ABB Power T&D Company Inc.
Relay Division
Coral Springs, FL
Allentown, PA

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dated May, 1972
Mailed to: E, D, C/41-300A

Device Number: 87B

Types LC-1, LC-2 Linear Coupler Bus Differential Relays

Application

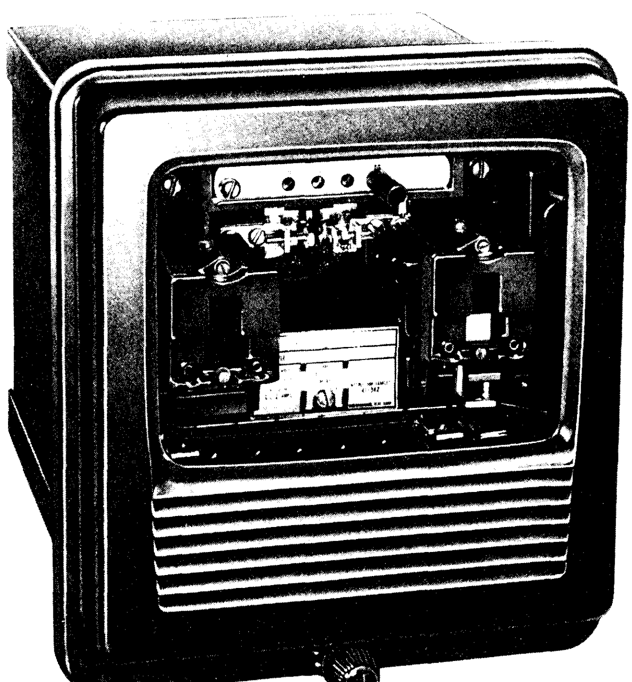
The linear coupler system provides a high-speed, easy-to-apply, set, and maintain bus differential system that is extremely flexible for switching or changes in bus layout. The use of linear couplers eliminates iron and its attendant saturation which is always an inherent problem with current transformers.

The linear coupler method of bus protection utilizes air core mutual reactors instead of the usual current transformers. They are wound on non-magnetic torodial cores to have accurate constant mutual impedance with respect to the primary circuit and negligible mutual inductance to any external or neighboring circuits.

The energy output of the couplers makes possible the use of low energy, high speed relays types LC-1 and LC-2. Each of these is provided with impedance taps so that the impedance of the relay can be more closely matched to the impedance of the linear couplers when required for maximum sensitivity.

When the relay and coupler impedances are matched there is a maximum amount of operating energy transferred from the coupler to the relay. Since the standard linear coupler induces 5 volts secondary per 1000 amperes primary, the couplers (unlike current transformers) can be safely open-circuited. Hence, danger to personnel is eliminated. Further, when the protective zone is affected by bus switching, linear couplers are easily switched.

LC-1 Relay



LC-2 Relay

ABB

Application, Continued

The basic differential relaying scheme using linear couplers is shown in figures 10 and 11. The linear coupler method of differential protection is essentially a voltage differential scheme and, consequently, a series circuit is used in contrast to the parallel circuit employed with current transformer schemes. In the case of an external fault as shown in figure 10, the sum of the voltage induced in the linear coupler is zero. $E_1+E_2-E_N=0$.

This occurs because the sum of the currents flowing to the bus is equal to the sum of the currents flowing out to the system . . . and the relay does not trip. In the case of an internal fault, see figure 11, the above voltage cancellation does not exist, and the difference voltage appears at the terminals of a high speed, low energy, linear coupler relay which trips instantaneously. The linear couplers are in effect air core mutual reactors. They are similar to current transformers in general appearance and structural detail, except that the secondary coil winding has an air core with a permeability of 1.0; thus will not saturate or cause error currents even when the heavy primary currents exist.

This type of protection is particularly applicable to the protection of station buses where the dc component of short circuit current has a long time constant and causes saturation in current transformers of conventional design.

The problems associated with the saturation of the core of current transformers are eliminated when linear couplers are used.

The linear coupler consists of a toriodal or ring type secondary winding on a nonmagnetic core. It is usually mounted in a circuit breaker or transformer bushing and can be designed to fit into the space available for a conventional current transformer.

The single conductor in the bushing forms the primary of the linear coupler reactor and, because of the absence of iron, avoids problems due to saturation and provides a definite linear relationship between primary currents and secondary voltage. All of the linear coupler secondaries of a particular phase are connected in series with one type LC relay to form a closed loop. Under normal conditions, or when external faults occur, the induced voltages in all the linear couplers are cancelled out. On internal faults, a net voltage is available for relay operation.

The scheme is fast in operation, simple, and easily checked while in service.

The ratio between maximum external fault current and minimum internal fault current is limited to 25/1 (except when a separate ground LC relay is used), not because of the relay, but because of the economic manufacturing tolerances of the couplers. Couplers are made to plus or minus 1-percent accuracy. The possibility exists that one coupler may be +1% and another in the same circuit −1% with maximum current flow. This gives a 2-percent accuracy spread which, combined with a 2/1 safety factor, limits the relay pickup to not less than 4-percent of the maximum through fault current or a ratio of 1/25 between minimum internal and maximum external fault currents.

Assuming a 5000 ampere maximum external fault current, the LC relay should not be set to pick up on less than 4-percent of 5000 or 200 amperes primary current. Therefore, 200 amperes primary current is the minimum internal fault the relay can be set to detect.

When systems are grounded through a current limiting impedance, the ground fault current on the single phase to ground fault is so much less than interphase fault current that a fourth or ground type LC relay may be required. This relay is set much more sensitively than the phase relays, and to prevent it from picking up on error current during a heavy external phase fault, a type HVS supervisory relay is required. The HVS relay operates on zero sequence voltage and has its contacts connected in series with the ground type LC relay contacts.

When even more sensitive ground fault detection is required, LC-2 ground relays are connected in series with the LC phase relays and one HVS relay is used to supervise the contact circuits of the three LC-2 ground relays.

Selection of LC-1 or LC-2

The anticipated relay current is calculated by the following formula:

$$I\ \text{relay} = \frac{I\text{ext} \times E_M}{25 \times 2 \times Z_c \times N}$$

This gives the approximate value.

Iext = Maximum external primary fault current in amperes.

E_M = 5 volts/1000 amps = Mutual impedance of one coupler.

25 = 25/1, which is ratio of maximum external to minimum internal fault current. Includes coupler tolerance and safety factor.

2 = Reduction factor: If coupler series impedance (Z_c) is 60 ohms, then double this value because the relay would be set on the 60 ohm tap and adds 60 ohms additional impedance to relay circuit.

Z_c = Impedance of one coupler-average of 10 ohms each.

N = Number of series couplers in one phase.

For Relay Currents:	Use Relay Type
10- 50 mA	LC-2
50-200 mA	LC-2 plus external parallel resistor①
200-400 mA	LC-1

① The external fixed resistor assembly (19 ohms) used with the LC-2 relay reduces the relay current (I_r) to a value within the recommended operating range of the relay. In setting the LC-2, the resistor is used for coarse adjustment, and the flux shunts on the polar unit are used for more exact calibration.

Required Information

Maximum External Fault Current: phase and ground.

Minimum Internal Fault Current: phase and ground.

Number of Couplers Per Phase.

Coupler Impedance (estimate at 10 if unknown).

Application Guide

1. Are separate ground relays required?
   Yes, if minimum internal line-to-ground fault current is less than 8% of the maximum external fault current.
2. How many ground relays are required?
   If answer to (1) is yes, refer to Curve A. Use solid curves, VA=0.0085 if possible. Special care required in setting relays to get more sensitive settings.
3. Selection of LC-1 or LC-2
   If three ground relays are used, refer to Curve B. Otherwise use Curve C.
4. Is 19 ohm fixed resistor required?

   If LC-2 phase relays are to be used, refer to Curve C or B to determine if resistor is required.

   When applications involving the LC-2 relay require a sensitivity between 0.0085 and .0025 volt-amperes, it may be necessary to adjust the flux shunts on the polar unit of the relay to obtain the desired sensitivity. If the external resistors are required, they should be connected in parallel with each of the LC-2 phase relay coils, so as not to decrease the sensitivity of the series connected LC-2 ground relays.

Fig. 1: (Curve A)
Approximate LC-2 ground relay sensitivity (phase relay on number 30 tap).

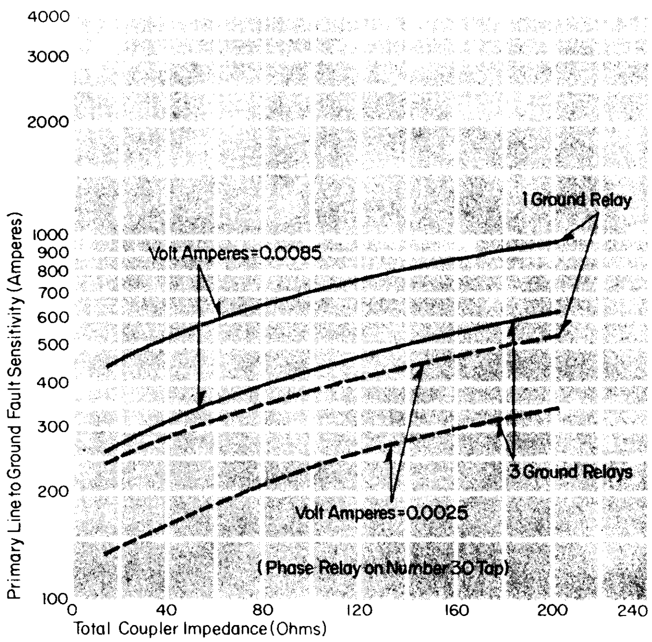


Fig. 2: (Curve B)
Approximate phase relay sensitivity (3 ground relays on number 30 tap).

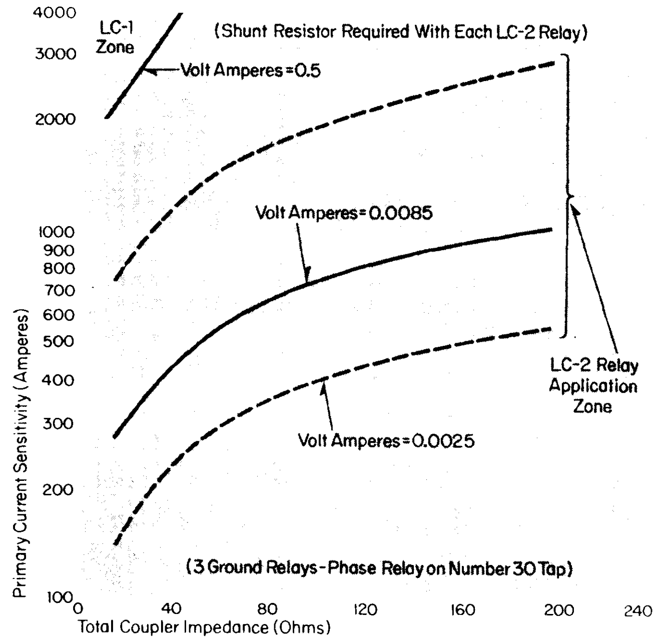
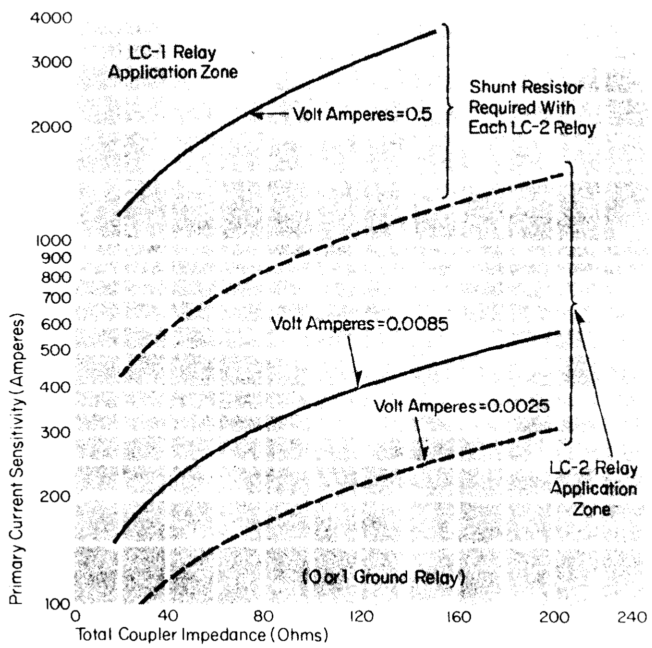


Fig. 3: (Curve C)
Approximate phase relay sensitivity (0 or 1 ground relay).



Construction

LC-1

The LC-1 relay has an ac contactor switch-type solenoid operating unit connected through an impedance matching transformer with 30, 40, 60 and 80 ohm taps. Maximum transfer of energy from the linear couplers to the LC-1 relay occurs when the relay and coupler impedances are matched.

The solenoid unit has a scale plate calibrated in decimal fractions of an inch which indicates the amount of free contact travel on the unit. Adjustments between 0.06 to 0.24 inches gives between 90 to 550 MA pick-up depending on the transformer tap. See Figure 7.

LC-2

The LC-2 relay is a dc polar unit energized through a silicon diode full-wave rectifier and an impedance matching transformer, also with 30, 40, 60 and 80 ohm taps. Adjustments of the magnetic shunts changes the pickup from 10 to 50 MA over the recommended setting range depending on the taps. See Figures 8 and 9.

An auxiliary dc solenoid switch (VS) is used in the trip circuit to provide added security to the sensitive polar unit. This is primarily to prevent undesired tripping due to severe mechanical vibrations, such as slamming of panel doors on which the relay is mounted.

Impedance Transformer Taps

Solenoid Operating Unit

Auxiliary Switch (VS)

Polar Unit

Indicating Contactor Switch (ICS)

Impedance Matching Transformer

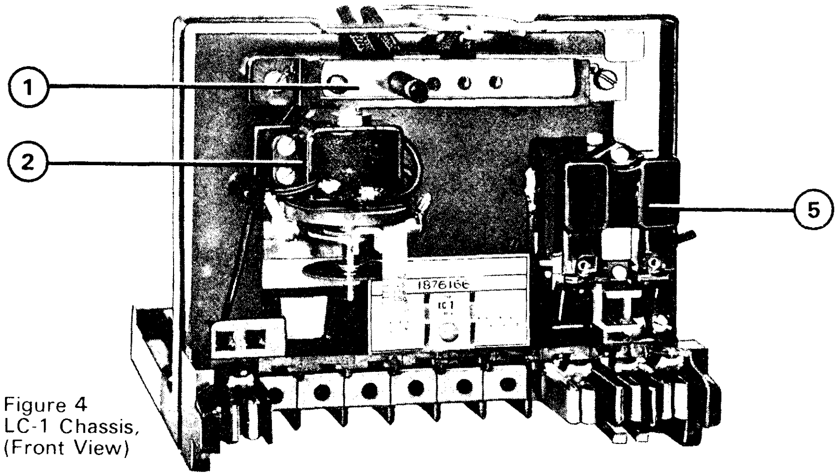


Figure 4
LC-1 Chassis,
(Front View)

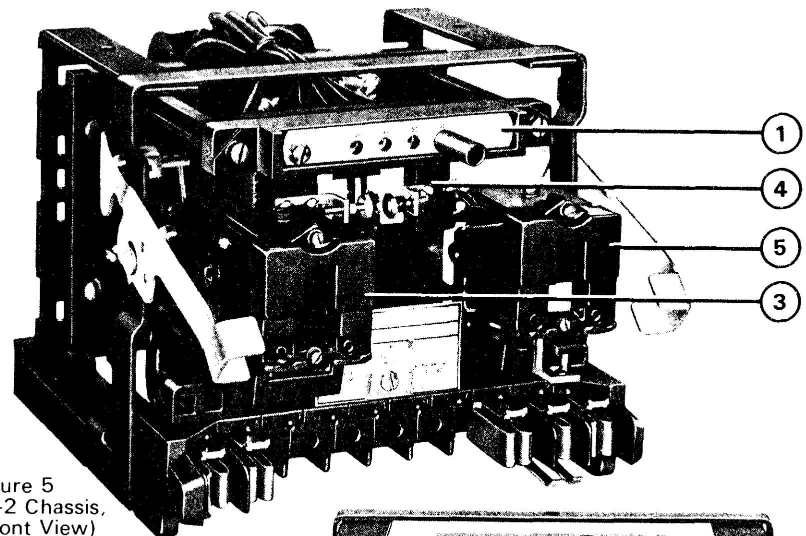


Figure 5
LC-2 Chassis,
(Front View)

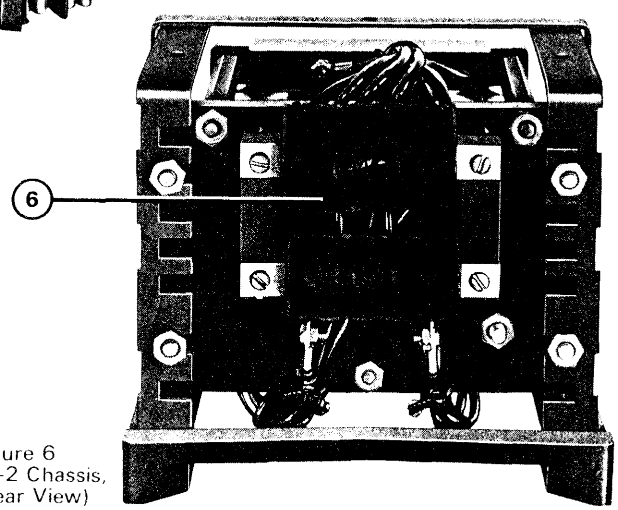


Figure 6
LC-2 Chassis,
(Rear View)

Performance Curves

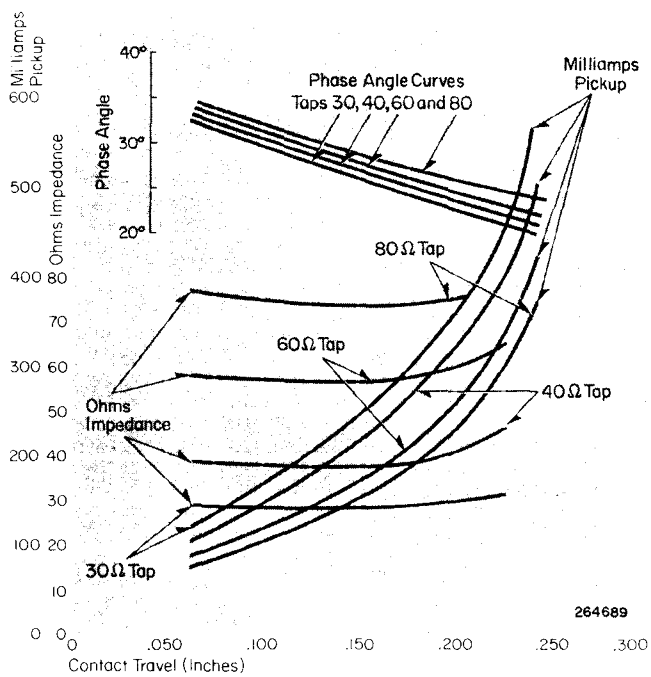


Fig. 7: LC-1 Characteristic Curves.

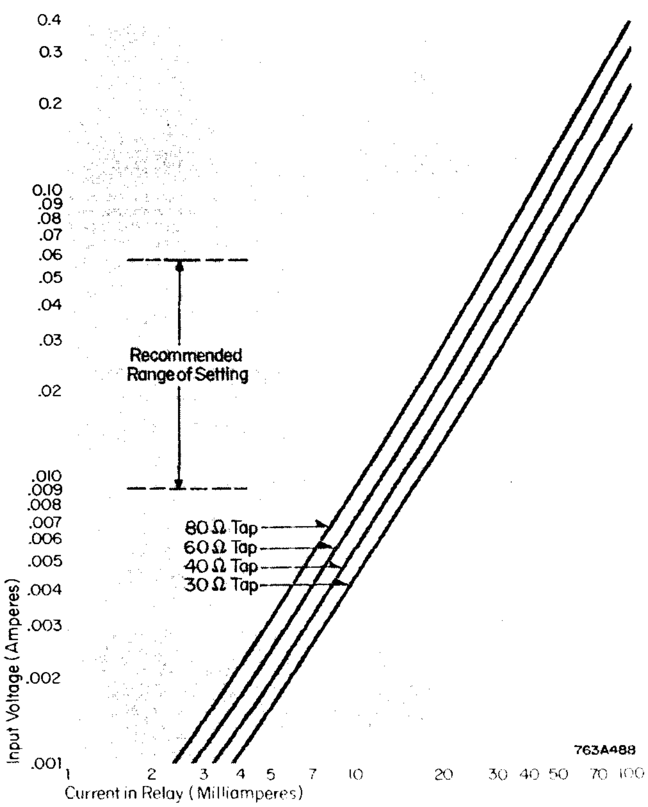


Fig. 8: LC-2 Typical Volt-ampere Curves.

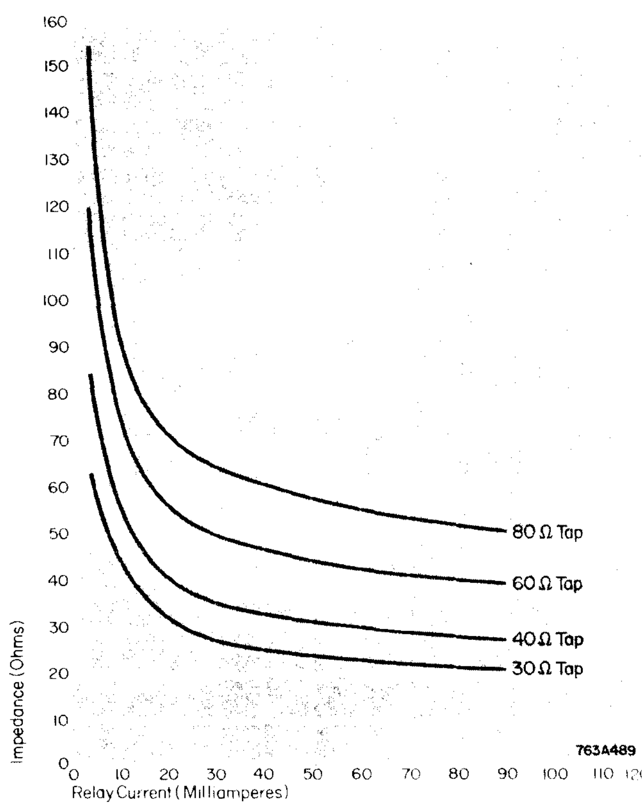


Fig. 9: LC-2 Typical Impedance Curve (impedance is at 22° angle).

Operation

As shown in Figures 10 and 11, linear coupler protection is a series voltage differential system. Linear couplers must be connected in series, rather than in parallel like current transformers, as they have a very low magnetizing impedance due to the absence of iron. Because their magnetizing is low, linear coupler secondaries can be safely open circuited.

For external faults, the voltages induced in the linear couplers by currents entering the bus are balanced out by the voltage induced in the linear coupler in the faulted circuit, where the fault current leaves the bus.

For internal faults, current entering the bus induces a voltage in the linear coupler circuit. This voltage is not balanced out, since the fault current leaves the faulted phase through a path containing no linear couplers. Thus, a net voltage is induced in the secondary circuit to cause relay operation.

Characteristics

LC-1 Relay (Single Phase, 50 or 60 Hertz)

Contacts: Spst-cc.

Operating Time: 1 cycle or less above 150% of pickup.

Sensitivity: 0.5 volt-amperes.

Impedance Matching Taps: 30, 40, 60 and 80 ohms.

Relay Case: FT-11 Flexitest.

LC-2 Relay (Single Phase, 60 Hertz)

Operating Time: 1.25 to 1.75 cycles including time for VS contactor.

Sensitivity: .0085 to .062 volt-amperes.

Impedance Matching Taps: 30, 40, 60 and 80 ohms.

Relay Case: FT-11 Flexitest.

External Fault

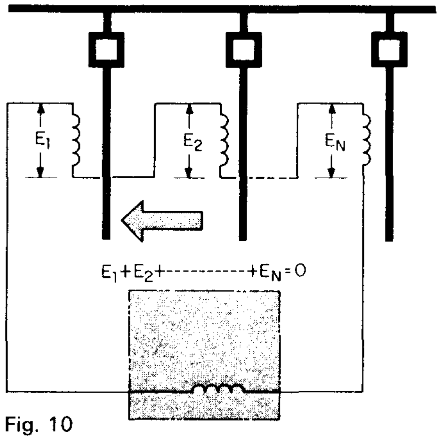


Fig. 10

Internal Fault

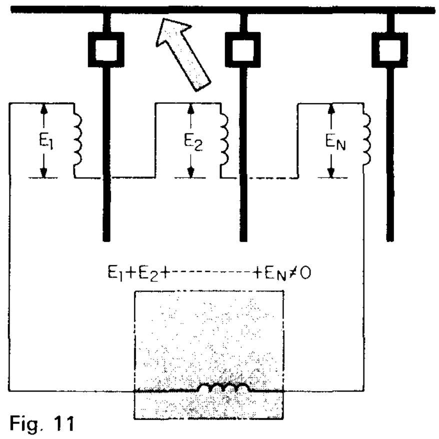
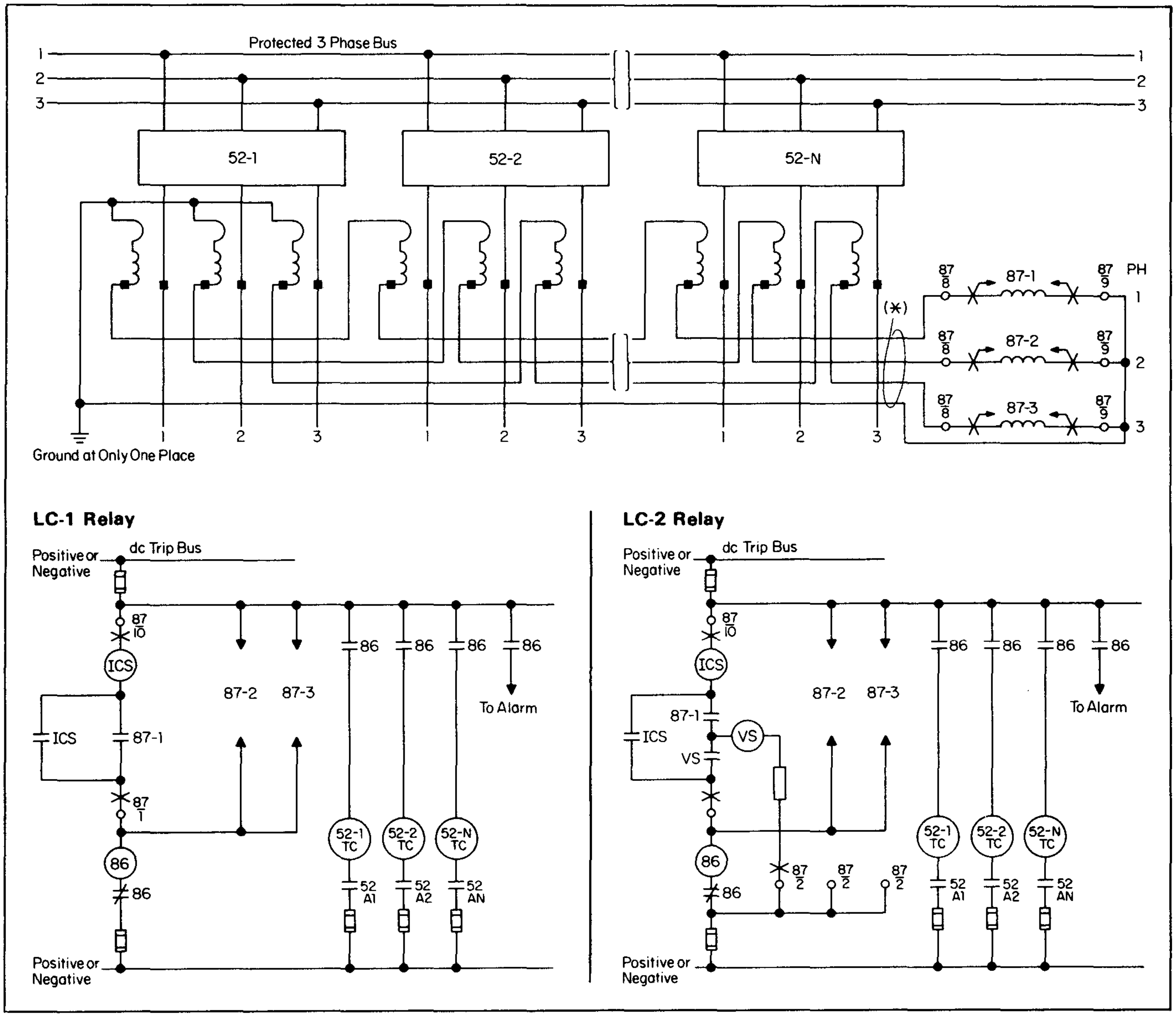


Fig. 11

External Wiring



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Device Number Chart
87 – Linear coupler bus differential relay, type LC-1 or LC-2
86 – Auxiliary tripping relay, type WL
52 – Power circuit breaker
a – Breaker auxiliary contact
TC – Breaker trip coil
* – in same conduit or duct and transposed with respect to all other circuits

Fig. 12: External Schematic for LC-1 or LC-2 relay

Internal Wiring Diagrams (Front View)

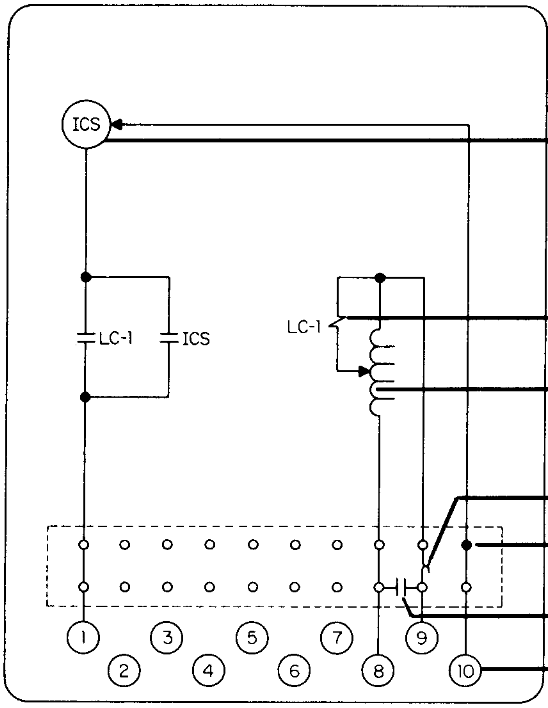

Figure 13
LC-1
Internal Schematic
FT-11 Flexitest Case

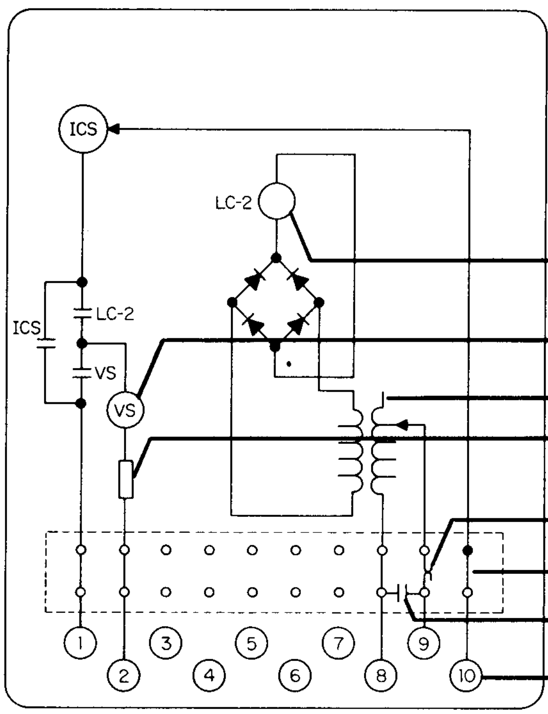

Figure 14
LC-2
Internal Schematic
FT-11 Flexitest Case

Further Information
List Prices: PL 41-020
Technical Data: TD 41-025
Application Data: AD 41-301E
Instructions: IL 41-342
Flexitest Case Dimensions (FT-11): DB 41-076
Other Protective Relays: Application Selector Guide, TD 41-016

Linear Couplers:
Refer to coupler manufacturers Catalogs.

Printed in U.S.A.

July, 1991
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Mailed to: E, D, C/41-300A

Types LC-1, LC-2 Linear Coupler Bus Differential Relays

Linear Coupler Differential, Instantaneous Single Phase (Device Number: 87)

Type	Application	Contacts	Indicating Contactor Switch③	Rating		Relay Data		
				Ohms	Volts, Dc	Internal Schematic	Style Number	Case Size
LC-1①	Bus, and phase	Spst-cc	0.2/2.0 Amps dc	30-80	...	57D7918	1876 166	**FT-11**
LC-2①	Bus, Phase, and ground			30-80	48	762A696	606B504A09	
					125	848A931	606B504A13	
					250		606B504A11	

Permanent Test Facilities For Linear Coupler System

Equipment	Quantity	Internal Schematic	Style Number
W-2 Test Switch	1	407C096	781A444G01②
Test Transformer	1		7526A15G02②
Resistor, 0.5 Ohm, 4″	1		1002399-A②
RC-351 Voltmeter, 0.5 Volt (for total bus load up to 2500 amp)	3		409C535A21
RC-351 Voltmeter, 1.0 Volt (for bus loads 2500 to 5000 amp)	3		409C535A22

① 50 Hertz relays and auxiliaries can be supplied at same price. Order "Similar to Style Number ...., except 50 Hertz".

② Obtain price and shipment from
ABB Power T&D Company, Inc.
Low Voltage Transformers
Pinetops, NC 27864

③ **ICS**: Indicating Contactor Switch (dc current operated) having seal in contacts and indicating target which are actuated when the ICS coil is energized at or above pickup current setting. Suitable for dc control voltages up to and including 250 volts dc. Two current ranges available:
(1) 0.2/2.0 amps dc, with tapped coil.
(2) 1.0 amp dc, without taps.

Rating of ICS unit used in specific types of relays is shown in price tables. All other ratings must be negotiated.

When ac current is necessary in a control trip circuit, the ICS unit can be replaced by an **ACS** unit.

The ACS unit may be supplied in place of an ICS unit at no additional cost. Specify system voltage rating on order.