論文
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The New Type Pulse Generator Adopted Cascading Technique

(소형트랜스의 Cascading 방식을 적용한 임펄스 출력특성)

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ABSTRACT

This paper introduced cascading technique as a new technology composed of two pulse transformers and presented the experimental data and results. To obtain the stable pulse voltage adopted cascading technique, we designed and tested a compact pulse generator by adjusting the load resistors and input voltage. Adopting cascading technique to load, we found that average cascading voltage was about 62% of theoretical value. Cascading ratio was calculated at almost 19 compared with non cascading voltage.

요 약

이동통신(Mobile Telecommunication), X선 발생장치, 오존발생기, 레이저시스템 등에 사용되는 임펄스의 지속시간(pulse duration)은 충분히 짧고 빠른 상승률을 갖는 임펄스 전압을 발생시킬 수 있는 펄스발생장치(Pulse Generator)가 필요하다. 펄스발생장치 설계시 회로정수, 전력용 스위치는 임펄스 특성을 직접적으로 결정하게 된다. 펄스발생장치는 출력에너지가 순간적으로 부하에 전달될 때 최소의 손실로 전류지속시간 동안 안정성을 갖고 전류차단시 소호특성이 우수한 전력용스위치가 요구된다. 펄스에너지 효율은 펄스 상승시간(rising time), 첨두치(peak value), 지속시간(pulse duration), 부하와의 임피던스 매칭(impedance matching) 등에 따라 민감하게 반응한다. 또한, 짧은 펄스지속시간과 높은 첨두치의 펄스에너지를 얻기 위해서는 펄스발생장치의 크기 및 경제성을 고려하지 않을 수 없다. 본 연구에서는 수μs의 펄스지속시간(pulse duration), 수 100ns의 상승시간(rising time) 및 수 10kV의 첨두값(peak value), 수 10 ~ 100회의 반복율 갖는 안정적인 임펄스 형성을 위해 소형 펄스트랜스 2개를 조합한 cascading 방식을 적용하여 컴팩트(compact)한 펄스발생장치(pulse generator)를 구성하여 부하에 직접 제작한 임펄스를 인가한 결과 우수한 효과를 거둘수 있었고, 그 적용에 대한 연구는 차후에 진행하고자 한다.

1. INTRODUCTION

Recently the pulse power systems have been widely used to many fields, such as E/P(Electrostatic Precipitator) to remove the industrial dust, DeNOx/DeSOx power system[1-2], ozone generator and power source of laser beam[3], etc.

Many countries are interested in the solution of environmental pollution by using the practical and economical Pulse Generator (P/G)[4-6]. In Ref.[4], the author constructed a pulse transformer of turn ratio about 5, and tested insulation breakdown of oil submerged pulse transformer in USA. Ref.[5]

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indicated that they designed pulse transformer and experimented the response for one kind of pulse transformer in Japan.

It's required that a P/G can make a pulse voltage with very steep increment ratio of pulse duration to treat the environmental pollution[6]. Our approach to increase pulse voltage with a compact pulse transformer. : we used not oil insulation, but layer insulation of the pulse transformer that had pulse duration of several (s, rising time of a few hundred ns and withstood peak voltage of several tens kV.

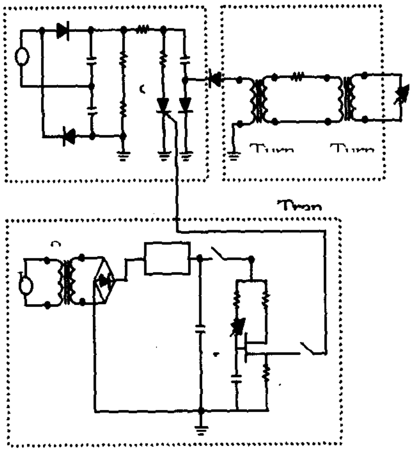
In this study, we propose a new technology, cascading technique(CT), to increase pulse voltage as new method. We have been developed a compact pulse generator applied to CT to be made of two pulse transformers with each diameter 40mm and compared the cascading voltage with non cascading one by applying the pulse energy to load. We obtained a stable impulse with duration of several (s, rising time of a few hundred ns, several tens to hundreds repetition rate and peak voltage of several tens kV in pulse generator.

2. PULSE GENERATOR

2.1 Pulse Generator Circuit

The P/G and SCR control circuit is shown in Figure 1. In this circuit, the parameters are as follows : Capacitor3 (C3) 0.5 μF, L_{p1}=11 μH (primary inductance of Tr1), L_{s1}=720 μH(secondary one of Tr2), L_{p2}=720 μH(primary one of Tr2), L_{s2}=268mH (secondary one of Tr2). And coupling coefficient K is equivalent to 0.78.

The charging voltage in C3 is discharged in Tr1 by triggering the gate of SCR(Silicon Controlled Rectifier). The storage energy in Tr1 is transferred to Tr2 and to load. The turn ratio a_1 of Tr1 is about 1:8 and a_2 of Tr2 is about 1:7.



[Fig. 1] P/G and SCR control circuit

We designed the storage system in the range from input minimum voltage 60V to maximum one 180V. Likely figure 1, we introduced a new technology, CT, and observed the impulse waveforms by using resistor in load. The storage energy of capacitor (*We*) and inductor (*Wh*) per unit volume are given each equation 1 and 2. [7]

$$We = \frac{1}{2}ED = \frac{1}{2}\varepsilon E^2 = \frac{1}{2}\frac{D^2}{\varepsilon}[J/m^3] \quad (1)$$

$$W_h = \frac{1}{2}BH = \frac{1}{2}\mu.\ ^2 = \frac{1}{2}\frac{B^2}{\mu}[J/m^3] \quad (2)$$

Here, E : electrical field intensity[V/m], : ε permittivity[F/m] , D : electric flux density[C/m^2] : : permeability[*H/m*], B : magnetic flux density[*wb/m*^{2}].

And joule loss(W_L) and total storage energy of inductor(W_I) are given each equation 3 and 4. [7]

$$W_I = \int_0^T vidt = \int_0^I Lidi = \frac{1}{2}LI^2[J] \quad (3)$$

$$W_L = \int_0^T Ri^2dt = \frac{I^2}{3}RT[J] \quad (4)$$

Here, W_L : Joule loss of inductor[J], W_I : total storage energy of inductor[J], T : charging time[s], R : electrical resistor of inductor[Ω], i : charging current of inductor[A], I : current after charging inductor[A]. Also, output voltage of pulse in load is each equation 5 and 6.[7]

$$V = \frac{V_O R}{Z+R}\{1 - e^{-at}(\frac{a}{w}\sin wt + \cos wt)\}$$

$$(a^2 < b) \qquad (5)$$

Here, V_o : input voltage[V],

$a = \frac{1}{2}(\frac{Z}{L} + \frac{1}{CR}),\ b = \frac{1}{LC}(\frac{Z+R}{R})$,

$w = \sqrt{b - a^2}(a^2 < b)$,

Z : circuit impedance[Ω],

R : load resistor[Ω] and . $\zeta = a/\sqrt{b}, \tau_0 = 2\pi/\sqrt{b}$

Also, $a = 2\pi\zeta/\tau_0, b = 4\pi^2/\tau_0^2$

$$V = \frac{V_O R}{Z+R}\{1 - e^{\frac{2\pi\zeta}{\tau_0}t}(\frac{\zeta}{\sqrt{1-\zeta^2}}\sin(2\pi\sqrt{1-\zeta^2}\frac{t}{\tau_0}) + \cos(2\pi\sqrt{1-\zeta^2}\frac{t}{\tau_0}))\}(\zeta < 1) \qquad (6)$$

By changing load resistor(R), we can adjust overshoot in voltage waveform.

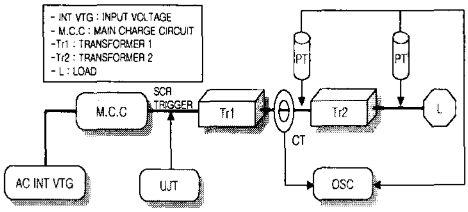
At equation (6), V has overshoot in voltage waveform likely figure 4.

$$L = \frac{\mu \cdot e}{l} N^2 [H] \qquad (7)$$

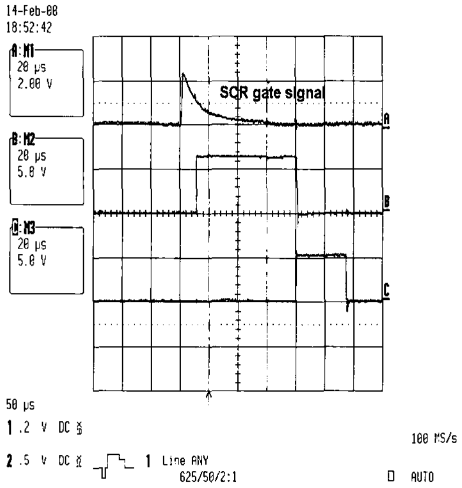
Here, Ae[m2] is the cross area of magnetic flux. And N is turns of transformer.

2.2 Pulse generator circuit

[Figure 2] indicates the experimental block diagram and SCR gate signal. By using voltage divider(Model : NorthStar PVM-1, 1/1000) and CT(Model : Pearson Current Monitor 4997, 1/100), we monitored the pulse waveforms by using oscilloscope (Model : LeCroy 9310AM). And we designed the control circuit parameters with UJT (Uni Junction Transistor) to feed transmission charging energy of C3 to load in 10(s.



(a) P/G block diagram



(b) SCR gate signal

[Fig. 2] P/G block diagram and SCR gate signal

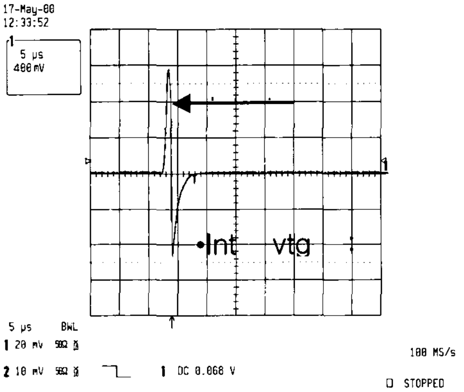
3. EXPERIMENTS AND MEASUREMENT

3.1 Pulse voltage characteristics of load resistor 12kΩ

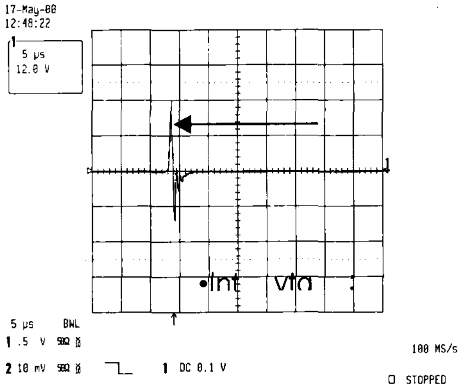
[Figure 3] and [Figure 4] show the pulse voltage waveforms of Tr1_out(non cascading voltage) and

Tr2_out(cascading voltage) vs. input voltage 120V. We found that the voltage pulse with rising time of 200ns, duration of 1.5(s and peak voltage 580V in Tr1_out was obtained. And peak voltage 13kV in Tr2_out was obtained.

From these figures, negative voltage due to impedance non matching between storage system and load can be decreased as adjusting resistor value. They are similar to waveforms obtained by using electrodes, such as pin to pin or plate to plate electrodes instead of load resistor. For this condition, we chose resistor value and tested. We'll later study possible influence of negative voltage on the gas ionization.



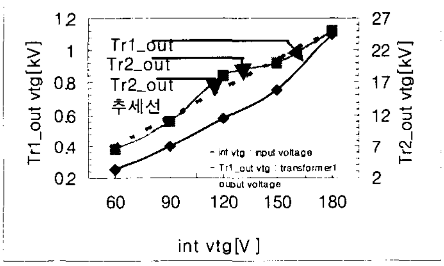
[Fig. 3] Pulse voltage waveform of Tr1_out(non cascading voltage)



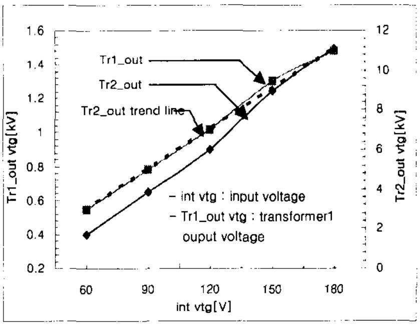
[Fig. 4] Pulse voltage waveform of Tr2_out(cascading voltage) vs. input voltage

[Figure 5] gives voltage increment ratio of Tr1_out and Tr2_out in the range of AC input voltage from 60V to 180V. We found that peak voltage is plotted in the form of linearity and yet to saturate in this figure. Table 1 provides the T.V(theoretical value) and M/T(measured/ theoretical value) of Tr1_out & Tr2_out.

The theoretical value was based on the assumption that coupling coefficient K of pulse transformer was 1. The average value of Tr2_out, cascading voltage, had about 58% of theoretical value. And this value adequately has to be considered on designing pulse transformer. We obtained the cascading pulse voltage with rising time 300ns, width 1(s, peak voltage over 18kV by using compact pulse transformer adopted cascading technique.

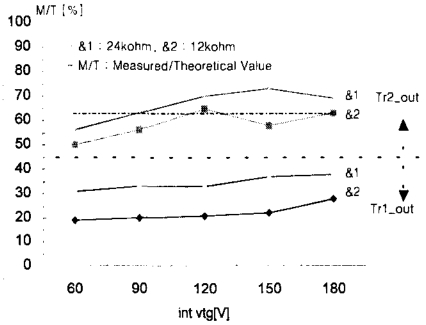


[Fig. 5] Voltage increment ratio of Tr1_out and Tr2_out in the range of AC input voltage from 60V to 180V in load resistor 12kΩ



[Fig. 6] Voltage increment ratio of Tr1_out and Tr2_out in the range of AC input voltage from 60V to 180V in load resistor 24kΩ

<Table 2> provides that M.V(measured value) and cascading ratio of Tr1_out & Tr2_out. Even though the same turn ratio (, it's different in Tr2_out M.V according to the primary and secondary inductance \each of Tr1, Tr2. The more inductance had the secondary value of Tr1 than the primary one of Tr2 under same turn ratio (, the more the peak voltage decreased compared with same inductance. Because of regarding the secondary turns of Tr1 and primary turns of Tr2 as a kind of transformer, peak voltage possibly was decreased.



[Fig. 7] Voltage increment ratio according to load resistor

<Table 1> T.V and M/T value of Tr1_out & Tr2_out (1:8, 1:10)* T.V : Theoretical Value, M/T : Measured/Theoretical Value

Int vtg[V]	Tr1_out T.V[kV]	Tr2_out T.V[kV]	Tr1_out M/T [%]	Tr2_out M/T [%]
60	1.3	13	19	50
90	2	20	20	56
120	2.7	27	21	65
150	3.4	34	22	58
180	4	40	28	63

<Table 2> M.V and cascading ratio of Tr_1 out & Tr_2 out* M.V : Measured value
* cascading ratio= Tr2_out M.V/ Tr1_out M.V

Int vtg[V]	Tr1_out M.V[kV]	Tr2_out M.V[kV]	Cascading ratio
60	0.25	6.5	26
90	0.4	13	32
120	0.58	18	31
150	0.75	20	27
180	1.1	25	23

3.2 Pulse voltage characteristics of load resistor 24kΩ

[Figure 6] indicates voltage increment ratio of Tr1_out and Tr2_out in the range of AC input voltage from 60V to 180V. Likely figure 5, we find that peak voltage is plotted in the form of linearity and yet to saturate in this figure. This output characteristics is similar to load resistor 12k(. Table 3 provides the T.V and M/T of Tr1_out & Tr2_out.

The average value of Tr2_out, cascading voltage, had about 66% of theoretical value.

[Figure 7] shows voltage increment ratio according to load resistor. Adopting the cascading technique to pulse transformer, as a result, we obtained the average cascading voltage increased about 62% of theoretical value compared to not cascading one.

4. DISCUSSION AND CONCLUSIONS

On the basis of design considerations, we built a compact pulse generator using cascading technique. Adopting cascading technique to load, we found average cascading voltage was about 62% of theoretical value. Cascading ratio was obtained about 19 compared with non cascading voltage.

Even though the same turn ratio (, it's different in Tr2_out M.V according to the secondary and primary inductance each of Tr1, Tr2. The more inductance had the secondary value of Tr1 than the primary one of Tr2 under same turn ratio (, the more the peak voltage decreased compared to same inductance. On designing the cascading type pulse transformer, we have to consider the primary inductance of Tr1 and secondary one of Tr2. These results could be attributed to other applications, such as removal of industrial pollution[6] and pulse generator required for a stable impulse with duration of several (s, rising time of a few hundred ns and peak voltage of several tens kV in pulse generator.

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