Design and Construction of High Voltage Diode 100 kV

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Abstract

Diode high voltage the equipment assembles. That have necessity and important for a room practices for test experiment, research, and for the instruction. But diode high voltage to bring an element in a room practices something still must buy from the foreign countries and expensive. This problem corrects by designing and establish by oneself. This project has designed and build to diode high voltage for a laboratory by diode high voltage 100 kV. That can bring assemble all circuit get the circuit voltage multiplier etc. Building from the inventory at can seek can buy in house diode high voltage. That design and build that is the series diode on print circuit and electric oil insulator. Base principle of diode data technical of the components for applies in designing. The way builds to diode high voltage diagnose of designing builds consider the test diode high voltage the office designs. Which test has followed the objective is pass the power frequency withstand voltage test 120 kV, 22 mA

Key words: diode, high voltage, circuit, insulator

1. Introduction

High voltage diode is the device which is very needed and important for the lab for teaching. But now a day, there are still not produce high voltage diode as an industrial product in Thailand. It is needed to buy high voltage diode from oversea which is very high cost that is the reason to design and create high voltage diode for own using. It is to improvement technology and brings to use in the lab. To create high voltage diode for lab in this project, there will use divided diode to connect with sequence for being high voltage diode that return 300 kV consist in the plastic pipe. Induce is gasoline so that it could bring to support in the teaching as well.

2. Diode Structure

2.1 High Voltage Diode

To connect sequence diode is to increase electricity voltage rate pressure, it would make voltage pressure ratio of diode has total amount of each diode. High voltage diode would use Semiconductor diodes Silocon to connect the sequence as on Figure 1. Diode Silicon will have high power capacity which would good result in extend voltage when bring many diodes to sequence connected.

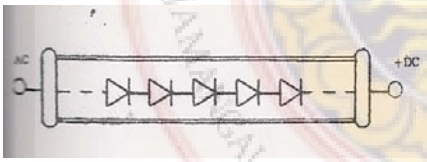

Figure 1. High Voltage Diode and line character

2.2 Analyses the Load Line

Load line is the line that helps us know the working point of diode which is appropriate with Load in circuit. Q-point of diode, it could find from cutting point of kerve characteristic. It's help us to know the electric voltage pressure that is the Q-point of diode V_{DQ} and electricity that Q-point of diode I_{DQ} as showing on Figure 2. while direct bias is as resistance, see Figure 3. Current will flow through diode when there are pressures across on diode more or equal to 0.7 V. On the other hand bias will like diode open circuit as the figure 4 which will not have current pass through diode.

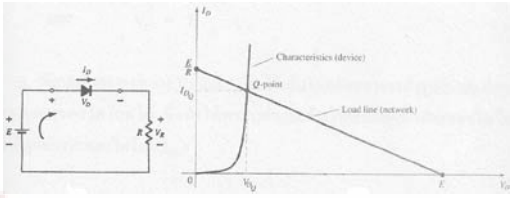

Figure 2. DC load line circuit.

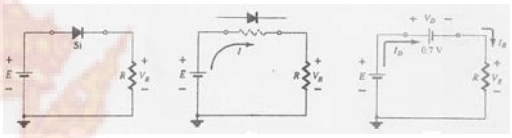

Figure 3. Direct Circuit while Bias straight

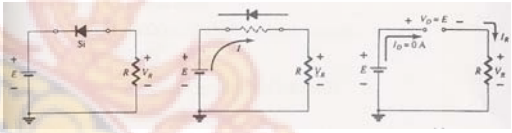

Figure 4. Direct Circuit while Bias reverses

3. To design and create high voltage diode

3.1 To design high voltage diode

To design high voltage diode side 100 kV which would diode have durable the pressure = 2 Vpeak = $2*100*\sqrt{2}=283$ kVpeak. For safety, it should have 5% safety. So that to be durable $283+(283*5)/100\approx 300$ kV by using diode number GD 1200 1.2kV 500 mA. The amount equal to 300 kV/1.2 kV = 250 pieces as Figure 5.

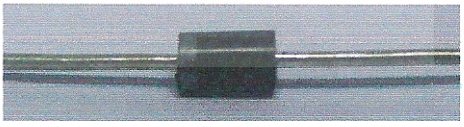

Figure 5. Diode Number GD 1200

3.2 To design tube for contain high voltage diode.

To design a clear acrylic insulator tube, it should concern about the period of endurable of insulator toward electric pressure and electric filed stress on the insulator tube skin. For the direct electric pressure the length should not more than 3.9 kV/cm in the air or 2.7-2.9 m/MV [1]. It is necessary to identify the height of high voltage diode. To find the height of a clear acrylic insulator tube is 3.9*(100kV/1MV) = 0.39 m.

3.3 To design the layer of diode

High voltage diode, it should use 250 diodes, number GD 1200. Acrylic tube has a diameter 10 cm. Cutting print sheet diameter for 8 cm and put 7 diodes in each layer. Each layer could endurable 8.4kV. So that all layer is 300 kV/8.4 kV = 36 layers as figure 6.

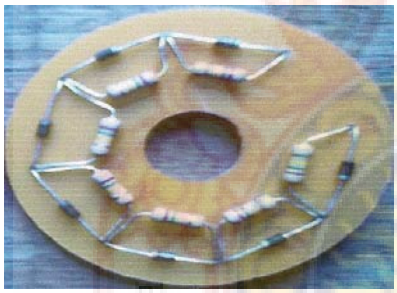

Figure 6. Diode Circuit in each layer

For diode would be able to expand the pressure constancy during bias reverse. It has to connect resistance across every diode. Diode has pressure bias reverse 283 kVpeak . A pressure across diode it would worthy equal to 283/250 = 1.1 kVpeak by select resist 1 W which would get resist per diode cross equal to

$$R = V^2 \Big/ P = \left(1.1kV / \sqrt{2}\right)^2 / 1 = 6.05k\Omega$$

So using diode 6 $k\Omega$ 1 W

3.4 Insulator technique

Inside Insulator would use print sheet and put insulator oil [3] that has insulator character 60 kV/2.5mm. In each layer could endurable for 8.4 kV so that the length of layer is equal to 80/36 = 2.22 cm that has transformer insulation oil. So that there are identify the length 2 cm as Figure 7. For connecting acrylic tube with corner of high voltage diode tube as Figure 8. It would design silicone being a connector to corner.

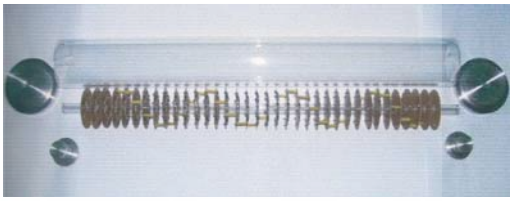

Figure 7. Component of high voltage diode

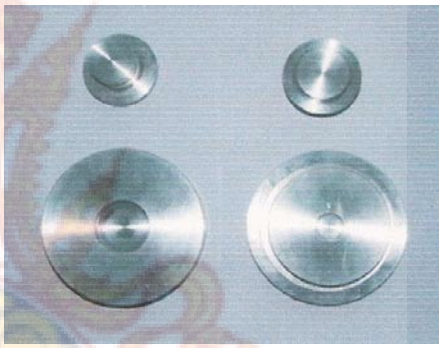

Figure 8. Connector of high voltage diode tube

4. Testing Result

4.1 Testing the inside resistance.

To test resistance of diode that it can be endurable for pressure. It has to use Mega ohmmeter pressure size 2.5 kV DC for testing. The result is by using test during direct bias has inside resist equal to $0M\Omega$ and Bias reverse has inside resist equal to $175M\Omega$

4.2 Power Frequency Withstand Voltage Test

High voltage has design for size 100 kV so that during using time, it would endurable the pressure more than 100 kV. That's why it should have Power Frequency Withstand Voltage Test as Figure 9. The testing

result is according to Table 1.As following:

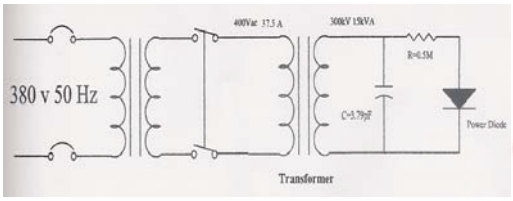

Figure 9. Power Frequency Withstand Voltage Circuit Testing

Table 1. Testing high voltage diode by using Power Frequency Withstand Voltage Test

No / App.	Supply (kV)	Current (mA)	Duration (Sec)	Remark
1/Pos.	120	22	300	withstand
1/Neg.	120	22	300	withstand
2/Pos.	120	22	300	withstand
2/Neg.	120	22	300	withstand

4.3 Testing voltage Rectifier Circuit of anode Half wave.

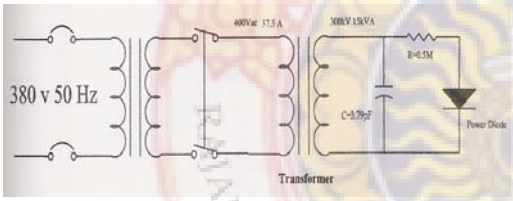

Figure 10. Circuit Testing voltage Rectifier Circuit of anode Half wave.

Table 2. Testing voltage Rectifier Circuit of anode Half wave.

Input Voltage (kV)	Output Voltage (kV)
10	8.603
20	17.978
Input Voltage (kV)	Output Voltage (kV)
30	26.974
40	36.076
50	44.910
60	53.358
70	62.597
80	71.234
90	81.257
100	89.494

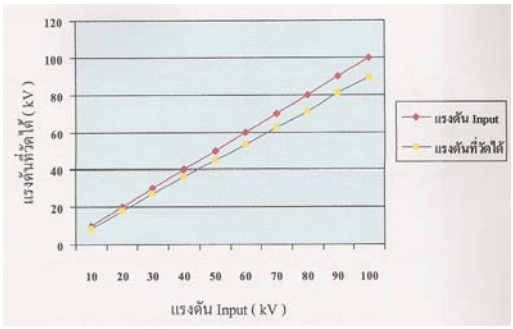

Figure 11. Graph between inside voltage and voltage measured

Table 3. Testing current Rectifier circuit of anode Half wave

Input Voltage (kV)	Output Current (mA)
10	2.28
20	4.65
30	6.98
40	9.26
50	11.56
60	14.02
70	16.26
80	19.85
90	21.35
100	23.30

Table 4. Comparing between voltage measured and calculation from the testing Rectifier Circuit of anode Half wave

Input Voltage (kV)	Measurement Output Voltage (kV)	Calculation Output Voltage (kV)	% Error
10	8.603	8.86	2.90
20	17.978	17.67	1.69
30	26.974	26.51	1.64
40	36.076	35.37	1.99
50	44.910	44.22	1.56

60	53.358	52.99	0.69
70	62.597	61.87	1.17
80	71.234	70.07	1.65
90	81.257	79.32	2.43
100	89.494	88.35	1.29

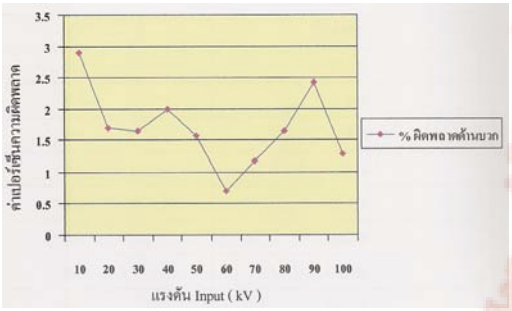

Figure 12. Graph percentage of error in Rectifier Circuit of anode Half wave

4.4 Testing voltage Rectifier Circuit of cathode Half wave

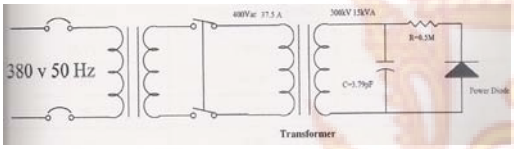

Figure13. Circuit testing voltage Rectifier Circuit of cathode Half wave

Table 5. Testing voltage measured Rectifier Circuit of cathode Half wave

Input Voltage (kV)	Output Voltage (kV)
10	-8.932
20	-17.455
30	-26.042
40	-35.943
50	-44.878
60	-52.722
70	-60.886
80	-71.933
90	-80.131
100	-89.532

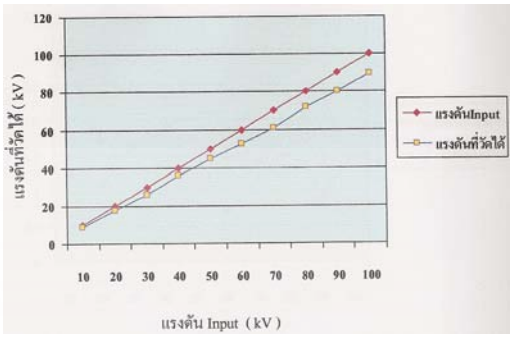

Figure14. Graph between inside Voltage and voltage measured

Table 6. Testing current Rectifier Circuit of cathode Half wave

Input Voltage (kV)	Output Current (mA)
10	-2.35
20	-4.71
30	-7.07
40	-9.42
50	-11.78
60	-14.14
70	-16.49
80	-18.85
90	-21.21
100	-23.92

Table 7. Comparing between voltage measured and calculation from testing Rectifier Circuit of cathode Half wave

Input Voltage (kV)	Measurement Output Voltage (kV)	Calculation Output Voltage (kV)	% Error
10	-8.93	-8.82	1.21
20	-17.45	-17.64	1.07
30	-26.04	-26.46	1.59
40	-35.94	-35.29	1.85
50	-44.87	-44.11	1.74
60	-52.72	-52.93	1.49
70	-60.88	-61.57	1.40
80	-71.93	-70.57	1.92
90	-80.13	-79.39	0.92
100	-89.53	-88.21	1.49

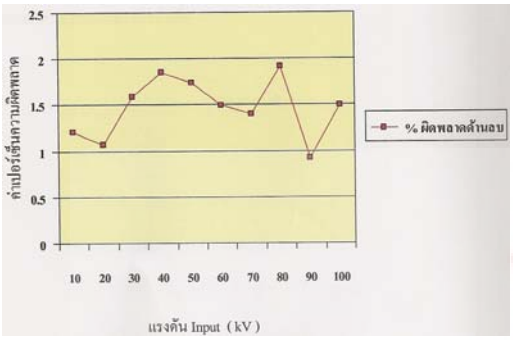

Figure 15. Graph percentage of error in Rectifier Circuit of cathode Half wave

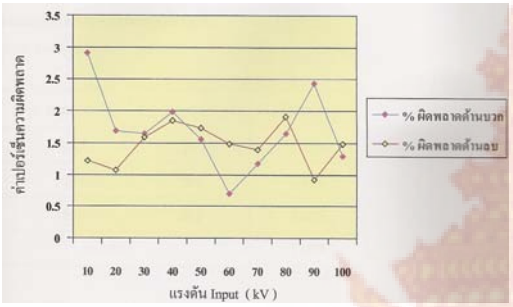

Figure 16. Graph percentage of error in Rectifier Circuit of Half wave between anode and cathode

Table 8. Comparing percentage of error in Rectifier Circuit of Half wave

Testing voltage measured of Rectifier Circuit of Half wave	% Error	
	Standard IEC 60-2 (1994)	Testing Result
Anode	±3%	1.76
Cathode	±3%	1.37
Testing durability against electric voltage	PASS	

4.5 Testing Direct Current of high voltage which is built up

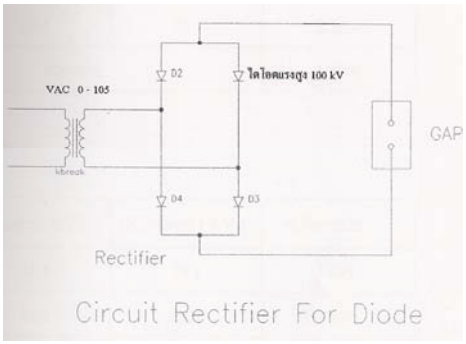

Figure 17. Direct Current of high voltage which is built up

Table 9. Direct Current Output of Voltage measured in length of Gap: 0.5 cm

No.	AC Input (kV)	DC Output (kV)	% Error
1	29.3	29	1.02
2	28.5	28.8	1.05
3	29.8	29.2	2.01

Table 10. Direct Current Output of voltage measured in length of Gap: 1.0 cm

No.	AC Input (kV)	DC Output (kV)	% Error
1	54.3	53.8	0.92
2	55.8	54.8	1.79
3	57.1	58.3	2.10

Table 11. Direct Current Output of voltage measured in length of Gap: 1.5 cm

No.	AC Input (kV)	DC Output (kV)	% Error
1	74.3	75.1	1.07
2	81.1	82.3	1.47
3	76.1	77.5	1.83

Table 12. Direct Current Output of Voltage measured in length of Gap: 2.0 cm.

No.	AC Input (kV)	DC Output (kV)	% Error
1	100.6	102.5	1.88
2	105.1	107.5	2.28
3	98.5	106.4	2.74

Table 13. Direct Current Output of Voltage testing

Testing Direct Current high voltage measured	% Error	
	Standard IEC 60-2 (1994)	Testing Result
ระยะ Gap: 0.5 cm.	±3%	1.66
ระยะ Gap: 1.0 cm.	±3%	1.86
ระยะ Gap: 1.5 cm.	±3%	1.45
ระยะ Gap: 2.0 cm.	±3%	2.3
Testing Direct Current voltage	PASS	

5. Testing Result

To create high voltage diode size 100 kV by using transformer oil to be insulator for endurable the voltage according to the size. There is the result as following. Testing the inside resistance found out that while Bias straight do not have inside resistance. And Bias Reverse have inside resistance equal to $175M\Omega$. That is on the IEC [2] standard. For Power Frequency Withstand Voltage Test size 120 kV current 22 mA. There are found out that high voltage diode can endurable for pressure testing without damage. For testing of direct current high voltage, there are some error in the IEC 60-2 (1994) standard, specify is not more than $\pm 3\%$

6. References

[1]Somruay Sangsa-ard, HighVoltage Engineering.Edition2 Chulalongkorn University, 2528

[2] IEC Publication No.60-2 “High Voltage test techniqued Part 2: Measuring Systems.”,1994

[3] IEC Publication No.156 “Method for the determination of the electric strength of insulating Oil.”., 1994

[4] Supawud Nedphograw, High Voltage Engineering. Edition1-2 Rajamangala University of Technology Phra Nakhon (RMUTP.),2550-2551