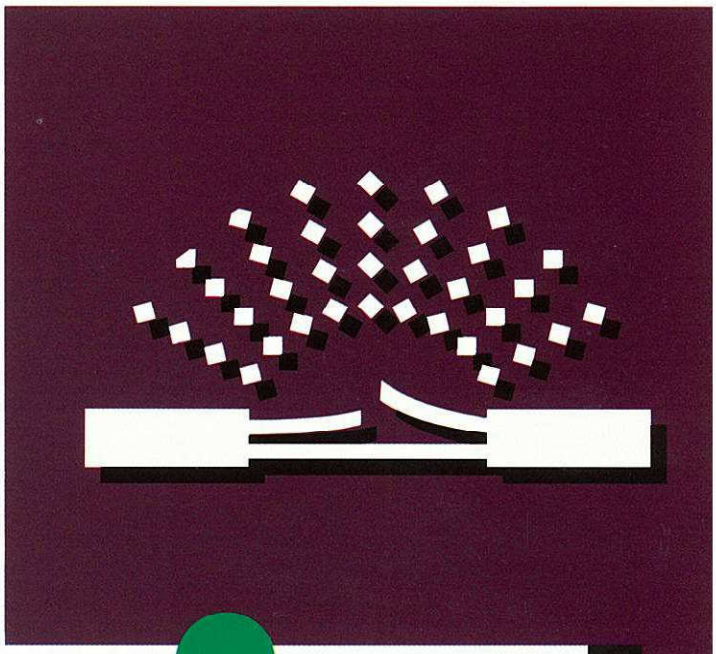
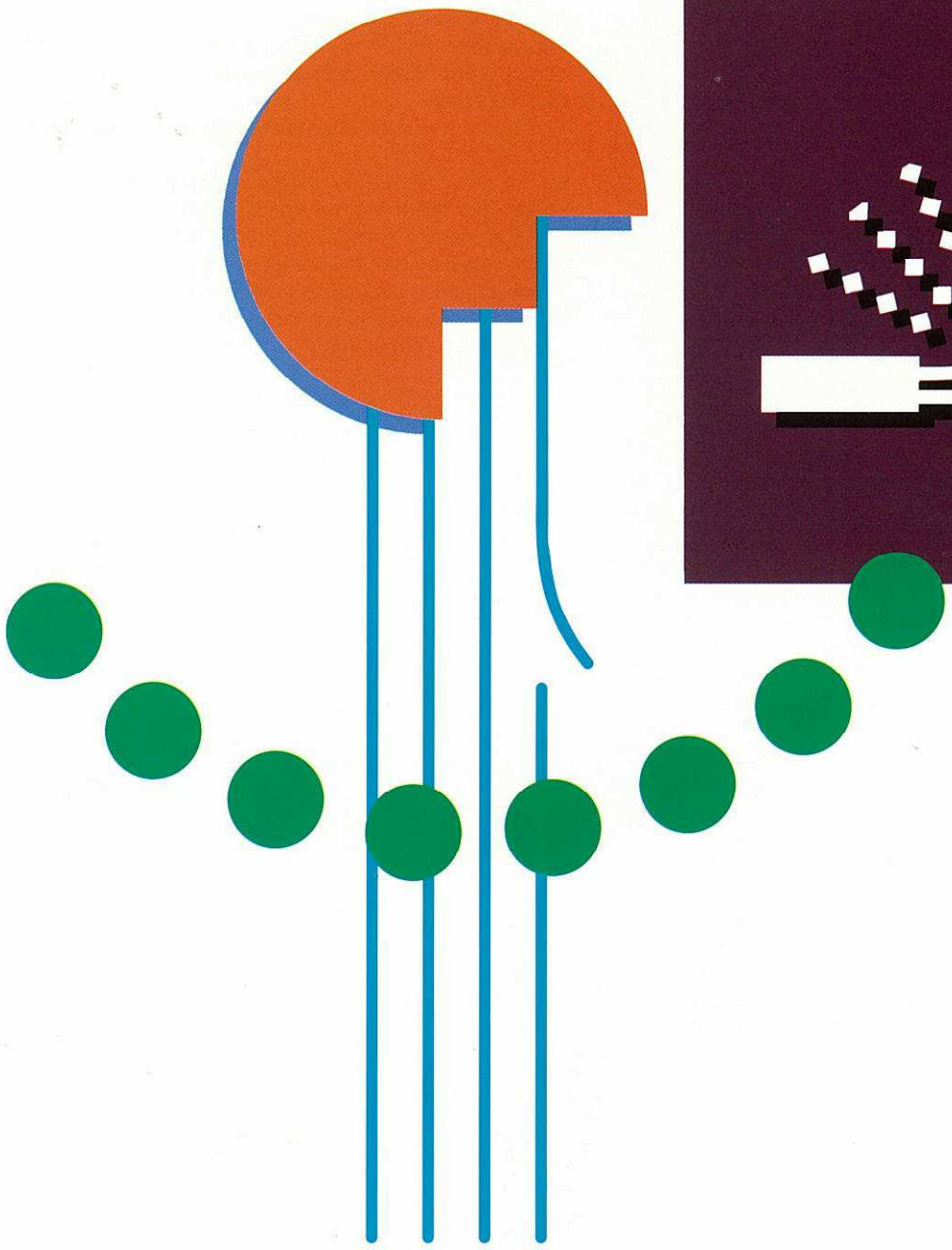
CABLE FAULT LOCATORS





CABLE FAULT LOCATION

1. Types of Cable fault

The dielectric breakdown fault (hereinafter called fault) of the power cable is roughly divided into the ground fault, short-circuit fault, and disconnection fault, and in some cases, two or more types of fault may be combined, and the fault may occur over many phases.

The ground-fault resistance after the ground fault/short-circuit has a very wide range from low resistance of 0.1MΩ or lower to high resistance of several hundreds of MΩ or higher. The high-resistance ground fault includes such a flashover fault that even in the burning work to apply high voltage to the faulty cable, only the arc discharge occurs intermittently at the fault point and the ground-fault resistance does not decrease so easily.

In some disconnection fault cases, the resistance between conductors after the disconnection ranges from low resistance of several Ω to several tens of MΩ, and the ground fault occurs simultaneously. Thus, the power cable fault is varied and to locate them, it is important to make correct judgment on the fault condition and to select an optimum measuring instrument. Figure 1 shows the fault location flow chart.

2. Electrical Characteristics of Fault Point

Figure 2 shows a DC burning circuit to reduce the ground-fault resistance by applying high voltage to an ordinary high-resistance ground fault and causing the arc discharge at the fault point and an approximate equivalent circuit of the faulty cable. The current limiting reactor in the figure is inserted to limit the DC current to about 100mA or less even when the arc discharge occurs at the fault point. Figure 3 shows a voltage-current change model when burning.

It shows the current-voltage characteristic when the voltage regulator is stopped at a voltage a little higher than the voltage at which the discharge occurs at the fault point.

(1) Flashover fault (when discharging is repeated at fault point)

This is the case of Process 1 in Fig. 3. If discharging occurs at the fault point when the applied voltage of the cable is gradually increased,the charge charged to the cable (C) up to the discharge voltage value runs to the fault point simultaneously with the discharging. This discharge current becomes the value obtained by dividing the discharge voltage by 1/2 of the surge impedance or several hundreds of amperes or higher (about 600A at discharge voltage 10kV, surge impedance 32Ω). Since the discharge energy is proportional to the square of the discharge voltage, very large arc discharge occurs at the fault point for a long-distance cable with high discharge voltage. This carbonizes the cable insulation and jacket forming a carbonized passage which is, however, blown up due to the severe arc discharging and the insulation at the fault point is recovered. Then, again, the cable is charged with the burning power supply and the same process is repeated. In such a case, the ground-fault resistance does not decreases so easily. It seems that such an fault often occurs on a long XLPE/Oil-Filled cable of 22kV class or higher and along the pencil-sharpened portion of the cable termination/joint, and the ground-fault resistance reaches several tens of MΩ or higher.

(2) Fault in which ground-fault resistance decreases after discharging (when burning is possible)

This is the case of Process 2 to Process 3 in Fig. 3. While the charging and discharging of the cable is repeated as aforementioned, the discharge voltage decreases and at the same time, the current increases and is finally stabilized when the voltage is 200 to 300V or lower, and this type of fault occurs particularly on the paper-insulated cables/XLPE cables of 3300V to 33kV class. This fault seems to occur often when the ground-fault resistance is several MΩ to 100MΩ. If the insulation resistance is measured with a megger, etc. After the burning, it often happens that the ground-fault resistance increases to several tens of MΩ or higher, and so it is recommended to select a possible measuring method during burning operation.

(3) Low-resistance ground fault (when arc discharge does not occur at the fault point and ground-fault resistance decreases)

This is the case of Process 3 in Fig. 3. When the applied voltage is gradually increased, small discharge occurs at the fault point when the voltage is 1 to 2kV or lower, and then immediately stabilized current runs, and this type of fault occurs on the paper-insulated cables/XLPE cables of 6600V class or lower.

This fault often occurs when the ground-fault resistance is 5 to 7MΩ or lower.

As described above, the electrical characteristic of the fault point of the cable is rather complicated, and it often happens that the state in Item (2) returns to the state in (1) as time elapses or the state in (3) changed to the state in (2). It also largely changes depending on the laid condition of the cable (direct burying, laying in conduit, existence or nonexistence of moisture in cable line).

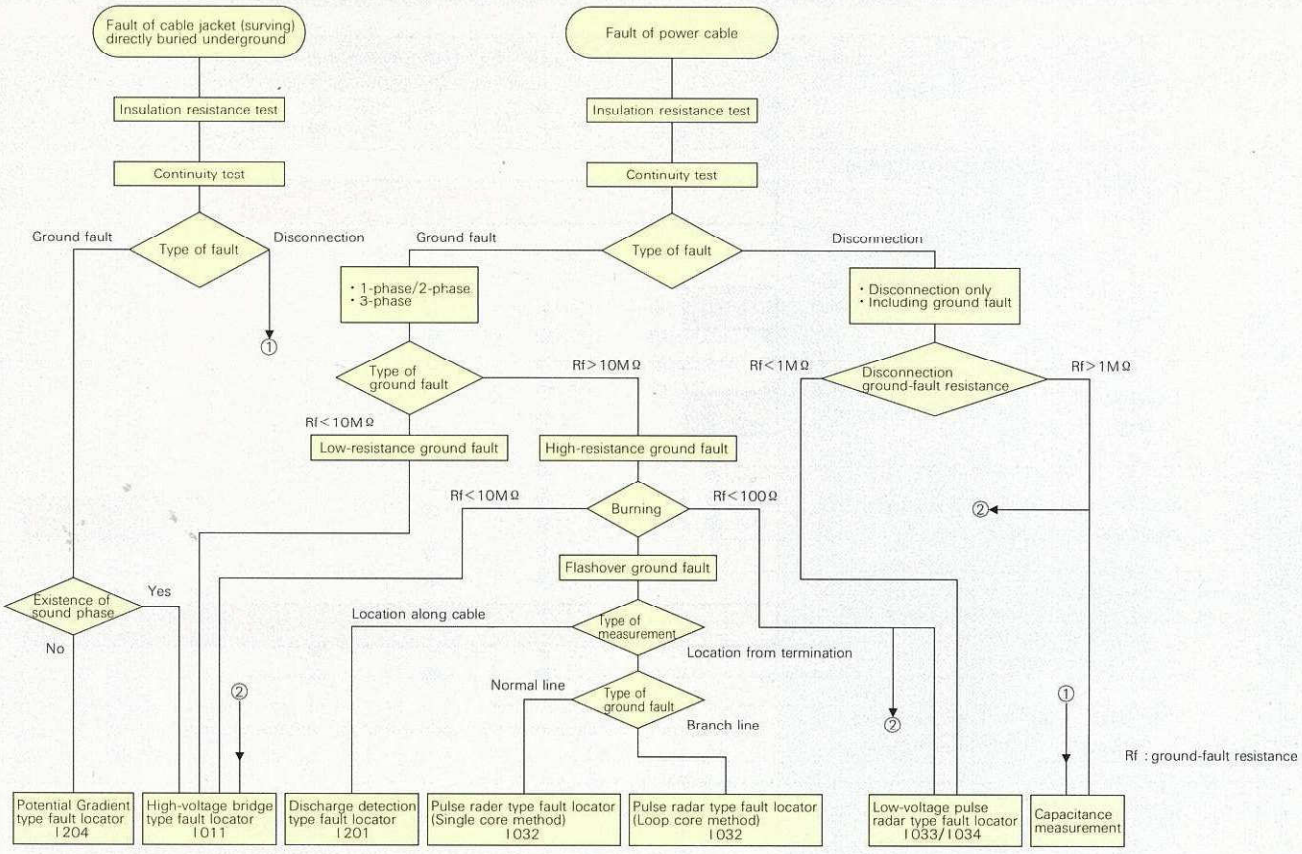


Fig. 1 Fault Location Flow Chart

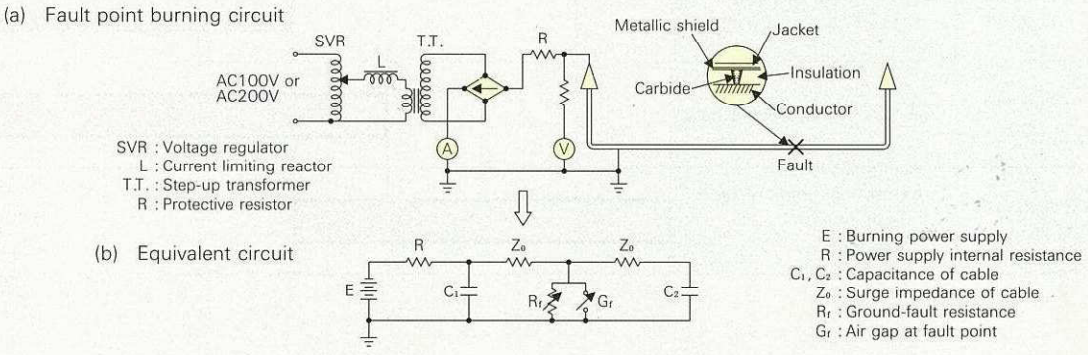


Fig. 2 Example of Cable Fault Point Burning Circuit and Equivalent Circuit

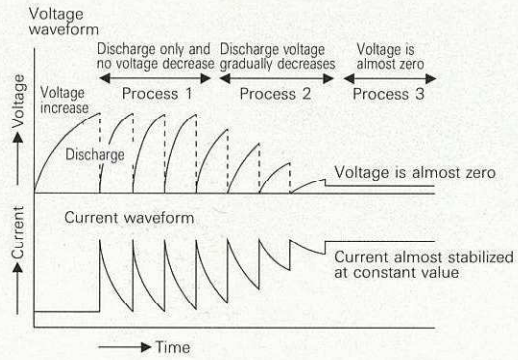
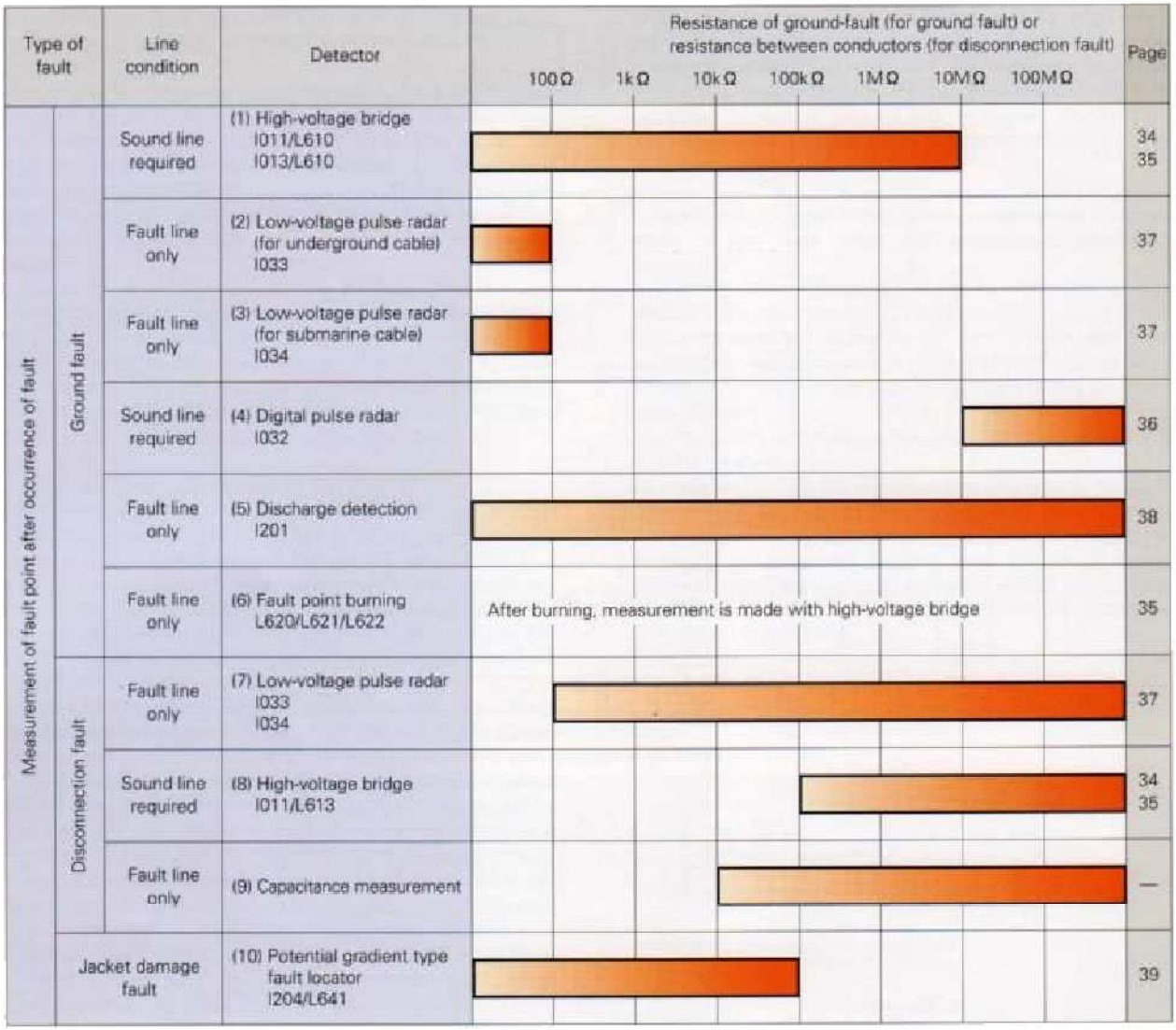


Fig. 3 Voltage/Current Change Model in Burning Process

GUIDE TO SELECTION OF CABLE FAULT LOCATORS

SELECTION OF CABLE FAULT LOCATORS



COMBINATION OF CABLE FAULT LOCATOR SYSTEM FOR CABLE VOLTAGE CLASS

Cable class / MAIN Locator	Low-voltage	3300V	6600V	22kV/33kV	66kV/77kV	154kV	Remarks	Page
(1) I011 I013	◎●L610 ●H601	◎●L610 ●H601	◎●L610 ●H601	◎●L610 ●H601	◎●L610 ●H601	◎●L610 ●H601		34
(2) I033		○CRT	○CRT	○CRT	○CRT	○CRT		37
(3) I034			◎CRT	◎CRT			For submarine cable	37
(4) L530 L531			○●L630 ●H601 ●L532 ●CRT	○●L631 ●H601 ●L533 ●CRT	◎●L632 ●H602 ●L534 ●CRT	◎●L632 ●H602 ●L534 ●CRT		36
(5) I032			○●L630 ●H601 ●L532 ●L530	○●L631 ●H601 ●L533 ●L530 ●L531	◎●L632 ●H602 ●L533 ●L530 ●L531			36
(6) I201			○●L636 ●L630 ●H601	○●L636 ●L630 ●H601			Tracer type (measurement along the cable on the ground)	38
(7) L620 L621 L622		○●L620 ●H601	○●L620 ●H601	○●L621 ●H601	○●L622 ●H601	○●L622 ●H601	Used for directly buried line Cannot be used when there is a fear of fire due to burning.	35
(8) I204	◎L641						Tracer type (measurement along the cable on the ground)	39

CRT : oscilloscope ○ : Good ◎ : Best

FOR HIGH RESISTANCE GROUND-FAULT/DISCONNECTION FAULT

HIGH-VOLTAGE BRIDGE TYPE FAULT LOCATOR

MURRAY LOOP METHOD

STANDARD TYPE — DIGITAL DISPLAY TYPE

TYPE 1011(HB-10) TYPE 1013(HD-10)

High-voltage bridge type cable fault point measuring instrument to measure the ground-fault, short-circuit, and disconnection fault of the cable line.
There are three types, the conventional dial display tyte 1011 widely used by users, digital display type 1013 to prevent reading error, and 1014/L810 type to make the measurement possible even when induced voltage occurs in the line to

Type : 1011

Type : 1013

FEATURES

1. The measuring accuracy is high (0.5%) and the operation is easy.
2. Ground fault and short-circuit fault can be easily measured.
3. High-resistance ground fault (10MΩ or higher) can also be measured due to the burning effect of the fault point.
4. Since there is no high-voltage exposed portion, the measuring work can be safely done than usual.
5. The distance to the fault point can be obtained just by multiplying the reading by the line length.
6. Since it is small and light, field measuring can be easily done.

PERFORMANCE

Type	1011	1013
Name	High-voltage bridge type fault locator	Digital high-voltage bridge type fault locator
Bridge		
Method	Murray loop, northlap	
Bridge arm resistance	100Ω	
Measuring range	0.5% to 100% of total cable length	0.1% to 100% of total cable length
Error	Not more than 0.2%, but 0.3% for 20% or shorter of total line length	
Max. working voltage	DC 10kV	
Max. working current	80mA	
Max. allowable induced voltage	AC 8V, 50/60Hz	
Galvanometer		
Method	FET chopper system, AC-DC IC galvanometer	
Sensitivity	DC±100μV/F.S. equivalent, AC1mV/F.S. equivalent	
Max. input induced voltage	AC 3V, 50/60Hz	
Supply voltage	DC 9V(6 SUM-3 batteries)	AC 100V, 50/60Hz
Dimensions/weight	350W×260H×250D(mm), 10kg	360W×260H×270D(mm), 12kg
Accessories		
Bridge cable	4-core cable 10m×1 for DC10kV	
Input cable	Single-core cable 2m×1 for DC10kV	
Short-circuit cable	100mm² single-core cable 2m×1	
Output cable	—	
Power cable	—	2-core cable 2m×1
Battery	6 SUM-3 batteries	—
Accessory storage box	500W×500H×150D (mm), 20kg (when accessories are contained)	

FOR HIGH-VOLTAGE BRIDGE TYPE LOCATOR, PULSE RADAR TYPE LOCATOR, FAULT POINT BURNING

POWER SUPPLY SYSTEM EQUIPMENT

POWER SUPPLY FOR HIGH-VOLTAGE BRIDGE TYPE LOCATOR

TYPE L610, L613 (DCG-10, HFG-1)

POWER SUPPLY FOR BURNING

TYPE L620, L621, L622 (DCG-40E, DCG-50E, DCG-60E)

POWER SUPPLY FOR PULSE RADAR TYPE LOCATOR

TYPE L630, L631, L632 (DCG-30B, DCG-60B, DCG-100B)

The L610 power supply unit for high-voltage bridge is a high-voltage power supply unit of DC10kV equipped with the power supply for burning and is used for the resistance type ground-fault. The L613 high-frequency generator is a 2kHZ high-frequency power supply unit to be used for the disconnection fault.

The L620, L621, and L622 are to carbonize/burn the high-resistance or flashover type fault point. As a result of the burning, the measurement can be made using the high-voltage bridge type fault locator.

The three models, L630, L631, and L632 are DC high-voltage power supply for pulse radar type fault locator, and the optimum model can be selected in accordance with the type of fault cable and discharge voltage at the fault point.

PERFORMANCE

Type	L610	L613
Name	High-voltage power supply for bridge	High-frequency generator
System	Magnetic leakage transformer current limiting system	Automatic oscillation, power amplifying system
Generated voltage	DC 10kV (at no load), negative	About 30Vrms (at no load)
Generated current	DC 45mA±5mA(at short-circuit)	AC 30mA, internal impedance 1kΩ
Generated waveform	DC	2kHz±5% sine wave
Power supply	AC 100V, 50/60Hz*1	DC 9V (6 SUM-2 batteries)
Dimensions	350W×220H×250D(mm)	200W×120H×120D(mm)
Weight	22kg	3kg
Accessory	Power cord 2m	6 SUM-2 batteries

Type : L610

Type : L613

Type	L620	L621	L622
Operating portion			
Name	Power supply unit for burning		
System	Short-circuit current limiting system by means of current limiting reactor		
Output voltage	AC 0~200V, 1φ, 5kVA	AC 0~200V, 1φ, 6kVA	AC 0~200V, 1φ, 7.5kVA
Power supply	AC 200V, 50/60Hz*2		
Dimensions	600W×820H×520D(mm)	610W×820H×520D(mm)	920W×970H×650D(mm)
Weight	145kg	145kg	270kg
DC high-voltage generator			
Type	Full-wave rectification/oil-immersed self-cooling system		
Generated voltage	DC40kV (at no load), negative	DC50kV (at no load), negative	
Generated current	DC 150mA (at short-circuit)	DC 120mA (at short-circuit)	DC30kV, DC240mA (at short-circuit) DC60kV, DC120mA (at short-circuit)
Input capacity	5kVA	6kVA	7.5kVA
Dimensions	650W×700H×380D(mm)	610W×865H×420D(mm)	730W×965H×550D(mm)
Weight	170kg	235kg	280kg
Accessory	Power cable 5m×1, Control cables 5m×2, High-voltage cable 15m×1, Insulating oil 1ℓ		

Operating portion

DC high-voltage generator

Type : L620

Type	L630	L631	L632
Name	DC high voltage generator		
Application	6600V cable fault point measurement/ withstand voltage test	22/33kV cable fault point measurement/ withstand voltage test	66/77kV or higher cable fault point measurement/withstand voltage test
Generated voltage	30kV (negative)	60kV (negative)	100kV (negative)
Generated current	10mA (2 hours)/20mA (2 minutes)	5mA (2 hours)/10mA (2 minutes)	2mA (2 hours)/5mA (2 minutes)
Power supply	AC 100V, 50/60Hz, 1φ		
Power consumption	700VA	1kVA	1kVA
Dimensions/weight	250W×380H×360D(mm), 40kg	Operating portion 250W×390H×320D(mm), 30kg High voltage portion 310W×420H×140D(mm), 23kg	Operating portion 250W×390H×320D(mm), 30kg High voltage portion 310W×490H×146D(mm), 26kg
Accessories	Power cord 3m×1, Output cable 15m×1, Insulating oil 500cc		

*1 : Generators for other voltages than AC100V can be manufactured. *2 : Specify the power supply frequency when ordering.

High voltage portion *Operating portion*

Type : L631

FOR FLASHOVER TYPE GROUND-FAULT

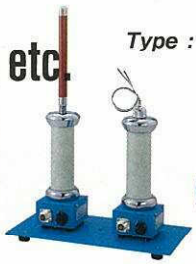
DIGITAL PULSE RADAR TYPE FAULT LOCATOR

DIGITAL DISPLAY TYPE SINGLE-CORE/LOOP-CORE METHOD

TYPE 1032, L530, L531 (DL-41D, PD-30C, PD-30EX), etc.

Fault point measuring instrument adopting the digital display system to improve accuracy and operationability of the waveform observing in pulse radar type fault location.
With this digital display system using a crystal oscillator of 100MHz, the measurement can be made at the high resolution of 1m.

Type : 1032



Type : L530

Type : L531

FEATURES

1. The cable fault point measuring can be done in two modes of loop-core method or single-core method.
2. Using the fault phase and sound phase, the pulse time difference caused at the fault point is measured accurately, and through the operating function, the distance to the fault point is digital-displayed accurately.
3. Since it utilizes the traveling pulse caused by the discharging at the fault point, a small DC high-voltage power supply unit with small capacity can be used.
4. No burning work is required.

PERFORMANCE

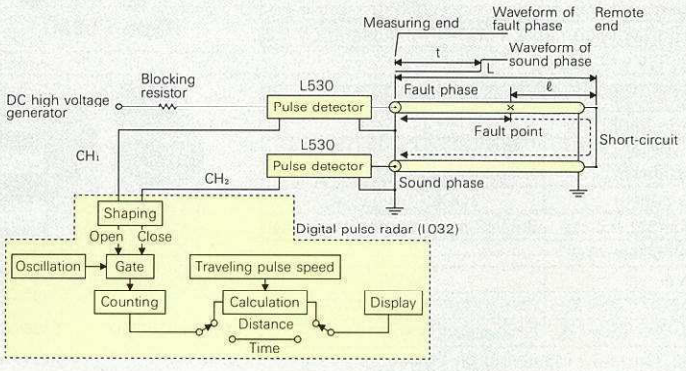
Name, Type	Digital pulse radar type 1032
Max. indication	Distance x 1 : 9999m, x 10 : 9999 x 10m Time x 1 : 99.99 μs, x 10 : 999.9 μs
Resolution	Distance x 1 : 1m x 10 : 10m Time x 1 : 0.01 μs, x 10 : 0.1 μs
Measuring error	Distance x 1 : 2 - 3% of line length ± 1m Time x 1 : 2 - 3% of measurement time ± 0.01 μs Distance x 10 : 2 - 3% of line length ± 10m Time x 10 : 2 - 3% of line length ± 0.1 μs
Traveling speed	0~299.9m/μs, 0.1m/μs step
Clock pulse	100MHz crystal oscillator
Repetition rate	30 times/sec or less
Input voltage	13.5V to 135V no adjustment
Power supply	AC 100V, 50/60Hz, about 100VA
Dimensions/Weight	320W×140H×365D(mm), 11kg

Oscilloscope for observing waveform and waveform photographing unit are also available upon request.

Name, Type	Pulse detector L530	Extention unit L531
Method	CR parallel voltage dividing system	
Max. working voltage	DC 30kV, Imp 50kV	
Voltage dividing resistor	50MΩ	
Voltage dividing capacitance	100pF	
Voltage division ratio	30kV/135V	
Blocking resistor	L532 (1kΩ)	L533 (3kΩ) or L534 (5kΩ)
Dimensions/Weight	100W×220H×200D(mm), 4kg	70φ×220H×170D(mm), 2kg

The working voltage increases 30kV each time one extension L531 is made. The blocking resistor L533 (3kΩ) or L534 (5kΩ) is used for one or two extentions of L531.

MEASURING PRINCIPLE



$$\ell = \frac{v \times t}{2} = v \times \frac{t}{2} = \frac{2L}{T} \times \frac{t}{2} = \frac{t}{T} \times L$$

ℓ : Distance from remote end to fault point (m)
L : Length of fault cable (m)
t : Time difference between 1st wave of fault phase and 1st wave of sound phase (μs)
T : Time difference between 1st wave of fault phase and 1st wave of sound phase when a dummy fault point is provided at the measuring end and discharging is done (μs) (time to reciprocate total length)
v : Pulse traveling time (μs)

Note 1. Two pulse detectors are required.
2. It is also possible to display the distance from the measuring end through internal calculation.
3. For the single-core method, the open/close signal of the gate is obtained using one pulse detector.

FOR LOW RESISTANCE GROUND-FAULT/DISCONNECTION FAULT

LOW-VOLTAGE PULSE RADAR TYPE FAULT LOCATOR

FOR UNDERGROUND CABLE

TYPE 1033(PG-3)

Type : 1033

High-output pulse generator to be used for low-voltage pulse radar method. It is used in combination with an oscilloscope. It is free from the error of measuring lead wires and disturbance of waveform and best suited for measuring simultaneous faults of disconnection/ground fault of the power cable, submarine cable, etc.

FOR SUBMARINE CABLE/UNDERGROUND CABLE

TYPE 1034(FL-1F)

Type : 1034

OPTIONS (STORAGE BOX, OSCILLOSCOPE)

●The waveform photographing unit is also available upon request.

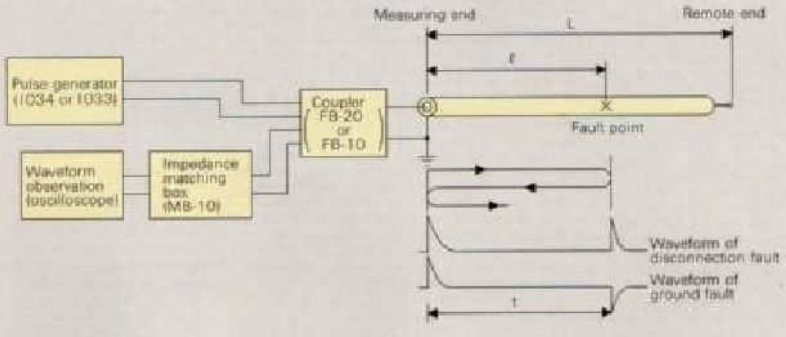
FEATURES

1. The operation is easy.
2. It is very effective for measuring a low-resistance ground fault point of 100Ω or lower.
3. The disconnection fault point can be easily measured.

PERFORMANCE

Name, Type	Pulse generator 1033	Low-voltage pulse radar 1034
Method	Mercury relay switching type pulse generating system	Capacitor charging transistor switching type pulse generating system
Application	For underground cable, low-voltage pulse radar and discharge calibration of partial discharge	For underground cable and submarine cable, low-voltage pulse radar measurement
Output voltage	0~10, 0~30, 0~100V	Fixed at 100V
Polarity	Both negative and positive	Positive
Waveform	Fault point measurement : Pulse width 0.2, 2, 20μs exponential damped wave Partial discharge calibration : Rise time 30ns or less, square wave 10 to 100pC	0.2, 2, 20, 50μs exponential damped wave
Repetition rate	100 or 120pps power synchronous	100pps power asynchronous
Output impedance	50Ω, unbalanced type	
Power supply	AC 100V, 50/60Hz, about 20VA	AC 100V, 50/60Hz, about 100VA
Dimensions/weight	240W×105H×154D(mm), 2.1kg	240W×105H×130D(mm), 5kg
Accessories	Coupler FB-10 1 pc. Matching box MB-10 1pc. Signal cord 3D-2V 15m×2 Power cord 2m×1 Measuring cord 0.5m×2	Coupler FB-10 1 pc. Matching box MB-10 1pc. Signal cord 5D-2V 15m×2 Power cord 2m×1 Synchronizing cord 3D-2V 1m×1 Measuring cord 1m×6

MEASURING PRINCIPLE



$$\ell = \frac{v \times t}{2}$$

ℓ : Distance to fault point (m)
v : Pulse traveling speed in cable (m/μs)
t : Time difference between 1st wave and 2nd wave (μs)

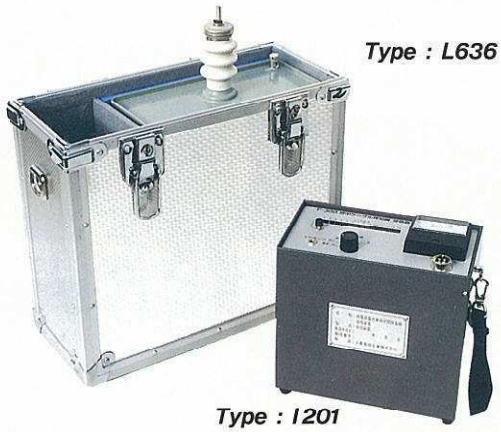
FOR GROUND-FAULT

DISCHARGE DETECTION TYPE FAULT LOCATOR [TRACER METHOD]

ELECTROMAGNETIC WAVE MEASURING SYSTEM

TYPE 1201, L636 (F-30B, IMP-15)

Measuring instrument to detect the fault point by observing the maximum level (holizontal antenna method) or position where a constant level sharply decreases (vertical antenna method) while detecting the electromagnetic wave due to the discharging from the fault point of the underground cable, using a loop antenna on the ground.
This instrument is to be used in combination with the DC high-voltage power supply unit, L630.



Type : L636

Type : 1201

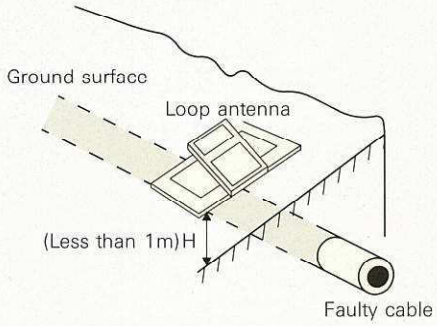
FEATURES

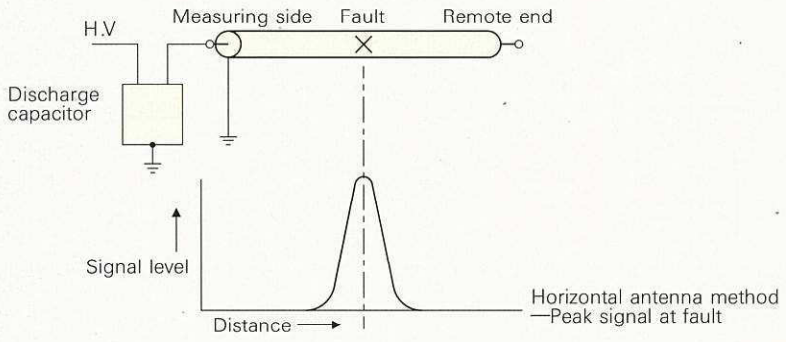
1. Easy-to-handle small detector which can detect the fault point from the ground.
2. Even for a low-resistance ground fault, discharging can be forcefully done by means of the impulse wave voltage generator.
3. Since it uses the impulse wave generator (capacitor), a small DC high-voltage power supply unit with small capacity can be used.
4. By utilizing the directivity of the antenna, it is also possible to detect the route of the line buried.

PERFORMANCE

Receiver	
Name, Type	Discharge detection type fault locator 1201
Receiving system	Loop antenna
Receive frequency	3.5kHz±700Hz—3dB
Sensitivity	Low, medium, high (45, 60, 80dB)
Level display system	Bar graph, maximum level held
Power supply	DC6V (4 SUM-1 batteries)
Dimensions/weight	Main body : 190W×105H×170D(mm), 2.6kg Loop antenna : 400W×20H×300D(mm), 1.5kg
Impulse voltage generator	
Name, Type	Capacitor for discharge detection L636
Method	Gap discharge
Capacitance	2.5μF
Max. voltage	DC 15kV
Charging resistor	500kΩ
Dimensions/weight	220W×355H×100D(mm), 8kg
Accessories	Resistor for charging, Gap device

MEASURING PRINCIPLE





FOR CABLE JACKET (SERVING) FAULT

POTENTIAL GRADIENT TYPE FAULT LOCATOR [TRACER METHOD]

GROUND SURFACE POTENTIAL MEASURING SYSTEM

TYPE 1204, L641 (F-20, DCG-15F/1)

This equipment is to detect the fault places of power cable jacket (serving) from ground surface. It is to detect the fault point by applying the DC voltage between the fault line and ground and measuring the potential produced on the ground surface by the current which leaks to the ground from the fault point, and it can detect the place just above the fault point with minimum error.

Type : 1204

Type : L641

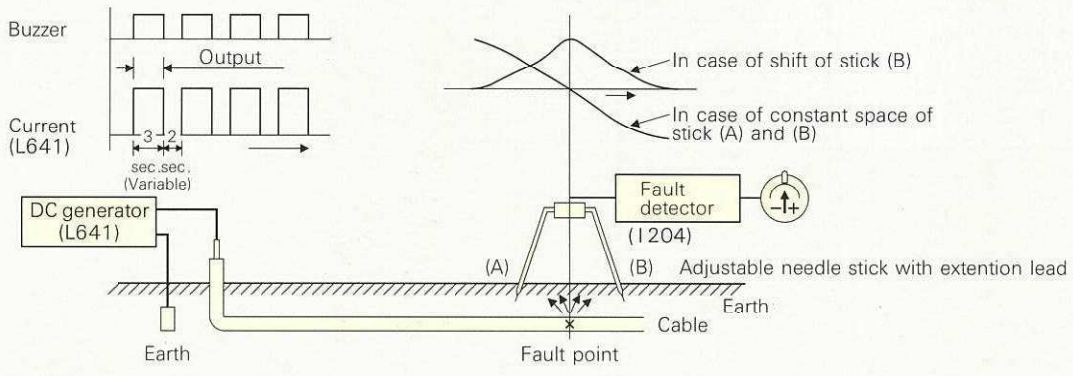
FEATURES

1. It can detect the place just above the fault point within the error of 0.5m.
2. In consideration of stray current and induced voltage, a filter circuit and wide-range zero adjusting circuit are incorporated to make the measurement easy.
3. Since the input impedance is high, the potential on the ground surface can be accurately measured.
4. Since a flicker device is incorporated in the DC power supply (L641), the stray current and induced voltage can be easily discriminated.
5. Since it is small and portable, it is best suited for the field measurement.

PERFORMANCE

Measuring portion	
Name, Type	Cable fault point detector 1204
Input impedance	5MΩ
Voltage measuring range	5 ranges of ±25mV, 100mV, 500mV, 25V, 10V
Zero adjust range	10 times the measuring voltage for each range
Allowable input voltage	10 times the measuring voltage for each range
Power supply	DC6V (4 SUM-3 batteries)
Dimensions/weight	165W×80H×110D(mm), 1.5kg
Accessories	Stick (3-step switching) 1 set Arrow type probe 2 pcs. T-type probe 2 pcs. Wet type probe 2 pcs. Curl code 30cm×1. Extension lead 10m×1. Earthing conductor 10m×1.
Dimensions/weight	330W×195H×250D(mm), 12kg (main body, including accessories)
Power supply portion	
Name, Type	DC power supply L641
Method	Current control system by means of series capacity
Max. generated voltage	DC 15kV no-load/negative polarity
Max. generated current	30mA (at short-circuit)
Indicator	Voltage 15kV, current 40mA switching
Energize/cutoff time	Energize 3 sec, cutoff 2 sec Buzzer volume adjustable during energization
Power supply	AC 100V, 50/60Hz, 600VA
Dimensions/weight	350W×220H×300D(mm), 30kg
Accessories	Power cord 3m×1, Output cord 3m×1

MEASURING PRINCIPLE



UNDERGROUND CABLE MEASUREMENT

TRAINING EQUIPMENT

CABLE INSULATION DIAGNOSIS/FAULT POINT LOCATION TRAINING

TYPE Q005(DMC-5)

Training equipment to simulate the power cable line. Various devices are designed for the terminals and accessories so that various measurements of the insulation and fault point can be easily conducted. It is very convenient for the practice of handling and checking/calibration of the measuring instruments.

Type : Q005

FEATURES

1. Since the delay cable is used for the dummy line, the structure is small, although the length is long.
2. General measurement training of insulation diagnosis and fault-point measurement can be easily done.

PERFORMANCE

Type	Q005
Measurement type and rated voltage	1. Insulation resistance measurement……3 phases DC 1kV 2. Fault point location……3 phases a. Low-voltage pulse radar method DC 50V b. Discharge detection pulse radar method DC 10kV c. High-voltage bridge method DC 10kV 3. Insulation deterioration measurement……1 phase only a. DC leakage current measurement DC 10kV Normal leakage current characteristics Kick current characteristics Leakage current control characteristics b. Dielectric loss tangent measurement AC 4kV
Cable used	PE delay cable (for pulse radar/insulation measurement) Manganin line (for high-voltage bridge measurement)
Max. working voltage	DC 10kV
Conductor size	150mm²·250mm² equivalent
Line length	Total length 1000m/phase (including branch)
Surge impedance	About 230Ω
Propagation speed	About 180m/μs ±5%
Power supply	AC 100V, 50/60Hz, 60VA
Dimensions/weight	1200W×1490H×750D(mm), 210kg