as follows

$V_{RN} = V_{an} = V_m \text{ Sin } \omega t$

$V_m =$ Max Phase Voltage

$V_{YN} = V_{bn} = V_m \text{ Sin } (\omega t - 2\pi/3) = V_m \text{ Sin } (\omega t - 120^{\circ})$

$V_{BN} = V_{cn} = V_m \text{ Sin } (\omega t + 2\pi/3) = V_m \text{ Sin } (\omega t - 240^{\circ})$

Where V_m is the peak phase voltage.

The corresponding line to line voltage are

$V_{RY} = V_{ab} = (V_{an} - V_{bn}) = \sqrt{3}\, V_m \text{ Sin } (\omega t + \pi/6)$

$V_{YB} = V_{bc} = (V_{bn} - V_{cn}) = \sqrt{3}\, V_m \text{ Sin } (\omega t - \pi/2)$

$V_{BR} = V_{ca} = (V_{cn} - V_{an}) = \sqrt{3}\, V_m \text{ Sin } (\omega t + \pi/2)$

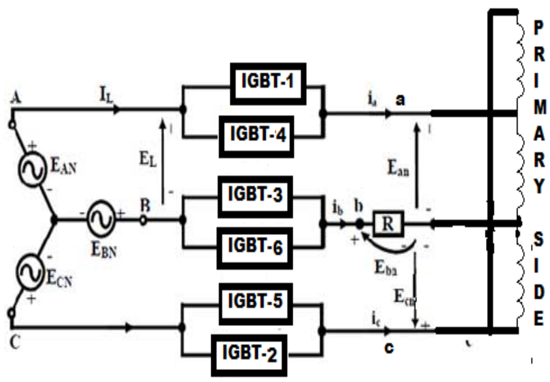
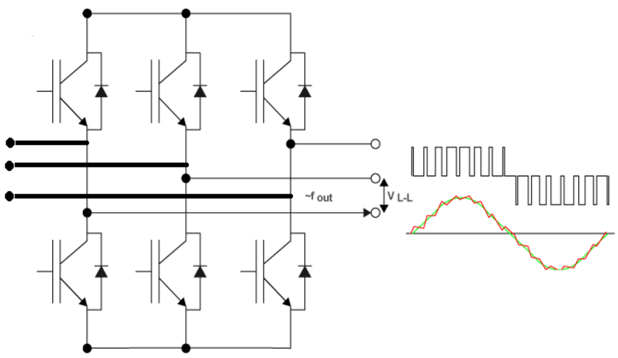
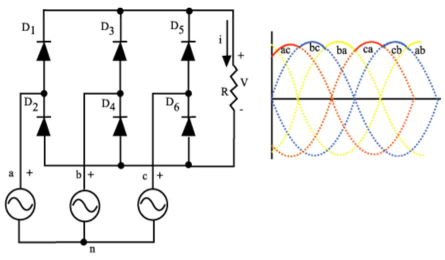


Fig : 1 Three-phase IGBT Circuit Connected to Primary side of Transformer



Three phase IGBT Circuit



Three Phase Rectifier

Output Waveform

Fig : 5 Secondary side rectifier output wave forms

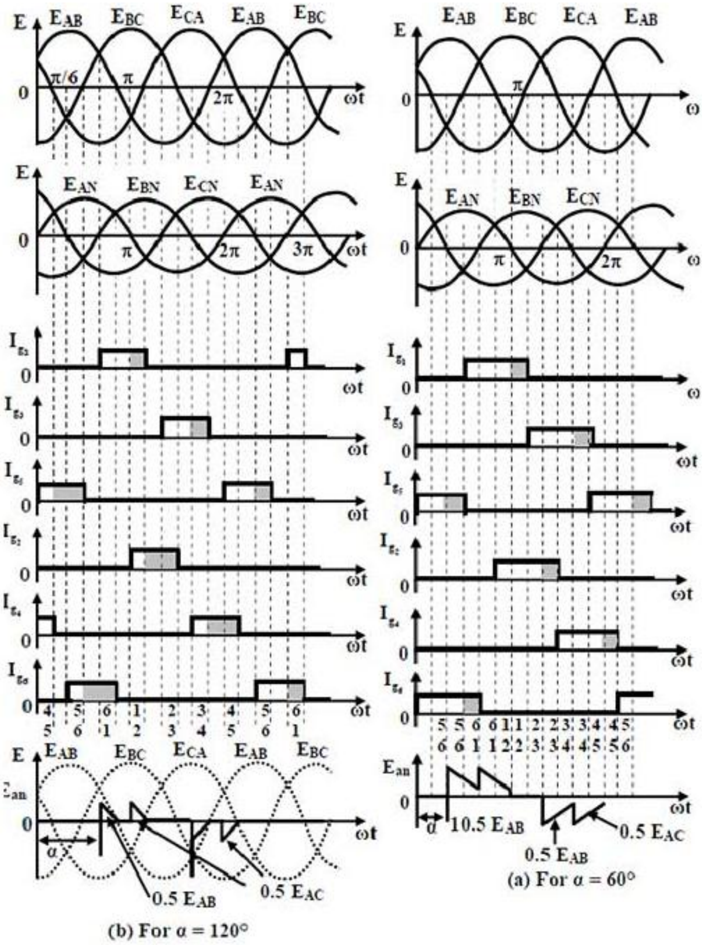


Fig : 2 IGBT Conduction level at different firing angles

Three phase Rectifier:

six-pulse bridge controlled converter connected to a three-phase source. In this converter, the number of pulses is twice that of phases, that is **p = 2m**. Using the same converter configuration, it is possible to combine two bridges of the six-pulse to obtain a twelve or more pulses converter. When commutation is not available, two diodes will conduct at any particular time. Furthermore, to obtain a voltage drop across the load, two diodes must be at positioned at opposite legs of the bridge. For example, diodes 3 and 6 cannot be ON at the same time. Therefore, the voltage drop across the DC load is a combination of line voltage VL from the three-phase source.

It is important to note that more the number of pulses, the greater the utilization of the converter. In addition, the fewer the number of pulses the lesser the utilization of the converter.

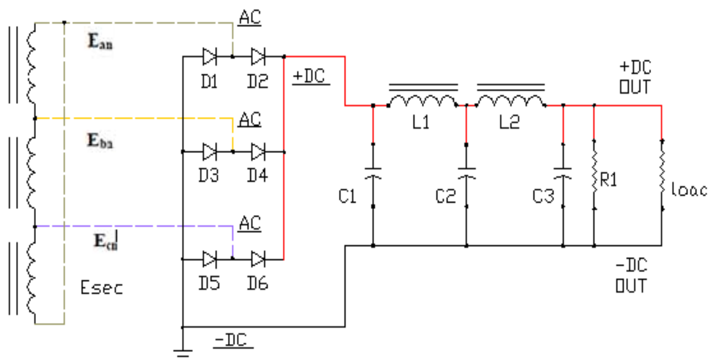


Fig :3 Secondary side of Transfomer

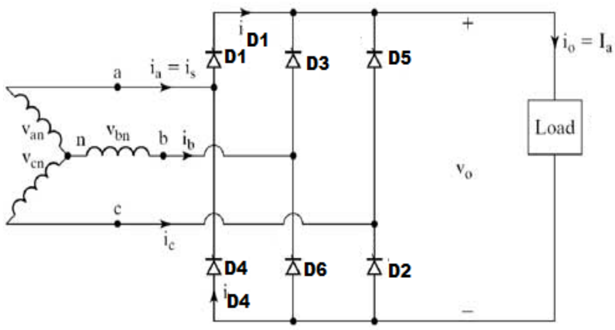


Fig :4 secondary side of transformer

conduction interval	conduction diode pair
ac	1 & 6
bc	3 & 6
ba	3 & 2
ca	5 & 2
cb	5 & 4
ab	1 & 4

conduction interval	conduction diode pair
$\mathbf{V_{ax} = 0}$	(Diode 1 is on)
$\mathbf{V_{cy} = 0}$	Diode 6 is on)
$\mathbf{V_{ac} = V_{ay} = +V_m}$	(Diode 2 is off)
$\mathbf{V_{bc} = V_{by} = +0.5}$	(Diode 4 is off
$\mathbf{V_{ba} = V_{bx} = -0.5\ V_m}$	(Diode 3 is on)
$\mathbf{Vca = Vcx = -\ V_m}$	(Diode 5 is off)

THREE PHASE FULL CONVERTER BY USING THYRISTOR:

Three phase full converter is a fully controlled bridge controlled rectifier using six thyristors connected in the form of a full wave bridge configuration. All the six thyristors are controlled switches which are turned on at a appropriate times by applying suitable gate trigger signals, more switching losses and harmonic distortions are minimized with the help of this process when compared to the diode bridge rectifier circuit.

The **three phase full converter** is extensively used in industrial power applications upto about 120kW output power level, where two quadrant operations is required. The figure shows a **three phase full converter** with highly inductive load. This circuit is also known as three phase full wave bridge or as a six pulse converter. At $\omega t=(\prod/6 +\alpha)$, thyristor is already conducting when the thyristor is turned on by applying the gating signal to the gate of . During the time period $\omega t=(\prod/6 +\alpha)$ to $(\prod/2 +\alpha)$, thyristors and conduct together and the line to line supply voltage appears across the load.

At $\omega t=(\prod/2 +\alpha)$, the thyristor T_2 is triggered and T_6 is reverse biased immediately and T_6 turns off due to natural commutation. During the time period $\omega t=(\prod/ +\alpha)$ *to* $(5\prod/6 +\alpha)$, thyristor T_1 and T_2 conduct together and the line to line supply voltage appears across the load.

The thyristors are numbered in the circuit diagram corresponding to the order in which they are triggered. The trigger sequence (firing sequence) of the thyristors is 12, 23, 34, 45, 56, 61, 12, 23, and so on. The figure shows the waveforms of three phase input supply voltages, output voltage, the thyristor current through T_1 and T_4, the supply current through the line 'a'.

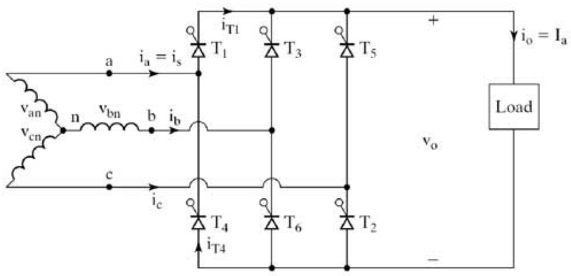


Fig : 6 Secondary side AC to DC Conversion

We define three line neutral voltages (3 phase voltages) as follows

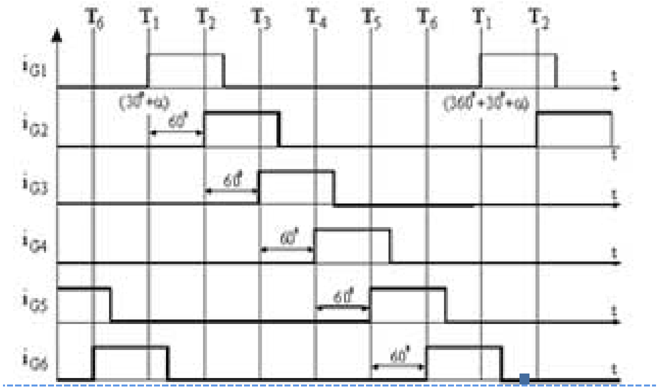
$V_{RN} = V_{an} = V_m Sin\omega t$: Where V_m = Max Phase Voltage.
$V_{YN} = V_{bn} = V_m Sin(\omega t - 2\prod/3) = V_m Sin(\omega t - 120)$
$V_{BN} = V_{cn} = V_m Sin(\omega t + 2\prod/3) = V_m Sin(\omega t + 120) = V_m Sin(\omega t - 240)$

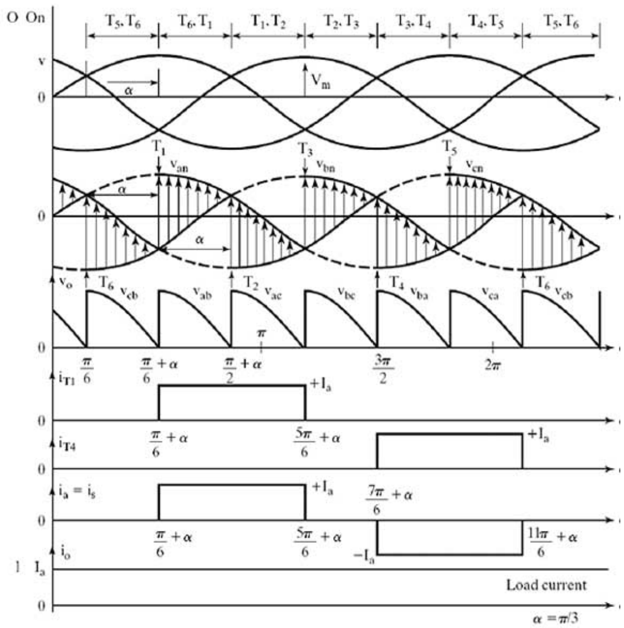
Where V_m the peak phase voltage of a star connect source corresponding lint to line voltage are

$V_{RY} = V_{ab} = (V_{an} - V_{bn}) = \sqrt{3}\ V_m\ Sin((\omega t + \prod/6)$

$V_{YB} = V_{bc} = (V_{bn} - V_{cn}) = \sqrt{3}\ V_m\ Sin((\omega t - \prod/2)$

$V_{BR} = V_{ca} = (V_{cn} - V_{an}) = \sqrt{3}\ V_m\ Sin((\omega t + \prod/2)$





The output load voltage consists of 6 voltage pulses over a period of 2∏ radians, hence the average output voltage is calculated as

$V_{O(dc)} = V_{dc} = 6/2\pi\int_{\pi/6+\alpha}^{\pi/2+\alpha} v_o\, d\omega t$

$V_O = V_{ab} = \sqrt{3}\ V_m\ Sin((\omega t + \prod/6)$

$V_{dc} = \int_{\pi/6+\alpha}^{\pi/2+\alpha} \sqrt{3}\ V_m\ Sin((\omega t + \prod/6)$

$$V_{dc} = 3/\pi \int_{\pi/6+\alpha}^{\pi/2+\alpha} \sqrt{3}\, V_m \, Sin((\omega t + \prod/6)\, d\omega t$$

$$V_{dc} = 3\sqrt{3}\, V_m/\pi \cos\alpha = 3\, V_{m\,L}/\pi \cos\alpha$$

Where $V_{m\,L} = \sqrt{3}\, V_m$ *is line to line voltage*

The maximum average dc output voltage is obtained for delay angle $\alpha = 0$

$$V_o = [6/2\pi \int_{\pi/6+\alpha}^{\pi/2+\alpha} v V_0^2 d(\omega t)]^{1/2}$$

$$V_o = [6/2\pi \int_{\pi/6+\alpha}^{\pi/2+\alpha} v\, V^2_{ab}\, d(\omega t)]^{1/2}$$

$$V_o = [3/2\pi \int_{\pi/6+\alpha}^{\pi/2+\alpha} 3\, V_m^2 \sin^2(wt_{+\pi/6})^2 d(\omega t)]^{1/2}$$

$$V_o = \sqrt{3}\, V_m\, (1/2 + 3\sqrt{3}/4\pi \cos 2\alpha)^{1/2}$$

High frequency transformer with transformer switchover:

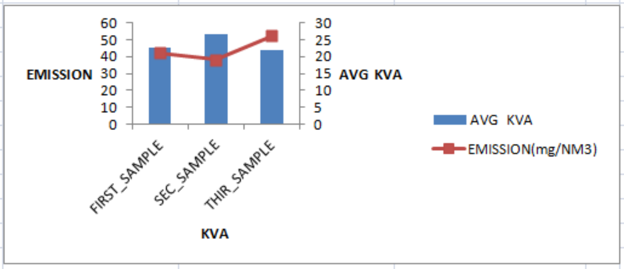
One of the many requirements of the modern inverter is a broad, coordinated input and voltage range with a consistently high degree of efficiency across the entire operating range of the inverter.To satisfy this requirement, implementing a high frequency transformer (HF transformer) in most of its current inverters. This HF transformer has a transformer switchover that ensures a consistently high degree of efficiency right across the input voltage range.It is often incorrectly assumed that the maximum degree of efficiency at a particular voltage is one of the factors responsible for producing a good annual yield, when it is in fact the more or less constant degree of efficiency over the entire voltage range, maximum efficiency

HIGH FREQUENCY TRANSFORMER WITHOUT IGBT CIRCUIT

T/r set used : High Frequency Transfomer Rectifier.
Spent wash feed : 11,487 kg/hr to 12 kg/hr
Coal feed : 4.5 to 5 tph.
Application : E.S.P for 12 tph boiler(spent wash/coal fired).
Boiler : 37.6 tph
Turbine load : 3.16 mw.

	KVA(1& 2 Field)	KVA(3rd Field)	KVA(4th Field)	AVG KVA	EMISSION(mg/NM3)
Fir_sampl	38.66	11.20	17.67	22.51	42.14
Sec_samp	44.31	17.38	18.67	38.38	44.32
Thi_samp	30.25	17.64	18.24	22.04	52.43

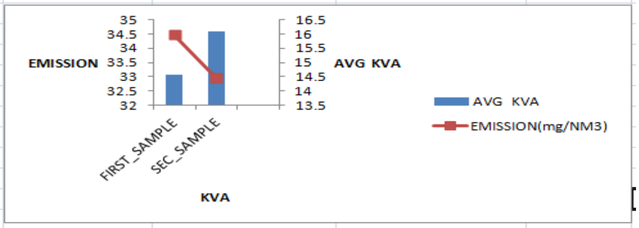
	AVG KVA	EMISSION(mg/NM3)
FIRST_SAMPLE	22.51	42.14
SEC_SAMPLE	26.78	38.38
THIR_SAMPLE	22.04	52.43



T/R SET : THREE PHASE(3-ɷ) TRANSFORMER RECTIFIER CIRCUIT
Spent wash feed : 11,487 kg/hr to 12 kg/hr
Coal feed : 4.5 to 5 tph.
Application : esp for 12 tph boiler(spent wash/coal fired).
Boiler : 37.6 tph
Turbine load : 3.16 mw.
Condition : all fields are on condition at 12 spent wash.

	KVA(1 &2	KVA(3^{rd} Field)	KVA(4^{th} Field)	AVG KVA	EMISSION(mg/NM^3)
First Sam	7.67	16.71	18.22	14.20	
	6.004	20.64	18.16	14.93	
AVG				14.56	34.47
Second Sam	6.03	21.44	18.32	15.26	
	11.06	**21.44**	**18.30**	**16.93**	
				16.09	**32.95**

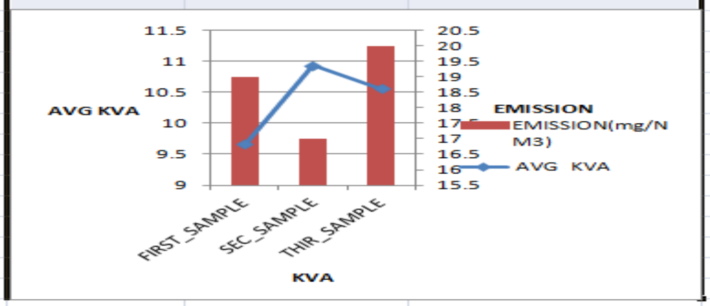
	AVG KVA	EMISSION(mg/NM3)
FIRST_SAMPLE	14.565	34.47
SEC_SAMPLE	16.09	32.95



THREE PHASE(3-φ) T.R SET READINGS WITH IGBT -CIRCUIT.
Tr-set used: Three phase transformer rectifier with IGBT power circuit.
Application : esp for 12 tph boiler(spent wash/coal fired).
Boiler load : 37.7 ,36.7,36.6 tph.
Spent wash : 12,11.8,11.4 tph.
Coal feed : 4.1 to 4.5 tph.

	Kva(1&2 field)	Kva(3^{rd} field)	Kva(4^{th} field)	Avg kva	Emission mg/nm^3
First sample	5.6	13.7	12.7	9.66	19
Second sample	6.5	14.23	12.11	10.94	17
Third sample	4.5	15.4	11.79	10.56	20

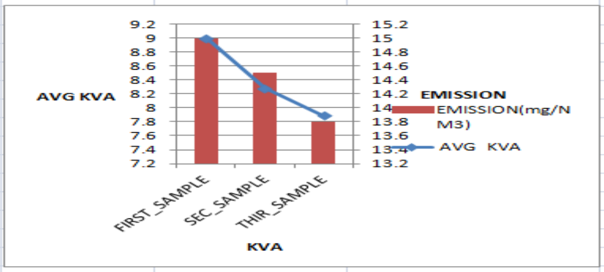
	AVG KVA	EMISSION(mg/NM3)
FIRST_SAMPLE	9.66	19
SEC_SAMPLE	10.94	17
THIR_SAMPLE	10.56	20



TRANSFORMER WITH IGBT POWER CIRCUIT AT PRIMARY AND THYRISTOR AT SECONDARY SIDE.
Tr-set used : Three phase transformer with igbt ,thyristor
set readings.
Application : esp for 12 tph boiler(spent wash/coal fired).
Boiler load : 37.7 ,36.7,36.6 tph.
Spent wash : 12,11.8,11.4 tph.
Coal feed : 4.1 to 4.5 tph.

	Kva(1&2 field)	Kva(3^{rd} field)	Kva(4^{th} field)	Avg kva	Emission mg/nm^3
First sample	3.6	11.7	11.6	9	15
Second sample	4.5	10.23	10.11	8.28	14.5
Third sample	3.5	10.4	9.79	7.89	13.8

	AVG KVA	EMISSION(mg/NM3)
FIRST_SAMPLE	9	15
SEC_SAMPLE	8.28	14.5
THIR_SAMPLE	7.89	13.8



HIGH FREQUENCY TRANSFORMER CONDITION Application : esp for 12 tph boiler(spent wash/coal fired). Spent wash : 11,600 kg/hr to 12.1 kg/hr Coal feed : 4.2 to 4.6 tph. Boiler : 37.7 tph Turbine load : 3.18 mw.				
APPLICATION		E.S.P FOR 1 x 40 TPH BOILER(SPENT WASH/COAL FIRED)		
FUEL USED		SPENT WASH + INDIAN/IMPORTED COAL		
SPECIFICATION NO		**(ALL FIELDS ARE ON CONDITION 12 TPH)**		
S.NO	PARAMETER	UNIT	DESIGNED	MEASURED
1	No of mechanical / Electrical fields	No.	4 MECH 4 ELECTRICAL	4 MECH/4 ELECTRICAL
2	Gas Flow At Inlet (Total)	AM3/HR	147600	150295
A	Gas Flow Per Pass	AM3/SEC	**41**	27.483
B	Gas Flow At Outlet	AM3/HR	95000	98940.48
3	Gas Temp At Inlet (Operating)	DEG C	200	200
3a	Gas Temp At Outlet	DEG C	175	175
4	Moisture	% v/v	16.06	14.85
5	Inlet dust load	GMS/NM3	77.63	77.63
6	Emission guarantee	MGMS/NM3	**100**	**134**
7	Collection efficiency	%	99.87	99.98
8	Plate area (total)	M2	4320	4320
A	Plate area (per pass)	M2	4320	4320
9	SCA	M2/M3/SEC	105.37	130.37
10	Velocity	M/SEC	0.57	13.29
11	Migration velocity (wd)	CM/SEC	5.51	7.418
	Treatment time	SEC	21.1	8.126
12	Suction pressure at esp Inlet	(-)MMWC	±400 mmWC	±400 mmWC
13	Pressure drop across The esp(top entry)	MM OF WC	25-30	9.2
14	Esp penhouse temp	ıC	90-110	100
15	Boiler capacity	TPH	40	36.6
16	Oxygen	%	6.45	6.15

THREE PHASE TRANSFORMER CONDITION
Application : Esp for 12 tph boiler(spent wash/coal fired).
Spent wash : 11.8 kg/hr to 12 kg/hr
Boiler load : 36.7 ,37,37-tph.

Spent wash : 12,11.5,11.8.
Coal feed : 4.1 to 4.5 tph.
Condition : all fields are on condition

APPLICATION			E.S.P FOR 1 x 40 TPH BOILER(SPENT WASH/COAL FIRED)	
FUEL USED			SPENT WASH + INDIAN/IMPORTED COAL	
S.NO	PARAMETER	UNIT	DESIGNED	MEASURED
1	No of mechanical / Electrical fields	No.	4 MECH 4 ELECTRICAL	4 MECH/4 ELECTRICAL
2	Gas Flow At Inlet (Total)	AM3/HR	147600	150295
A	Gas Flow Per Pass	AM3/SEC	**41**	27.483
B	Gas Flow At Outlet	AM3/HR	95000	98945.48
3	Gas Temp At Inlet (Operating)	DEG C	200	200
3a	Gas Temp At Outlet	DEG C	175	175
4	Moisture	% v/v	16.06	14.85
5	Inlet dust load	GMS/NM3	77.63	77.63
6	Emission guarantee	MGMS/NM3	**100**	**17.33**
7	Collection efficiency	%	99.87	99.99
8	Plate area (total)	M2	4320	4320
A	Plate area (per pass)	M2	4320	4320
9	SCA	M2/M3/SEC	105.37	130.37
10	Velocity	M/SEC	0.57	13.29
11	Migration velocity (wd)	CM/SEC	5.51	7.418
	Treatment time	SEC	21.1	8.126
12	Suction pressure at esp Inlet	(-)MMWC	±400 mmWC	±400 mmWC
14	Esp penhouse temp	ıC	90-110	100
15	Boiler capacity	TPH	40	36.6
16	Oxygen	%	6.45	6.15

THREE PHASE TRANSFORMER WITH POWER CIRCUIT IGBT CONNECTED TO PRIMARY OF TRANSFORMER
Application : Esp for 12 tph boiler(spent wash/coal fired).
Spent wash : 11.8 kg/hr to 12 kg/hr
Boiler load : 36.7 ,37,37-tph.
Spent wash : 12,11.5,11.8.
Coal feed : 4.1 to 4.5 tph.

APPLICATION			E.S.P FOR 1 x 40 TPH BOILER(SPENT WASH/COAL FIRED)	
FUEL USED			SPENT WASH + INDIAN/IMPORTED COAL	
S.NO	PARAMETER	UNIT	DESIGNED	MEASURED
1	No of mechanical / Electrical fields	No.	4 MECH 4 ELECTRICAL	4 MECH/4 ELECTRICAL
2	Gas Flow At Inlet (Total)	AM3/HR	147600	150295
A	Gas Flow Per Pass	AM3/SEC	**41**	27.483
B	Gas Flow At Outlet	AM3/HR	95000	98945.48
3	Gas Temp At Inlet (Operating)	DEG C	200	200
3a	Gas Temp At Outlet	DEG C	175	175
4	Moisture	% v/v	16.06	14.85
5	Inlet dust load	GMS/NM3	77.63	77.63
6	Emission guarantee	MGMS/NM3	**100**	**16.3**
7	Collection efficiency	%	99.87	99.997
8	Plate area (total)	M2	4320	4320
A	Plate area (per pass)	M2	4320	4320
9	SCA	M2/M3/SEC	105.37	130.37
10	Velocity	M/SEC	0.57	13.29
11	Migration velocity (wd)	CM/SEC	5.51	7.418
	Treatment time	SEC	21.1	8.126
12	Suction pressure at esp Inlet	(-)MMWC	±400 mmWC	±400 mmWC
13	Pressure drop across The esp(top entry)	MM OF WC	25-30	9.2
14	Esp penhouse temp	ıC	90-110	100
15	Boiler capacity	TPH	40	36.6
16	Oxygen	%	6.45	6.15

THREE PHASE TRANSFORMER WITH IGBT AT PRIMARY AND THYRISTOR SECONDARY OF TRANSFORMER
Application : Esp for 12 tph boiler(spent wash/coal fired).
Spent wash : 11.8 kg/hr to 12 kg/hr

Boiler load : 36.7 ,37,37-tph.
Spent wash : 12,11.5,11.8.
Coal feed : 4.1 to 4.5 tph.

APPLICATION			E.S.P FOR 1 x 40 TPH BOILER(SPENT WASH/COAL FIRED)	
FUEL USED			SPENT WASH + INDIAN/IMPORTED COAL	
S.NO	PARAMETER	UNIT	DESIGNED	MEASURED
1	No of mechanical / Electrical fields	No.	4 MECH 4 ELECTRICAL	4 MECH/4 ELECTRICAL
2	Gas Flow At Inlet (Total)	AM3/HR	147600	150295
A	Gas Flow Per Pass	AM3/SEC	**41**	27.483
B	Gas Flow At Outlet	AM3/HR	95000	98945.48
3	Gas Temp At Inlet (Operating)	DEG C	200	200
3a	Gas Temp At Outlet	DEG C	175	175
4	Moisture	% v/v	16.06	14.85
5	Inlet dust load	GMS/NM3	77.63	77.63
6	Emission guarantee	MGMS/NM3	**100**	**15.1**
7	Collection efficiency	%	99.87	99.998
8	Plate area (total)	M2	4320	4320
A	Plate area (per pass)	M2	4320	4320
9	SCA	M2/M3/SEC	105.37	130.37
10	Velocity	M/SEC	0.57	13.29
11	Migration velocity (wd)	CM/SEC	5.51	7.418
	Treatment time	SEC	21.1	8.126
12	Suction pressure at esp Inlet	(-)MMWC	±400 mmWC	±400 mmWC
14	Esp penhouse temp	ıC	90-110	100
15	Boiler capacity	TPH	40	36.6
16	Oxygen	%	6.45	6.15

Field connected High Tension Cable

Three phase supply connected to the Transfomer

Transformer Bushing(supply is connected to Transfomer Bushing

Transfomer Bushing

High Tension Cable connected to the Field of E.S.P

Power Triggering Controller

Emission Control at Outlet

Control Panel with Meter Reading

HIGH TENSION CABLE CONNECTED TO THE TRANSFORMER BUSHING

Control card assembly

Current Transformer and Voltage Transforme to the Contactor

High tension Cable connected to Transformer Bushing

Reator connected to the field before High tension cable connect to Reactor

Precaution of Earthing Before Testing Transformer with High Tension Cable

Transformer Out put to the field connection

Parameter adjustment Control Panel

High tension cable bushing befor connecting to Transfomer

Transformer Control panel

High tension Cable Alighnment before connecting to the field