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FUJI MIDDLE POWER RECTIFIER DIODES AND THYRISTORS

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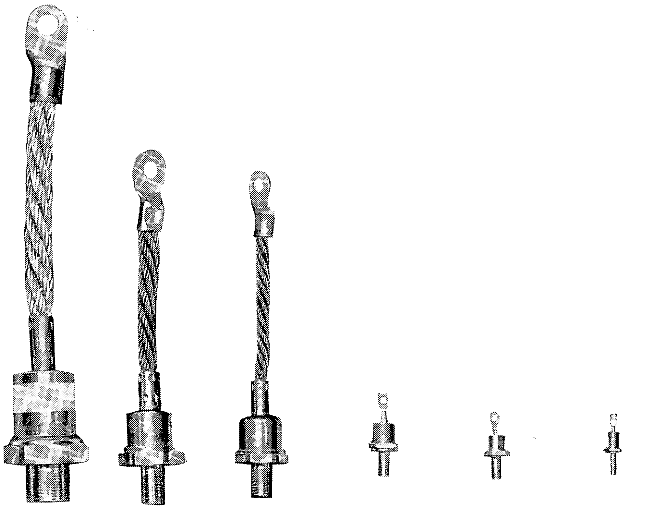
I. INTRODUCTION

Fuji Electric has now replaced its former series of diodes (DS and Si type) and series of thyristors (GSi type) with new series of semi-conductor elements (Refer to *Fig. 1* and *2*). The features of the new sesies of the semiconductors are improved blocking ages, high volt reliability, the use of pressure contact construction and the introduction of new encapsulating techniques. The dimensions are in conformity with IEC standards so that they are interchangeable with products of foreign companies.

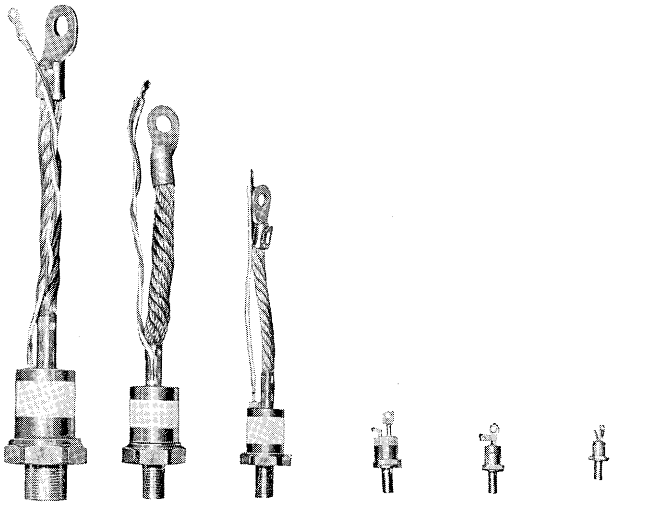
When deciding the ratings and characteristic curves of these semiconductors, the fundamental constants have been as well defined as possible so that users can calculate as they please.

Various calculations can also be made using a computer. This article describes basic thinking used in the calculation of various characteristics and the properties of these series of diodes and thyristors. It also gives an outline of the protective methods and reliability of the middle power diodes and thyristors.



SIN 01 SIL 01 SIH 01 SIG 01 SIE 01 SID 01

Fig. 1 Middle power rectifier diode series



GTN 02 GTL 01 GTH 02 GTG 02 GTE 02 GTD 02

Fig. 2 Middle power thyristor series

II. SERIES OF THE DIODES AND THYRISTORS

The main characteristics of the new series of diodes and thyristors are shown in *Table. 1.* In addition to the series shown in this table, we have also series of small power semiconductors, high power elements, high voltage flat packaged diodes and thyristors as well as high speed thyristors.

III. CHARACTERISTICS OF NEW SERIES OF DIODES AND THYRISTORS

Since we first announced alloy type diodes as silicon rectifier diodes of the Si series several years ago, rectifier diodes with reverse blocking voltages of 1,000 V have come into practical use and satisfactory results have been accumulated. In this period, a thyristor series with blocking voltages of 600 V has been developed and put into practical use. We have improved the semiconductor series by considering the standardization of the dimensions (IEC standard), the introduction of standard AC 440 V middle power supply in industry and the mutual problems when diodes and thyristors are used together in the field of application.

Thanks to the alloy diffusion method, the improvement of characteristics and construction have been possible because of the great progress in manufacturing and production control techniques for semiconductors.

Table 1 Fuji Diode and Thyristor Series

Fuji diode series

Item \ Type	SID 01	SIE 01	SIG 01	SIH 01	SIL 01	SIN 01
Maximum peak reverse voltage	1,200 V	1,200 V	1,200 V	1,200 V	1,200 V	1,200 V
Forward voltage drop 25°C	1.5 V/30 A	1.5 V/50 A	1.5 V/100 A	1.5 V/200 A	1.5 V/600 A	1.35 V/900 A
Rated average forward current	9.0 A	16 A	30 A	90 A	200 A	300 A
Surge current	220 A	350 A	800 A	1,800 A	3,200 A	7,500 A
Tj_{max}	150°C	150°C	150°C	150°C	150°C	160°C

Fuji thyristor series

Item \ Type	GTD 02	GTE 02	GTG 02	GTH 02	GTL 01	GTN 02
Maximum peak forward and reverse voltage	1,200V	1,200 V	1,200 V	1,200 V	1,200 V	1,600 V
Forward voltage drop 25°C	1.55 V/15 A	1.55 V/30 A	1.55 V/60 A	1.55 V/120 A	1.50 V/300 A	1.50 V/600 A
Rated average forward durrent	8.0 A	15 A	25 A	75 A	150 A	300 A
dv/dt	20 V/μs	20 V/μs	20V/μs	20 V/μs	20 V/μs	100 V/μs
di/dt	20 A/μs	20 A/μs	20 μs	20 A/μs	20 A/μs	20 A/μs
Surge current	150 A	300 A	600 A	1,200 A	2,500 A	6,300 A
Tj_{max}	125°C	125°C	125°C	125°C	125°C	125°C
I_G/V_G	20 mA/2 V	80 mA/3 V	100 mA/3 V	120 mA/3 V	300 mA/3 V	300 mA/2 V

1. Manufacturing Techniques of the Semiconductors

The junction construction in all the new series of thyristors and diodes employs the alloy diffusiom method. The typical manufacturing process for diodes can be outlined as follows.

(1) n-type silicon crystal slicing and lapping
(2) III impurity diffusion (pnp wafer)
(3) Lapping (pn wafer)
(4) Alloying (forming ohmic contact)
(5) Surface bevel lapping
(6) Etching (surface treatment)
(7) Mounting
(8) Encapsulation

In such a process the following points cause problems.

1) Crystalline properties
2) Diffusion (diffusion length, diffusion to insure long life, junction uniformity)
3) Alloying (junction flatness)
4) Surface treatment (stability of characteristics, mainly blocking voltage)
5) Encapsulation techniques (Investigation of heat cycle)

The crystalline properties of silicon monocrystals tend to decrease as the diameter of the silicon increases. However, it is absolutely necessary to consider the crystalline characteristic carefully in order to insure excellent characteristics and junction uniformity. At present, crystal precision manufacturing techniques have progressed considerably and silicon with a diameter of about 40 ϕ and excellent crytalline properties can be produced.

Since the forward voltage drop is influenced by diffusion length and doping concentration in the diffusion process, it is necessary to carry out diffusion under a very strict temperature control.

Since life time killer diffusion in the diffusion process has a very adverse effect on the forward voltage drop, it is essential to take measures against the diffusion of lifetime killer of heavy metals etc. The forward voltage drop of the diode was expressed by Herlet according to the following equation :

$$U_a=\frac{kT}{e}\cdot \ln\left(\frac{\overline{n}}{n_i}\right)^2+2\frac{kT}{e}\cdot f\left(\frac{d}{L}\right) \cdots\cdots\cdots (1)$$

The relation between the specific resistance ρ and the avalanche voltage V_B in respect to the blocking voltage is as follows :

$$V_B=\alpha\rho^{\beta} \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (2)$$

Therefore, it is necessary that the resistivity be high in order to insure a high blocking voltoge, but in such cases the extent of the space charge layer is increased. When the base width is narrow and the space charge layer is wide, the socalled punch through phenomenon arises. In order to avoid this, the base width is generally greater than the width of the space charge layer, but in such a case, the forward voltage drop increases. We use very high level of diffusion techniques to combat this problem and even in elements with bolcking voltages of 1,800 V, the forward voltage drop can be kept to 1.5 Volts or less which presents no problem in practice. The reverse blocking voltage is influenced by the internal breakover as well as the state of the surface. Since the surface breakover can cause permanent damage to the element, it is essential to insure surface stability. The angle lap technique is generally used for this purpose. However, we also use an independently developed surface treatment technique which guarantees higher reliability of the blocking voltage. The encapsulation technique used in middle power series of diodes and thyristors is the pressure contact method which is employed in the rectifier including H and the above type. For elements used in cases with wide fluctuations in load current and a high frequency of use such as electric welders, electric trains and motor speed controllers, there is a problem due to the differences in expansion coefficients of the silicon and copper base and this influences the life and reliability considerably. Since the silicon monocrystal plate is comparatively weak in respect to bending tension, the cracks and the ruptures occur easily, metals with expansion coefficients comparatively close to that of the silicon monocrystal plate such as molybdenum and tungsten are usually alloyed with the plate so that bending stress is not applied during the mounting process and thermal treatment when the element is manufactured. In the former diodes, the molybdenum or tungsten was connected to the copper base with soft solder.

However in cases with wide load current fluctuations, the soldered part was subjected to shearing stress because of the differences of expansion coefficients between the copper and these metals so the thermal fatigue could not be avoided. Therefore after several thousand load current fluctuations, the characteristics would tend to deteriorate. In the new series, this soft soldering has been completely eliminated and contact is made under pressures of 10 to 100 kg. When the contact surface is properly processed and both the intermediate metal plate and copper base are specially treated, resistance and thermal impedance in the contact part present almost no problem and the thermal impedance between the junction and base can be made sufficienctly small and uniform. Thermal distortion is absorbed in the up and down directions by means of springs under tension and from the sides by sliding between the base and silicon part. Therefore, thermal fatigue is completely eliminated even under the most rigorous operating conditions desrcibed previously. By these means, high reliability of Fuji Electric Semiconductors is guaranteed.

2. Ratings and Characteristics

In these new series of semiconductors there has been coordination in characteristics between thyristors and diodes and the blocking voltage has been selected as 1,200 V for operation at line voltages of 440 V which will soon be standard. The current ratings include the output current at the standard case temperature as a maximum rating and also ratings which take into account the influence of transient temperature rise in the junction due to overloads. The surge current characteristics which are the critical characteristics of the elements are excellent because of the uniform junction which can be attained with the high level of diffusion techniques now in use. Unlike in previous types, differences in thermal impedance have been indicated by waveforms and more rational design calculations have become possible. Consequently, when employing Fuji Electric Semiconductors, they can all be used appropriately if the ratings and characteristics tables are understood fully. There is absolutely no need to consider allowances or margins.

3. Standardization of Dimensions

The external dimensions of both the diodes and thyristors have been coordinated to provide the most appropriate utilization. To insure interchangeability to provide the most appropriate utilization. To insure interchangeability with the products of foreign firms, the dimensions have been standardized in accordance with IEC specifications.

Table 2 **IEC Guidance and Dimensions of Fuji Diode and Thyristor**

Fuji Electric elements		IEC Guidance dimensions*				
Diode	Thyristor	Screw diameter	Hexagon flat length	Screw length (Long series)	Screw length (Short series)	Lead wire length
SID 01	GTD 02	M 5	11	11±1	—	—
SIE 01	GTE 02	M 6	14	12±1	—	—
SIG 01	GTG 02	M 8	17	14±1	—	—
SIH 01	GTH 02	M 12	27	18±1	—	150±15
SIL 01	GTL 01	M 16	32	20±1	—	SIL 01 150±15 GTL 01 200±20
SIN 01	GTN 02	M 24	41	—	9±1	250±25

*IEC TC47 (CO) 157, 47 (CO) 122

IV. RATINGS AND CHARACTERISTICS OF NEW SERIES OF SEMICONDUCTORS

The items and suitable methods which form the basis for calculating the ratings and characteristics of general power diodes and thyristors will be explained below. *Table 3* shows the main fundamental constants for these new series.

Table 3 Fundamental Constants

Diode

Type / Item	SID 01	SIE 01	SIG 01	SIH 01	SIL 01	SIN 01
V_{R0}	1,200 V	1,200 V	1,200 V	1,200 V	1,200 V	1,200 V
U_d (150°C)	$0.85+18 \times 10^{-3}\ ip$	$0.85+11 \times 10^{-3}\ ip$	$0.85+6 \times 10^{-3}\ ip$	$0.85+2.7 \times 10^{-3}\ ip$	$0.85 +0.87 \times 10^{-3}\ ip$	$0.75 +0.50 \times 10^{-3}\ ip$
$T_{j\max}$	150°C	150°C	150°C	150°C	160°C	160°C
R_{th}DC	2.10 deg/W	1.20	0.80	0.20	0.15	0.15
R_{th} 120°el	3.08 deg/W	1.76	1.08	0.26	0.17	0.17
R_{th} 180°el	2.61 deg/W	1.50	0.96	0.24	0.16	0.16
R_{cf} (Contact)	0.30 deg/W	0.20	0.10	0.03	0.01	0.01

Thyristor

Type / Item	GTD 02	GTE 02	GTG 02	GTH 02	GTL 01	GTN 02
V_{R0} $V_{F}{}^{0}$	1,200 V	1,200 V	1,200 V	1,200 V	1,200 V	1,600 V
U_d (115°C)	$0.95+30 \times 10^{-3}\ ip$	$1.01+15 \times 10^{-3}\ ip$	$0.92+8.3 \times 10^{-3}\ ip$	$0.95+4 \times 10^{-3}\ ip$	$1.01+1.3 \times 10^{-3}\ ip$	$0.90 +0.76 \times 10^{-3}\ ip$
$T_{j\max}$	125°C	125°C	125°C	125°C	125°C	125°C
R_{th}DC	2.10 deg/W	1.30	0.90	0.50	0.22	0.15
R_{th} 120°el	2.80 deg/W	1.70	1.13	0.63	0.27	0.17
R_{th} 180°el	2.50 deg/W	1.60	1.03	0.508	0.25	0.16
R_{cf} (Contact)	0.30 deg/W	0.20	0.10	0.05	0.02	0.01

1. Fundamental Constants of Blocking Characteristics

In diodes the maximum repetitive peak reverse voltage V_{R0} and in thyristors the maximum peak forward and reverse voltages V_{F0} and V_{R0} are fundamental constants. The effective input voltage $(V_{\text{in}})_{\text{eff}}$ for the AC circuit in respect to the resistance load is determined by the following equation.

$$V_{\text{in}}=\frac{V_{R0},\ (V_{F0})}{\sqrt{2}\times 1.1\times\alpha} \quad \cdots\cdots\cdots\cdots (3)$$

In this equation, α is determined by the overvoltage protective circuit and is generally between 1.5 and 2.5. (Refer to section **V**).

2. Output Current Characteristics

1) Forward voltage drop

$$V_F=e_b+r_p\cdot i_p \quad \cdots\cdots\cdots\cdots (4)$$

This is the most appropriate forward voltage drop since the maximum temperature limit characteristics are used. The ordinary temperature characteristics are standard values when the elements are delivered. The fundamental constants e_b and r_p of the high temperature forward voltage drop are known as the threshold voltage and slope resistance respectively. These constants are shown in *Table 3*.

2) Forward loss

Since the loss in respect to the average current is usually calculated as the mean forward loss, it is necessary to determine the relations of this loss. Because the mean forward loss varies with differences in the waveform, a form factor (f_i) must be obtained. The forward loss is calculated by equation (5) where α is the conduction angle.

$$W=e_b\cdot I_D+(f_i)^2\times r_D\cdot I_D{}^2 \quad \cdots\cdots\cdots\cdots (5)$$

$$(f_i)^2=\pi(\pi-\alpha+\sin\alpha\cdot\cos\alpha)/(\cos\alpha+1)^2$$
sine half wave $\cdots\cdots\cdots\cdots$ (6)

$$(f_i)^2=2\pi/(\pi-\alpha)$$
square wave $\cdots\cdots\cdots\cdots$ (7)

3) Thermal Impedance

To calculate the rated current of the semiconductors, it is necesssary to know the loss and the thermal impedance between the junction and the case. This impedance can be express as in equation (8) by theoretically correcting experimental values.

$$r_{th}=r_1(1-e^{-\alpha_1 t})+r_2(1-e^{-\alpha_2 t}) + r_n(1-e^{-\alpha_n t}) \quad \cdots\cdots\cdots\cdots (8)$$

Details of this equation will be published in a separate report. The r_{th} when $t\rightarrow\infty$ as in equation (8) is indicated as the DC thermal resistance $R_{th\text{DC}}$.

Table 4 Form Factor

Conduction angle	180°el	150	120	90	60	30
Sine half wave	1.57	1.66	1.88	2.22	2.81	4.01
Square wave	1.41	1.55	1.73	2.00	2.45	3.47

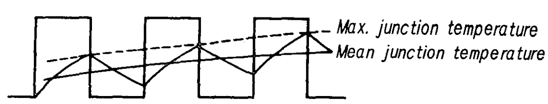


Fig. 3 Heat pulses and temperature rise

4) Normalization of transient thermal impedance (σ)

The maximum junction temperature differs according to the duty cycle or waveform as can be seen from *Fig. 3*. This is usually indicated by means of a normalized transient thermal impedance curve constructed on the basis of equation (8). *Fig. 4* shows the normalized transient thermal impedance for the GTN 02 thyristor.

If $\rho=1/D\times R_{thDC}\times\delta$ is calculated from when the the time is t_1 ms and the duty D, the thermal impedance $R_{thDC}+\rho$ is obtained for calculating the maximum junction temperature in respect to the mean loss (The duty is D and the time which the current flows is t_1). These characteristics can also be used in calculating ratings for diodes and thyristors which are used at frequencies other than 50 Hz.

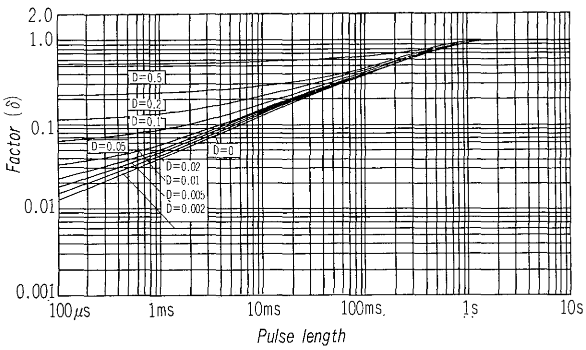


Fig. 4 **Normalized transient thermal impedance of GTN 02**

5) Thermal impedance of cooling fin (R_{fa})

Data related to the thermal resistance of the cooling fin has already been published as Fuji Electric technical data. Please refer this for details.

6) Contact thermal resistance

The contact thermal resistance is influenced by the surface and binding conditions. For the contact thermal resistance of Fuji Electric semiconductor elements and cooling fins under standard binding conditions, refer to our technical data.

7) Determination of rated current

(1) Maximum rating indication for case temperature

$$W_F=(T_{j\max}-T_c)/(R_{thDC}+\rho) \cdots\cdots\cdots\cdots\cdots (9)$$

I_D is calculated from equations (5) and (9). The temperature T_c is used which corresponds to the output current when a standard cooling fin is applied. ($R_{thDC}+\rho$) depends on the waveform.

(2) Recommeded rating when standard cooling fin is used

$$W_{F0}=(T_{j\max}-10-T_a)/(R_{thDC}+\rho+r_{cf}+R_{fa}) \cdots\cdots\cdots\cdots\cdots (10)$$

I_D is calculated from equations (5) and (10), and T_a is the ambient tempertature.

These characteristics have already been shown on a rating characteristic curves. The ($T_{j\max}$ -10) in this equation is considered so as to protect against overload currents by means of gate tripping for the thyristors. We shows over load characteristic curve in respect to 0%, 50% and 100% initial load current. The designer should reduce the initial current in accordance with the overload when applying gate tripping.

8) Overload characteristics curves

The overload characteristic curves show the overload currents in respect to the time in which the

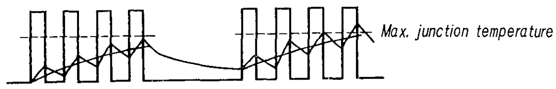


Fig. 5 **Temperature rise of intermittent load**

maximum permissible junction temperature is reached. The allowable loss can be expressed as follows:

$$W_{\mathrm{0ver}}=\frac{T_{j\max}-T_a}{r}-P_0\left(\frac{R_{th\mathrm{sum}}}{r}-1\right) \cdots\cdots\cdots (11)$$

Where r: transient thermal resistance considering differences in wave form (including the cooling fin)

$R_{th\mathrm{sum}}$: $R_{thDC}+\rho+r_{fc}+R_{fa}$ (when $t\to\infty$, $r=R_{th\mathrm{sum}}$)

P_0: Mean loss due to initial current

Since the loss is calculated as in equation (11), the $I_{D\mathrm{transient}}$ can be calculated from equation (5).

9) Characteristic curves for intermittent load

When the characterics of the intermittent load are considered, calculations be made in accordance with *Fig. 4* considering the duty and the waveform. However this problem has already been described and details will not be given here.

10) Other characteristics

The rated characteristics for items other than those mentioned above for the general diodes and thyristors are decided on the basis of statistical methods. Such items have already been widely reported and such data should be referred to.

V. PROTECTION OF DIODES AND THYRISTORS

Information concerning the protection of semiconductor elements has already been given in the technical data. This section will describe the relation between the surge absorber capacitor and the blocking voltage. Basic thinking concerning the relation between the fuse and overcurrent coordination is also discussed.

1. Overvoltage Protection

1) Types of surge voltage

Surge voltages can roughly be classified as those based on external factors and those based on internal factors. The former include surges such as direct and inductive lightning surges. The latter include intermittent arcing ground faults in the power cable, power cable switching surges and surge voltages due to the Hall storage effect and so on.

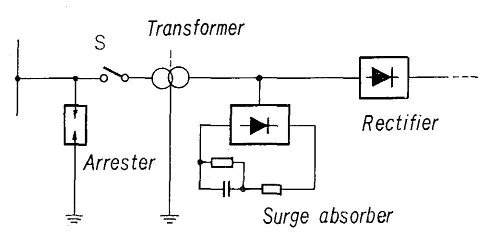


Fig. 6 **Overvoltage protecting system**

2) Determining surge absorbers for external surges

When a surge voltage is transmitted from the AC side via transformer it is necessary to consider electrostatic transmission due to the stray capacity between the primary and secondary windings of the transformer. As well as the electromagnetic transmission caused by operation of the transformer. However, electro-static shielding in the potential transformer protects against electrostatic transmission and it is sufficient if a comparatively large capacitor against stray capacity of the transformer is connected between the ground and the secondary winding of the transformer. For the surges due to electromagnetic transmission, a lightning arrestor in the AC side is considered at first. The surge voltage is estimated from this arrestor and the magnitude of the capacitor is determined from equation (12) so that the attenuations of the surge voltages will be within the permisssible range.

$$C \geqq 1/20(k-1)^2 L \ \mu F \cdots\cdots\cdots\cdots\cdots (12)$$

Where L: The sum of the line inductance and leakage inductances of the transformer which have been converted into secondary impedances.

k: The maximum peak forward (reverse) voltages multiplied by the peak value of the rated AC voltage

$$k = V_{F0},\ (V_{R0})/\sqrt{2} \times V_{\text{in}} \times 0.9 \geqq \alpha$$

α: Usually between 1.5 and 2.5

The α of equation (3) is determined in respect to the surge absorber decided in this way.

3) Determination of the surge absorber for switching surges

By the interruption of the exciting current when the switch is opened during no load, there is a possibility that the energy accumulated in the transformer inductance might be applied to the semiconductors. In such cases, there is no problem if the transformer energy has been absorbed by the capacitor and the terminal voltage of the semiconductor is within allowable voltage. This is the basis of equation (13).

$$\frac{1}{2} L_e I_e^2 = \frac{1}{2} C V_{R0}^2 - \frac{1}{2} C V_0^2 \cdots\cdots\cdots\cdots (13)$$

Where L_e: Transformer exciting inductance

I_e: Transformer exciting current

C: Surge absorber capacitor

V_{R0}: Allowable reverse voltage of semiconductor.

V_0: Capaciror terminal voltage

The energy accumulated in the exciting inductance is also consumed by arcing energy during switching and therefore, the capacitor can be determined in respect to about 50% of the total energy.

Single phase coupling

$$C = \varepsilon \cdot P_T \cdot 10^9/100\ \omega\ (V_{R0}^2 - V_0^2)\ \mu F \cdots\cdots\cdots (14)$$

Three-phase coupling (DC side)

$$C = \varepsilon \cdot P_T \cdot 10^9/200\ \omega\ (V_{R0}^2 - V_0^2)\ \mu F \cdots\cdots\cdots (15)$$

ε: Percentage exciting current of transformer

P_T: Rated capacity of transformer (kVA)

The damping resistance is determined so that there will be no resonance between the surge absorber capacitor and the transformer leakage inductance. This value is generally twice the surge impedance.

Single phase coupling:

$$R = 2\sqrt{L_s/C},\quad L_s = V_2^2 \cdot V_s/100\ \omega \cdot P_T$$

Three phase coupling:

$$R = 2\sqrt{L_{sp}/C},\quad L_{sp} = V_2^2 \cdot V_s/100\ \omega \cdot P_T$$

Where V_2: Transformer secondary voltage

L_s and L_{sp}: Leakage inductance of the one phase of transformer

V_s: % of stray valtoge in respect to rated voltage of transformer

The magnitude of the capacitor calculated in section 2) is generally larger than that of calculated in 3). However in circuits where there is no external lightning surge, the surge absorber capacity obtained in 3) can be used. In such cases when α is the ratio of the blocking voltage of the semiconductor and the peak value of the AC input voltage, equations (14) and (15) become:

$$C = k/V_0^2(\alpha^2 - 1) \cdots\cdots\cdots\cdots\cdots\cdots (16)$$

k = Fixed value

From this relation, the α of equation (3) can be determined.

4) Others

When the DC current is interrupted, a high voltage arises in the source reactance, DC reactor, motor winding reactance etc. The voltage which arises in the source reactance can be absorbed by the AC side surge absorber. But a high surge voltage arises in the source reactance when there is a flashover of a motor, it can not be absorbed by the surge absorber alone, it is necessary to increase the capacitance of the AC side surge absorber or add a capacitor to the DC side of the rectifier. In either case the appropriate protective method are essential in accordance with the surge voltage conditions.

2. Overcurrent Protection

There are various systems which can be used to protect semiconductors against overcurrents. In this article, however, only short circuit protection using fuses will be described.

1) Normal current

There are 'element fuses' connected in series with the element and 'line fuses' connected in the AC line. The rated current of the element fuse is smaller. The line fuse is sufficient for overload and short circuit protection. When applicable, the element or line current is calculated in accordance with the circuit and fuses with large current ratings are selected. In such cases, 0.9 times the rated current of the fuse with the element or line current should be compared.

2) Coordination in the overload range

The overload curve of the fuse is shown by effective values and the half wave peak value is indicated

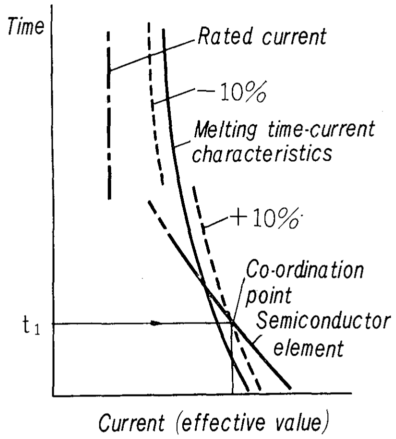


Fig. 7 **Overcurrent characteristics of fuse and semiconductor rectifiers**

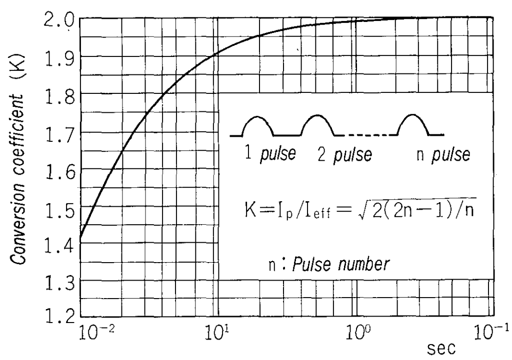


Fig. 8 **Conversion coefficient (sine half wave to effective value)**

for the semiconductors. So it is necessary to convert these half wave peak values into effective values when constructing a coordination curve. The conversion coefficient is as shown in *Fig. 8*. In the case it is best to consider the coordination by multiplying the fuse melting time—current characteristic curve by 1.1.

3) Short circuit protection

By comparing the I^2t, the I^2t of the fuse and semiconductors under cold conditions must be compared. It is evident that the former must be smaller than that of the semiconductors. Since the I^2t of the fuse has voltage dependence characteristics, it is necessary to consider this in applications. The smaller the I^2t of the fuse, the more proportional to the applied voltage it becomes.

VI. RELIABILITY OF NEW SERIES

Reliability tests for diodes and thyristors include mean forward current and the junction temperature high temperature storage tests, forward and reverse blocking tests and load tests. Here will ba described the results of an equivaient load test on the SIE 01 which was intended to reproduce actual conditions as much as possible. In the circuit in *Fig. 9,* a

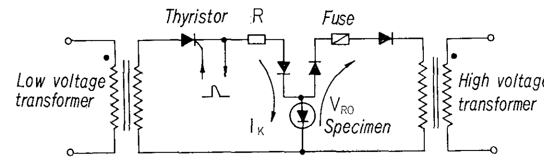


Fig. 9 **Equivalent load test circuit**

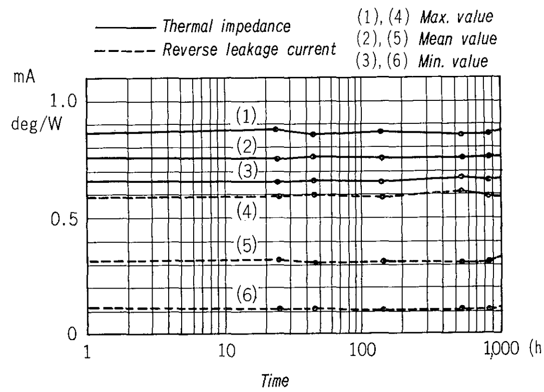


Fig. 10 **Equivalent load test result**

is the allowable value. In the blocking interval, a voltage evuivalent to the repetitive peak reverse voltage was applied from a separate power source. Fifty pieces were tested for 1,000 hours and the reverse characteristics (1,200 V, 150°C) and the the thermal resistance were measured. There were no main faults and the changes in the characteristics were very slight. It is difficult to predict the life from these test results but from our wide experience in marketing of these new type semiconductors, it is probably safe to say that there is a reliability of about $10^{-8}h^{-1}$.

VII. CONCLUSION

General problems concerning the new series of diodes and thyristors have been touched upon but lack of space has prevented detailed explanations. This article should prove useful as a reference when employing Fuji Electric middle power elements.