MH UBH.

■ Type MBCI Relay: Translay 'S' Differential Feeder and Transformer Feeder Protection

Features

$I_N - I_0$ summation CT cancelling

MBCI Pilot wire differential protection relay

- High stability for through faults
- High speed operation for in-zone faults
- Simultaneous tripping of relays at each line end
- Low current transformer requirements
- Low earth fault settings → high sensitivity
- Designed for the unit protection of overhead and underground feeders
- Suitable for pilots up to 1kΩ or 2.5kΩ with pilot isolation transformers due to pilot voltage
- Four electrically separate contacts
- Can be used as definite time overcurrent relay in the event of pilot failure ↑ short pilot

Models Available

- MBCI 01
- MBCI 02

Optional Extras

MRTP Supervision relay for ac pilot circuits

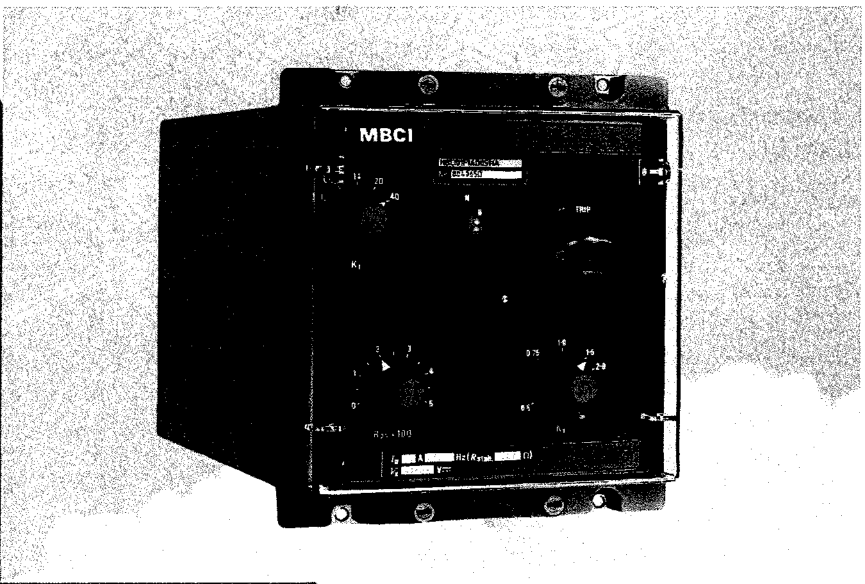
- Alarm and indication of pilot failure and supervision supply failure
- Suitable for pilot circuits insulated for 5kV or 15kV with pilot isolation transformers

MVTW Destabilising and intertripping relay

- For use with pilot wire relays
- Destabilises the feeder protection so that tripping occurs short one side and open one side
- Intertripping: injects ac voltage into the pilot circuit so that tripping occurs

MCRI Instantaneous overcurrent and start/check relay

- High speed operation
- Not slowed by dc transients
- Wide setting range
- Two phase and earth fault relay



not used in CLP

MCTH Transformer inrush current detector

- Allows MBCI to be applied to transformer feeders
- Blocks operation of the MBCI relay during transformer inrush conditions
- Blocking does not occur for zero, normal load, or genuine fault current

Application

The Translay S differential schemes have been designed for the unit protection of overhead and underground feeders and transformer feeders.

Plain Feeders

Differential protection

Differential feeder protection requires a comparison of the currents entering and leaving the protected zone. For faults occurring within the protected feeder it is desirable to trip the circuit breakers at each end to isolate the fault. Two MBCI relays are therefore required, one for each end of the feeder. A pair of pilot wires is used to transmit information between the two relays so that each may be able to compare the current flowing at its respective end with the current at the other. # not hard wire circuit! pilot wire resistance divert current into restraint / op sensor.

The relays at both line ends operate simultaneously, providing rapid fault clearance irrespective of whether the fault current is fed from both line ends or only one line end.

When applying this protection to overhead lines the limiting factor is generally the length of the pilot circuits: for cable feeders the limiting factors are more likely to be the level of line charging current and the method of system earthing.

MBCI

P. 1

Pilot supervision

Correct interchange of information over the pilot circuit is essential for the proper functioning of any differential feeder protection. Pilots may be exposed to hazards and some risk of damage and failure always exists. The most common pilot failure is to the open circuit state, caused by the accidental excavation of buried pilots or storm damage to overhead pilots. With the pilots open circuited the differential protection will be unstable and will trip the feeder if sufficient through current is flowing.

For this reason the circulating current system is often preferred as such schemes will fail safe and trip so that attention is immediately drawn to the fault.

The addition of pilot supervision will not prevent tripping for pilot faults but will indicate the cause. It will also detect short circuit and cross-connected pilot conditions which would not otherwise be detected. Indication is also provided for loss of the supervision supply.

open/short cct can still be operation. The supervision is just for an alarm purpose.

Destabilising/intertripping

When the protected line is connected to a busbar system, a fault on the busbars will in general be cleared by the busbar protection by opening some or all of the local circuit breakers. Although such faults will usually appear to the feeder protection as through faults, with resultant stability of the feeder protection, it may be desirable to open the remote line circuit breaker also, to clear the line completely. The remote unit of the differential feeder protection can be caused to operate, provided sufficient line current is flowing, by open circuiting the pilots. If line current is not flowing, the remote unit can be operated (intertripped) by injecting a current into the pilots. intertrip by injection

Overcurrent check/starting

Although the supervision scheme provides indication of pilot failure it does not prevent the protection operating if primary current above setting is flowing. Where this hazard is unacceptable it is necessary to add an overcurrent check feature.

The current transformer requirements are not modified by the addition of overcurrent elements since they present a very low burden.

open pilot not operative due to OC guard.

due to OC guard

When the starting feature is used the overall operation time of the scheme is increased by 3–5ms. However, there is no increase in the overall operation time when the overcurrent protection performs a check function only.

When overcurrent relays are used the protection cannot be intertripped by ac injection into the pilots, and destabilising the protection will result in tripping only if an overcurrent condition exists simultaneously. ~PIT (require local oc)

Emergency use for overcurrent protection

In the event of a pilot failure which cannot quickly be rectified, the Translay S scheme may be adapted for use as a definite time overcurrent relay as follows:

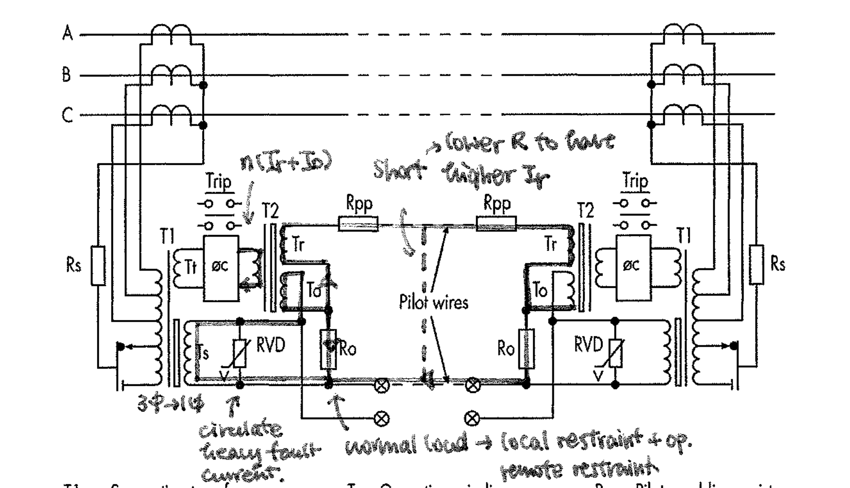
If overcurrent relay is fitted

- disconnect pilot wires and leave terminals open circuited T1 ≈ T2 → ✓ be gate
- set Kt to 3(300ms)
- check that overcurrent elements are on the required setting above maximum anticipated load current.

If overcurrent relay is not fitted

- disconnect pilot wires and connect a 1kΩ resistor across pilot terminals of relay Short pilot to avoid burning → +R
- set padding resistors Rpp to maximum (600Ω)
- set Kt to 3 (300ms) Setting required to change
- set Ks to required open circuit setting: Ks = 1 gives three phase equal to rated load In.

Note: Other fault settings will depend upon the summation ratio.



T1 - Summation transformer
T2 - Auxiliary transformer
RVD - Non linear resistor
Ts - Secondary winding
To - Operating winding
Tr - Restraining winding
Tr - Tertiary winding
Ro - Linear resistor
Rpp - Pilots padding resistor
øc - Phase comparator

Figure 1:
Basic circuit arrangement

T1: 1.25 : 1 : N
N taken as 3. (=6 for low EF setting)

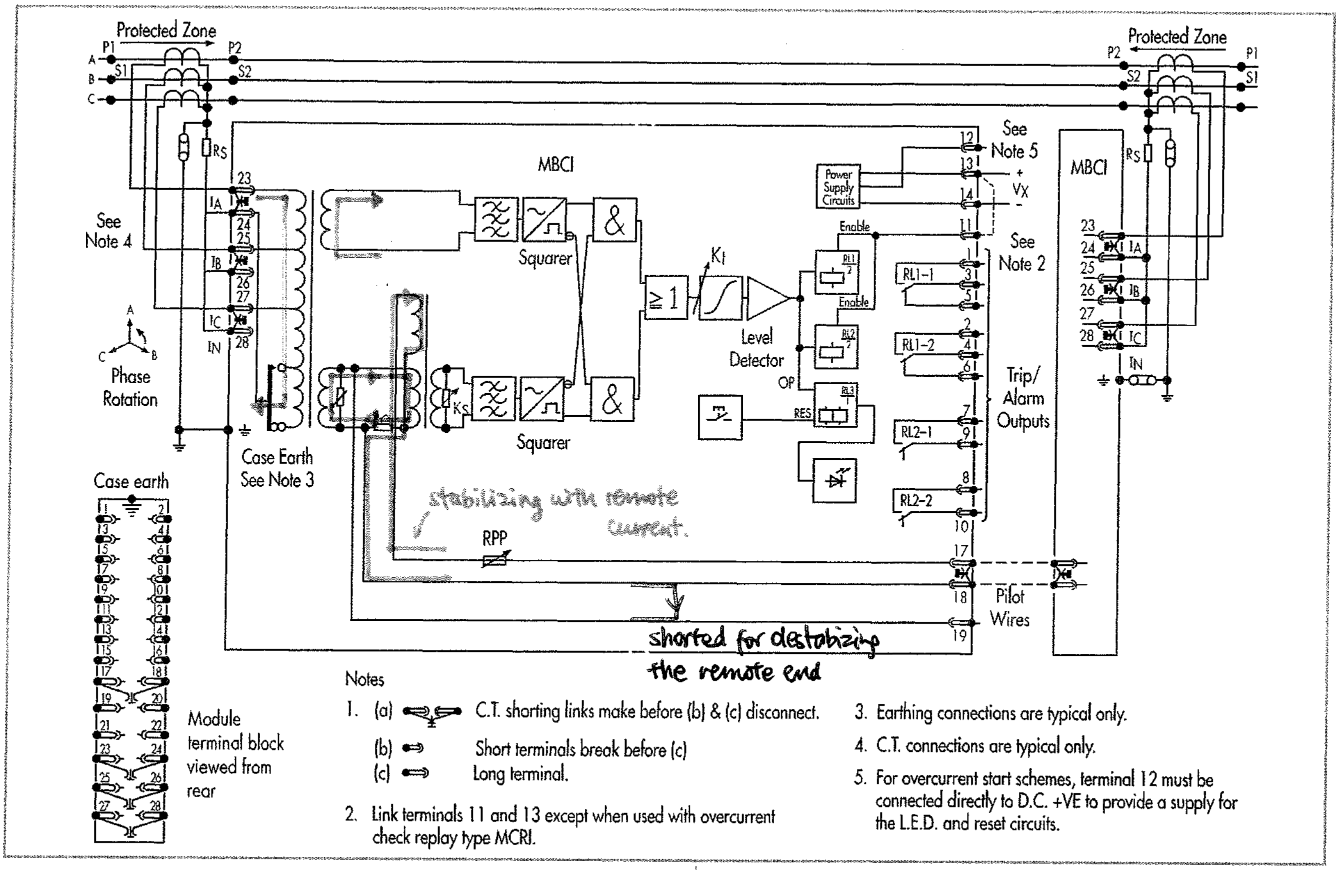


Figure 2 | Application diagram: differential feeder protection relay type MBCI

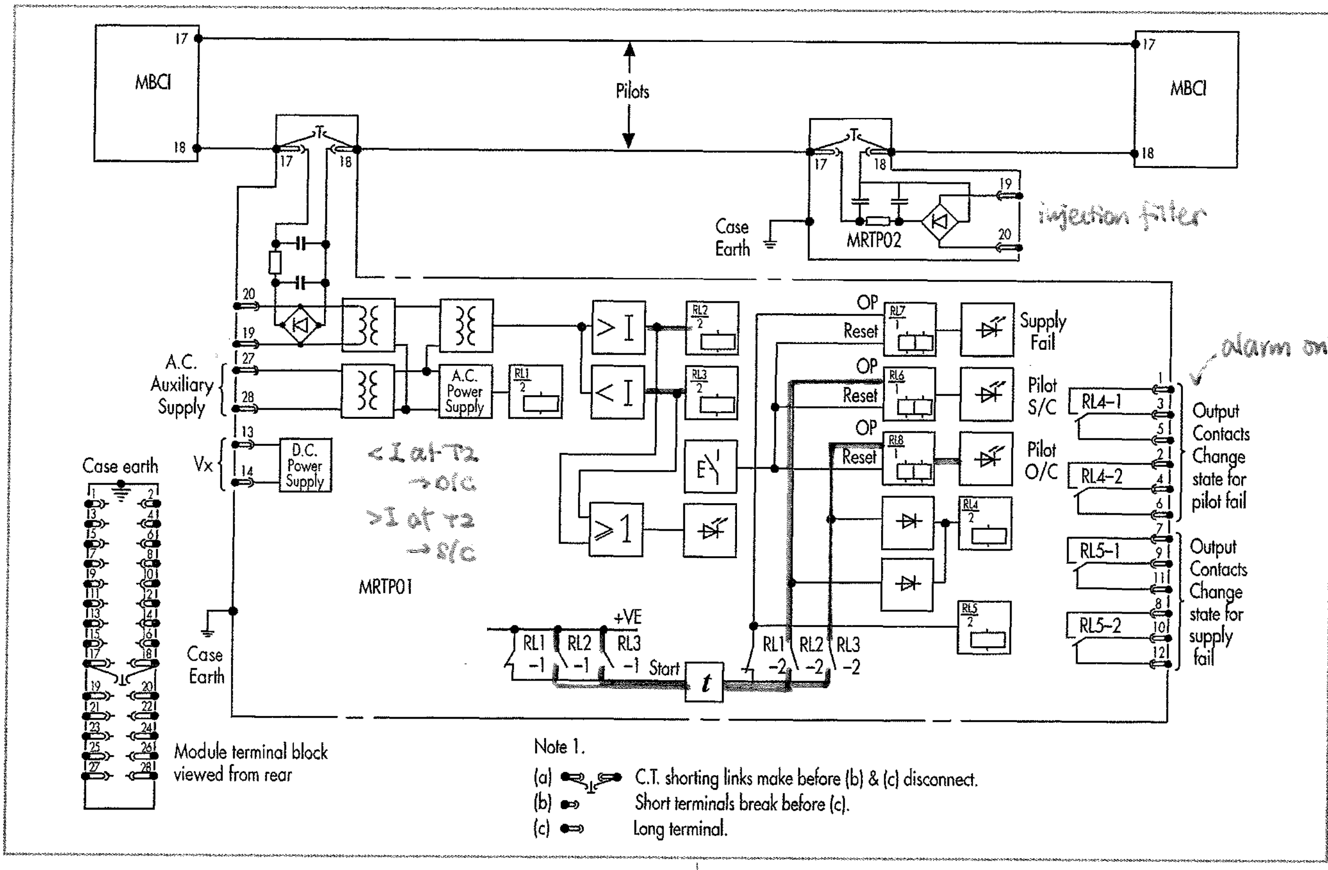


Figure 3 | Application diagram: pilot supervision relay and injection filter type MRTP 01

R3

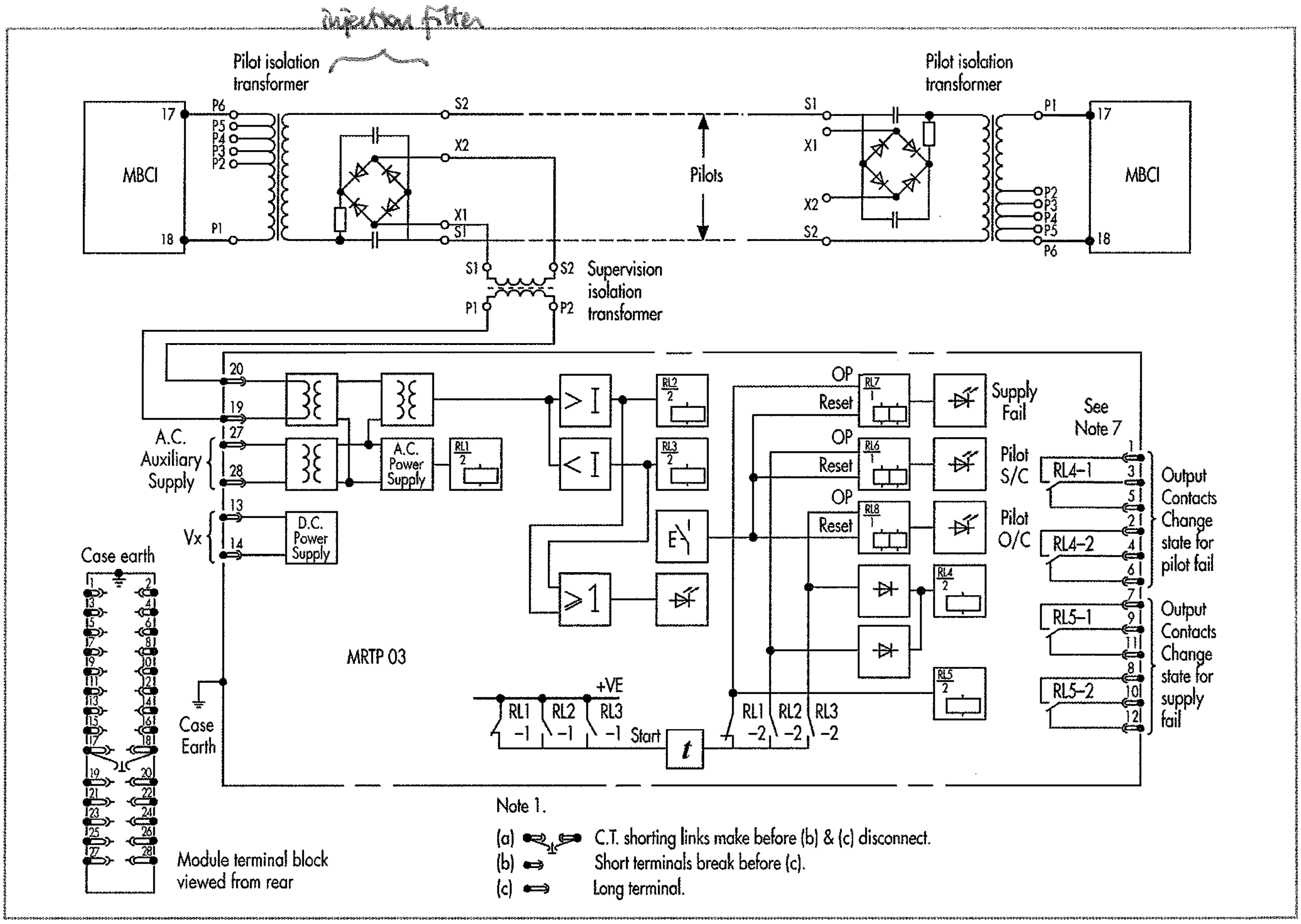


Figure 4 | Application diagram: pilot supervision relay 15kV isolation type MRTP 03

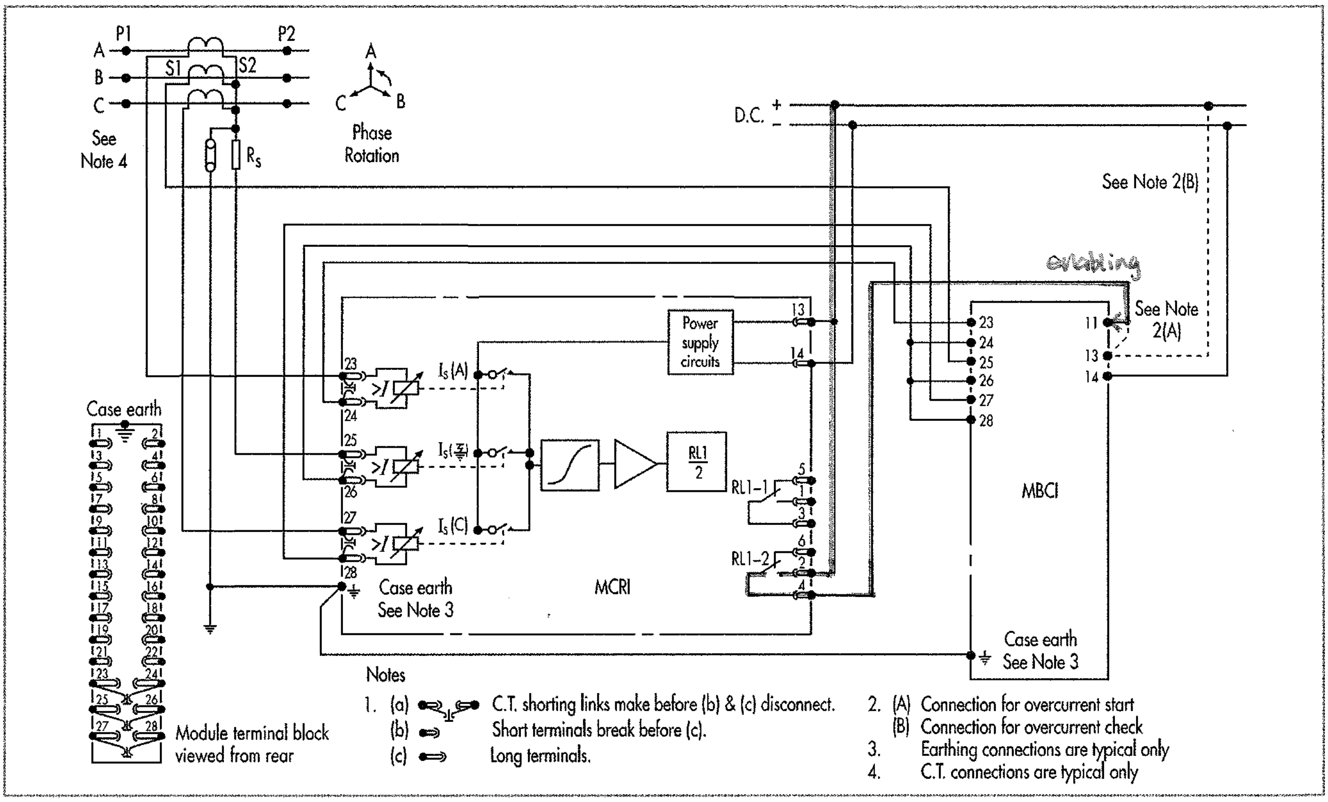


Figure 5 | Application diagram: overcurrent relay type MCRI 01

P.K

• = included
– = excluded.

Transformer Feeders (use of transformer inrush current detector)

In the case of transformer feeders where there is no circuit breaker separating the transformer from the feeder, the phenomenon of transformer magnetising inrush must be considered. This is a transient condition which may occur at the instant of transformer energisation, or immediately following a system voltage drop due to a nearby heavy fault condition. Magnetising inrush current is not a fault condition and therefore does not necessitate the operation of protection equipment which, on the contrary, must remain stable during the inrush transient. The inclusion of a type MCTH relay, designed to provide a blocking signal in the presence of transformer inrush currents, enables a pilot wire differential protection scheme to be applied to a transformer feeder. Where line and therefore transformer energisation can occur at one end only of the transformer feeder, then a MCTH unit would be required on that side only.

Energy inrush

When the feeder transformer is energised any resulting inrush current will be detected by the MCTH relay, the output blocking unit of which will pick-up causing the pilot wires of the Translay S to be short-circuited. This will stabilise the differential relay and prevent it from responding to what would otherwise appear to be an in-zone fault. The immunity to operation due to inrush current is coupled with fast fault clearance times and the built-in overcurrent detectors of the MCTH relay ensure that the blocking feature is overridden if a fault is detected in one phase whilst inrush is present in another.

require stabilising both side by shorting

Symbols:


15kV Isolating transformer


15kV Isolating transformer with injection filter

Scheme	Pilot Insulation Level (kV)	Supervision	O/C Start/Check	Arrangement of Equipment (Viewed from front)
A	5kV	—	—	1 ---- 1
B	15kV	—	—	1 ---- 1
C	5kV	•	—	2 1 ---- 3 1
D	15kV	•	—	4 1 ---- 1
E	5kV	—	•	1 5 ---- 1 5
F	15kV	—	•	1 5 ---- 1 5
G	5kV	•	•	2 1 5 ---- 3 1 5
H	15kV	•	•	4 1 5 ---- 1 5

Table 1. Typical scheme arrangements for plain feeders. See key below.

Scheme	Pilot Insulation Level (kV)	Supervision	Transformer Arrangement	Arrangement of Equipment (Viewed from front)
I	5kV	—	Δ/Y	1 8 9 7 ---- Pilots ---- 1 8
J	15kV	—	Δ/Y	1 8 9 7 ---- 1 8
K	5kV	•	Δ/Y	1 8 2 9 7 ---- 1 8 3
L	15kV	•	Δ/Y	1 8 4 9 7 ---- 1 8
M	5kV	—	Y/Δ/Y	1 8 ---- 1 8
N	15kV	—	Y/Δ/Y	1 8 ---- 1 8
O	5kV	•	Y/Δ/Y	1 8 2 ---- 1 8 3
P	15kV	•	Y/Δ/Y	1 8 4 ---- 1 8

Table 2. Typical scheme arragements for transformer feeders. See key below.

No.	Type of relay	
1	MBCI 01/02	Differential
2	MRTP 01	Pilot supervision and injection filter
3	MRTP 02	Injection filter
4	MRTP 03	Pilot supervision
5	MCRI 01	Overcurrent start/check
6	MVTW 01	Destabilising
7	MVTW 03	Destabilising and Intertripping Schemes A to D can be fitted with relay types 6 or 7. Schemes E to H can be fitted with type 6 which will provide destabilising if the overcurrent start/check relays (MCRI 01) have operated. Schemes I to L must use type 7 or 8.
8	MCTH 01	Transformer inrush current detector
9	MFAC 14	High impedance earth fault relay
10	MMLG	Test plug/block It is advisable on all schemes to include the test unit to facilitate commissioning and routine testing. The unit will be situated on the right-hand side of the scheme.

open pilot → no restraint current

short pilot → higher restraint current due to smaller R

Description

Differential protection

The differential feeder protection circuit is derived from the well known Merz-Price circulating current system but employs phase comparators as the measuring elements. This novel combination provides high stability performance for external faults with the minimum of bias (restraint) quantity thereby ensuring that the low earth fault settings are effectively retained even when load current is flowing. Figure 1 shows the basic circuit arrangement. A summation current transformer T1 at each line end produces a single phase current proportional to the summated three phase currents in the protected line. The neutral section of the summation winding is tapped to provide alternative sensitivities for earth faults. 3φ → 1φ

The secondary winding supplies current to the relay and the pilot circuit in parallel with a non-linear resistor (RVD). The non-linear resistor can be considered to be nonconducting at load current levels. Under heavy fault conditions it conducts an increasing current and thereby limits the maximum secondary voltage. # At normal current levels the secondary current flows through the operating winding T_o on transformer T2 and then divides into two separate paths, one through R_o and the other through the restraint winding T_r of T2, the pilot circuit and resistor R_o of the remote relay.

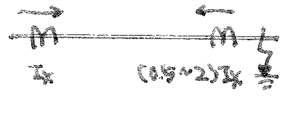
The resultant of the currents flowing in T_r and T_o is delivered by the third winding on T2 to the phase comparator and is compared with the voltage across T_t of Transformer T1. The emf developed across T_t is in phase with that across the secondary winding T_s which is in turn substantially the voltage across R_o.

Taking into account the relative values of winding ratios and circuit resistance values, it can be shown that the quantities delivered for comparison in phase are:

$(I_X + 2I_Y)$ and $(\boxed{2I_X} + I_Y)$ normal load/ through fault

where I_X and I_Y are the currents fed into the line at each end (for through faults I_X=I_Y). The expressions are of opposite sign for values of I_Y which are negative relative to I_X and are between $0.5I_X$ and $2I_X$ in value. The system is stable with this relative polarity and operates for all values of I_Y outside the limits.

$sgn(I_Y) = -sgn(I_X)$ → stability.



CT polarity

The phase comparator has angular limits of ± 90° giving a circular bias characteristic in the complex plane. # If the pilots are open circuited, current input will tend to operate the relay. Conversely, short-circuited pilots will cause the relay to restrain, holding its contacts open.

Transformers T1 and T2 also provide the necessary insulation barriers for static circuitry. The input circuits of the phase comparator are tuned to the power frequency so that the threshold of operation increases with frequency. This de-sensitises the relay to the transient high frequency charging current that flows into the line when it is energised. A further advantage provided by the # tuned input is that the waveform of the derived signal, which may be severely distorted by current transformer saturation, is improved, ensuring high speed operation under adverse conditions. In order to maintain the bias characteristic at the designed value it is necessary to pad the pilot loop resistance to 1kΩ. CT sat

A padding resistor Rpp is provided in the relay for this purpose.

Pilot isolation transformers

When pilot isolation transformers are used, the range of primary taps enables pilots of loop resistance up to 2.5kΩ to be matched to the relay. The pilot insulation level is also raised to 15kV by these transformers.

Telephone type pilots

When the pilots to be used are of the telephone type, an alternative limiter based on a zener diode is available to ensure that the maximum voltage which can appear on the pilot system is within prescribed limits. Pilot isolating transformers can be used in this arrangement also, both to provide insulation to 15kV and also indirectly to enable pilots of relatively high resistance to be used.

Pilot supervision

Figure 3 shows the arrangement for pilot supervision in a pilot circuit insulated for 5kV. In this instance the injection filters and the supervision unit are assembled with the relay case. (Types MRTP 01/02).

nominal setting = 2× pilot open fault setting due to 2Ix factor.

Figure 4 shows the similar arrangement for pilot circuits insulated for 15kV (Type MRTP 03).

The injection filters are then assembled as part of the isolation transformer and have to be isolated from the supervision relay. The supervision isolation transformer provides the necessary 15kV isolation barrier. For further technical information see Publication R6026.

Destabilise and Intertrip Facilities

MVTW01

shorted side keep stable

Refer to Figure 6.

Operation of the destabilising relay (UN) results in the summation current transformer in the differential relay being short circuited and the local relay prevented from tripping. The remote relay then sees a single end feed condition and trips, provided the through current exceeds the no-load fault setting of the protection (see Table 5 page 18). Typical operating times are shown in Figure 7.

Terminals 17 and 20 should normally be linked together on the destabilising relay. However, the operating level of the remote equipment can be reduced to one half of the normal fault setting (under destabilising operation only) if this link is omitted. # remove for lower setting

It should be noted that, with this link omitted, if the destabilising relay UN is operated for longer than the supervision time delay (6-10 seconds) an indication of pilot failure will be given. This does not apply if pilot isolating transformers are used.

When overcurrent elements are used to provide a starting or check function there is no advantage in removing this link 17-20 since, for operation, the through current must exceed the overcurrent setting.

MVTW 03

A circuit diagram for the MVTW 03 type relay which depicts the destabilising, intertrip and inverter function is shown in Figure 8. On energising the relay, a green LED illuminates and the normally closed contacts of RL1 open to indicate the supply is healthy and the inverter is operating.

The MVTW 03 incorporates a full bridge inverter, which receives complementary square wave signals from the oscillator circuit at a frequency of 80Hz. This frequency was chosen because it lies sufficiently far from the pilot frequency of 50 or 60Hz and cancellation of the intertripping signal will not be caused by the beat frequency that may be produced.

The inverter is continually energised and supplies a transformer which isolates the pilots to 5kV from the input circuits. The transformer supplies the intertripping current and the power supply for the output relay (RL2).

Intertripping is initiated by applying a trip signal to terminal 11 which energises the output relay.

The signal is isolated from the pilots to 5kV by the opto isolator. When the output relay (RL2) is operated, the local MBCI is made stable by shorting terminal 18 to terminal 19. This action destabilises the remote MBCI. If the load current level is greater than the differential current setting the remote MBCI trips; however if the current level is lower than the setting the remote MBCI does not trip. To ensure intertripping occurs the output relay (RL2) injects a 20mA intertrip current into the pilots; the remote MBCI sees the intertrip current as a differential current which causes it to trip.

For further technical information see Publication R6027.

A typical scheme for a delta–star power transformer is shown in Figure 9. The line current transformers are connected in star on the delta side of the transformer. Appropriate choice of CT ratios ensures that for normal load and through fault conditions, equal currents flow into the differential tripping units (MBCI) at each end.

A high impedance differential relay (type MFAC 14) is included in the neutral lead of the star-connected line transformers to give lower earth fault settings on the delta side of the power transformer. The MFAC 14 high impedance differential relay may be used to initiate an intertrip unit (type MVTW 02).

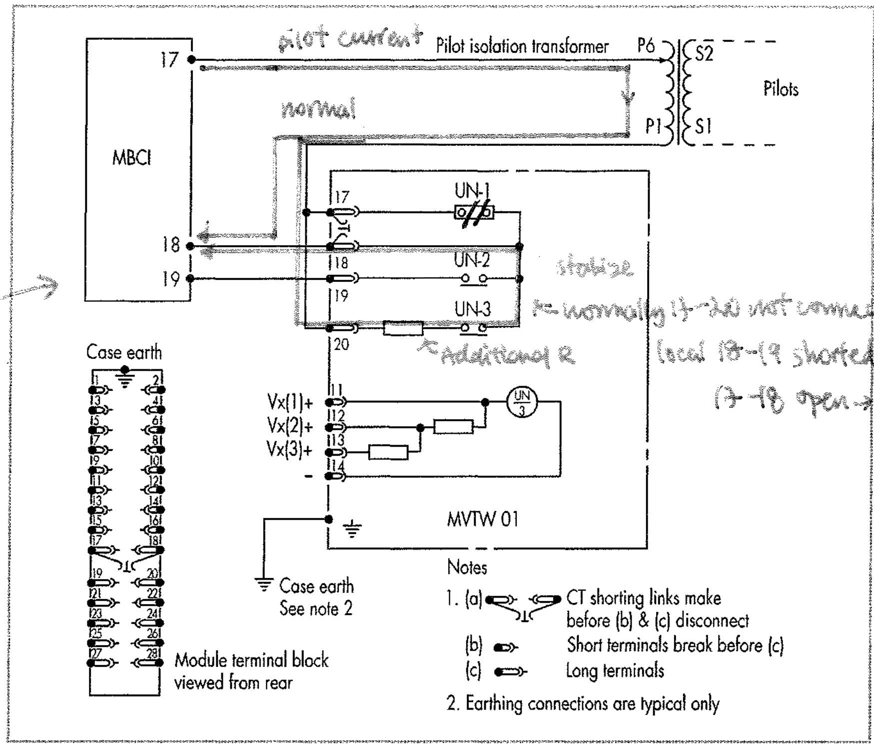


Figure 6 | Application diagram: destabilising relay type MVTW 01

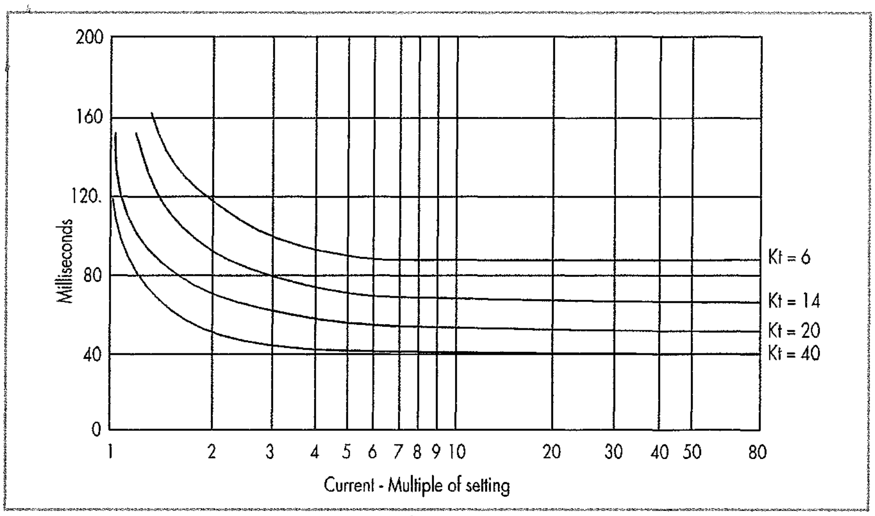


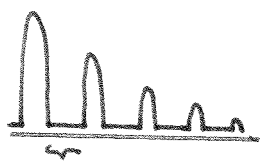
Figure 7 | Time characteristic for destabilised operation

Transformer Inrush Current Blocking

Transformer inrush current detector feature

Refer to Figure 9.

The principle of operation of the transformer inrush current detector (MCTH) is based upon a unique feature of substantially zero for significant periods in each cycle. During load or fault conditions, the current waveform remains at zero for negligible periods in each cycle. The relay detects these zero periods in the inrush waveform and initiates a blocking relay, which causes the pilot wires of the Translay S relay to be short-circuited, preventing tripping for transformer inrush current.



detect zero period.

Figure 8 | Destabilising and intertripping relay type MVTW 03

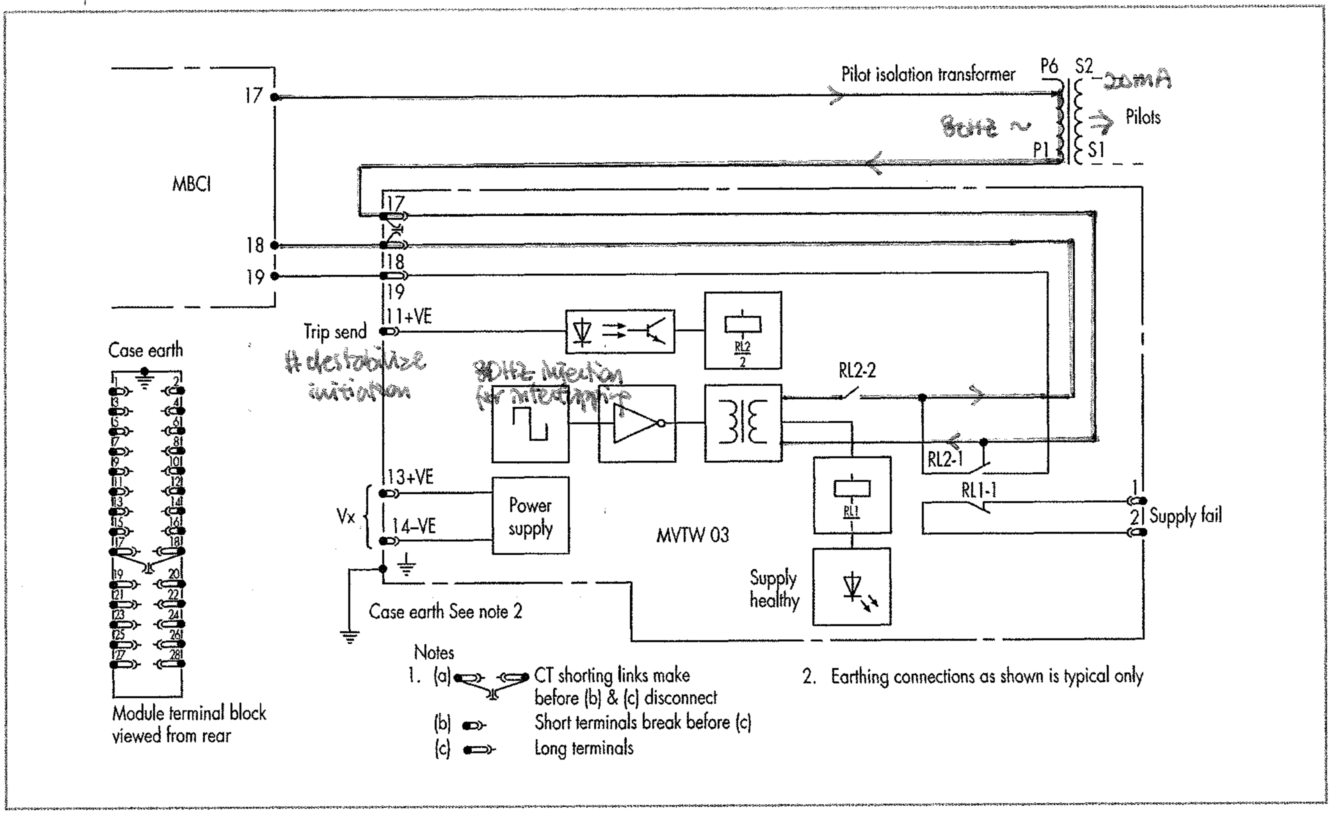
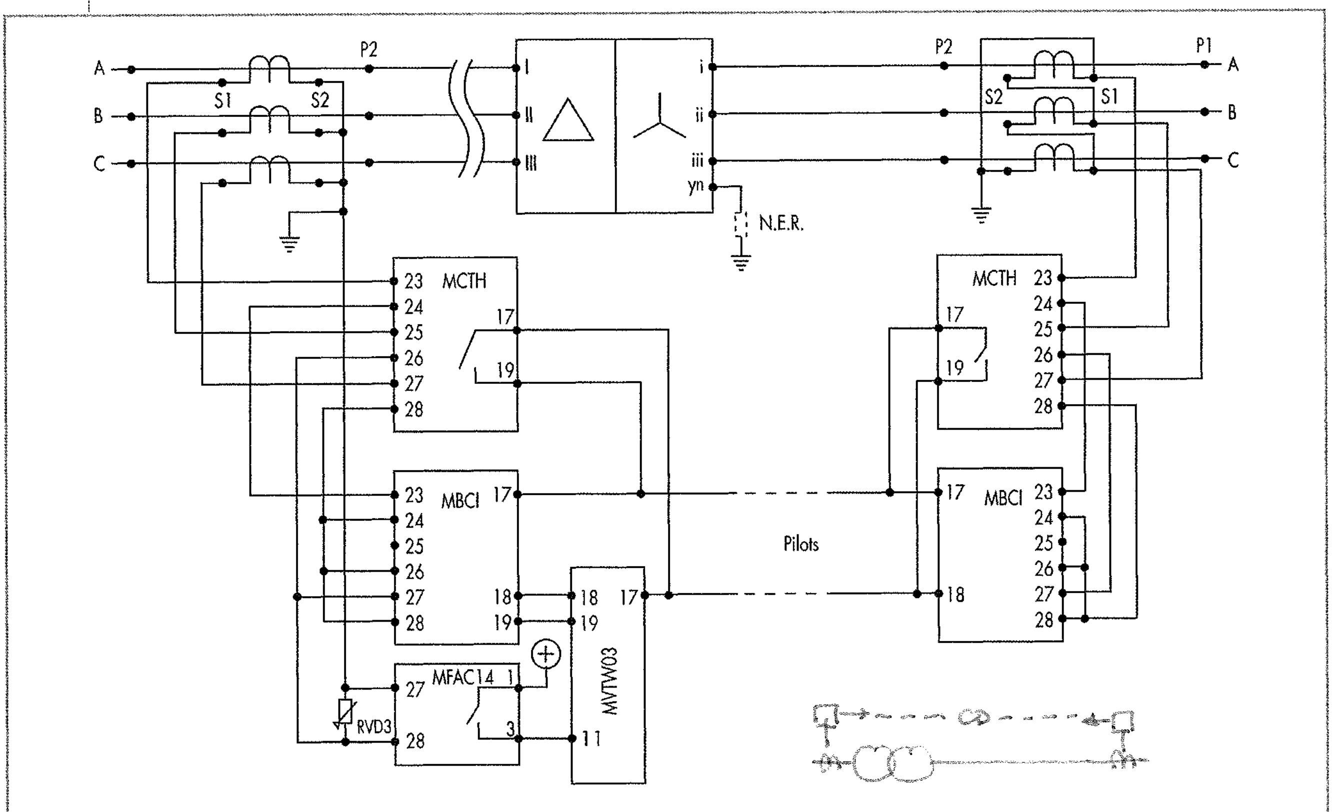


Figure 9 | Typical application diagram: overall protection of transformer feeders



Note1: It is essential that the current transformer connections are earthed at one point only.

Figure 11

Pilot voltage characteristics

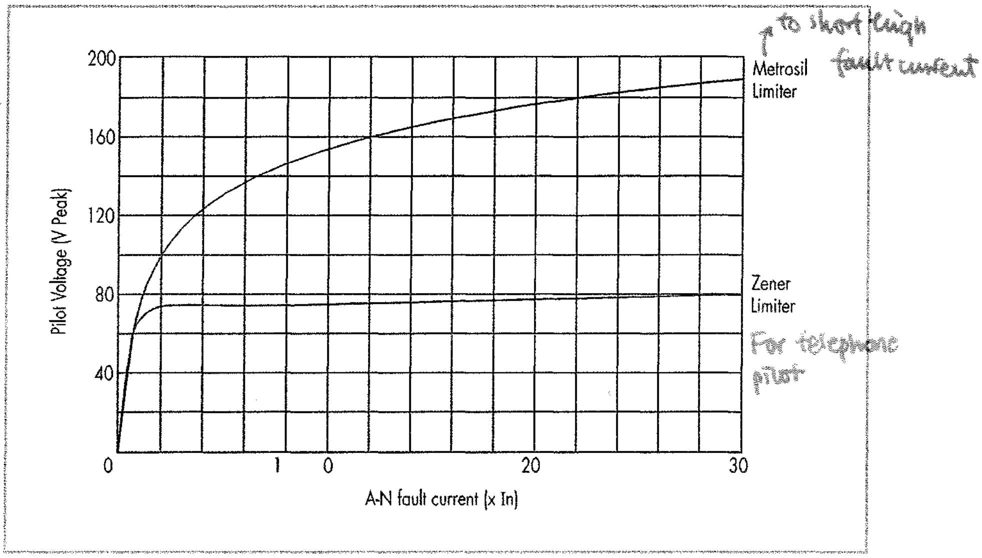
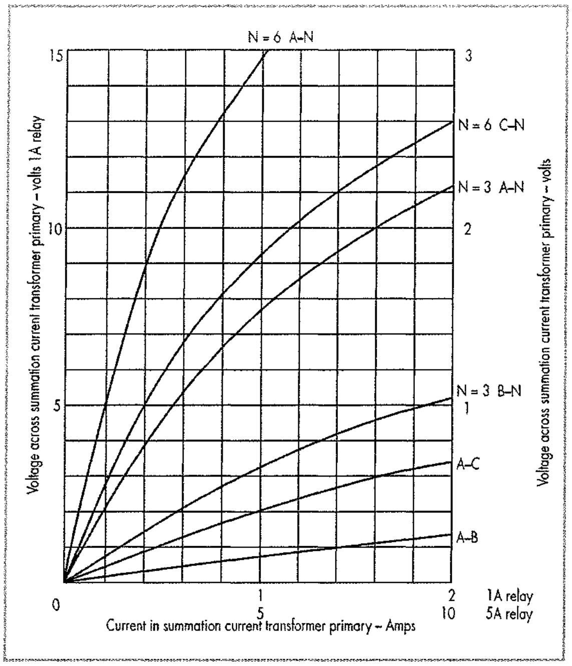


Figure 10: Current circuit burden



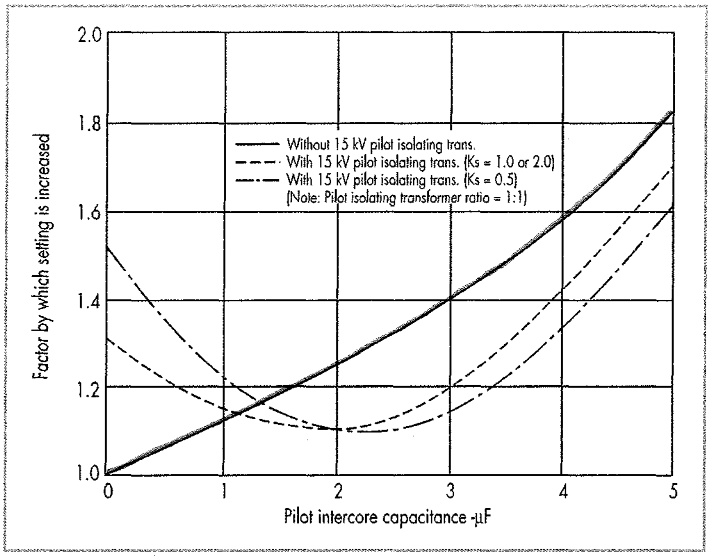
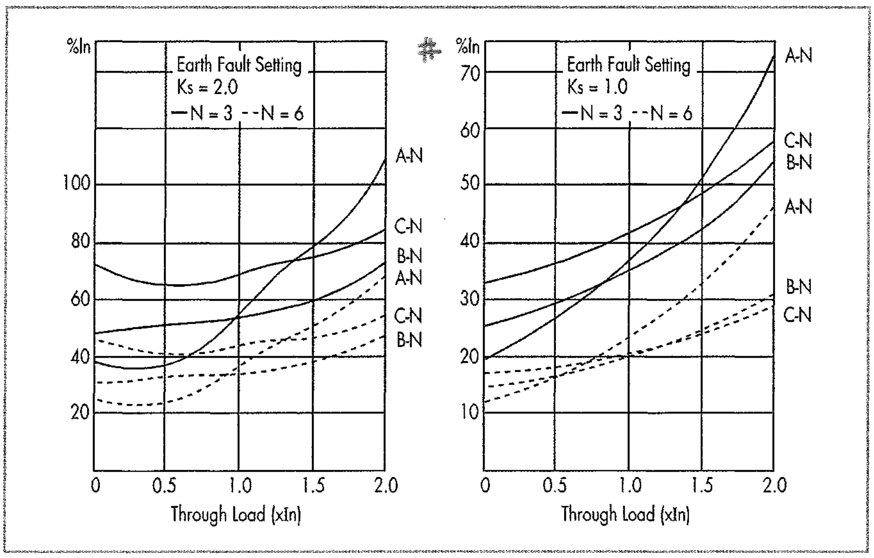


Figure 12 | Effect of pilot capacitance and pilot isolating transformers on setting

Figure 13

Minimum earth fault current for operation with through load



stabilizing effect

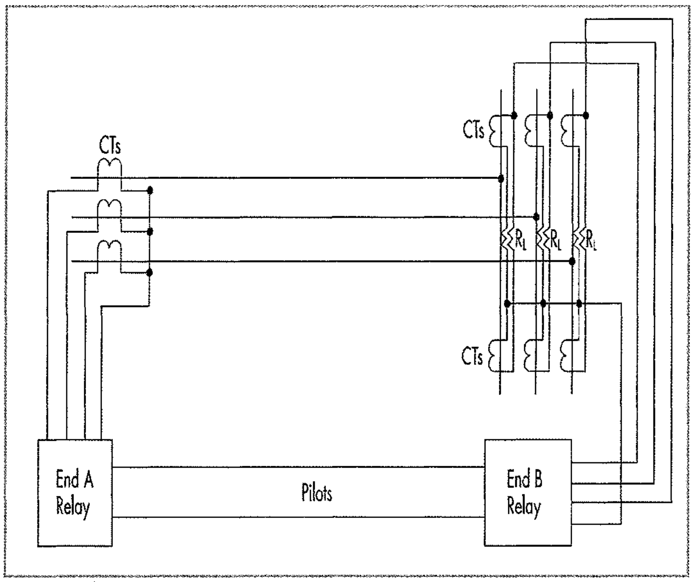


Figure 14 | Mesh type switchgear arrangements

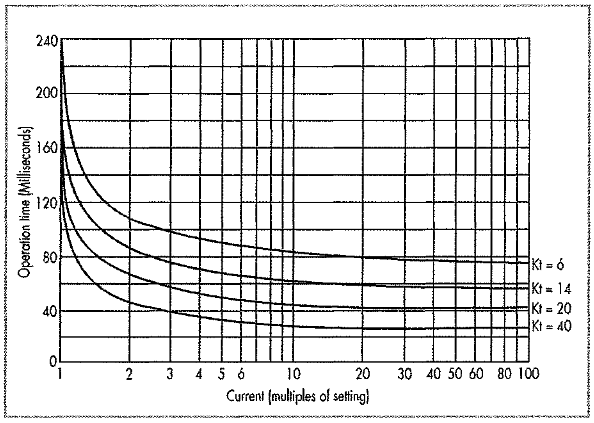
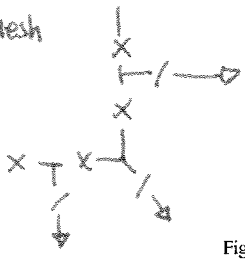


Figure 15 | Time characteristics for internal faults

Kt = time dependent constant

= 40

Mesh



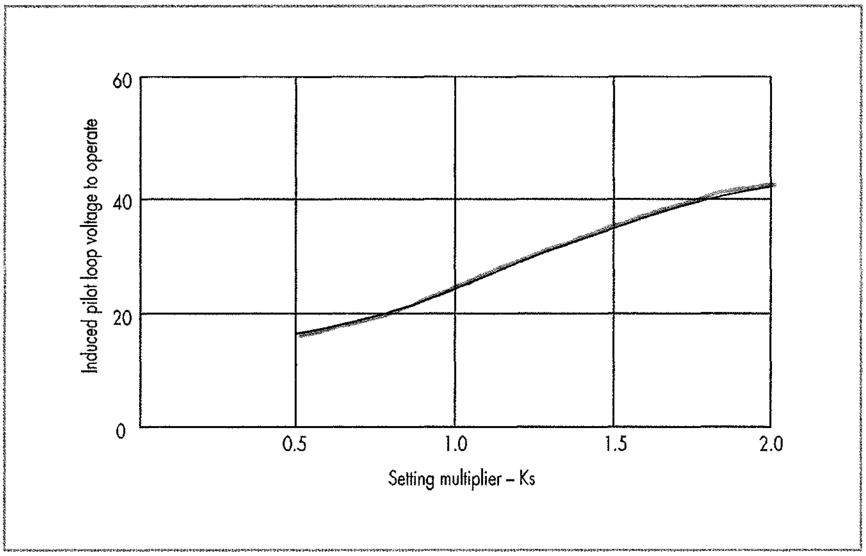


Figure 16

Response to spurious induced loop voltage in pilots

driving loop current

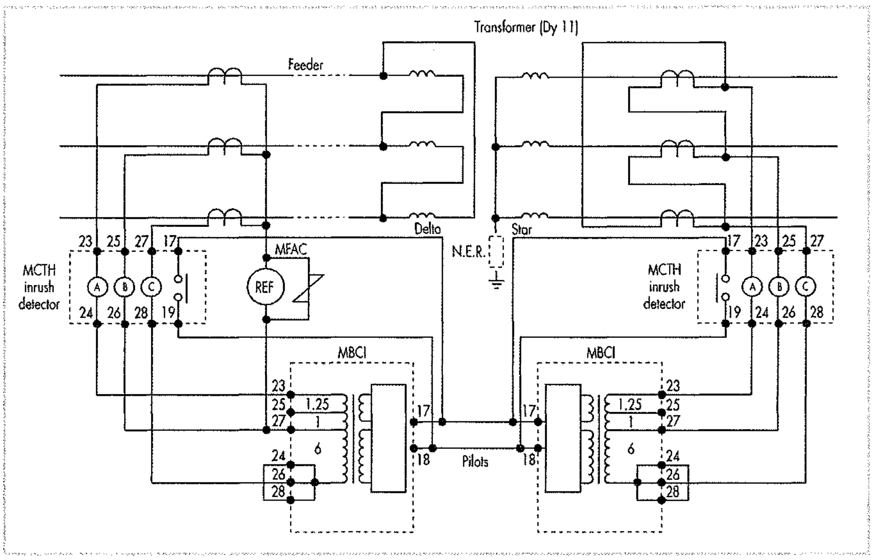


Figure 17

Overall protection of transformer feeders showing connections to MBCI relay

Technical Data (MBCI Relay)

Current rating (In)

1A, 2A or 5A

Frequency rating

50Hz or 60Hz

Current withstand ratings

Duration (s)	Differential
Continuous	2In
3	45In
2	55In
1	80In
0.5	100In

Table 2

Current circuit burden

Highest phase burden
(with three phase rated current)
6VA N = 6
3.5VA N = 3
At setting current 0.5VA

Auxiliary supply

Rated voltage (Vx)	Operative range (V)	Current drain (mA) Quiescent	Operated
24/27	19.2–32.4	30	17.5
30/34	24–37.5	15	175
48/54	37.6–72	15	175
110/125	87.5–150	15	90

Contacts

Contact arrangements
2 make and 2 change-over
(See Figure 2)

Contact ratings

- Make and carry for 0.2s 7500VA subject to maxima of 30A and 300V ac or dc
- Carry continuously 5A ac or dc
- Break
  ac 1250VA
  dc 50W resistive
  25W inductive
  L/R = 0.045s
  subject to maxima of 5A and 300V

Durability

- Loaded contact
  10,000 operations minimum
- Unloaded contact
  100,000 operations minimum

Reset time

Less than 100ms

Indication

A non-volatile LED trip indicator is used. If the auxiliary supply is lost the LED will return to the same state when the supply is restored.

Stability level

The stability of the protection for through faults is greater than 50In

High voltage withstand

- Dielectric withstand

IEC 60255-5: 1977
2.0kV rms for 1 minute between all terminals and case earth.

2.0kV rms for 1 minute between all terminals of independent circuits, with terminals on each independent circuit connected together.

5.0kV rms for 1 minute between pilot terminals and all other terminals and case earth.

1.0kV rms for 1 minute across normally open contacts.

- High voltage impulse

IEC 60255-5: 1977
Three positive and three negative impulses of 5.0kV peak, 1.2/50µs, 0.5J between all terminals and all terminals and case earth.

Electrical environment

- DC supply interruption

IEC 60255-11: 1979
The unit will withstand a 10ms interruption in the auxiliary supply, under normal operating conditions, without de-energising.

- AC ripple on dc supply

IEC 60255-11: 1979
The unit will withstand 12% ac ripple on the dc supply.

- High frequency disturbance

IEC 60255-22-1: 1988 Class III
2.5kV peak between independent circuits and case.

1.0kV peak across terminals of the same circuit.

- Fast transient disturbance

IEC 60255-22-4: 1992 Class IV
4.0kV, 2.5kHz applied directly to auxiliary supply.

IEC 60801-4: 1988 Level 4 4.0kV, 2.5kHz applied to all inputs.

- Surge immunity

IEC 61000-4-5: 1995 Level 3
2.0kV peak, 1.2/50ms between all groups and case earth.

2.0kV peak, 1.2/5-ms between terminals of each group.

- EMC compliance

89/336/EEC
Compliance to the European Commission Directive on EMC is claimed via the Technical Construction File route.

EN 50082-2: 1994
EN 50082-2: 1995
Generic Standards were used to establish conformity.

- Product safety

CE 73/23/EEC
Compliance with the European Commission Low Voltage Directive.

EN 61010-1: 1993/A2: 1995
EN 60950: 1992/A11: 1997
Compliance is demonstrated by reference to generic safety standards.

Atmospheric environment

- Temperature

IEC 60255-6: 1988
Storage and transit –25°C to +70°C
Operating
–25°C to +55°C

IEC 60068-2-1: 1990 Cold

IEC 60068-2-2: 1974 Dry heat

• Humidity

IEC 60068-2-3: 1969
56 days at 93% RH and 40°C

• Enclosure protection

IEC 60529: 1989
IP50 (dust protected)

• Mechanical environment

Vibration
IEC 60255-21-1: 1988
Response Class 1

Pilots

Pilots isolation

Pilot isolation transformers are required when any longitudinally induced voltage in the pilot circuit is likely to exceed 5kV: in effect this means when protecting feeders operating at voltages in excess of 33kV, unless these are short in length.

The use of pilot isolation transformers also extends the acceptable range of pilots. This is achieved by the matching ratios available as shown in Table 4.

Pilot voltage

The voltage applied across the pilots varies with fault current as shown in Figure 12. For normal through load conditions the peak pilot voltage will be in the order of 50V rising to a maximum of: 200V for MBCI 01, 80V for MBCI 02 under fault conditions.

When pilot isolation transformers are used this value of voltage is multiplied by K_M.

Note: Types MBCI 01 and 02 are not compatible. Relays should be of the same type at either end.

Pilot current

The pilot current is typically 30mA for normal through load conditions and rises to a maximum of 300mA under through fault conditions.

Ko=1.1

Line charging current

In applications pertaining to cables, with or without in zone shunt reactors, and overhead lines, it is necessary for the most sensitive fault setting to be increased to:

• 1.1 times the steady state line charging current for solidly earthed systems

• 3.2 times the steady state line charging current for resistance earthed systems

• 1.9 times the steady state line charging current for resistance earthed systems with one relay per phase

In all cases, allowance should be made for some system overvoltage.
This requirement ensures stability during external ground faults which will cause the three phase capacitance currents to be unequal, resulting in an increased output from the summation transformer.

The high frequency line in-rush currents can be neglected because the setting of the relay automatically increases at high frequencies by a factor:

$$\frac{\text{Inrush frequency}}{\text{Rated system frequency}}$$

Pilots

K_M	0.8	1.0	1.2	1.5	2.5	Matching ratio
Loop resistance	800	1000	1200	1500	2500	Ω
Capacitance	6.25	5	4.2	3.3	2	µF
Terminals	P1-P6	P1-P5	P1-P4	P1-P3	P1-P2	

Table 4

Where K_M = (turns ratio)2 for respective tap of pilot isolation transformers.

When pilot isolation transformers are not used K_M = 1.

KM = 1.0 to match P1/P5 tap of Isolation transformer.

The optimum value for KM is the nearest value $R_p/1000$ in Table 4, where R_p is the measured pilot loop resistance.

There are two types of pilot isolation transformers: ZC0244-002 for schemes without pilot supervision: HN0068-001 for schemes with pilot supervision. The latter includes the injection filter for the pilot supervision circuit.

The pilot padding resistor (R_{pp}) at each end should be set to:

$1/2(1000 - R_p/K_M)$

rated earthing config

$0.19 K_S I_r \geq K_0 I_c$ charging current

$I_{ef} \geq 2 \cdot 0.33 K_S I_r$

min EF.

Overcurrent starter/check element settings

The maximum resetting value of the overcurrent elements is not less than 90% of the operating value. Thus, to ensure that they will reset when the current is restored to the full load level, the setting should be at least 1.2 times the maximum anticipated through load current.

The setting of the earth fault elements should be at least 1.2 times any standing zero sequence current and not higher than 80% of the minimum earth fault current. mainly due to charging

The value chosen as an assessment of minimum earth fault current must be conservative, due allowance being made for all aspects of minimum system operating conditions and fault impedance; alternatively, a larger tolerance below the nominal minimum fault current value is advisable.

Unit Protection of Plain Feeders

Fault settings for plain feeders

The input transformer has a summation ratio of 1.25:1:N where N = 3 for normal use. N = 6 is used where low earth fault settings are needed. The minimum operating current will therefore be dependent on the phase or phases involved in the fault. The minimum earth fault current (If) should be greater than twice the least sensitive earth fault setting to ensure rapid fault clearance.

The range setting of fault settings is shown in Table 5.

Differential (Summation ratio = 1.25/1/N)	Fault	Settings N=3	N=6
Ks is a setting multiplier	A – N	$0.19K_s$.In	$0.12K_s$.In
and may be varied	B – N	$0.25K_s$.In	$0.14K_s$.In
from 0.5-2.0	C – N	$0.33K_s$.In	$0.17K_s$.In
In is the rated relay current	A – B	$0.8K_s$.In	
	B – C	$1.0K_s$.In	
	C – A	$0.44K_s$.In	
	A – B – C	$0.5K_s$.In	

Table 5

The minimum operating current of the relay will be increased by any shunt impedance connected across the pilot wires, for example, pilot capacitance and the magnetising path of the pilot isolation transformers. The effect of the pilot capacitance is shown in Figure 12.

Values of Ks from 0.5 to 1.0 are provided to achieve effective fault setting equal to the nominal value indicated in Table 5. This is achieved by single end injection tests during commissioning. Values of Ks from 1.0 to 2.0 are used to increase the setting when the application demands. Refer to section: Line charging current.

Minimum operation for earth faults with through load

Bias being a direct function of through current, increases minimum operating current with through load. Figure 14 shows the minimum earth fault current required for various levels of through load.

The curves shown are for the first relay to trip. The second relay will trip sequentially provided the resulting in-feed at that end is above the setting value. To ensure that simultaneous tripping will occur the minimum fault current should be greater than twice the minimum operating current given in Figure 14.

Line current transformer requirements for plain feeders

Class X BS 3938

- $V_K \geq 0.5N\, K_t\, I_n\, (R_{CT} + XR_L)$

Where

V_K = knee point voltage of current transformers for through fault stability

R_{CT} = resistance of current transformer secondary circuit (Ω)

R_L = lead resistance of single lead from relay to current transformers (Ω)

X = 1 for 4 wire connections between the main current transformers and the relay: 2 for 6 wire connections

N = relative neutral turns on summation transformer winding (3 or 6, as shown under heading Current Settings)

K_t = the selected time-dependent constant (40, 20, 14, 6 or 3)

*Note; For all applications at or above 220kV where X/R ratios are large use:

$V_K \geq N\, K_t\, I_n\, (R_{CT} + XR_L)$

$\rightarrow K_t < \dfrac{V_K}{N\, I_n\, (R_{CT} + XR_L)}$.

→ Kt selected to be 40, to enable fastest operation.

It is not necessary for the line current transformers at the two ends of the protected system to have the same knee point voltage. Differences of up to 4:1 can be tolerated provided both are above the minimum value. However, the three line current transformers at any one end should have similar magnetising characteristics.

• Magnetising current:

In order that the minimum effective operating current of the relay remains low, it is necessary to apply a limit to the value of the magnetising current demanded by the line current transformers:

$$I_M \leq 0.05\ I_n \text{ at } \frac{10}{I_n} V$$

• Mesh type switchgear arrangements

The relay may be fed by parallel connected current transformers as shown in Figure 15. It is essential to balance the lead resistance in the circulating secondary current path to ensure stability for a through busbar fault. Connecting the current transformers as shown in Figure 15 will result in the required balance being obtained. It is essential that the current transformers at the same end should have similar magnetising characteristics. The value of R_{CT} to be used in calculations should be the resistance of one current transformer plus the resistance of one lead between the two parallel connected current transformers. The value of RL should be the resistance of a single lead from the common connection of the current transformers to the relay.

• Methods of reducing the current transformer requirements:

In general the larger the current transformer the better the overall performance. However, when current transformer size is critical the following notes should prove helpful.

• The operation time varies with fault current as shown in Figure 16. Stability is maintained with smaller current transformers if the value of K_t is reduced.

This will of course result in the operation time increasing, typical operation times being:

K_t	40	20	14	6	3
Time at 5x setting	30	50	65	90	300(ms)

• Kt= 20 will suit most current transformers on distribution systems Kt = 40 is the preferred setting for EHV systems where high speed operation is required

• It should be noted that the knee point requirement increases with the nominal current rating I_n. Advantage is therefore obtained by using a low value of rated current eg. 1A or even 0.5A.

• Wires may be connected in parallel to reduce the lead resistant (R_L) and hence the current transformer requirements.

• If the relay is fed from delta connected line current transformer then N = 1.

• If one relay is used per phase then assume N = 1

Stabilising resistance

$$R_s = \frac{V_K}{40 I_n}\ \Omega \text{ but not greater than } \frac{12}{I_n^2}\ \Omega$$

Note: This resistor is not required for single phase protection or when Translay S is fed from delta connected current transformers.

Additional requirements:

• It is a stability requirement that the relays at both ends have the same value of N & Kt selected.

• It is preferred, although not absolutely essential, that the equipment at the two line ends have the same rated current I_n.

Small in-zone teed loads

Small three phase loads may be connected to the feeder within the protected zone; normally these will be supplied by a delta/star transformer connected to the line through HRC fuses. Substantial faults on this circuit will cause the fuses to blow very quickly before the differential relay can operate.

The limiting condition is a value of fault current which will just produce an A–C phase setting current in the relay: this current must cause the fuse to operate quickly enough to discriminate. Most fusing time curves show pre-arcing time and some allowance must be made for the arcing period.

To accommodate the largest teed load, use may be made of the Ks (setting multiplier) adjustment, and/or selection of a value of Kt corresponding to a lower operating speed.

The particulars tabulated below for teed loads connected to a fused 11kV feeder may be helpful as a general example.

Feeder 11kV 300A rating

Tee Transformer rating(kVA)	Fuse rating (A)	K_s	K_t
300	20	1	40
400	25	1.7	40
400	25	1.5	6
500	30	1.75	3

Table 6

The table above refers to individual teed loads. When smaller loads are connected at separate locations, on the basis that only one will be subject to a fault at any instant, the aggregate load may be greater. For example twelve 100kVA transformers each protected by 10A fuses could be connected to the above line, with main protection settings K_s = 1 and K_t = 40. Similarly for ten 300kVA transformers each protected by 20A fuses, relay settings K_s = 2.0 and K_t = 20 would be suitable. In general the aggregate tee-off load should not exceed $0.25K_s$ x current transformer rating.

Maximum induced pilot loop voltage

Ideally the pilot cores should be wormed (twisted together) so that the induced loop voltage is kept to a minimum. The required level of this voltage to cause operation varies with the setting multiplier Ks as shown in Figure 17.

Unit Protection of Transformer feeders

Fault Setting

The relay internal summation is identical to that used for plain feeders but the turns ratio used is 2.25:6. This is connected as shown in Figure 18 and will result in secondary settings as given in the table below:

Relay setting in amps = Ks x I_n constant in table below

A to N	0.44
B to N	∝
C to N	0.17
A to B	0.44
B to C	0.17
C to A	0.12
3 Phase	0.14

Table 7

Where

Ks = setting multiplier which may be adjusted between 0.5 and 2.0

I_n = relay rated current.

NB. The Figures quoted in this table are those to be expected under conditions of secondary injection testing

Note 1: As shown in Figure 18 there is a restricted earth fault relay in the neutral of the star connected CTs on the delta side of the power transformer. This provides protection against earth faults on the delta side of the power transformer when the infeed is into the delta. It will provide settings lower than any of the phase to neutral settings given above.

Note 2: The MBCI relay, when used in the transformer feed application, does not require a stabilising resistor.

Line Current Transformer Requirements for Transformer Feeders:

Operating times less than 80ms will be achieved and through fault stability assured provided the following CT requirements are satisfied (K_t = 14):

For star connected CTs

$$V_k \geq 50\ I_n \left(\frac{2.2}{I_n^2} + R_{CT} + R_L\right)$$

For delta connected CTs

$$V_k > \frac{50 I_n}{\sqrt{3}} \left(\frac{9.7}{I_n^2} + R_{CT} + R_L\right)$$

If longer operating times can be tolerated CT requirements to the following formulae will give operating times less than 160ms and assured through fault stability (K_t = 14):

For star connected CTs

$$V_k \geq 35\ I_n \left(\frac{2.2}{I_n^2} + R_{CT} + R_L\right)$$

For delta connected CTs

$$V_k > \frac{35 I_n}{\sqrt{3}} \left(\frac{9.7}{I_n^2} + R_{CT} + R_L\right)$$

Where

V_k = kneepoint voltage (V)

I_n = rated current of relay (A)

R_{CT} = resistance of CT secondary winding (Ω)

R_L = resistance of a single lead from the CTs to the relay (Ω)

Note 1: Operating times are quoted at 5x rated current.

Note 2: The above equations for through fault stability are applicable for up to 20% CT mismatch.

Note 3: In normal applications, to ensure the fast operation of the MFAC, the knee point voltage V_k must be greater than twice the voltage setting Vs of the MFAC relay. However, when used with the MBCI/MCTH relay combination, lower knee point voltage, down to V_s, may be used provided operating times up to the scheme operating time of 80ms are accepted.

$$Vs = I_f \left(\frac{3}{I_n^2} + R_{CT} + R_L\right)$$

Where

Vs = setting of MFAC (V)

I_f = maximum through fault current referred to CT secondary for which stability is required (A-rms)

I_n = rated currency of relay (A) R_{CT} = resistance of secondary winding (Ω)

RL = resistance of a single lead from the CTs to the relay (Ω)

The effective primary operating circuit (Iop) of the MFAC 14 is given by:

I_{op} = $n(I_R + N_I I_u)$

Where

IR = relay operating current and metrosil current at setting voltage (see MFAC publication)

I_u = current transformer magnetising current at setting voltage (A)

N_I = number of connected current transformers

n = current transformer turns ratio

The following notes on this application are also important:

- A setting of 14 is recommended for K_t to ensure sufficient time for inrush blocking. Tripping for internal faults will then occur (typically) within 60 – 80 ms.
- The N = 6 setting on the MBCI relay must be used to achieve increased sensitivity.
- Where the CT lead resistance is a predominant part of the CT burden at one, or both, line ends then the use of 1A line CTs is recommended. The selected rating of current transformers must be the same as the relays (MBCI and MCTH) which they supply.

• Additional conductors may be connected in parallel in order to reduce the lead resistance (R_L) and, hence, the current transformer requirements.

• The pilot resistance should not exceed 700Ω.

• With 15kV pilots, the MCTH output contacts should be connected on the relay side of the isolating transformer to terminate numbers 17 and 18 of the MBCI relay.

• The MCTH overcurrent settings for each phase, set by 3 front-mounted potentiometers (one per phase), should be set at least 50% above the maximum possible load current.

• The steady state magnetising current must not exceed the three phase fault setting of the MCBI relay. For a K_s = 1 setting, the three phase fault setting is 14% of rated current. If the transformer is likely to be subjected to overfluxing, with the corresponding increase in steady state magnetising current, then the three phase setting must be permanently set above this higher magnetising current by increasing K_s.

Cases

Relay type MBCI is provided in case size 6 as shown in Figure 18.

Auxiliary Equipment

For outline drawings of pilot isolation transformers, and stabilising resistor, see Figures 20, 21, 22 and 23.

Associated Publications

R6001 Midos system

R6026 MRTP supervision for ac pilot circuits

R6027 MVTW destabilising and intertripping relay

R6028 MCRI instantaneous overcurrent relay

R6004 MMLG/B test block

R6006 MSTZ power supply

R6007 MFAC high impedance differential relay

R6066 MCTH transformer inrush current detector relay

Information Required with Order

Basic scheme reference (refer to Table 1)

Type(s) of relay

Type of pilots (private or telephone)

Pilot loop resistance and intercore capacitance values.(This information is required to determine whether pilot isolating transformers are required for matching purposes.)

Pilot insulation level (5kV or 15kV). Is pilot supervision equipment required?

Is the overcurrent relay required?

Is the destabilising facility or destabilising/intertrip facility required?

Pilot voltage: Metrosil (MBCI 01) or Zener limiting (MBCI 02).
See Figure 11.

Current rating

Frequency rating

Auxiliary dc supply rating

Auxiliary ac supervision supply rating

AC intertrip supply rating

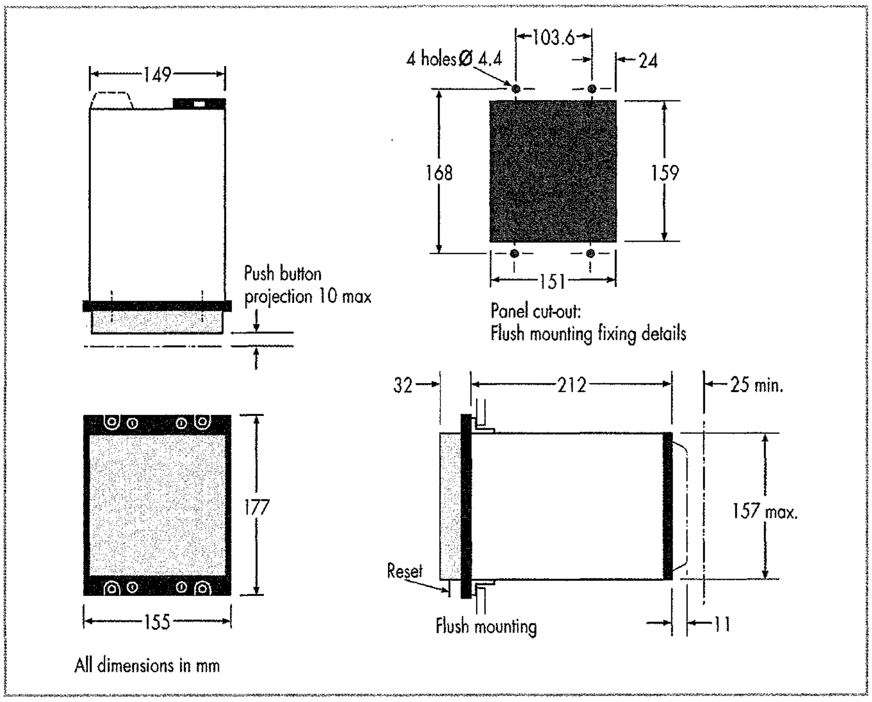


Figure 18

Case outline size 6

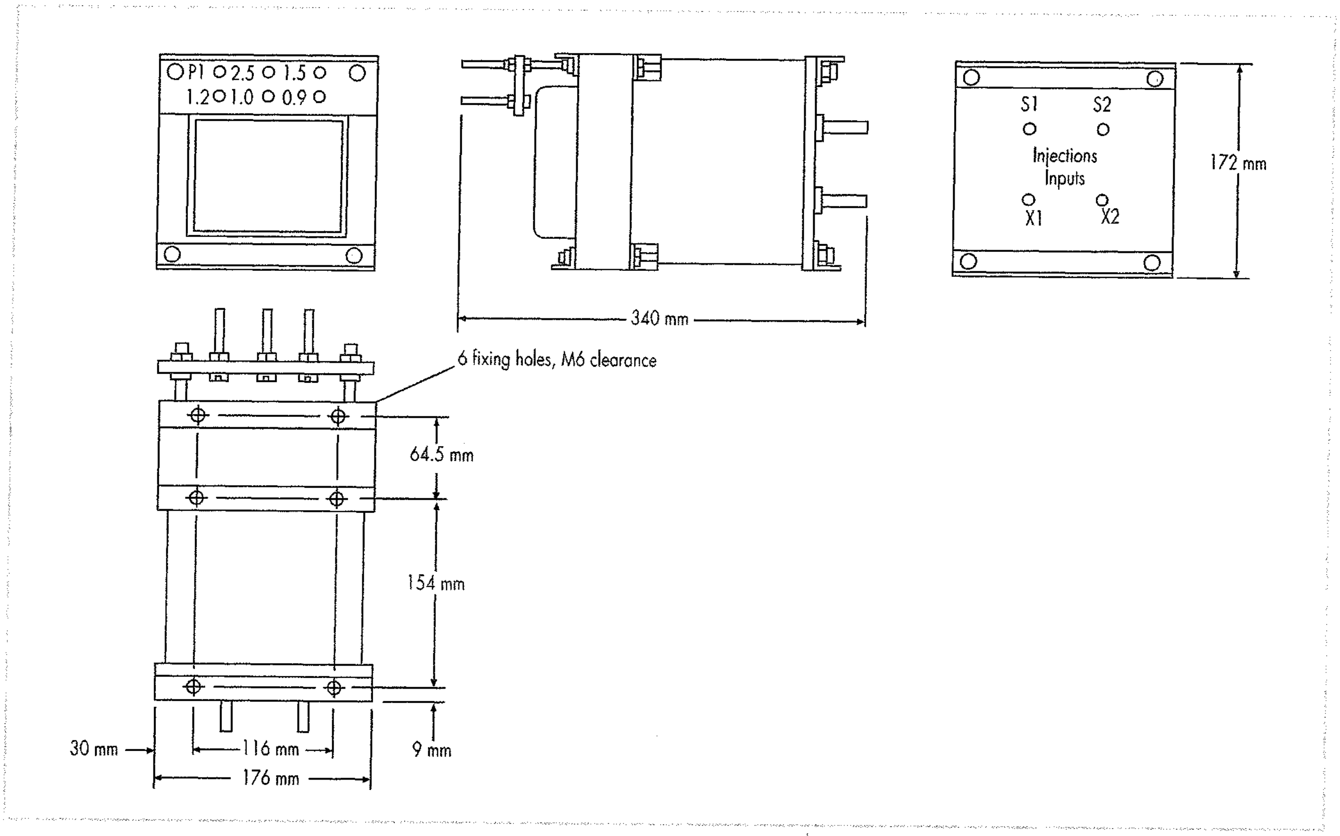


Figure 19 | Pilot isolation transformer with filter. With insulation for 15kV

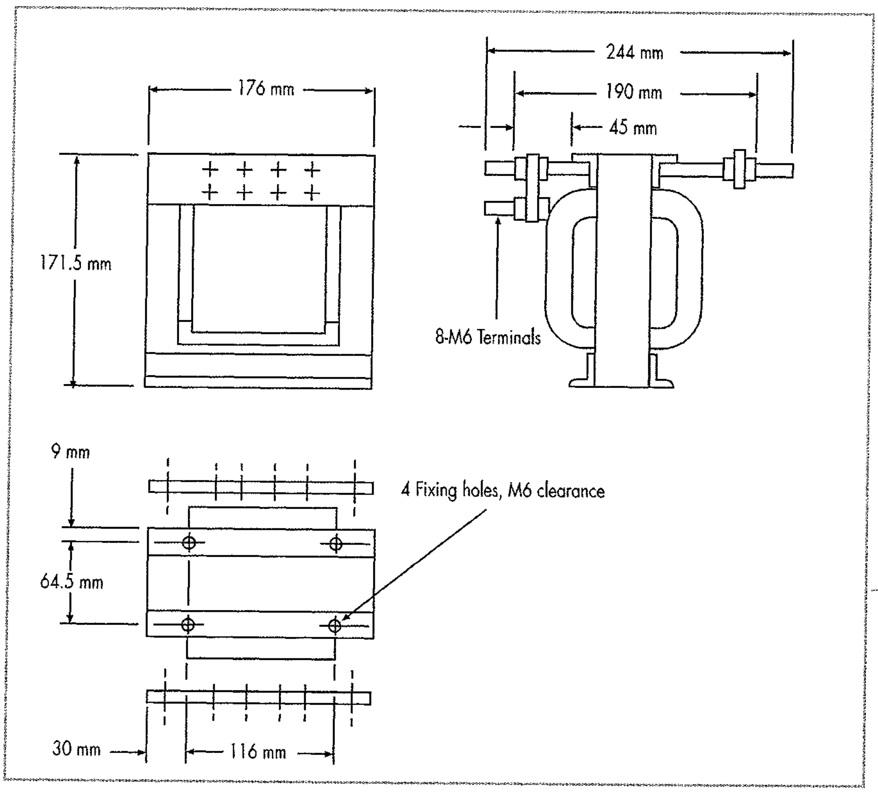


Figure 20

Pilot isolation transformer without filter. With insulation for 15kV

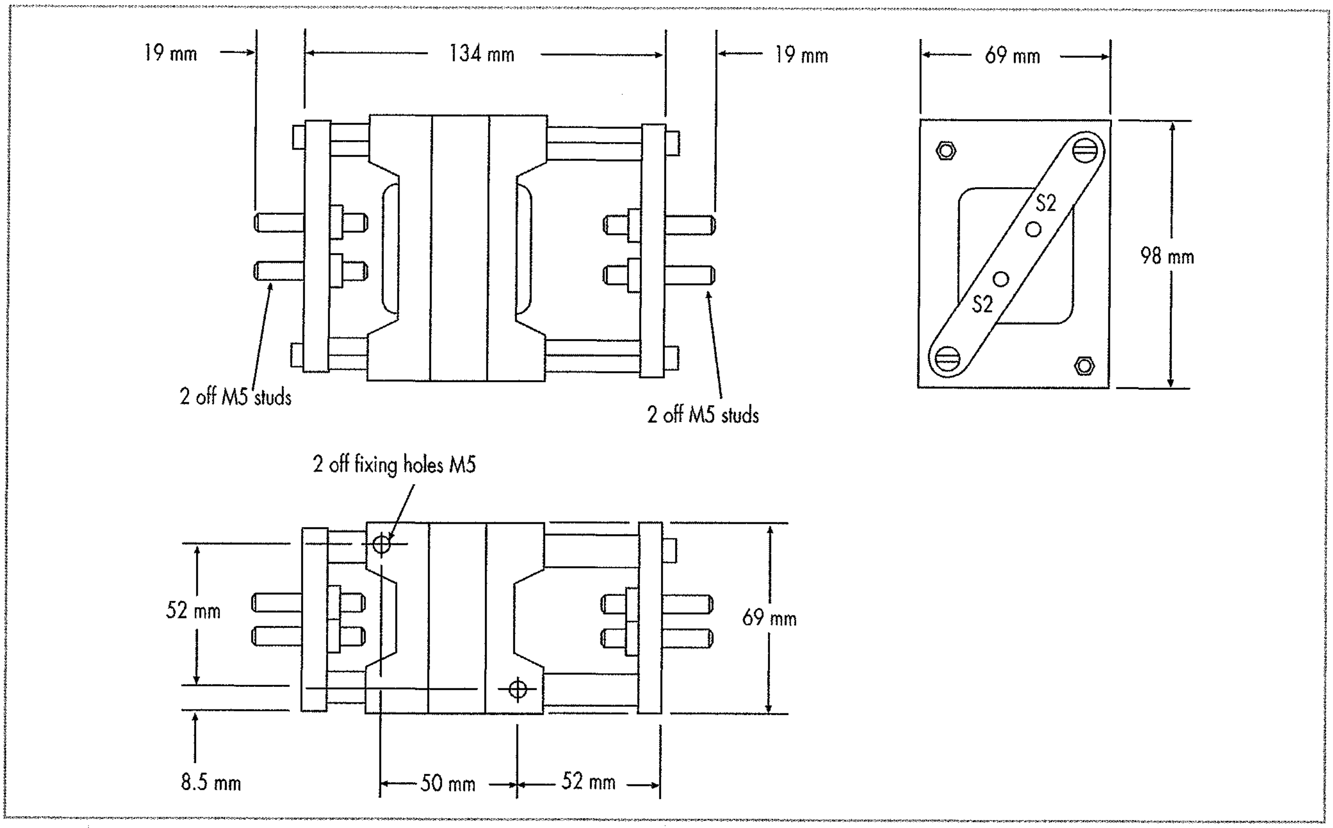


Figure 21 Pilot supervision isolation transformer. With insulation for 15kV

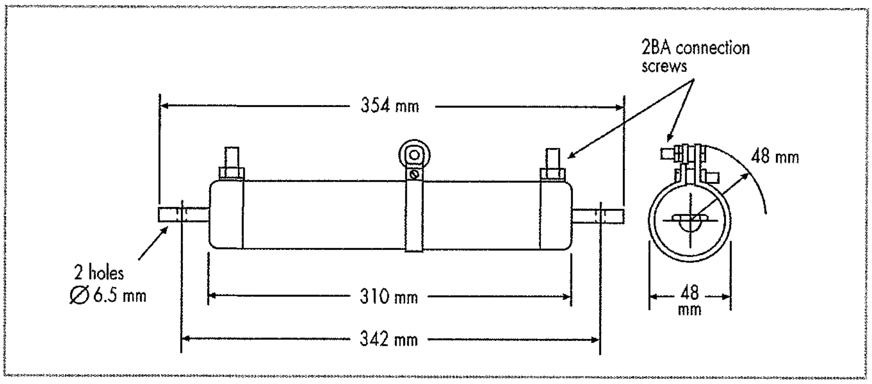


Figure 22 Stabilising resistor

M053 Ver.2

MAINTENANCE –TRANSLAY 'S' (MIDOS TYPE) RELAY TEST FORM

LOCATION		SYSTEM VOLTAGE
TSA		132 kV
CIRCUIT YUE No. 1		
DIFFERENTIAL RELAY ARTICLE NO. MBCI 101	DEFFERENTIAL RELAY SERIAL NO. –	RELAY RATING 1A

1. Relay Service Setting

1.1 ☑ Check relay settings against protection data sheet.

K_s	K_t	K_m	N	R_{pp}	R_s	OC Starting / Check	
						O/C	E/F
1	40	1	3	475	12	1.0	0.2

1.2 Instrument List

Instrument Type:	DMM			
Company No.:	4072768			
Calibration Date:	15.04.2023			

next

2. Isolation

2.1 ☑ Short-circuit incoming Translay 'S' pilot at pilot isolation link terminals and remove pilot isolation links.

3. Test on MCRI01 Overcurrent Start/Check Relay

3.1 ☑ Insert MMLG test plug and connect wiring from terminals 13 to 14 and from 15 to 16 at MMLG plug respectively for DC supply.

3.2 ☑ Monitor the MCRI01 relay operation by measuring DC voltage at terminal 2, 4.

3.3 ☑ Setting Test:

Phase	Setting (A)	Injected Current (A)	
		Operate (±10%)	Reset (≥98% of Op value)
R	1.0	1.03	1.0
EF	0.2	0.209	0.206
B	1.0	1.04	1.0

4. Test on MBCI01 Differential Relay

4.1 ☑ By-pass OC Start/Check Relay by short-circuiting terminals 2 and 4 on MCRI01 Relay.

4.2 ☑ If necessary, disconnect Isolation Transformer from Differential Relay by inserting a paper wedge on NC contact of MVTW01 Destabilising Relay for better accuracy.

4.3 ☑ Setting test with pilot open-circuited and N set at 3.

Fault	Injected Current (A)			
	Formula	Calculated	Operate (±10%)	Reset
R-N	$0.095\ K_s\ I_n$	0.095	0.096	0.087
Y-N	$0.125\ K_s\ I_n$	0.125	0.128	0.116
B-N	$0.165\ K_s\ I_n$	0.165	0.166	0.155
R-Y	$0.4\ K_s\ I_n$	0.4	0.407	0.370
Y-B	$0.5\ K_s\ I_n$	0.5	0.508	0.469
B-R	$0.22\ K_s\ I_n$	0.22	0.224	0.210

4.5 ☑ Check trip output contacts and trip indicator.

4.6 ☑ Timing test at 5X setting current :

K_t	Expect Op Time	Actual Op Time
40	30 mS	35 mS

K_t	40	20	14	6	3
mS	30	50	65	90	300

5. **Test on MVTW01 Destabilising Relay (if applicable)**

5.1 ☑ Operate the Destabilising Relay and check that Differential Relay does not operate when the injected ac current exceeds relay setting.

5.2 ☑ Check the Differential Relay operates instantly when Destabilising Relay is reset.

6. **Test on MRTP01 Pilot Supervision Relay (if applicable)**

6.1 ☑ Remove supervision supply and check that supply failure indicator operates after time delay: 10 seconds (6 ~ 10 seconds).

6.2 ☑ Check supply failure alarm output contacts.

6.3 ☑ Restore supervision supply and check that supply failure alarm can be reset after time delay: 5 seconds (~ 5 seconds).

6.4 ☑ Check that pilot failure indicators operate with time delay: 10 seconds (6 ~ 10 seconds)
- ☑ when pilot short-circuited.
- ☑ when pilot open-circuited.
- ☑ when pilot cross-connected.

6.5 ☑ Check pilot failure alarm output contacts.

7. **Restoration**

7.1 ☑ Replace Translay 'S' pilot isolation links and remove all test plug and connections. (Note: Remove short-wire on OC Start/Check Relay and paper wedge on Destabilising Relay.)

7.2 ☑ Check supervision supply and pilot failure indicators can be reset.

7.3 ☑ Check all output contacts open.

TESTED BY & DATE	CHECKED BY & DATE	APPROVED BY (TEAM LEADER)
15/3/2021 SH Chiu	–	[signature]

1. Principles of Operation and Application in CLP

The Translay 'S' feeder differential protection operating principle is derived from the well know Merz-Price circulating current system and employs phase comparators as the measuring elements. It is designed for the unit protection of overhead line and underground cable circuit, the protection requires a comparison of the current entering and leaving the protected zone. For faults occurring within the protected feeder it is desirable to trip the circuit breakers at each end to isolate the fault. Two relays are therefore required, one for each end of the feeder, and a pair of pilot wires is used to transmit information between the two relays so that each may be able to compare the current flowing at their respective end with the current at the other. It can provide a high stability performance for external faults, with the minimum of bias (restraint), thereby ensuring that the low earth fault settings are effectively retained even when load current is flowing. For more details concerning about the operation of Translay 'S' protection, please consult the relay publications.

In CLP application, Translay 'S' protection is employed in 400 and 132kV feeder main 'B' protection system in which distance protection cannot be applied due to high SIR ratio or lowest relay setting is reached with unacceptable protection coverages.

2. Features of the Translay 'S' Protection

- High stability for through faults
- High speed operation for in-zone faults
- Simultaneous tripping of relays at each line end
- Low current transformer requirements
- Low earth fault settings
- Designed for the unit protection of overhead lines and underground feeders
- Suitable for pilots up to 1000 ohms or 2500 ohms with pilot isolation transformers
- Pilot isolation for 5kV or 15kV
- Four electrically separate contacts
- Can be used as definite time overcurrent relay in the event of pilot failure

3. Types of Translay 'S' Relay Employed in CLP

There are two versions of Translay 'S' relay being adopted by CLP. The modular type and the Midos type. i.e. :

Modular Type		Midos Type	
Types of Relay and Functions		Types of Relay and Functions	
SDPC 101	Differential + Overcurrent start/check	MBCI 101	Differential
SDPT 101	Differential + Pilot supervision + Injection filter + Overcurrent start/check	MRTP01	Pilot supervision and injection filter
		MCRI01	Overcurrent start/check
		MVTW01	Destabilising

Many of the existing 'old' circuits are using the modular type Translay 'S' protection, but for the 'new' circuit, it is preferred to adopt the midos type Translay 'S' protection instead. However, they are similar in both applications and relay functions.

4. C.T. Requirement

The CT requirements for Translay 'S' protection is :

$$Vk \geq N*Kt*In*K(Rct+XRl)$$

Where

- Vk = CT knee point voltage
- N = Relative neutral turns on summation transformer winding (3 or 6)
- Kt = Time-dependent constant (40, 20, 14, or 6)
- In = Relay current rating, in Amp. (1A, 2A or 5A)
- K = For 132kV and above set K=1, for below 132kV, set K=0.5
- Rct = CT secondary resistance in ohms
- X = 1 for four wire connections between CT and the relay, 2 for six wire connections
- Rl = CT single lead resistance in ohms

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5. Translay 'S' Protection Schemes

5.1 Pilot Supervision

It is understood by us that correct interchange of information over the pilot circuit is essential for proper functioning of any differential feeder protection, but the damages on the pilot cable by third party was took place frequently and the most common pilot failure is the open circuit caused by the accidental excavation of buried pilots, if the pilots open-circuited then the differential protection will be unstable and will trip the feeder if sufficient through current is flowing.
The addition of pilot supervision will not prevent tripping for pilot fault but will indicate the cause. It will also detect short circuit and cross-connected pilot conditions which would not otherwise be detected. Indication is also provided for loss of the supervision supply.

5.2 Overcurrent Check / Starting

Although the supervision scheme provides indication of pilot failure it does not prevent the protection operating if primary current above setting is flowing. So, overcurrent check/start feature is to guard against mal-operation on pilot failure.
In starter mode, no d.c. is drawn from the auxiliary d.c. supply by the differential relay unless an overcurrent condition exists. When starter mode is used, the overall operation time of the scheme is increased by the operating time of the starter, say, is increased by 3-5 mS.
In check mode, a constant current is drawn from the auxiliary d.c. supply by the differential relay. The overcurrent check is to guard the differential relay output contact. In this mode, there is no increase in the overall operating time.

5.3 Protection Unstabilising and Intertripping

Operation of the unstabilising relay (UN) will short-circuits the local summation transformer secondary winding so that the relay at that end is rendered inoperative. At the same time this action open-circuits the pilot, so that the relay at remote end becomes unstable.
However, if there is no primary current flowing in the protected circuit, unstabilising the protection will not cause tripping to remote end . In order to intertrip the remote end it is necessary to inject an a.c. voltage into the pilot circuit. The intertrip relay (TD) operates approximately 120 mS. after the unstabilising relay to inject the intertrip voltage to the remote end.

5.4 Pilot Isolation Transformers

When pilot isolation transformers are used the range of primary tapes enables pilot of loop resistance up to 2500 ohms to be matched to the relay. The pilot insulation level is also raised to 15kV by these isolation transformers.

6. Setting Considerations for Translay 'S' Protection

6.1 Pilot Isolation Transformer / Pilot Padding Resistor(Rpp)

Pilot isolation transformers are required when the induced longitudinal voltage in the pilot circuit is likely to exceed to 5kV, in CLP applications, we adopted 15kV pilot isolation transformer for long line circuit in which both the pilot circuit induced voltage and capacitance charging current are significant.
The pilot padding resistor (Rpp) at each end should be set to : 0.5 (1000-Rp/Km), where Rp is the pilot loop resistance and Km is set at 1.0 which is matching the P1/P5 tapping of the isolation transformer.

6.2 Line charging Current

According to the relay recommendation, it is suggested to set Ko=1.1 times the steady-state line charging current for solidly earthed systems and set Ko=3.125 times the steady-state line charging current for resistance earthed systems. In CLP Translay 'S' protection applications, since the protection is adopted in 132 and 400kV systems and both are solidly earthed, therefore, Ko is set at 1.1 throughout.

6.3 Protection Fault Settings

Because of the turn ratio of summation input transformer for different phases are different, therefore the fault setting is depending on which phase or phases are being involved in the fault, in addition, since the input transformer has a summation ratio of 1.25:1:N where N=3 for normal use and N=6 is used where low earth fault settings are needed. In CLP practice, it is adopted to set N = 3. Besides, please also note that the minimum earth fault current (If) should be greater than twice the least sensitive earth fault setting to ensure rapid fault clearance.
The fault settings of Translay 'S' protection is shown below under pilot normal condition. With pilot open-circuited, the fault settings will be halved.

Fault	Settings	
	N=3	N=6
A - N	**0.19 Ks In**	**0.12 Ks In**
B - N	**0.25 Ks In**	**0.14Ks In**
C - N	**0.33 Ks In**	**0.17 Ks In**
A - B	**0.8 Ks In**	
B - C	**1.0 Ks In**	
C - A	**0.44 Ks In**	
A - B - C	**0.51 Ks In**	

Remarks :

a. In = the rated relay current

b. Ks = a setting multiplier and may be varied from 0.5 - 2.0 (Set Ks=1.0 in general)

c. Summation Ratio of the input transformer = 1.25 : 1 : N

6.4 Overcurrent Starter/Check Element Settings

Based on the relay recommendation and also the CLP practice, the suggested overcurrent and earth fault settings are :

Overcurrent : Greater than the rated load current and smaller than the 0.66 times of minimum phase-to-phase current, i.e. I rated < Is O/C < 0.66 Ipf

Earth fault : Greater than 1.2 times of the line capacitance charging current and small that the 0.66 times of the minimum earth fault current. i.e. 1.2 Ic < Is E/F < 0.66 Ief

And connected as ' CHECK ' mode.

6.5 Setting of the Selected Time-dependent Constant, Kt

A time dependent constant setting knob, Kt, provided by the Translay 'S' relay, and the function of it is to maintain the protection stability even when it is fed by the smaller size of current transformer, by increasing of the relay operating time.
According to the C.T. requirements of the relay, the selection of the Kt setting is determined by :

Kt < Vk/(NIn (Rct+XRl)*K)

And normally, it is recommended to set at Kt=40 to achieve the fastest protection operating time of 30 mS. at 5 times setting.

6.6 Choice of the Value of Stabilising Resistor

The ohmic value of stabilising resistor is selected to Rs=Vk/40In and not greater than $12/(In)^2$, in general, the value chosen is 12 ohms is reasonable and acceptable.

6.7 Example of the Setting Calculation for Translay 'S' Protection

Please refer to the Appendix 1 of the example of the setting calculation of Translay 'S' protection.

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7. Comparison between Translay 'S' and Solkor 'R' Protections

Table below shows the comparisons :

Items	Translay 'S'	Solkor 'R'
Operating principle	Purely circulating current differential protection with magnitude & phase comparison. Restrain function existing	Can be considered as circulating current differential protection. No restrain function
Version type	5kV or 15kV	
Pilot capacitance compensation	No compensation for pilot capacitance up to 2.5μF	
Pilot loop limitation	Up to 2500 ohms	Limited to 1000 ohms
Operating time	High speed, approx. 30mS at times setting	5kV - 60mS @ 3 times setting 15kV - 80mS @ 3 times setting
Fault setting	Low fault setting	High fault setting as compare with Translay 'S'
Open pilot fault setting	Decrease by half the normal pilot fault setting	Decrease by 7-11% of the normal pilot fault setting
Pilot short circuited	No tripping occurs, no matter how high the fault current because restrain function exists	Tripping occurs as no restrain function
Other features	O/C & E/F check or start, built-in unstabilizing relay and pilot supervision	Can achieve these features with additional equipment
C.T. requirement	High C.T. requirement for high speed operation (30mS). If 60mS operating time is adopted, C.T. requirement will be same as Solkor 'R'	Non-dependent on the relay operating time
Teed-off load	Teed-off load 0.25Ks x C.T. rating	20%
Commissioning & Maintenance	Because of sophisticated circuit design, therefore involve more testing and training	Robustness and simplicity easy to commission and maintain

- End -

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TRANSLAY 'S' RELAY SETTING INFORMATION / RECORD

CIRCUIT & SYSTEM	Circuit Name :	System Voltage	400 KV		Capacitive p.u. value
		Min Fault Level			(100MVA Base)
	YME - TWE	Phase Fault		Earth Fault	1.264 p.u.
		IPF	1631.00 A	IEF 1631.00 A	Pri. IC 114.19 A
	Current Rating : IN 1010 A (700MVA)	Ipf	0.82 A	Ief 0.82 A	Sec. Ic 0.0571 A
	System Earth	☐ Solid Earth		☐ Resistance Earth	

			END A (YME)		END B (TWE)	
C.T. PARAMETER	Ratio IN/In		2000 / 1		2000 / 1	
	Knee Point Voltage	VK	5155	V	1100	V
	CT DC Resistance	RCT	4.8	Ohm	1.89	Ohm
	Lead Resistance	RL	1	Ohm	1	Ohm
	Mag. Current at Vk	Im	25	mA	20	mA
	Im < 0.05In		☐ Yes	☐ No	☐ Yes	☐ No

			END A		END B	
RELAY & SCHEME	Relay Protection Scheme : A.B.C.D.E.F.G.H.					
	Relay Type		MBCI 01		MBCI 01	
	Relay Rating	Ir	1	A	1	A
	Overcurrent Scheme		☐ Check	☐ Start	☐ Check	☐ Start
	A.C. Wiring Scheme		☐ 4 Wire	☐ 6 Wire	☐ 4 Wire	☐ 6 Wire
	☐ Intertripping Scheme		☐ A.C. Injection		☐ A.C. Injection	
	☐ Nil		☐ Unstabilising		☐ Unstabilising	
	☐ Pilot Supervision Scheme		☐ Measuring		☐ Measuring	
	☐ Nil		☐ Substitution		☐ Substitution	
	☐ Isolation Transformer Tapping		P1/ P5		P1/P5	
	☐ Nil Isolation Transformer		KM = 1			

PILOT	Loop Resistance	Rpp = 0.5(1000-Rp/kM)	Shunt Capacitance
	Rp 30 Ohm		Cs Micro F
	☐ Rp < 1000 kM	Rpp 485 Ohm	☐ Cs < 5 / kM

RELAY SETTINGS	X	☐ For 4 Wire A.C. Scheme X = 1					
	K	☐ For 132 kV or Above K = 1					
	Ko	☐ For Solid Earth System Ko = 1.1					
	N	☐ N = 3		END A	END B	END A	END B
	Check	Ks	0.19Ks Ir >= Ko Ic	0.33 <= Ks <= 1.24	0.33 <= Ks < 1.24	Ks = 0.5 -2.0 (Ks = 1.0 IN GENERAL)	
			Ief >= 2(0.33Ks Ir)			0.5	0.5
		Kt	< VK / (N In (RCT + XRL) K)	Kt < 586.662	Kt < 251.24	40	40
		Rs	= VK / 40 In and < 12 / In^2	Rs = 128.875 & Rs < 12	Rs = 27.5 & Rs < 12	12 Ohm	12 Ohm
		O/C	> In and < Ipf / 1.5	0.51 < O/C <	0.5437	0.52 A	0.52 A
		E/F	> 1.2 Ic and < Ief / 1.5	0.0685147 < E/F <	0.5437	0.20 A	0.20 A

Note : Please refer to the manual for further information if A.C. Wiring Scheme = 6 Wire.

Calculated By & Date	Checked By & Date	Approved By & Date

Appendix 1 : Example of the setting calculation of Translay 'S' protection

FDI-185

TRANSLAY 'S' RELAY SETTING INFORMATION / RECORD

S514E (3/90)

CIRCUIT & SYSTEM

CIRCUIT NAME: TSA - YUE	SYSTEM VOLTAGE V: 132 KV		CAPACITIVE P.U. VALUE (100MVA BASE): Xc = 3.751 p.u. = 653.5Ω = 4.8 μF
	MIN FAULT LEVEL		
	PHASE FAULT	EARTH FAULT	
	IPF 4137 A	IEF 4213 A	PRI. IC 117 A
CURRENT RATING IN 1312 A	Ipf 2.59 A	Ief 2.63 A	SEC. Ic 0.073 A
SYSTEM EARTH: [x] SOLID EARTH [ ] RESISTANCE EARTH			

C. T. PARAMENTER

	S/S 1 TSA	S/S 2 YUE
RATIO IN/In 1600/800/1		
KNEE POINT VOLTAGE VK	2580 V	2650
CT DC RESISTANCE RCT	6.3 Ω	6.55 Ω
LEAD RESISTANCE RL	0.5 Ω	0.5 Ω
MAG. CURRENT AT ~~10 In~~ Vk Im	11 mA	11 mA
Im < 0.05 In	[x] YES [ ] NO	[x] YES [ ] NO

RELAY & SCHEME

RELAY PROTECTION SCHEME : A. B. C. D. E. F. G. H.

	S/S 1	S/S 2
RELAY TYPE	MBCI	MBCI
RELAY RATING Ir	1 A	1 A
OVER CURRENT SCHEME	[x] CHECK [ ] START	[x] CHECK [ ] START
A. C. WIRING SCHEME	[x] FOUR WIRE [ ] SIX WIRE	[x] FOUR WIRE [ ] SIX WIRE
[ ] INTERTRIPPING SCHEME [x] NIL	[ ] A. C. INJECTION [x] UNSTABILISING	[ ] A. C. INJECTION [x] UNSTABILISING
[x] PILOT SUPERVISION SCHEME [ ] NIL	[x] MEASURING [ ] SUBSTITUTION	[ ] MEASURING [x] SUBSTITUTION
[x] ISOLATION TRANSFORMER TAPPING [ ] NIL ISOLATION TRANSFORMER	P1/ P5 KM = 1	P1/ P5

PILOT

LOOP RESISTANCE Rp 50 Ω	SHUNT CAPACITANCE Cs 1.8 μF	Rpp = ½ (1000 − Rp / Km)
[x] Rp < 1000 Km Ω	[x] Cs < 5 / KM μF	Rpp = 475 Ω

RELAY SETTINGS

X	[x] FOR 4 WIRE A.C. SCHEME X = 1		[ ] FOR 6 WIRE A.C. SCHEME X = 2	
K	[x] FOR 132kV OR ABOVE K = 1		[ ] FOR BELOW 132kV K = 0.5	
Ko	[x] FOR SOLID EARTH SYSTEM Ko = 1.1		[ ] FOR RESISTANCE EARTH SYSTEM Ko = 3.125	
N	[x] N = 3	[ ] N = 6	S/S 1	S/S 2
CHECK Ks	0.19KsIr ≥ KoIc 0.19Ks × 0.82 1.1 × 0.073 0.1558 0.0803	0.12KsIr ≥ KoIc	Ks = 0.5 ~ 2.0 (Ks = 1.0 IN GENERAL)	
	Ief ≥ 2 (0.33KsIr) 2.63 2(0.33 Ks × 0.82) 0.5412	Ief ≥ 2 (0.17KsIr)	1	1
Kr	< VK / NIn (RCT + XRL) K		40	40
Rs	2580/40 = 64.5 = VK / 40 In and < 12 / In²		12 Ω	12 Ω
O/C	0.82 > In and < Ipf / 1.5 2.59/1.5 = 1.72		1.0 A	1.0 A
E/F	0.0876 > 1.2 Ic and < Ief / 1.5 1.753		0.2 A	0.2 A

CALCULATED BY & DATE	CHECKED BY & DATE	APPROVED BY & DATE
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MODULAR DIFFERENTIAL FEEDER PROTECTION TYPE TRANSLAY-S

CONTENTS

MODULAR DIFFERENTIAL FEEDER PROTECTION
TYPE TRANSLAY-S

1. INTRODUCTION

A new protection has been developed to reliably protect present day and future transmission and distribution systems. It is modular in construction; providing a compact, ecconomic package with provision for pilot supervision, overcurrent check and intertrip facilities. The new protection is known as TRANSLEY-S.

Figure 1 shows the basic Translay-S relay type SDPD101 and in figure 2 the composite Translay-S relay type SDPT101.

2. DIFFERENTIAL CIRCUIT

2.1 Principle of Operation

The differential circuit of the TRANSLAY-S is derived from the well-known Merz-Price Circulating Current System. Phase comparators are used for the measuring elements to form a novel combination which provides; compensation for pilot capacitance; high speed simultaneous tripping for internal faults; high stability for external faults; and optimum bias ensuring low earth fault settings are maintained when load currents are flowing.

Figure 3 shows the basic circuit arrangement. A summation transformer T1 at each line end produces a single phase current proportional to the summated phase currents in the protected line. The neutral section of the summation winding is tapped to provide alternative sensitivities for earth faults.

The secondary winding supplies current to the relay and the pilot circuit in parallel with a non-linear resistor (RVD). The non-linear resistor can be considered to be non-conducting at load current levels, and under heavy fault conditions conducts an increasing current and thereby limits the maximum secondary voltage. At normal current levels the secondary current flows through the operation winding To on transformer T2 and then divides into two separate paths, two thirds through resistor Ro and one third through the restraint winding Tr of T2, the pilot circuit and resistor Ro of the remote relay.

The resultant of the currents flowing in Tr and To is delivered by the third winding on T2 to the phase comparator and is compared with the voltage across T_t of transformer T1. The emf developed across T_t is in phase with that across the secondary winding Ts which is in turn substantially the voltage across Ro.

Assuming Tr = 2 To, and Ro = Rp (the pilot loop resistance) then as shown in figure 4 the signals to the phase comparator at one end are:- $S1 = \frac{I_X}{I_Y} - 2 \qquad S2 = \frac{I_X}{I_Y} - 0.5$

The phase comparator has angular limits of $\pm 90^\circ$ giving a circular characteristic as shown in Figure 5. For values of $\frac{I_X}{I_Y}$ between 0.5 and 2.0 and phase differences exceeding 90 degrees between S1 and S2 the system is stable.

2.2. Compensation for Pilot Capacitance

The pilot circuit of the relay can be represented by a ladder network of resistance and capacitance as shown in figure 6. The summation current transformers are represented by constant current generators at each end of the pilot circuit. In order to drive a current around the pilot circuit the generators must develop a voltage V_X at end X and V_Y at end Y. These voltages can be represented by two vectors as shown in figure 6. A line drawn from the tip of one vector to the tip of the other gives a representation of the voltage gradient along the pilot circuit.

Capacitance near the centre of the pilot has little voltage across it and as a result little capacitance current will flow. It is for this reason that circulating current schemes do not require special compensation for pilot capacitance up to 2.5 microfarads.

Capacitance at the ends of the pilot has a higher voltage across it and hence a more significant current will flow. This capacitance current is substantially in quadrature with the pilot voltage. The phase comparator has 90 degree angle limits and is therefore relatively insensitive to this quadrature current. The directional characteristic of the measuring element can cope with a further 2.5 microfarads of pilot capacitance.

2.3. Fault Settings.

The fault sensitivity of the protection varies with the type of fault because different sections of the summation winding are involved for the different faults. Fault settings are tabled in figure 7 including those for the alternative earth fault sensitivities.

2.4. Earth Fault Settings with Through Load.

Through current is arranged to cause the fault setting of the protection to increase. This is the principle of bias and is used to improve the through fault stability of the protection by increasing its tolerance to transformation errors.

The pilot voltage limiter affects the bias causing it to increase non-linearly. It is therefore necessary to control the bias characteristic so that the earth fault settings do not reach an unacceptable level.

The polar diagram is used to determine the earth fault setting under load conditions. Figure 8 shows the relationship between load and fault current on the polar characteristic. A vector drawn from the point 1.0 on the horizontal axis to the boundary of the characteristic represents the ratio of fault to load ampturns on the summation transformer at an angle of θ°. Hence by drawing vectors at the appropriate values of θ the earth fault sensitivity for each of the three phases can be determined.

By way of example a summation ratio of 1/1/N is considered in figure 9. For balanced three phase load the phase currents sum to zero at the B phase tap. Therefore the summated ampturns is proportional to $\dot{I}_A - \dot{I}_C = \sqrt{3}\ \dot{I}_B \angle{-30^\circ}$. Hence a vector drawn for $\theta = +30^\circ$ represents a resistive fault on phase A. Similarly vectors for $\theta = +150^\circ$ and $+270^\circ$ represent resistive faults on phases B and C respectively.

Note for Translay-S the summated ampturns is proportional to $1.25\ \dot{I}_A - \dot{I}_C = 1.95\ \dot{I}_R \angle -26^\circ$.

To calculate the earth fault settings the length of the vector is measured and multiplied by the three phase ampturns ($\sqrt{3}\ I_L$). This product is then divided by the summation winding turns associated with the fault.

The polar characteristic for the Translay-S passes through the points 0.5 and 2.0 on the in-phase (horizontal) axis. This results in earth fault settings which vary with load as shown in figure 10. For rated load the three earth fault settings are in the order of 40% or for the higher earth fault sensitivity 20%.

2.5. Phase Comparator.

Figure 11 shows the block diagram for the phase comparator. The input circuits are tuned to the power frequency so that the threshold of operation increases with frequency. This desensitises the relay to the transient high frequency charging current that flows into the line when it is energised. A further advantage provided by the tuned input is that the waveform of the derived signal, which may be severely distorted by current transformer saturation, is improved, ensuring high speed operation under adverse conditions.

The signal S1 is attenuated by a potentiometer to provide a setting multiplier Ks. Ks has a range of 0.5 to 2.0 and is adjusted to suit the application. Values between 0.5 and 1.0 are used to compensate for increases in setting caused by pilot capacitance and values between 1.0 and 2.0 are used to increase the earth fault settings above the steady state cable charging current.

A coincidence circuit produces pulses proportional in width to the phase difference between the signals from the band pass filters. An integrator derives a voltage proportional to the pulse width and a level detector produces an output when this voltage exceeds a set limit. The time constant of the integrator is varied to provide alternative operation times. This adjustment is attributed the symbol K_t; a constant that affects the operating time as shown in figure 12.

2.6. Summation Transformer

The summation ratio has a marked effect upon the through fault stability of the protection for interphase faults. Transient errors caused by saturation of the line current transformers during the initial cycles of fault current can result in an unbalance (spill) current. This current flows in the neutral section of the summation winding where its effect is accentuated by the large number of turns (N). The ratio of fault turns/spill turns is not the same for all interphase faults as will be seen from figure 13.

The ratio of spill turns for (A-B faults) to spill turns for (B-C faults) is 1.33 when N=3 and hence a better summation ratio is 1.33/1/3 instead of the more usual 1/1/3. However, when N=6 the optimum ratio is 1.16/1/6. As a compromise for

2.7. Stabilising Resistance

For three phase faults the output of a 1.25/1/N summation transformer is proportional to $(1.25\ \dot{I}_A - \dot{I}_C)$ where $\dot{I}_A$ and $\dot{I}_C$ are phase currents. However, there is an exponential d.c. component of fault current which causes partial saturation of the line current transformers. The current transformer outputs are reduced by saturation effects; and since the amplitude of the d.c. component will not be the same in the three phases the phase currents no longer sum to zero and a spill current then flows in the neutral section of the summation winding. The output of the summation transformer is then $(1.25\ \dot{I}_A - \dot{I}_C) + N\dot{I}_S$ where Is is the spill current.

The phase angle of the spill current depends upon point in the cycle at which the fault occurs. Hence the output of the summation transformer suffers both an amplitude and phase change which may not be matched at the other end of the feeder. This will result in the protection becoming unstable if the errors become excessive.

Single phase faults do not suffer quite the same problems because the spill current comes from the unsaturated phases, and since only one phase is involved there will be no spill current and the output of the summation transformer will only be reduced in the same proportion as the output of the feeding current transformer. Therefore a higher degree of saturation can be tolerated for single phase faults. This fact enables the overall stability to be improved by the addition of stabilising resistance.

This resistance is connected between the neutral connection of the summation winding and the star point of the line current transformers. Its purpose is to increase the resistance of the spill current path so that all three current transformers are forced into a similar degree of saturation. This reduces the spill current and hence reduces the error in the summated output. It is then possible to increase lead burden further before instability is reached.

Figure 14 shows the effect stabilising resistance has on the three phase stability. The general expression for stability is VKP = K′ If (RCT + XRL) and is represented by curve (a). Curve (b) shows the result when the optimum value of resistance is found, and curve (c) with too much resistance, which reduces the single phase stability unnecessarily without further improving the three phase result.

It follows that if the stabilising resistance is to cause partial saturation of the line current transformers then its value will be related to the knee point voltage of the current transformers.

Typically $R_S = \dfrac{V_{KP}}{K\ I_n}$ where K is a constant for the protection and

I_n = rated current

V_{KP} = CT knee point voltage.

2.8. Effect of Operation Time on Stability.

Figure 15 shows diagramatically how through fault stability is affected by the operation time of the measuring element. Transient errors will be of a complex exponential form as shown and will increase with loading on the line current transformers.

For stability the error signal must fall below the threshold setting of the differential circuit in less time than the relay takes to operate. It can be seen that if the operation time is increased from t1 to t2 a larger error can be tolerated. This means that either the current transformers can be smaller or more heavily loaded.

2.9. Current Transformer Requirements.

a) $V_{KP} \geqslant N K_t \; I_n (R_{CT} + XR_L)$

b) $I_M \leqslant 0.05 \; I_n$ at $\frac{10}{I_n}$ Volts

where V_{KP} = knee point voltage of CT

R_{CT} = resistance of CT secondary circuit (ohms)

R_L = lead resistance of single lead from relay to CT (ohms).

X = 1 for four wire connections between the main current transformers and the relay; 2 for 6 wire connections.

N = relative neutral turns on summation transformer winding (3 or 6).

K_t = the selected time dependent constant (40, 20, 14 or 6)

I_n = rated C.T. secondary current (A)

I_M = magnetising current of CT. (A)

There are two main requirements for the current transformers. The first (a) ensures stability for all applications. The required knee point voltage given by this expression may be halved for application to systems of less than 132kV. This reduction is possible because the X/R ratio of the system is lower at these voltages and transient errors will therefore be reduced. The expression has been derived from the results of more than 200,000 fault tests and ensures that the protection will be used within the area where stability is independent of fault level (see figure 14).

The second requirement (b) applies a limit to the magnetising current so that fault settings are not increased to unacceptable levels.

3. PILOT ISOLATION

The field of any adjacent conductor may induce a voltage in the pilot circuit; when the pilot is laid parallel to a power circuit the induced voltage may be considerable, particularly when a severe earth fault occurs on the power circuit. In these circumstances, particularly when the power system is part of a solidly earthed system, the voltage may amount to several thousand volts. The current that will flow if the pilot line

TRANSMISSION SYSTEMS ($>$132 kV)

$$V_{KP} \geq N\, K_t\, I_n\, (R_{CT} + x\, R_L)$$

TYPICALLY $N = 3$ $K_t = 40$

$$\therefore V_{KP} > 120\, I_n\, (R_{CT} + x\, R_L)$$

INDUSTRIAL & DISTRIBUTION SYSTEMS ($<$ 132 kV)

$$V_{KP} > \frac{N}{2}\, K_t\, I_n\, (R_{CT} + x\, R_L)$$

MAY BE HALVED BECAUSE OF LOWER SYSTEM X/R

TYPICALLY $N = 3$ $K_t = 20$

$$\therefore V_{KP} > 30\, I_n\, (R_{CT} + x\, R_L)$$

PHASE FAULT PROTECTION ONLY $N = 1$

PROTECTION OF SINGLE PHASE CABLES $N = 1$

is earthed at each end is limited only by the line resistance and may be of the order of 100A. The effect is therefore associated with substantial power and can cause considerable damage.

It should be realised that any auxiliary line run between two stations, for whatever duty, is inherently dangerous and should be treated at all times as a high voltage circuit.

The voltage that may be induced can be calculated from the following formula:

$$e = 0.232\ I_e \log_{10} \frac{D}{S}$$

where e = induced voltage per mile (V)
I_e = single - phase/earth fault current (A)
D = equivalent depth of earth return (typically 1500-3000 feet)
S = distance of pilot from phase conductor (feet)

The pilot circuit and all directly connected equipment should be insulated from earth and all other circuits to an adequate voltage level. The relay has its pilot circuit insulated for 5 kV and this can be increased to 15 kV by the addition of isolation transformers.

The relay alone will operate with pilot circuits having a loop resistance of 1000 ohms or less. Isolation transformers with tapped primary windings are used to provide matching of the relay to pilots of up to 2500 ohms loop resistance, as shown in figures 16 and 17.

4. PROTECTION UNSTABILISING AND INTERTRIPPING.

Figure 18 shows the arrangement for unstabilising and intertripping the protection. Operation of the relay (UN) short circuits the local summation transformer secondary winding so that the relay at that end is rendered inoperative. At the same time this action results in the protection becoming unstable so that the relay at the remote end operates.

However, if there is no current flowing in the protected circuit, unstabilising the protection will not cause operation. In order to intertrip the remote end it is necessary to inject an a.c. voltage into the pilot circuit. The intertrip relay (TD) operates approximately 120 milliseconds after the unstabilising relay to inject the intertrip voltage. The time delay ensures that the injection voltage can never block tripping when the line is carrying currents at the time the intertrip is initiated.

When pilot isolation transformers are not used the injection transformers for the intertrip voltage should be insulated for 5kV. If only the unstabilising feature is required, the latter transformers are not required and terminals D4 and D5 are linked together.

Figure 19 shows a typical application where intertripping is required. The differential feeder protection will see a transformer fault as a through fault condition and remain stable. The transformer protection will operate, trip the LV breaker and unstabilise the feeder protection so that the remote HV breaker is tripped.

5. PILOT SUPERVISION

Correct interchange of information over the pilot circuit is essential for the proper functioning of any differential feeder protection. Well installed pilots may be considered to be secure but others are more exposed to hazards and some risk of damage and failure always exists.

The most common pilot failure is to the open circuit state, caused by the accidental excavation of buried pilots or storm damage to overhead pilots. With the pilots open circuit the differential protection will be unstable and will trip the feeder if sufficient through current is flowing. For this reason the circulating current system is often preferred as such schemes will fail safe and trip so that attention is immediately drawn to the fault.

The addition of pilot supervision will not prevent tripping for pilot faults but will indicate the cause. It will also detect short circuit and deteriorating pilot insulation... which would not otherwise be detected. Indication is also provided for loss of the supervision supply.

Figure 20 shows the arrangement for pilot supervision, in a pilot circuit insulated for 5kV. In this instance the injection filters and the supervision unit are assembled in modules within the relay case.

The supervision circuit requires a low voltage a.c. supply to energise the measuring circuit and the pilots. The input transformer is provided with a primary winding to suit the available supply. The secondary voltage is converted to a clipped sinewave of constant amplitude by a zener diode connected in a rectifier bridge circuit. The d.c. voltage developed across the zener diode is used to power the measuring circuit (A_c) which in turn measures the current flowing into the injection filter.

The clipped sinewave voltage is rectified in the injection filter and a capacitor is charged to the peak value to produce a constant level d.c. voltage. A capacitor connected in the pilot circuit by-passes the a.c. pilot current and directs a d.c. current from the supervision around the pilot circuit. To enable crossed pilots to be detected and ensure correct indication for pilots which become short circuited at the remote end, it is necessary to include a second injection filter in the pilot circuit as shown for the remote line end. This filter ensures that remote short circuits eliminate sufficient resistance in the pilot loop to cause a detectable current change.

A change in the d.c. supervision current is indicative of a pilot fault and causes a corresponding change in the a.c. current supplied by the supervision unit. The measuring circuit monitors this a.c. current and initiates a PILOT FAILURE alarm after a time delay if a sufficient change takes place. The a.c. supervision supply is also monitored and in the event of failure a time delayed SUPPLY FAILURE alarm is initiated.

Figure 21 shows the similar arrangement for pilot circuits insulated for 15kV. The injection filters are then assembled as part of the isolation transformers and have to be isolated from the supervision module. The injection transformer provides the necessary 15kV isolation barrier.

6. OVERCURRENT CHECK

Although the supervision scheme provides indication of pilot failure it does not prevent the protection operating, if primary current above setting is flowing. Where this hazard is unacceptable it is necessary to add an overcurrent check feature.

A separate module is available, containing three overcurrent elements. Two of these are phase fault elements, and the third element is for earth faults.

When overcurrent relays are used the protection cannot be intertripped by a.c. injection into the pilots, and unstabilising the protection will result in tripping only if an overcurrent condition exists simultaneously.

7. EMERGENCY USE FOR OVERCURRENT PROTECTION.

In the event of a pilot failure which cannot quickly be rectified, the differential unit may be adapted for use as a definite time overcurrent relay as follows:

If overcurrent module is fitted:

* disconnect pilot wires and leave terminals open circuited
* set K_t to 3 (300 milliseconds)
* check that overcurrent elements are on the required setting above maximum anticipated load current.

If overcurrent module is not fitted:

* disconnect pilot wires and connect a 1000 ohm resistor across pilot terminals of relay.
* set padding resistors R_{pp} to maximum (600 ohms)
* set K_t to 3 (300 milliseconds)
* set K_s to required open circuit setting; $K_s = 1$ gives three phase setting equal to rated load (I_n). NOTE: Other fault settings will depend upon the summation ratio.

8. TYPICAL SCHEMES.

Figure 22 shows some of the most commonly used schemes of protection. Translay-S may be combined with other production protection, such as inverse time overcurrent relays, to form an integrated protection.

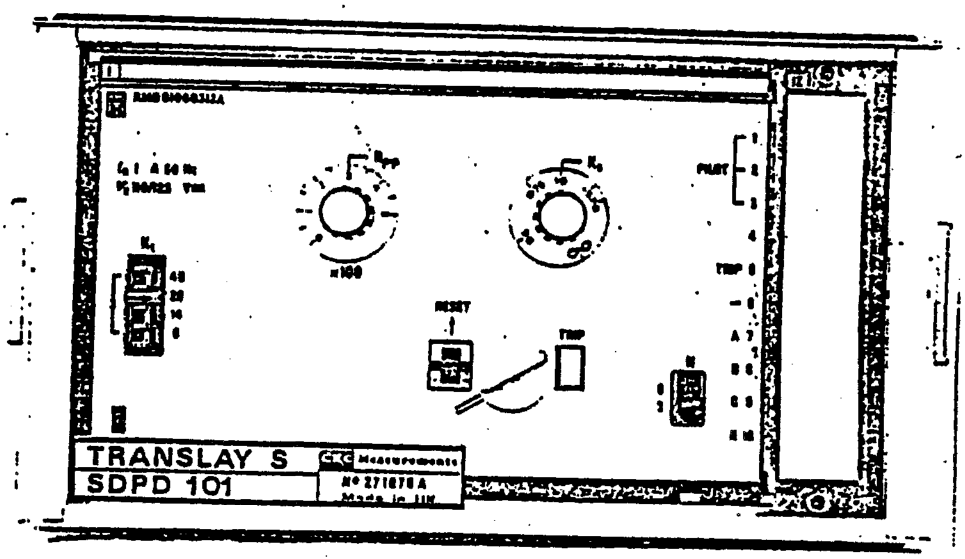

TRANSLAY S
SDPD 101
RESET
TRIP
PILOT
x100

FIG.1.

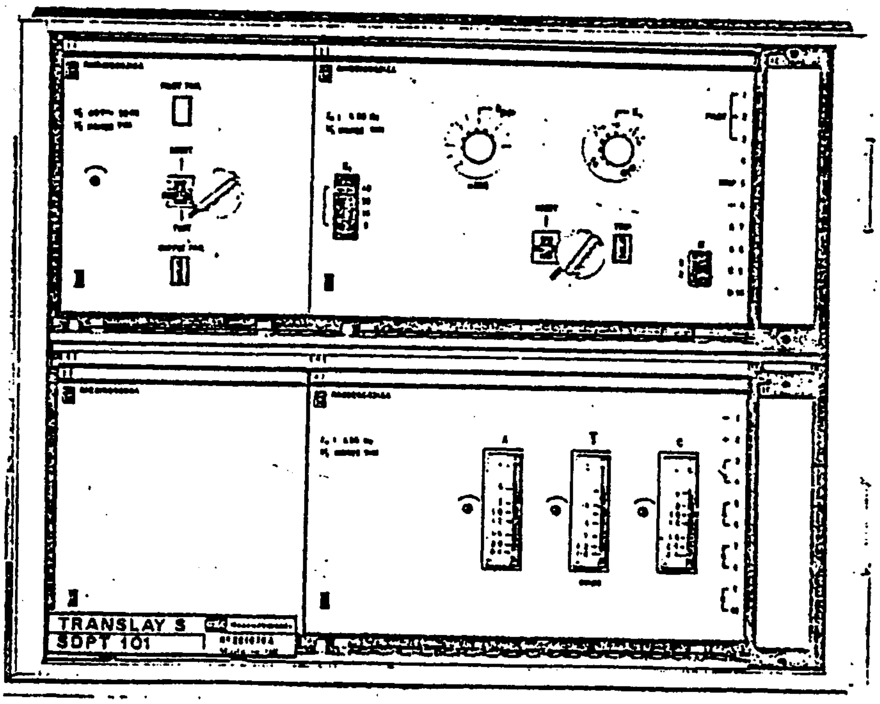
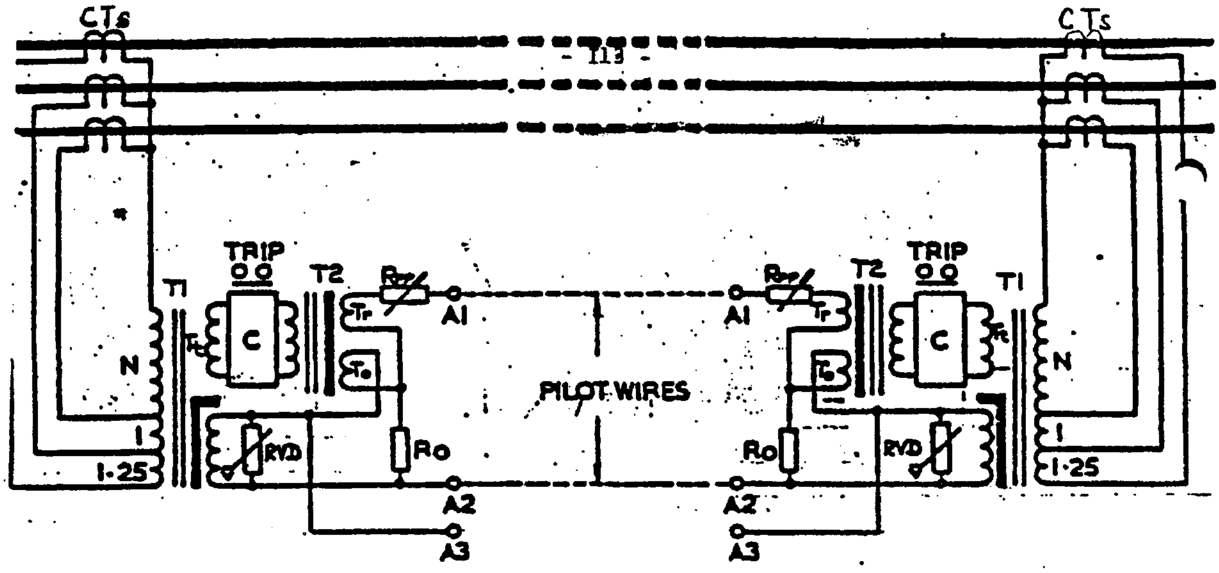
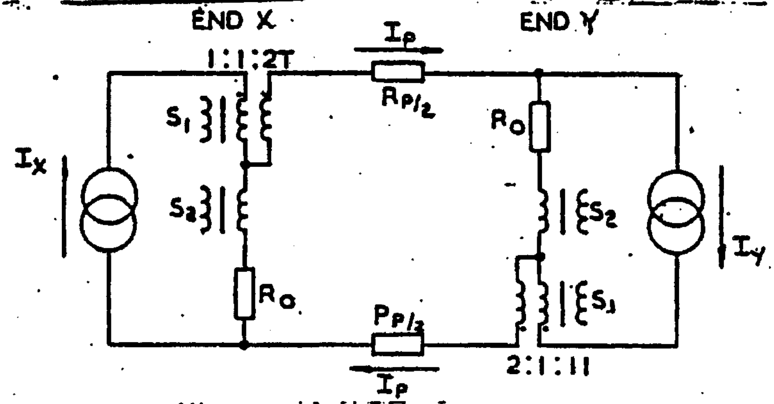

TRANSLAY S
SDPT 101

FIG.2.



3. CIRCUIT DIAGRAM FOR TRANSLAY S DIFFERENTIAL FEEDER PROTECTION



CONSIDER END X

$S_1 = I_X - 2I_P$

ASSUME $R_O = R_P$ THEN

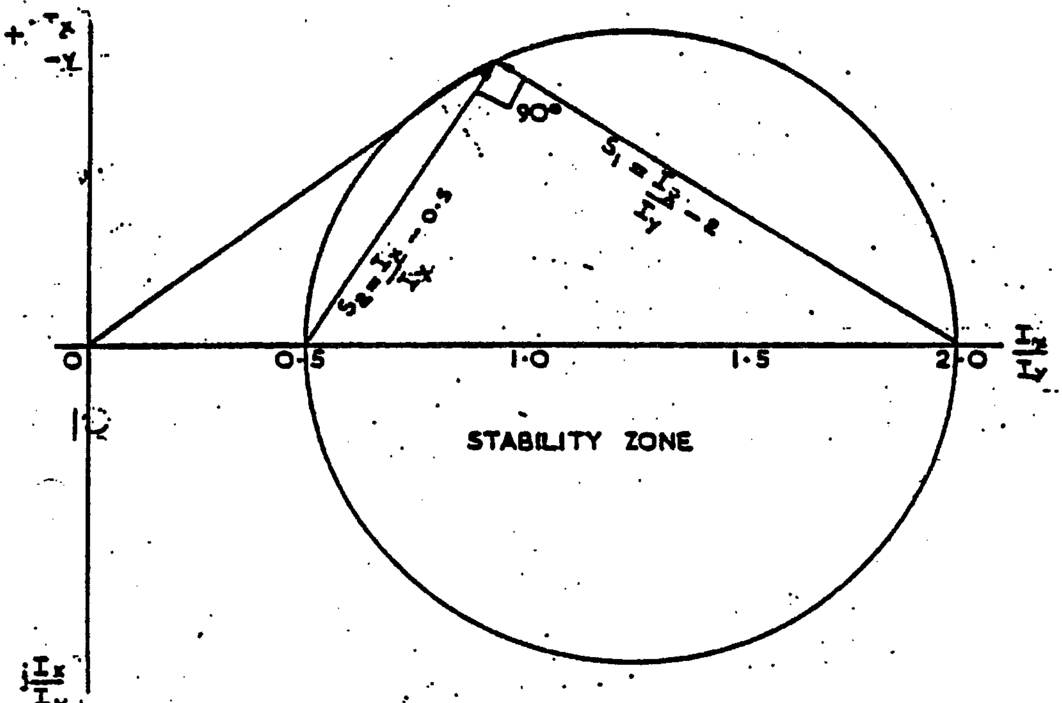
$$S_1 = I_X - 2\left[\frac{I_X}{3} + \frac{I_Y}{3}\right]$$

$$S_1 = I_X - 2I_Y \qquad \text{OR} \qquad \frac{I_X}{I_Y} - 2$$

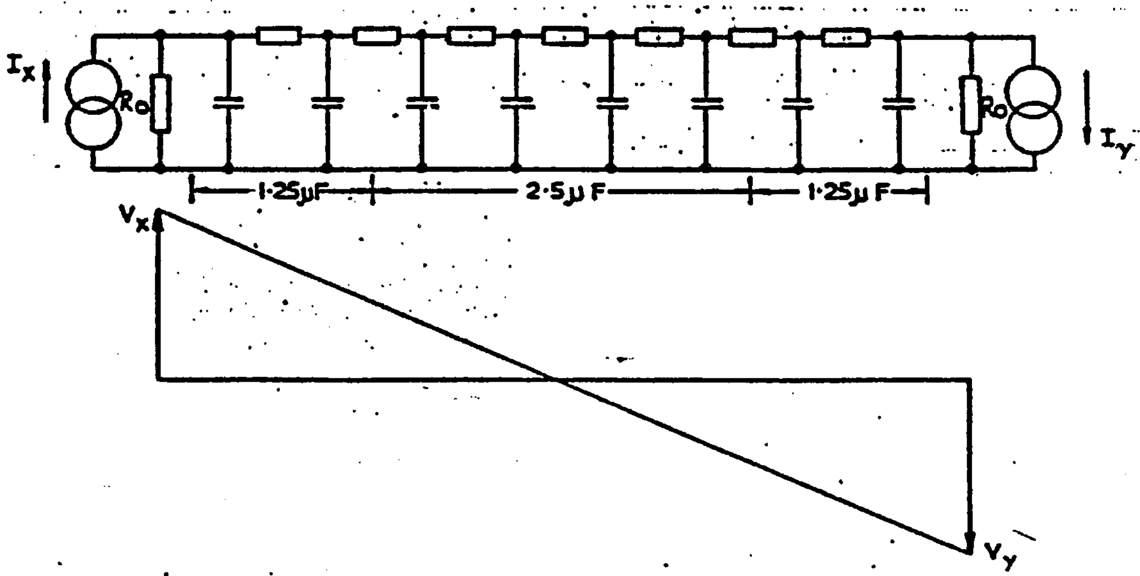
$$S_2 = \frac{2}{3} I_X - \frac{1}{3} I_Y$$

$$S_2 = 2I_X - I_Y \qquad \text{OR} \qquad \frac{I_X}{I_Y} - 0.5$$

4. EQUIVALENT CIRCUIT OF DIFFERENTIAL RELAY



5. TRANSLAY S POLAR BIAS CHARACTERISTIC



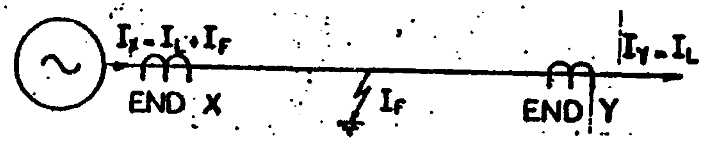
PILOT CAPACITANCE COMPENSATION – TRANSLAY-S

FAULT	SETTINGS	
	N = 3	N = 6
A – N	0·19 $K_s I_n$	0·12 $K_s I_n$
B – N	0·25 $K_s I_n$	0·14 $K_s I_n$
C – N	0·33 $K_s I_n$	0·17 $K_s I_n$
A – B	0·8 $K_s I_n$	
B – C	1·0 $K_s I_n$	
C – A	0·44 $K_s I_n$	
A–B–C	0·51 $K_s I_n$	

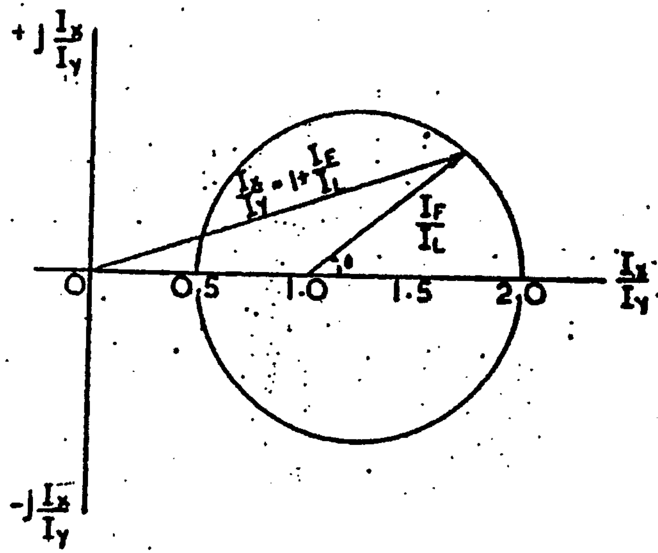
Ks is a setting multiplier and may be varied from 0·5–2·0

Summation Ratio = 1·25 : 1 : N

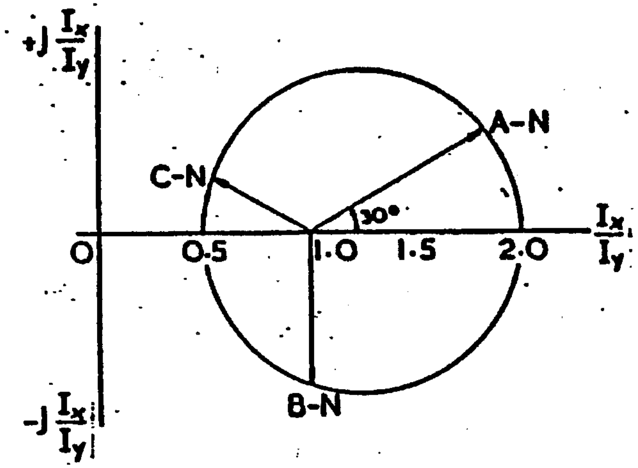
7. TRANSLAYS FAULT SETTINGS



$$\frac{I_x}{I_y} = \frac{I_L + I_F}{I_L} = 1 + \frac{I_F}{I_L}$$



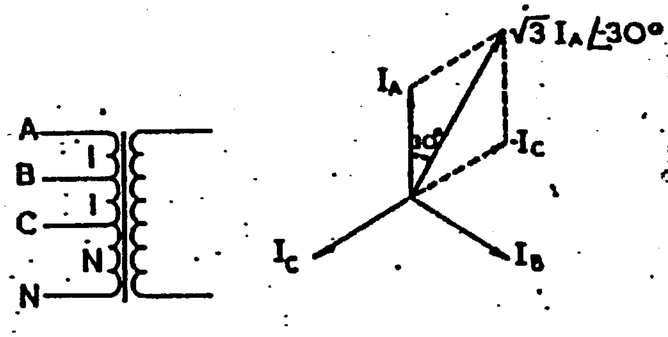
8. POLAR CHARACTERISTIC



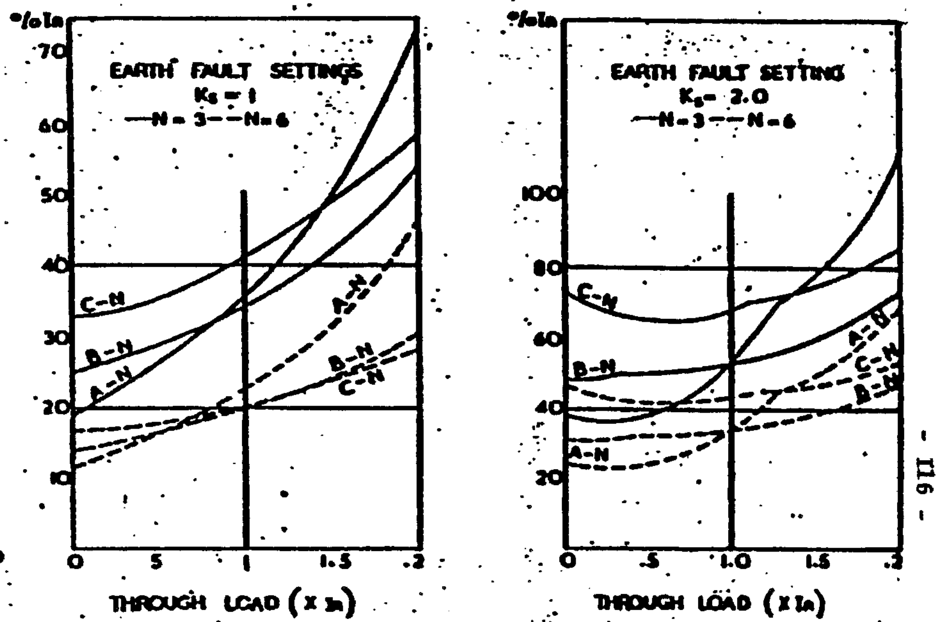
A-N Fault setting $= \overline{AN}\,\frac{\sqrt{3}\,I_L}{2+N}$

B-N " " $= \overline{BN}\,\frac{\sqrt{3}\,I_L}{1+N}$

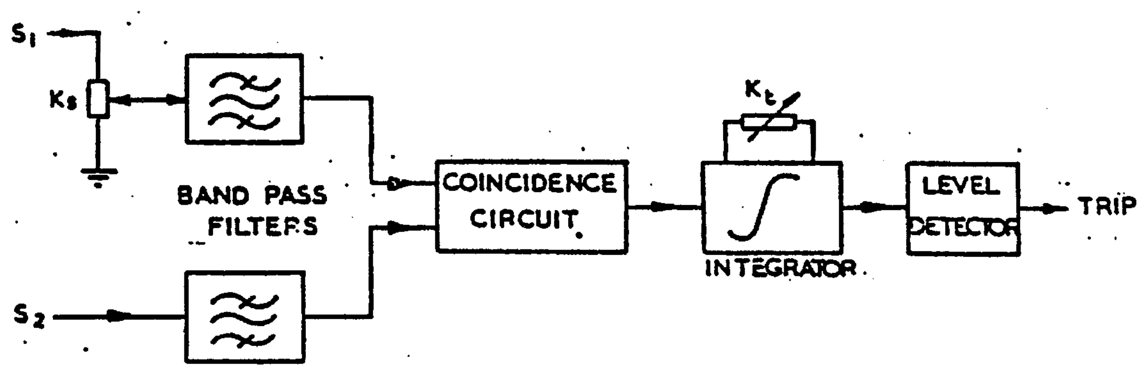
C-N " " $= \overline{CN}\,\frac{\sqrt{3}\,I_L}{N}$



9. FAULT SETTINGS WITH LOAD CURRENT



10. EARTH FAULT SETTINGS WITH THROUGH LOAD



11. BLOCK DIAGRAM OF PHASE COMPARATOR

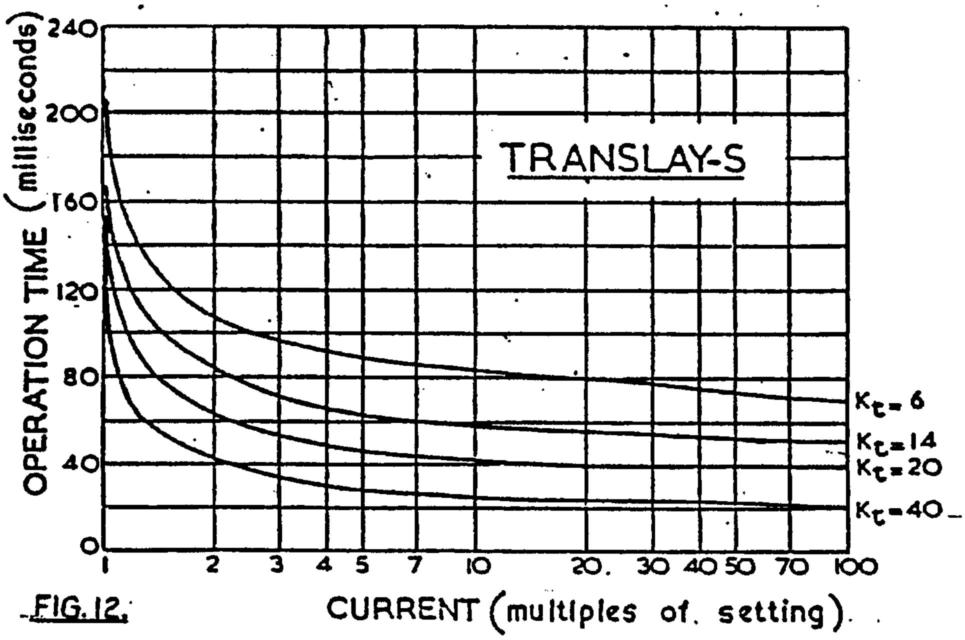
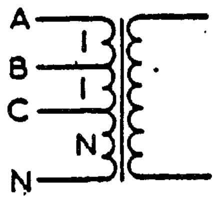


FIG. 12.



A - B Fault

Spill turns = 1 + N

B - C Fault

Spill turns = N

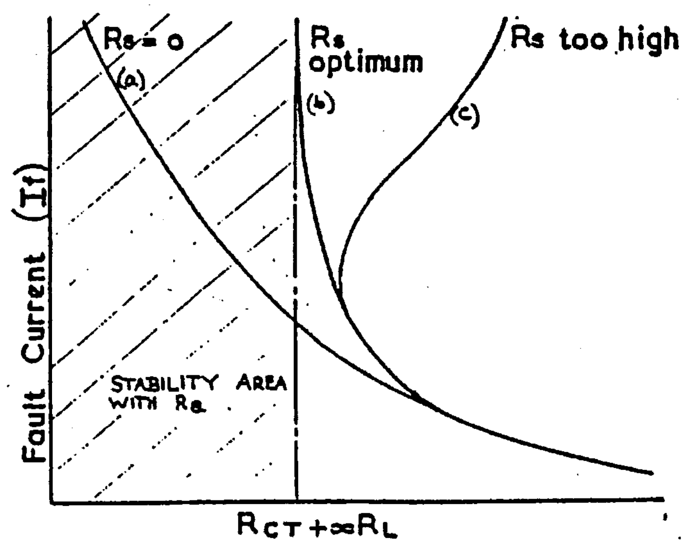
Ratio of spill turns = $\frac{1+N}{N}$

$= \frac{4}{3} = 1.33$ for $N = 3$

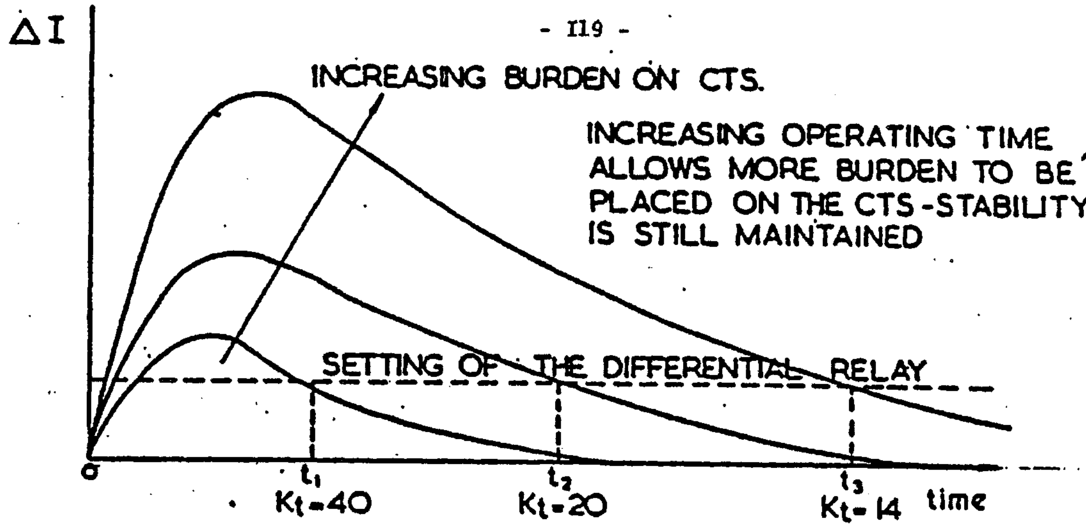
$= \frac{7}{6} = 1.16$ for $N = 6$

As a compromise A - B turns were made 1·25
Hence summation ratio = 1·25 / 1 / N

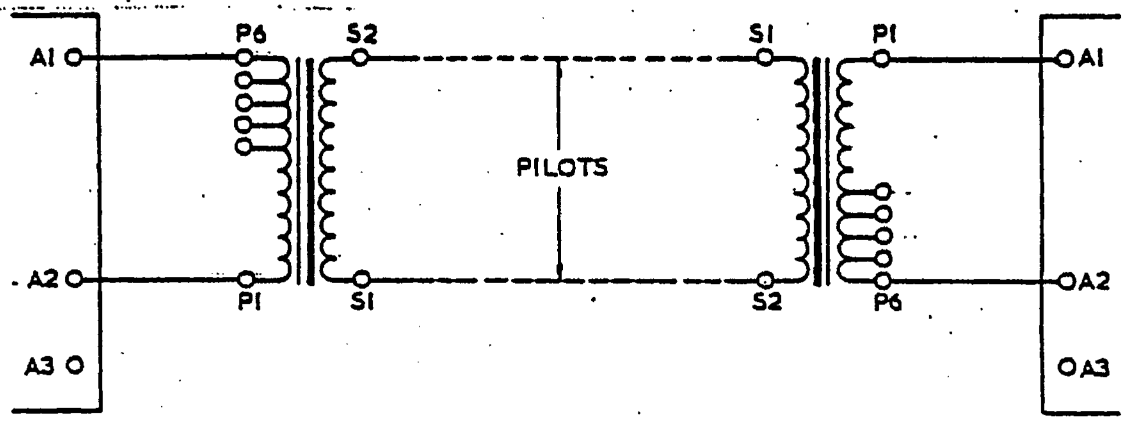
13. SUMMATION TRANSFORMER



14. EFFECT OF STABILISING RESISTANCE



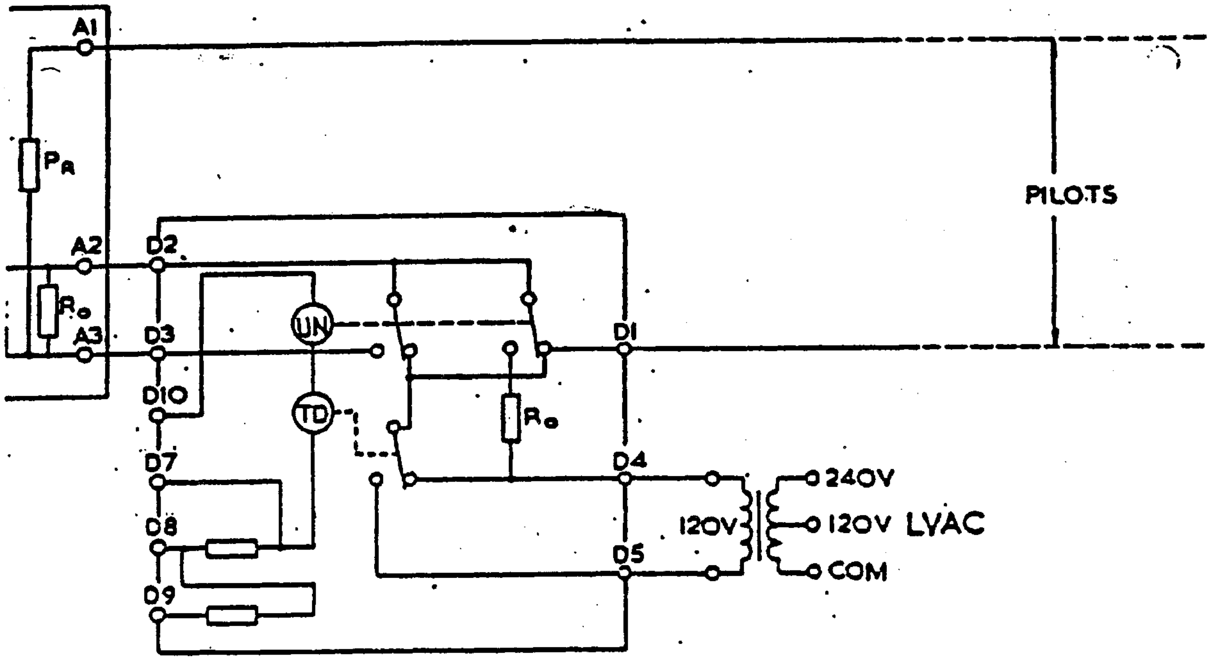
15. EFFECT OF OPERATION TIME ON STABILITY



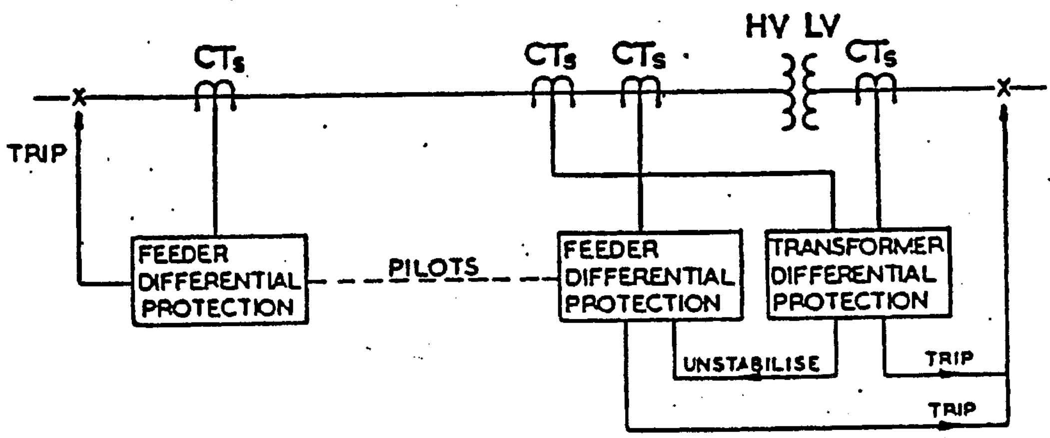
16 CONNECTIONS FOR PILOT ISOLATING TRANSFORMERS

Matching Ratio K_m	0·8	1·0	1·2	1·5	2·5
Loop Resistance Ω	800	1000	1200	1500	2500
Capacitance µF	6·25	5·0	4·2	3·3	2·0
Terminals	$P_1 - P_6$	$P_1 - P_5$	$P_1 - P_4$	$P_1 - P_3$	$P_1 - P_2$

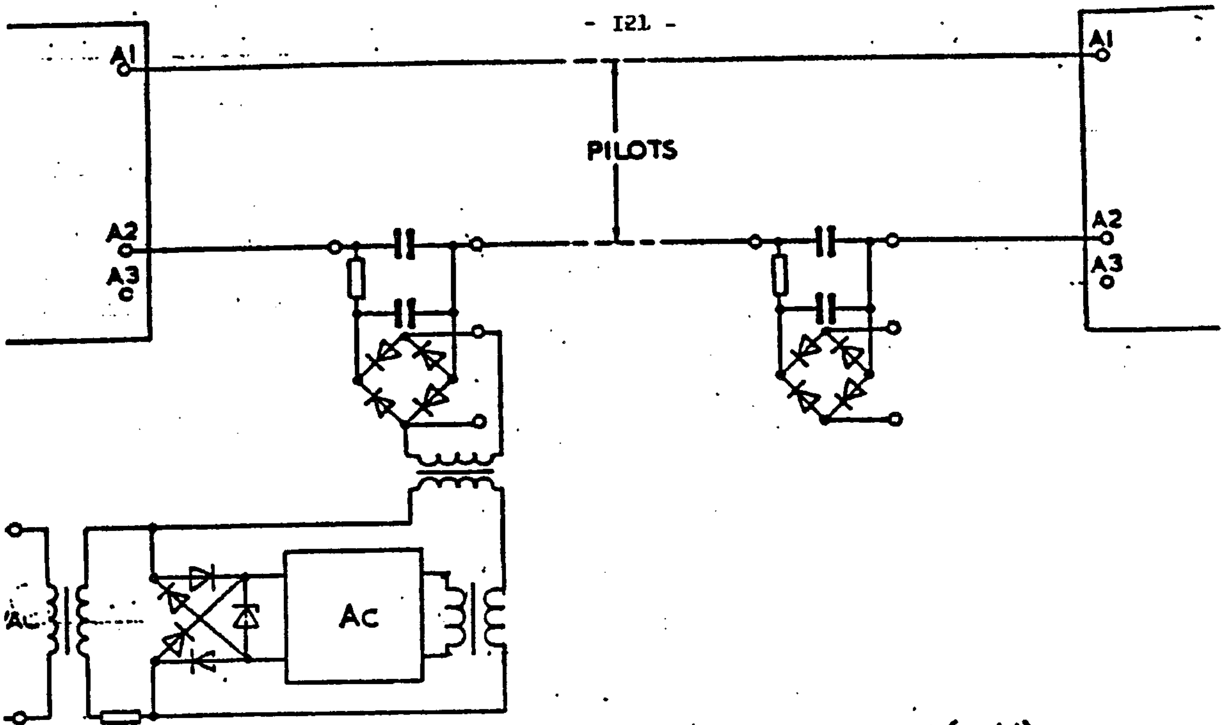
17. PILOT RANGE



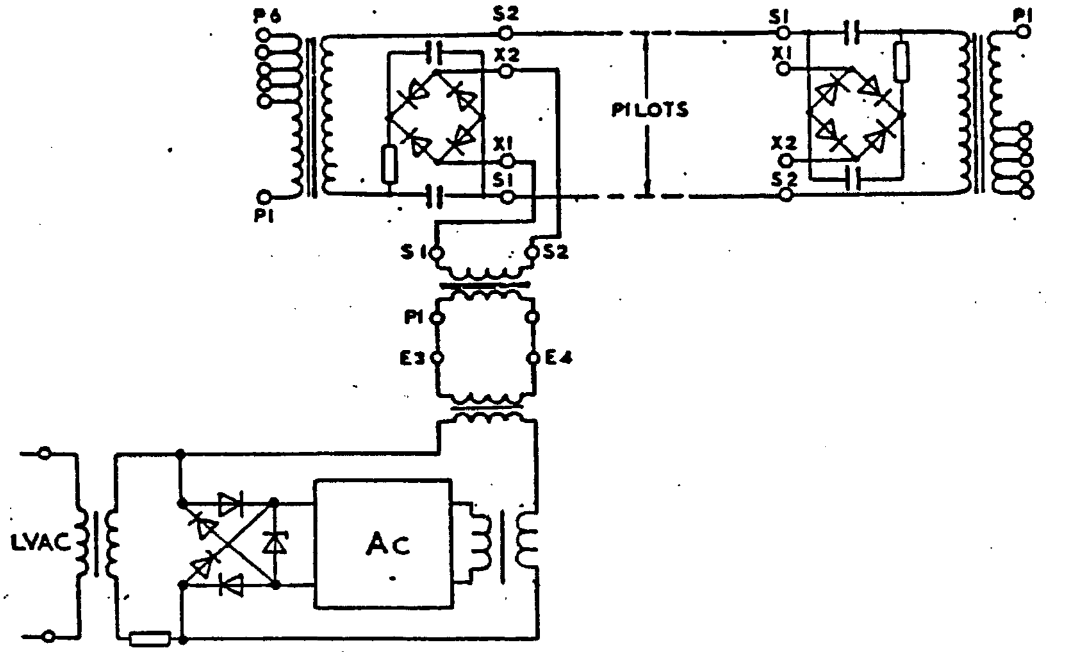
18. CONNECTIONS FOR INTERTRIP ELEMENT



19. PROTECTION OF TRANSFORMER FEEDERS



20. CONNECTIONS FOR PILOT SUPERVISION (5kV)



21. CONNECTIONS FOR PILOT SUPERVISION (15kV)

Translay S

1. Features

   a) High stability for through faults.

   b) High speed operation for in-zone faults.

   c) Simultaneous tripping of relays at each line end.

   d) Low current transformer requirements.

   e) Low earth fault settings.

   f) Suitable for both overhead lines and underground feeders.

   g) Suitable for pilots up to 2500 ohms.

   h) Pilot isolation for 5kV or 15kV.

   i) Four electrically separate contacts.

2. Principle of Operation (Figure 1 Refers)

   a) Using Merz-Price circulating current system.

   b) Phase comparators are used for the measuring elements.

   c) A summation transformer T1 at each end produces a single phase current for measurement. The neutral section of the summation winding is tapped to provide alternative sensitivities for earth faults.

   d) A non-linear resistor (RVD) at secondary output of T1 (conducting at heavy fault conditions is used to limit the maximum secondary voltage under heavy fault conditions.

   e) At normal condition, secondary current from TS flows through operation winding To on transformer T2 and then directs two-third through resistor Ro and one-third through the restraint winding Tr of T2, the pilot circuit and resistor Ro of the remote relay.

   f) The resultant of currents in Tr and To is delivered by transformer T2 to phase comparator (Øc) and is compared with voltage from Tt of transformer T1.

   g) Equivalent circuit (Fig. 2 & 3 refer) indicates the signals to the phase comparator.

   $$S1 = \frac{IA}{IB} - 2, \quad S2 = \frac{IA}{IB} - 0.5$$

   The relay system is stable under the conditions of :-

   $$0.5 < \frac{IA}{IB} < 2.0$$

   $$\text{Angle } S_1 - \text{Angle } S_2 > 90^o$$

3. Compensation for Pilot Capacitance

Equivalent circuit (Fig. 4 refers) shows that capacitance at centre of the pilot has little voltage, hence little capacitance current will flow. Capacitance at the ends of the pilot has a higher voltage, hence a more significant current will flow. This capacitance current is in quadrature with pilot voltage and the phase comparator has 90° angle limits, therefore the relay is insensitive to this quadrature current.

No compensation is required for pilot capacitance up to 2.5 microfarads.

4. Fault Settings

Fault settings shown in Fig. 5 indicate the settings for pilot normal. With pilot open-circuited, the fault settings will be halved.

5. Phase Comparator

Fig. 6 shows the block diagram for the phase comparator. The filtering input circuit, tuned to power frequency, is to improve the distorted waveform derived from current transformer saturation, in order to ensure high speed operation under adverse conditions.

The signal S1 is controlled by a setting multipler Ks with a range of 0.5 to 2.0.

The coincidence circuit produces pulses proportional in width to the phase difference between the signals from the filters.

The time constant Kt in the integrator is to provide variable relay operating time (Fig. 7 refers).

6. Stabilising Resistance

The resistor, connected between the neutral connection of the summation winding and the star point of the line current transformers, is to increase the resistance of the spill current path, so that all three current transformers are forced into a similar degree of saturation. This reduces the spill current and hence reduces the error in the summated output.

$$R_s = \frac{V_{KP}}{K I_n}$$

K: constant for the protection
I_n: rated current
V_{KP}: CT knee point voltage

7. Current Transformer Requirements

$$V_{KP} \geqslant N K_t I_n (R_{CT} + X R_L)$$

$$I_M \leqslant 0.05\, I_n \text{ at } \frac{10}{I_n} \text{ volts}$$

where V_{KP} = knee point voltage of CT

R_{CT} = resistance of CT secondary circuit (ohms)

R_L = lead resistance of single lead from relay to CT (ohms)

X = 1 for 4 wire connections between the main CTs and the relay : 2 for 6 wire connections

N = relative neutral turns on summation transformer winding (3 or 6)

K_t = the selected time dependent constant (40, 20, 14 or 6)

I_n = rated CT secondary current (A)

I_M = magnetising current of CT(A)

8. Protection Unstabilising and Intertripping

Operation of the relay UN (Fig. 8 refers) short-circuits the local summation transformer secondary winding so that the relay at that end is rendered inoperative. At the same time this action open-circuits the pilot, so that the relay at remote end becomes unstable.

In order to intertrip the remote end, a.c. voltage is injected into the pilot circuit. The intertrip relay TD operates approximately 120 ms after the unstabilising relay to inject the intertrip voltage.

9. Pilot Supervision

The pilot supervision will not prevent tripping for pilot faults but will indicate the cause. Indication is also provided for loss of the supervision supply (Fig. 9 refers).

10. Overcurrent Check/Starter

Overcurrent check/starter feature is to guard against mal-operation on pilot failure (Fig. 10 refers).

In starter mode, no d.c. is drawn from the auxiliary d.c. supply by the differential relay unless an overcurrent condition exists. When starter mode is used, the overall operation time of the scheme is increased by the operating time of the starter.

In check mode, a constant current is drawn from the auxiliary d.c. supply by the differential relay. The overcurrent check is to guard the differential relay output contact. In this mode, there is no increase in the overall operation time.

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(0559A)

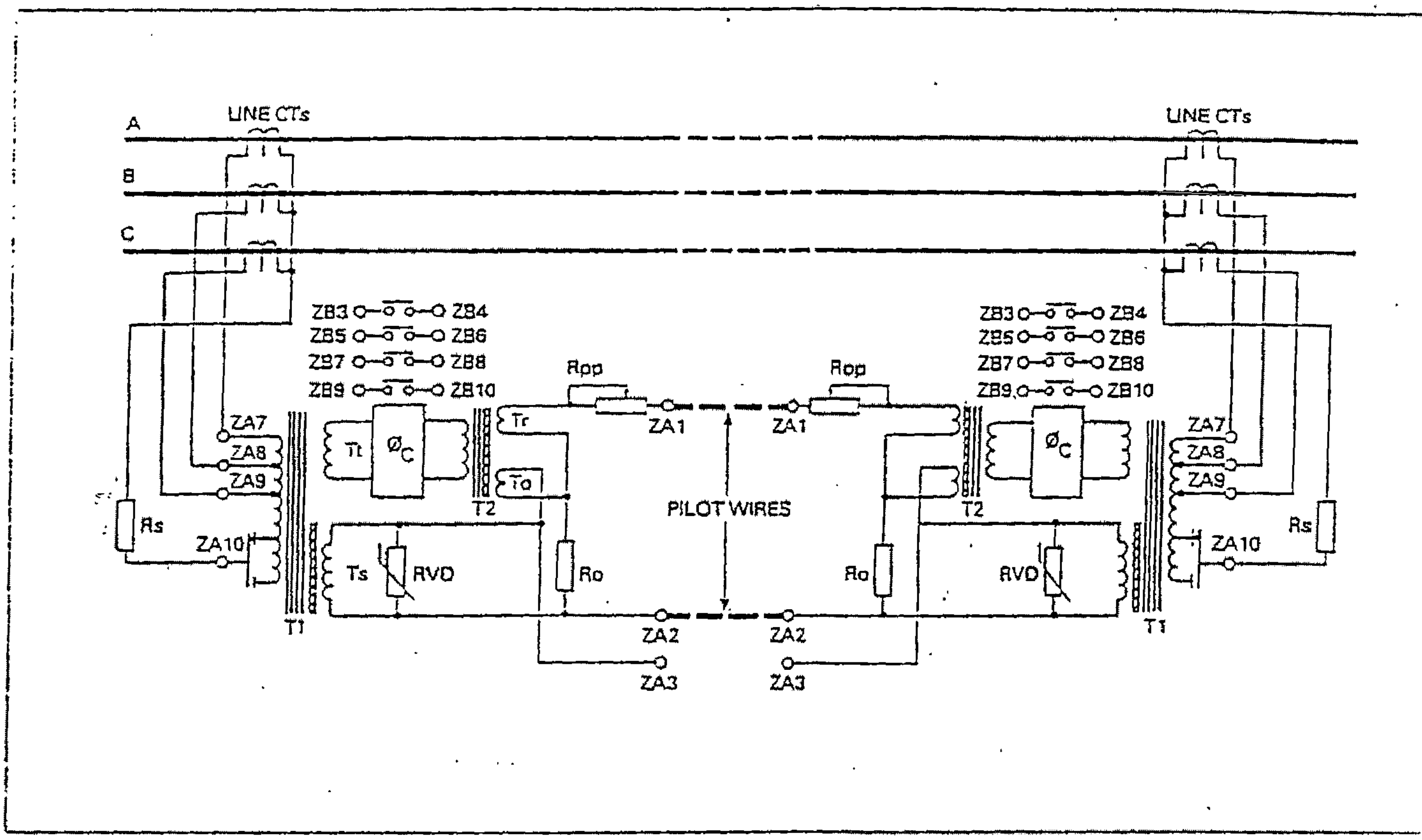
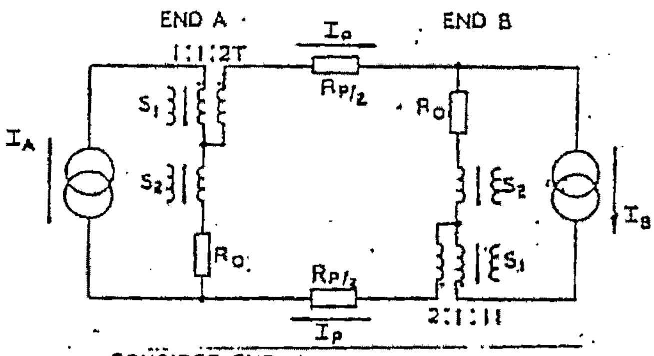


Figure 1. CIRCUIT DIAGRAM FOR TRANSLAY S DIFFERENTIAL FEEDER PROTECTION



CONSIDER END A

$S_1 = I_A - 2I_P$

ASSUME $R_O = R_P$ THEN

$S_1 = I_A - 2\left[\frac{I_A}{3} + \frac{I_B}{3}\right]$

$S_1 = I_A - 2I_B$ OR $\frac{I_A}{I_B} - 2$

$S_2 = \frac{2}{3}I_A - \frac{1}{3}I_B$

$S_2 = 2I_A - I_B$ OR $\frac{I_A}{I_B} - 0.5$

FIG. 2 EQUIVALENT CIRCUIT OF DIFFERENTIAL RELAY

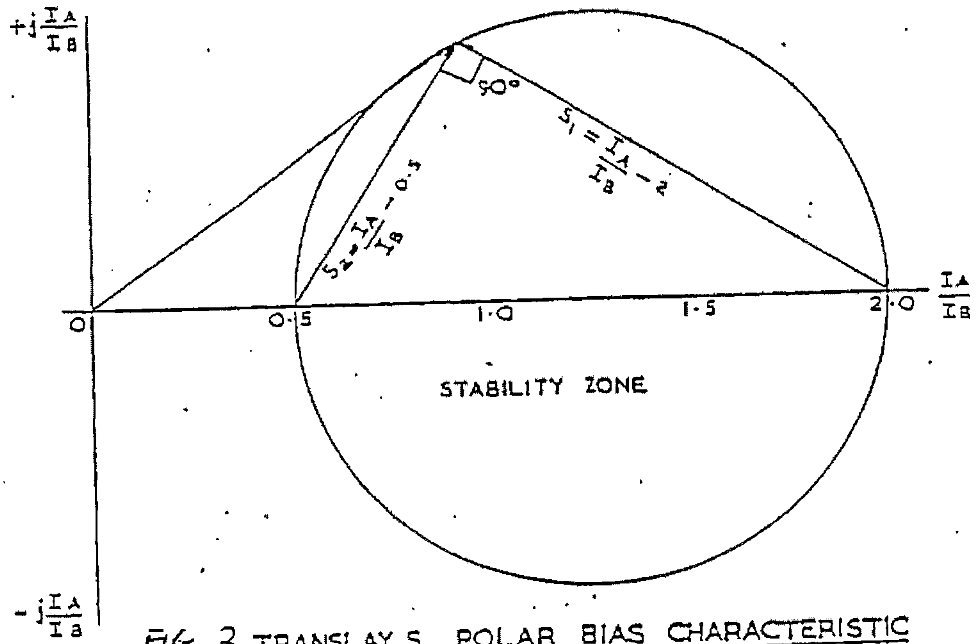


FIG. 3 TRANSLAY S POLAR BIAS CHARACTERISTIC

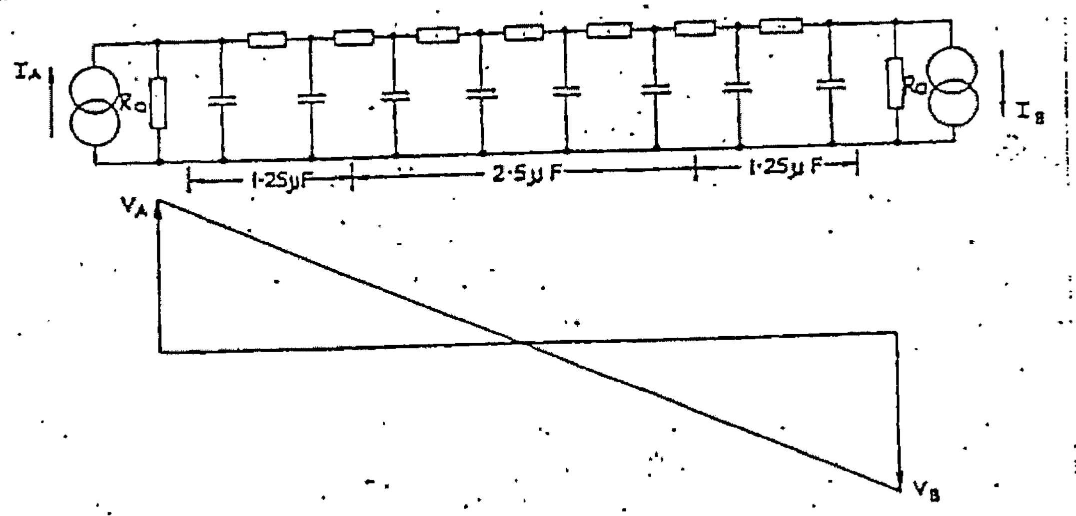


FIG. 4 PILOT CAPACITANCE COMPENSATION – TRANSLAY-S

FAULT	SETTINGS	
	N = 3	N = 6
A – N	0·19 $K_s I_n$	0·12 $K_s I_n$
B – N	0·25 $K_s I_n$	0·14 $K_s I_n$
C – N	0·33 $K_s I_n$	0·17 $K_s I_n$
A – B	0·8 $K_s I_n$	
B – C	1·0 $K_s I_n$	
C – A	0·44 $K_s I_n$	
A–B–C	0·51 $K_s I_n$	

K_s is a setting multiplier and may be varied from 0·5–2·0

Summation Ratio = 1·25 : 1 : N

FIG. 5 TRANSLAYS FAULT SETTINGS

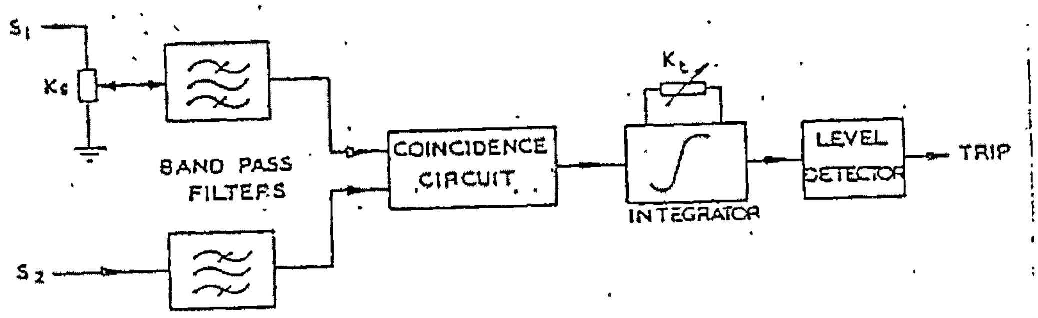


FIG. 6 BLOCK DIAGRAM OF PHASE COMPARATOR

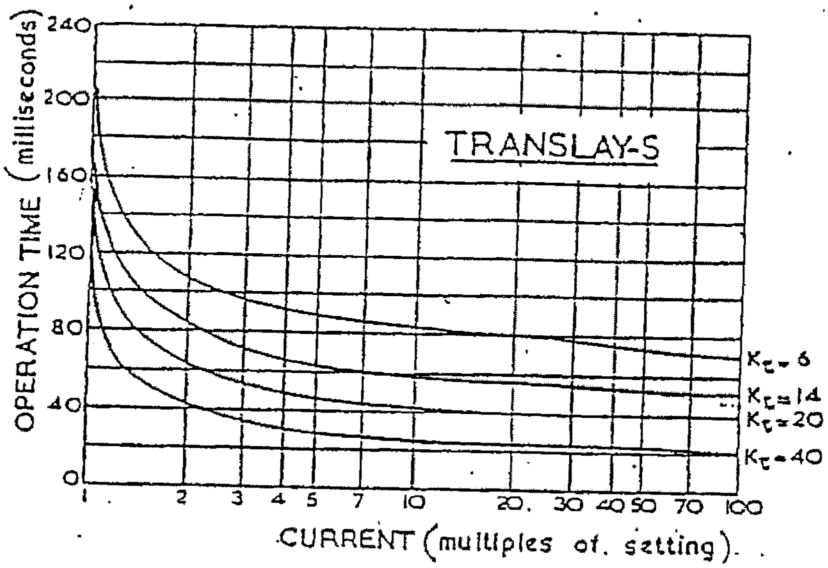


FIG. 7. OPERATION TIME CHARACTERISTICS

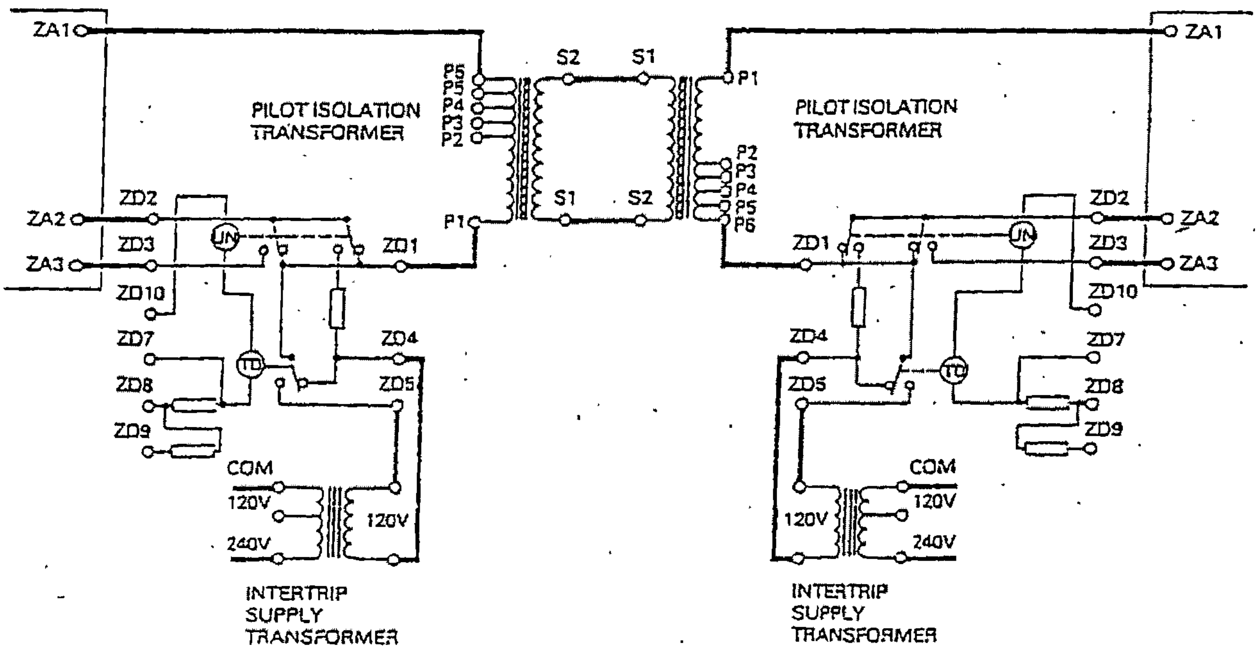


FIG. 8 CONNECTIONS FOR UNSTABILISING AND INTERTRIPPING FACILITIES

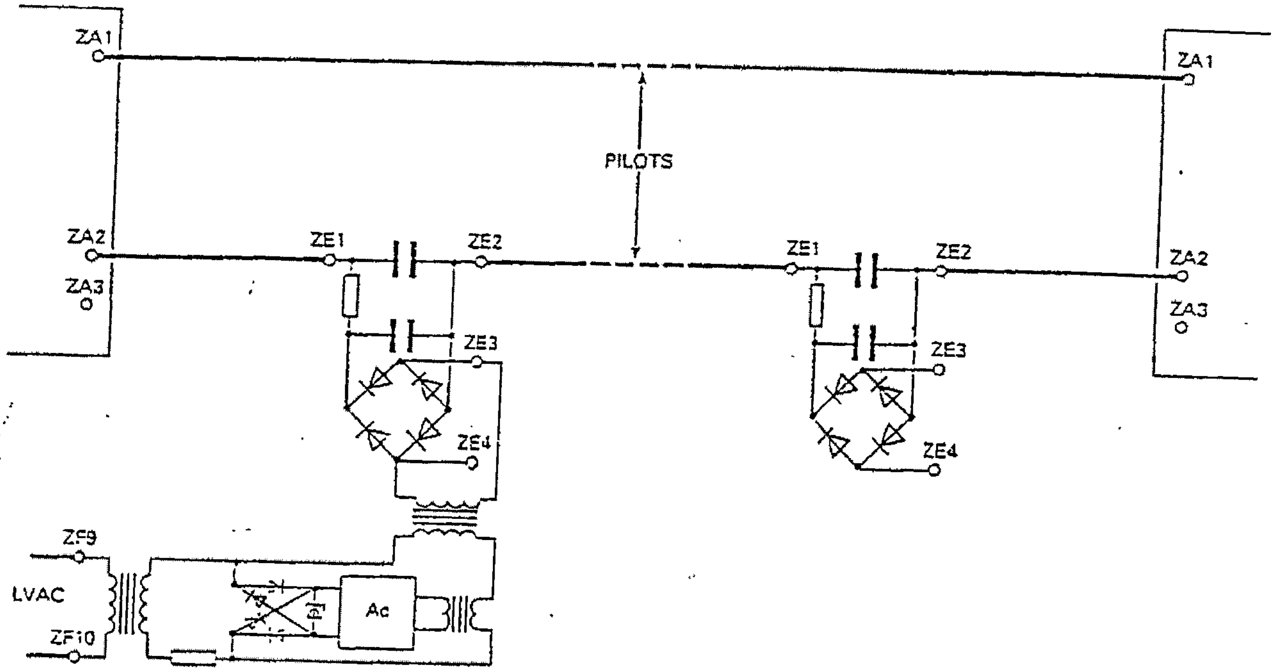


FIG. 9. PILOT SUPERVISION.

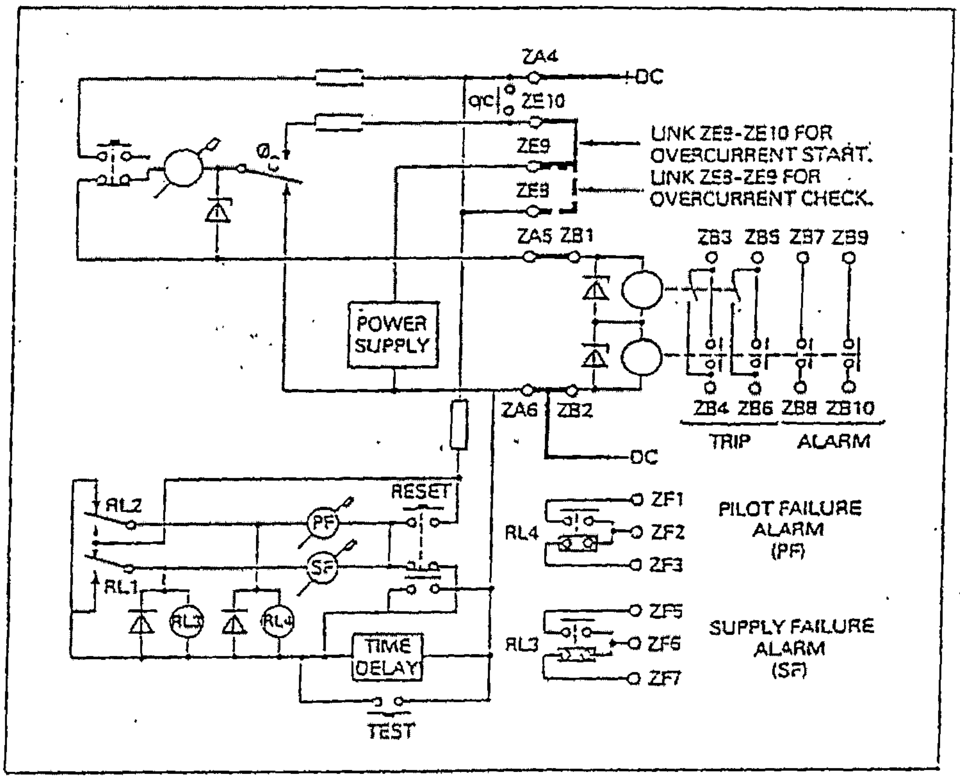
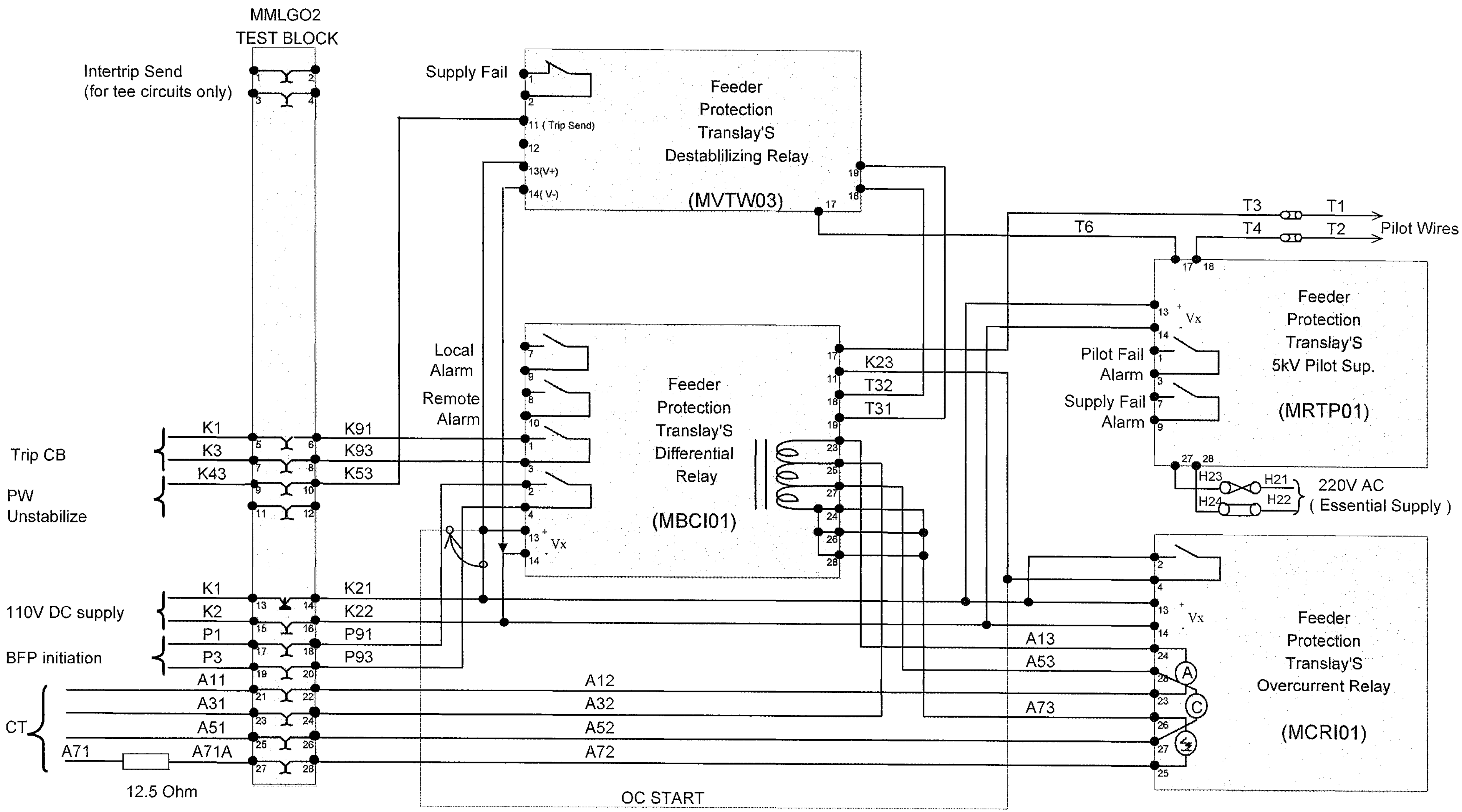


Figure 10. D.C. CONNECTIONS FOR DIFFERENTIAL RELAY WITH PILOT SUPERVISION AND OVERCURRENT CHECK STARTER



TECHNICAL SUPPORT SERVICES DEPARTMENT		CHINA LIGHT & POWER COMPANY, LIMITED
PROTECTION BRANCH		
DATE	30.10.2003	TITLE : Test Block Arrangement for 132kV Feeder Protection (Translay'S 5kV) sending End
DRAWN BY	K.Y.Poon	
CHECKED BY	P K Shek	DATE / DRG. NO.
APPROVED BY	P K Shek	REV. / P-132-10