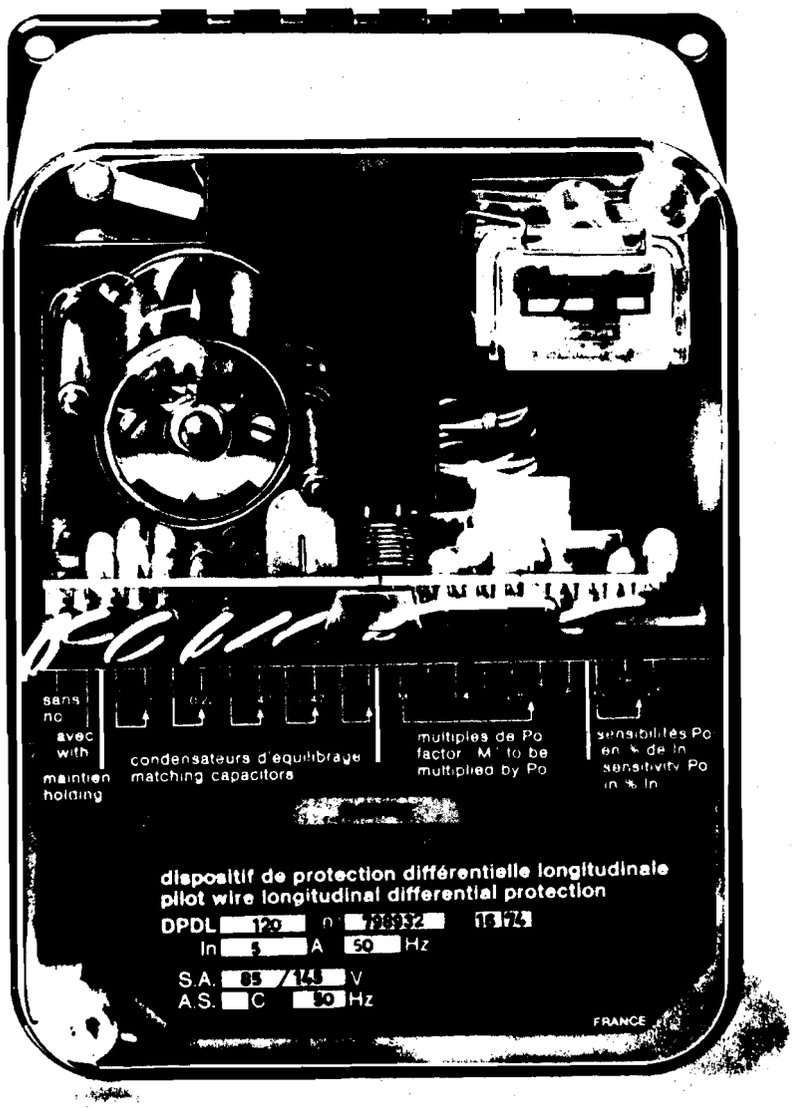
Selective feeder protection
DPDL 120
differential longitudinal protection with pilot wires

ENERTEC



December 1980

ENERTEC
Schlumberger

N 1.6625 A

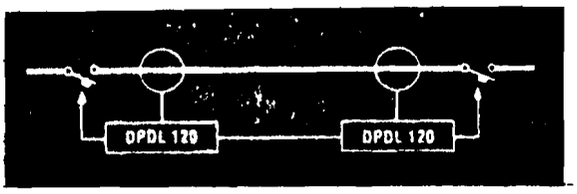
Protection DPDL 120 (patented by Enertec) is designed to protect lines or cables used for power transmission against faults between phases or between phase and earth. Its use presupposes the existence between both ends of the line, of one or more two wire pilot links. The protection is selective that is to say every fault occurring on the section of protected line is detected by the device whereas a fault appearing elsewhere does not cause it to operate. This protection can be used on every type of network. It ensures automatic tripping and signals the fault to each end of the defective line.

Differential longitudinal protection is based on the measurement of the vectorial difference of the currents at both ends of the feeder.

Such measurement enables the fault to be detected, because it is equivalent to that of the fault current. It is selective because the difference measured can only come from the existence of an internal fault, and is independent of external faults or load conditions.

MODELS

Unit DPDL 120 is available either in a projecting case with front or back connections or in a case for flush mounting. It can be made withdrawable by using an additional base. The choice of model must be made according to the location of the unit bearing in mind that terminals must be kept out of reach to comply with safety requirements. In positions readily accessible to employees only back connections should be specified. The component elements are fixed on an insulating base and are protected from dust by a cover in transparent material (projecting type) or by a case with transparent cover (flush type). Of robust construction, they are fully reliable in operation.
They can be adjusted with ease and accuracy. The equipment are protected from ambient factors, satisfying the conditions of climatic category 666 (Publications 68 of the I.E.C.).

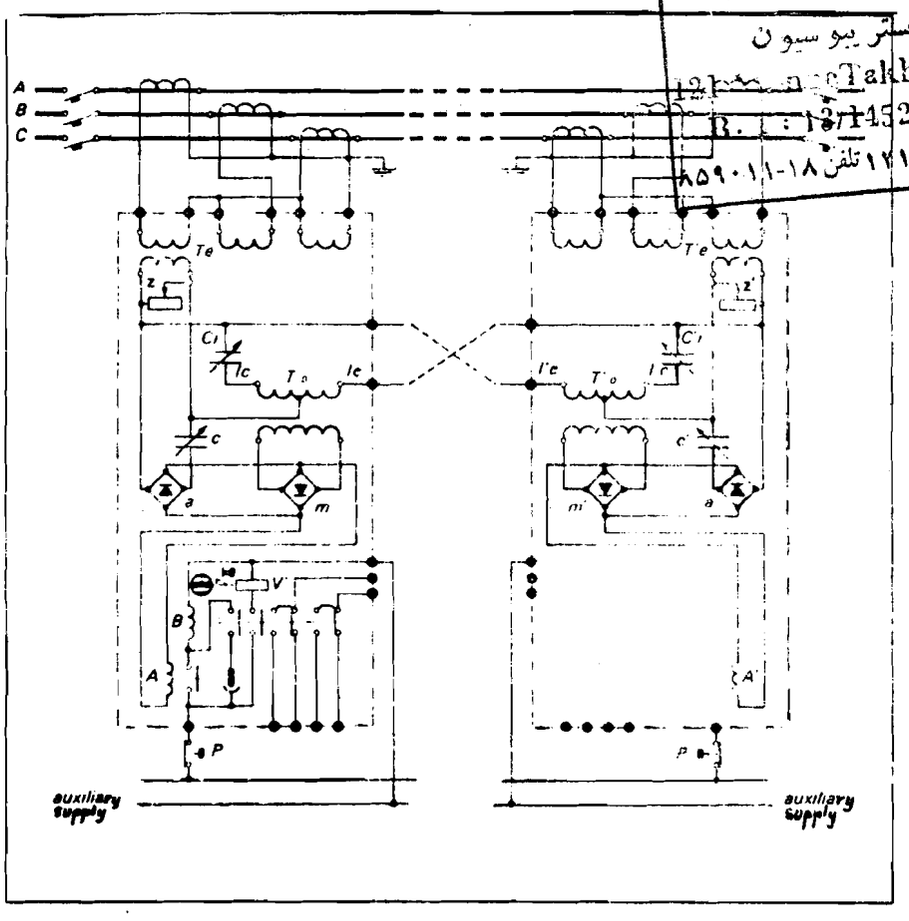


PRINCIPLE

DPDL 120 works on the principle of voltage balance comparison: the quantities compared are not directly the currents at both ends of the line, but of the voltage resulting from them. This principle offers the following advantages:

- Possibility of comparing voltages (related either to the phase currents, or an assymmetrical sum of the currents) with the same basic equipment, which can be adapted to many different applications.
- Zero circulating current in the pilot wires, in the absence of a fault.
- Reduced voltages, enabling the use of pilot wires with low voltage insulation.
  At each end of the line, the voltage resulting from the local line current is compared with the voltage resulting from the current at the other end of the line. The voltage difference is measured in relation to the local voltage by means of a module comparator; a galvanometric relay initiates the tripping of the unit when the differential "percentage" reaches the operating threshold. The detection by differential percentage offers these advantages:
- independence in relation to external faults,
- high sensitivity to internal faults.
  The balancing circuit is a symetrical arrangement with image capacity, so as to eliminate the influence of pilot wire capacity.
  It is also possible to insulate the pilot wire circuit by means of translators, which may be required in the case of induced large voltages relative to earth, or for the elimination of "cross talk" phenomena between neighbouring pairs of pilot wires.

BASIC DIAGRAM



FULMEN - distribution
شرکت فولمن - دیستریبوسیون
TakbteTavousTEH
B. : 18/1452 - tel. 8590
تهران - میدان تختی طاووس شماره ۱۲ تلفن ۸۵۹۰۱۱-۱۸

DESCRIPTION

Each DPDL unit consists of:

- a "voltage generator" assembly made up of a saturable input transformer Te with three primaries, feeding a load impedance with adjustable taps Z.

  Depending on the way the protection is connected, one, two or three primaries of the input transformer are connected to the secondaries of current transformers mounted on the feeder conductors. Transformer Te, is protected on the output side by a resistance/capacity circuit against overvoltage caused by a high fault current.

  The voltage supplied by the generator is a linear function of the line current or currents, for low values. It tends to assume a limit value for currents greater than double the rated current. In this way, the amplitude of the voltage applied to the pilot wires is limited, even for high values of fault currents. This voltage still remains perfectly sinusoidal, owing to the use of a resonance-limiter assembly acting as a low-pass filter. This assembly protects, moreover, the pilot wires against the voltage peaks of transformer Te, which contain harmonics of high frequency, and for which the influence of capacity between pilot wires would become very important.

  Finally, the time constant of the resonant circuit avoids the appearance of an untimely differential voltage derived from an external fault transient current.

- a "balancing" device. The voltage supplied by the generator is applied to two parallel circuits: on the one part, the pilot wire circuit, and on the other a circuit "image" made up of a condenser adjustable to half the capacity of the pilot line. A differential transformer Td supplies a secondary current proportional to the difference of the currents going through the two circuits.

- a "module comparator" made up by two rectifiers bridges whose outputs, in opposition, are connected to a sensitive electro-magnetic relay A of the series RMA 300 (List 16305). Their inputs are connected, one to the secondary of the differential transformer Td, the other to the voltage generator via a set of condensers C, fitted with tappings, to give two possible sensitivity ranges.

  One of the rectifiers "a" is supplied by a current proportional to the voltage supplied by the local voltage generator. The other rectifier "m" is supplied by the differential current from transformer Td.

- a signalling assembly comprising the contact of relay A and a "change-over" relay B.

  This assembly carries out the following operations:

a) Signalling, by energizing an electromagnetic indicator V, the fault which has initiated the relay operation,

b) Changing-over two reversing contacts NC-NO. An auxiliary contact is set aside for possible relay maintenance.

Unit DPDL 120 can be supplied without an electromagnetic indicator if it is not necessary to have the fault displayed on the equipment itself.

OPERATION

A DPDL 120 unit is connected to each end of the line to be protected on appropriate current transformers. Both units are required to have the same setting. A two-wire pilot connection is provided by two "balancing" assemblies.

IN THE ABSENCE OF AN INTERNAL FAULT:

The voltages supplied by the voltage generators at both ends are equal, and proportional to the load current in the linear range of the voltage generators. The pilot wires act as a capacitive load. Image capacity Ci, having been set at half the pilot capacity, currents ic and i_1 flowing in the primaries of the differential transformer Td balance each other. No current supplies rectifier "m" of the module comparator. In fact, there can remain a weak differential current due to inaccuracies in the current transformers, or to a slight unbalance of the capacities, but this current does not affect the operation of the equipment in any way.

IN THE CASE OF AN EXTERNAL FAULT :

Compared voltages at both ends remain practically equal and tend, when the fault current grows, to reach saturation limits.

IN THE CASE OF AN INTERNAL FAULT:

Compared voltages at both ends are of different values. If the fault current is weak, the vectorial difference of the voltages is proportional to the vectorial difference of the currents at both ends, and is thus proportional to the fault current.

If the fault current is large, the currents at both ends being more than twice the rated current, the compared voltages are equal in module, since they have reached the saturation value, but are in phase opposition through the connection of the protection. The differential voltage is practically double the saturation voltage.

In both cases, the current from the module comparator, acts on the electromagnetic relay A which trips when its control threshold is reached.

CHARACTERISTICS

Unit DPDL 120

- Rated current: 5 or 1 A.
- Consumption:
- in single phase arrangement, for rated current: 0.6 VA.
- in three phase current assymetrical load arrangement for a phase/earth fault at rated current: 2.8 VA
- Auxiliary supply: 20 to 34 V. 50 to 84 V.
  (50 cycles or d.c.) 85 to 145 V. 185 to 225 V.
- Operating range:
  Frequency: ± 10 % of rated frequency
  Temperature: — 5 °C to 40 °C.
- Contact breaking capacity:
  2.5 A at 24 V d.c. resistant circuit.
- Nominal sensitivity Pn:
  Ratio between the minimum current causing the unit to trip, and the rated current.
  In view of the many alternative methods of connecting the unit, the operating current is, by convention, that flowing in the two "phase" primaries in series with the input transformer Te, using pilot wires of negligible resistance and capacity.

  $$Pn = MPo.$$

- Po reference sensitivity (adjustable by setting condenser C).
- M multiplier coefficient (adjustable by setting resistance R).

  Pn is adjustable between 18 and 150 %.

	Pn	
	For P_o = 18 %	For P_o = 25 %
M = 1	18 %	25 %
1,4	25	35
2	36	50
2,8	50	70
4	72	100
6	108	150

- Operating time for a fault current greater than the rated current = 0.06 s.
- Outline dimensions EGE 301 (to drawing 2 018 300).
- Weight: 3 kg approx.

PILOT WIRES

(The following characteristics are those which must be possessed by the pilot wires for satisfactory operation of the protection).

- Maximum resistance per wire: 2000 ohms.
- Maximum capacitance between wires: 4.5 microfarads. These values correspond to a length of about 30 km.
- Maximum voltage between two wires of a pair: 48 V 50 cycles.
- Maximum voltage between pilot wires and earth: 500 V for use without translator.
  If the voltage between pilot wires and earth is liable to be greater than 500 V, it is advisable to use translators. Note. The pilot wires can be checked by means of unit BVCFP 220.

TRANSLATORS

Unit DPDL 120, being designed for L.V. circuits, cannot be directly connected to pilot wires if their voltage is raised by induction, to more than 500 V relative to earth. This is a safety requirement. It is therefore necessary to use translators whose characteristics are:

- Transformation ratio: 1
- Windings with balanced centre-point.
- Maximum resistance of windings: 100 ohms.
- Magnetizing current, for a voltage of 40 V: 0.75 mA ± 20 %
- Minimum saturation voltage: 100 V.
- Insulation between windings and earth: 8000 V.
- Electrostatic screen.

DIFFERENTIAL PROTECTION

- Effective sensitivity P. Ratio between the minimum current causing the protection to trip, and the rated current In of the current transformers in the line to be protected.

The operating reference current is that supplying the two series "phase" primaries of input transformer Te, the pilot wires having any given resistance and capacity. P depends on the nominal sensitivity of unit DPDL 120 and on the characteristics (resistance and capacity) of the pilot wires.

$$P = K\,Pn.$$

Coefficient K can be deduced from tables 1 and 2 which sets out for each value of pilot wire resistance (represented by the curves) and of the capacity between a pair of wires (abscissae):

a) Coefficient K (ordinates) for a given adjustment of Po (18 % or 25 %).

b) The possible choice of the values of M (setting range of each DPDL 120 unit).

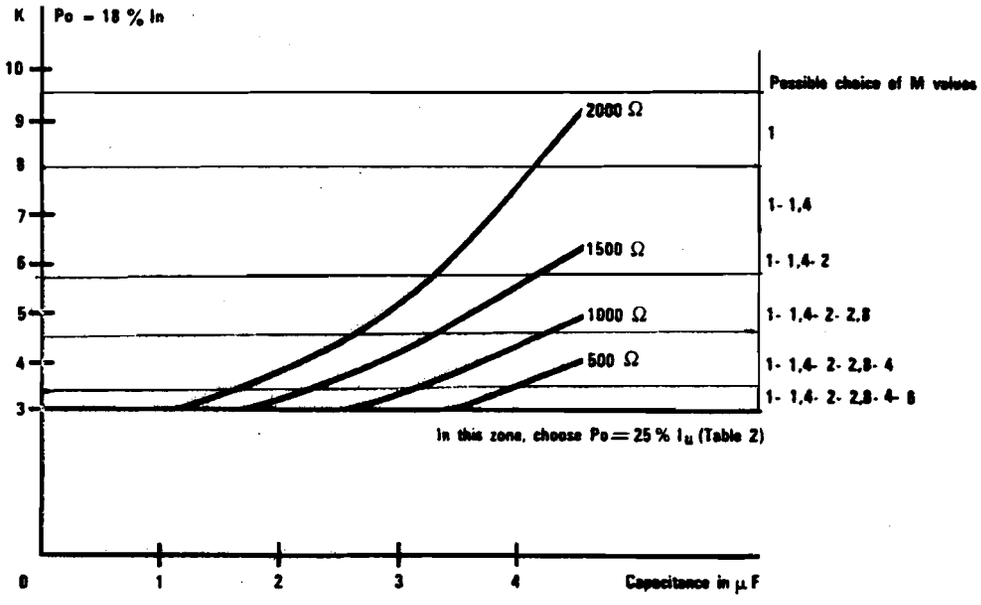


TABLE 1

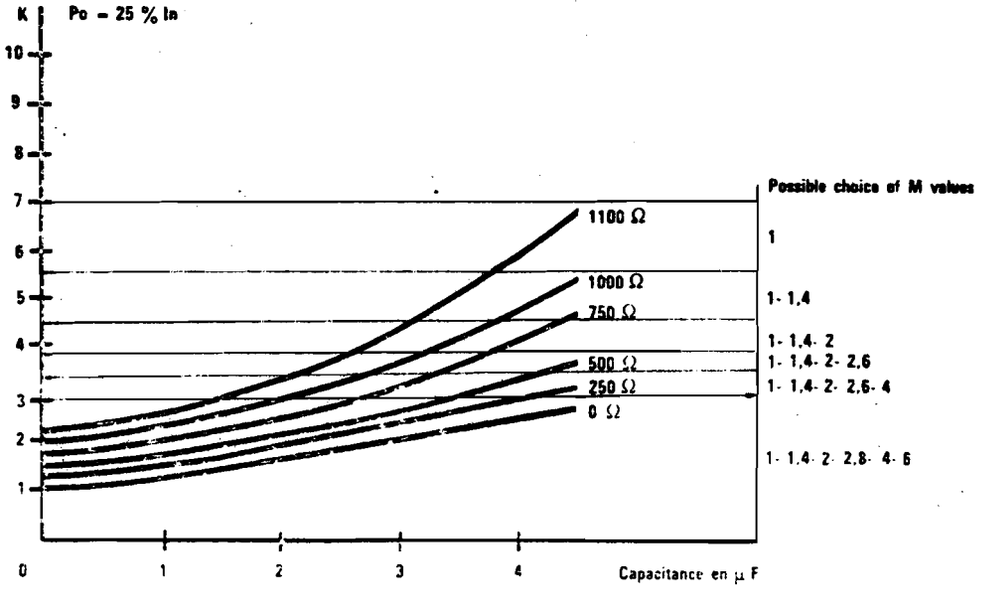


TABLE 2

APPLICATION

Unit DPDL 120 can be used to protect any line or cable in a distribution or transmission network. Many alternative methods of assembly are possible by merely altering the connections or settings.
There results in each case a sensitivity to the true current in the feeder which causes the protection to trip and depends on the nature of this current, i.e.:

- Phase fault current.
- Earth fault current.
- Capacitive current in the conductor.

In relation to these criteria, the setting values which determine the discrimination and selectivity of the protection are deduceable from:

- the sensitivity to fault currents,
- the insensitivity to capacitive currents.

The more commonly used arrangements are detailed in table 3.

CHOICE OF PROTECTION

For a given type of network, and as a function of the criteria of sensitivity and selectivity, the method of assembly will be chosen.
The choice of sensitivity P will have to be such that:

- the minimum fault current between phases I_p or between phase and earth I_t is certain to cause the protection to operate. Taking into account the variations in setting, the values of transformation ratios, etc., a maximum P is chosen so as to be at least equal to the theoretical sensitivity to capacitive currents,
- a capacitive current I_c in the line, does not cause the unit to trip under any circumstances. For the same reason, a minimum P is chosen equal to double the theoretical sensitivity to capacitive currents.

These two conditions define the limits between which the selection of sensitivity P should be made, the final choice being made according to the possibilities indicated in the paragraph headed "Characteristics". On the other hand, these same conditions involve a relation between capacitive current I_c and the minimum values of fault currents I_p and I_t, which provides the absolute theoretical limit in the choice of alternatives.
Strict compliance with the foregoing can lead, in certain cases, to a modification of the choice of assembly originally envisaged.
The limiting relations corresponding to various assemblies are explained in table 3.
In short, depending on the characteristics of the required protection, choose among the possible assemblies those which comply with the limits of theoretical use. Next to be calculated will be the limits of sensitivity setting and within these limits the values of the settings themselves.

EXAMPLE

For a three phase line with solidly earthed neutral.

- DATA

Cable 60 kV - length 25 km - Cross-sectional area 300 mm².
Capacitive operating current at 60 kV: I_c = 100 A.
Rated primary current of CTs: 500 A.
Rated secondary current of CTs: 5 A.
Pilot wires: length 25 km.
Resistance per wire: 180 ohms.
Capacitance between wires of a pair: 3,5 microfarads.
Minimum internal fault current:
between phases: 5000 A.
to earth: 3800 A.

- CALCULATION OF THE THEORETICAL LIMITS OF USE

$$\frac{I_p}{I_c} = \frac{5000}{100} = 50$$

$$\frac{I_t}{I_c} = \frac{3800}{100} = 38$$

An assembly with an assymmetrical sum of phase currents is not suitable. The choice remains between an assembly with separate phases or a three phase assembly with double relays.

	Separate phase assembly.	Double relay assembly
Fault between phases	$P \leq 0{,}50 \frac{I_p}{I_n} = 5{,}00$	$P \leq 0{,}25 \frac{I_p}{I_n} = 2{,}50$
Fault between phase and earth	$P \leq 0{,}50 \frac{I_T}{I_n} = 3{,}80$	$P \leq 0{,}25 \frac{I_T}{I_n} = 1{,}90$
Insensitivity to capacitive currents	$P \geq 5{,}20 \frac{I_c}{I_n} = 1{,}04$	$P \geq 2{,}60 \frac{I_c}{I_n} = 0{,}52$
Overall condition	$1{,}04 \leq P \leq 3{,}60$	$0{,}52 \leq P \leq 1{,}90$

- CHOICE OF DISCRIMINATION THRESHOLD IN RELATION TO PILOT WIRE CHARACTERISTICS.

Table II gives, for a resistance of 180 ohms per wire and a capacity of 3,5 microfarads:
Po = 25 %
K = 2,5
from which $P_n = \frac{P}{2{,}5}$

M = 1 — 1,4 — 2 — 2,8 — 4 or 6.

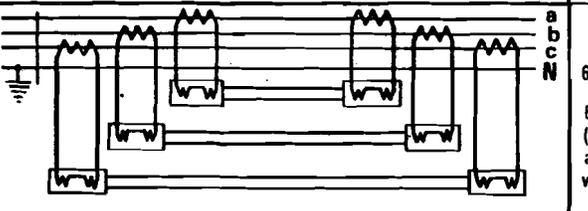
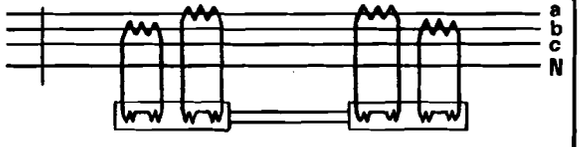
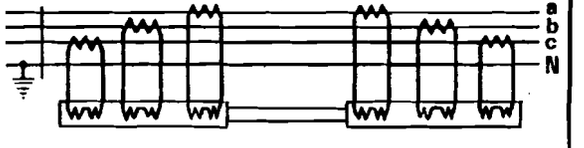
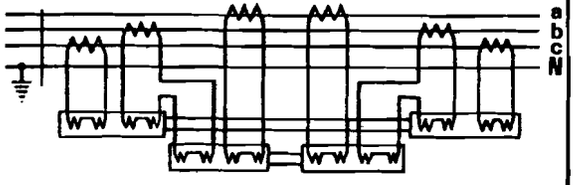
- FINAL CHOICE OF SETTING.

(for the minimum value of M):

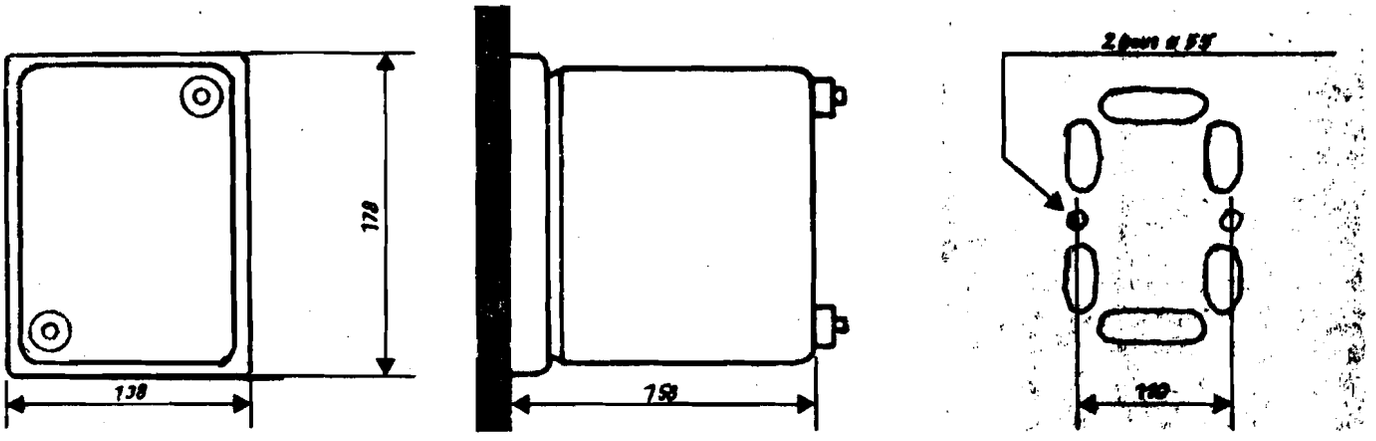
	Separate phase assembly	Double relay assembly
Possible limits of Pn	$0.42 \leq P_n \leq 1{,}52$	$0{,}21 \leq P_n \leq 0{,}76$
Minimum chosen value	$P_n = 50\ \% \ (25 \times 2)$	$P_n = 25\ \% \ (25 \times 1)$

Two types of arrangement are suitable:
A three phase assembly with double relays is the most economical 4 DPDL 120 units and 4 pilot wires only are necessary.
An assembly with separate phases has the same sensitivity to faults between phases and to earth faults; it permits in addition selection of the faulty phase.

Table 3

	Equipment at each end of line	Sensitivity of protection against fault current			Setting limits of P sensitivity			Absolute theoretical limits of use of the assembly		Utilisation	Total necessary equipment
		Between phases		Between phase and earth	For operation with minimum fault current: Between phases	For operation with minimum fault current: Between phase and earth	For non operation in presence of capacitive current Ic	Phase fault	Earth fault		
With separate phases	1 protection per phase conductor Phase selection	a - b b - c c - a a.b.c.	P x 1 P x 1 P x 1 $\frac{2}{\sqrt{3}}$ P	a P x 1 b P x 1 c P x 1	$P \leqslant 0{,}50 \frac{Ip}{In}$	$P \leqslant 0{,}50 \frac{It}{In}$	$P \geqslant 5{,}20 \frac{Ic}{In}$	$\frac{Ip}{Ic} \geqslant 10$	$\frac{It}{Ic} \geqslant 10$	1-, 2-, 3-, phase networks 	6 DPDL 120 6 pilot wires (or 4 pilot wires and common wire)
With of phase currents	1 protection per line Sensitivity variable according to the fault phases	a - b b - c c - a a.b.c.	P x 1 P x 2 P x 2 $\frac{2}{\sqrt{3}}$ P	— — — — — —	$P \leqslant 0{,}25 \frac{Ip}{In}$	—	$P \geqslant 2{,}60 \frac{Ic}{In}$	$\frac{Ip}{Ic} \geqslant 10$	—	3-phase network, neutral isolated from earth 	2 DPDL 120 2 pilot wires
With assymetrical sum of phase currents	1 protection per line Sensitivity variable according to fault phases	a - b b - c c - a a.b.c.	P x 1 P x 2 P x 2 $\frac{2}{\sqrt{3}}$ P	a P x $\frac{1}{3}$ b P x $\frac{1}{2}$ c P x $\frac{2}{5}$	$P \leqslant 0{,}25 \frac{Ip}{In}$	$P \leqslant \frac{It}{In}$	$P \geqslant 26 \frac{Ic}{In}$	$\frac{Ip}{Ic} \geqslant 100$	$\frac{It}{Ic} \geqslant 26$	3-phase network, earthed neutral 	2 DPDL 120 2 pilot wires
3-phase with double relay	2 protections per line Sensitivity equal to phase faults Sensitivity equal to earth faults	a - b b - c c - a a.b.c.	P x 1 P x 1 P x 2 $\frac{2}{\sqrt{3}}$ P	a P x 2 b P x 2 c P x 2	$P \leqslant 0{,}25 \frac{Ip}{In}$	$P \leqslant 0{,}25 \frac{It}{In}$	$P \geqslant 2{,}60 \frac{Ic}{In}$	$\frac{Ip}{Ic} \geqslant 10$	$\frac{It}{Ic} \geqslant 10$	3-phase network earthed neutral 	4 DPDL 120 4 pilot wires

DIMENSIONS



INFORMATION TO BE SUPPLIED WHEN ORDERING RELAY DPDL 120

- designation of the relay
- type of case
- auxiliary supply (voltage)
- electromagnetic indicator (if required)
- translator, current transformer } where necessary

NECESSARY DATA FOR SPECIFYING A PROTECTION

- Network rated voltage.
- Ratio of the current transformers.
- Length of cable.
- Capacitance or capacitive current (Ic) in the cable at rated voltage.
- Pilot wires:
  Number of pairs available.
  Length.
  Resistance per wire.
  Total capacitance between wires of a pair.
- Minimum phase-to-earth (I_T) fault current, inside the protected zone.
- Minimum between phases (I_P) fault current, inside the protected zone.
  If these minimum currents are not known, supply us with the necessary data to calculate them; i.e.

a Value of neutral earthing impedance.
b Power supply rating.
c Short-circuit ratings in the protected zone.
d Diagram of network with position of supply generators, earthing points and estimated distances.

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Enertec is bound by the foregoing specifications, dimensions and diagrams only after confirmation.