Instructions

SYNCHRONOUS MOTOR CONTROL RELAYS

DS28201751
DS2820C100A-L

GEH-4604A

Revised: November 1988

NOTICE

These instructions do not purport to cover all details or variations in equipment nor to provide for every possible contingency to be met during installation, operation and maintenance. Should further information be desired or should particular problems arise that are not covered sufficiently for the purchaser's purposes, the matter should be referred to General Electric Company, Drive Systems, Salem, Virginia, U.S.A.

SYNCHRONOUS MOTOR CONTROL RELAYS

IC28201751

IC2820C100A-L

Before any adjustments, servicing, parts replacement or any other act is performed requiring physical contact with the electrical working components or wiring of this equipment, the POWER SUPPLY MUST BE DISCONNECTED.

GENERAL

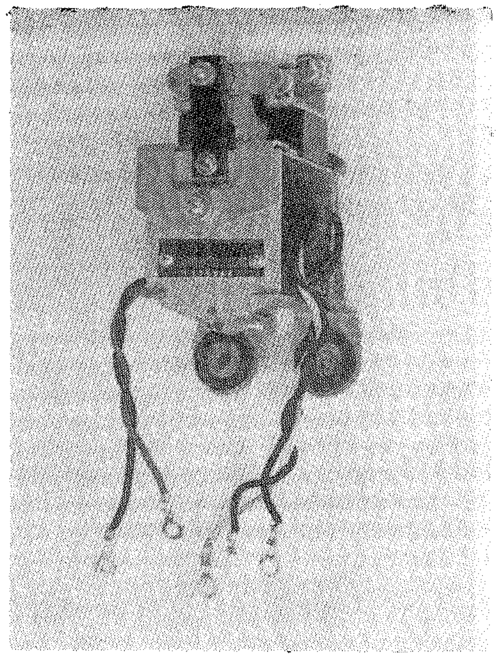
The DS2820C100 synchronous-motor-control relays apply direct-current field at the proper time to bring the motor up to the synchronous speed, and are shown on elementary wiring diagrams as FR and FRX. They usually have two normally open interlocks on the left and one normally closed interlock on the right, although other combinations are available with and without interlocks. The FR relays are also available with the half-wave rectifier (FR) in the discharge resistor circuits.

The DS28201751 Power-factor, Field-removal Relay (PFR) provides protection from damage due to pull-out from excessive load. Figure 2 shows how the relay is used and where coils and interlock (1 normally open) are located in the circuitry.

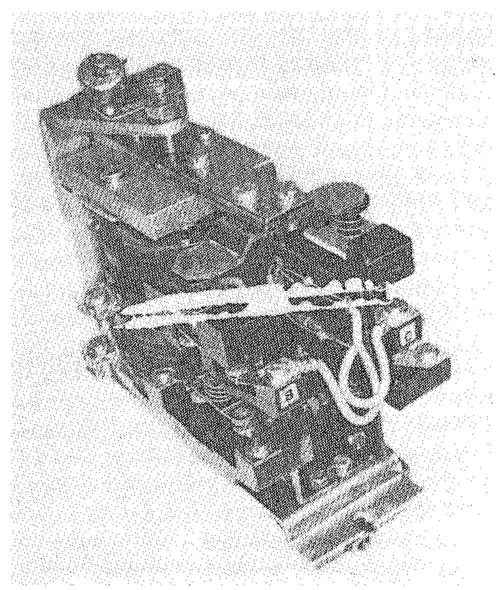
The DS3655A100SGR relay provides the same protection as the PFR relay. Full wiring diagrams and details as to how this relay is used are available in GEK-28768.

The DS2800F100 SCR squirrel-cage temperature protective relay protects the squirrel-cage winding (amortisseur winding) during starting. (See Fig. 2, wiring diagram.) Refer to GEH-1944 for further details of this relay.

These instructions apply to the various synchronous-motor starters, subassemblies and field panels supplied by the General Electric Company. It is the intent of these instructions to cover essential aspects of the complete synchronous-motor control system as it is conceived to function as a whole. Separate instructions covering partial assemblies or components are not included. If a complete starter is not supplied, the Purchaser is expected to interpret these instructions for applicability to his particular assembly by referring to diagrams supplied with the equipment purchased.



A. DS2820C100L FR relay



B. DS28201751 PFR relay

Fig. 1. Synchronous motor control relays

INSTALLATION

All wiring must be made per the overall elementary wiring diagram or the equivalent. Components are defined in nomenclature at bottom of elementary diagram. Elementary diagram applies to General Electric Company components supplied for our synchronous motor control.

FR and FRX relays must be mounted vertically with the armature springs at the top; PFR relay must be mounted vertically with the armature spring at the bottom. Before applying power to the relays, operate all moving parts manually to make sure they move freely and are free of all packing and other foreign materials. Adjustments have been made at the factory for most applications.

CONTROL FUNCTIONS

AC POWER SWITCHING TO THE MOTOR

Pressing the START button will cause the main line contactor to close, and full voltage will be applied to the motor terminals. Reduced voltage and other starting means can be applied in the recognized manner.

FIELD CONTROL

Induced current in the motor field, produced during starting, is passed through a discharge resistor in the starter by means of a closed contact on the field contactor. Voltage in the field winding is thus held to a safe value during the starting period. Dc voltage from an exciter is applied to the field at proper speed and favorable rotor angle by the field contactor which is closed by action of relays in the controller; the field-discharge resistor path being opened simultaneously.

Removal of field under overload is accomplished usually within the first slip cycle of pull-out by a PFR relay.

PROTECTION

The standard starter includes protection against overheating of the squirrel-cage (amortisseur) winding during starting, and protection against overheating of the stator winding during running. Protection from damage due to pull-out is accomplished by the PFR relay.

OPERATION

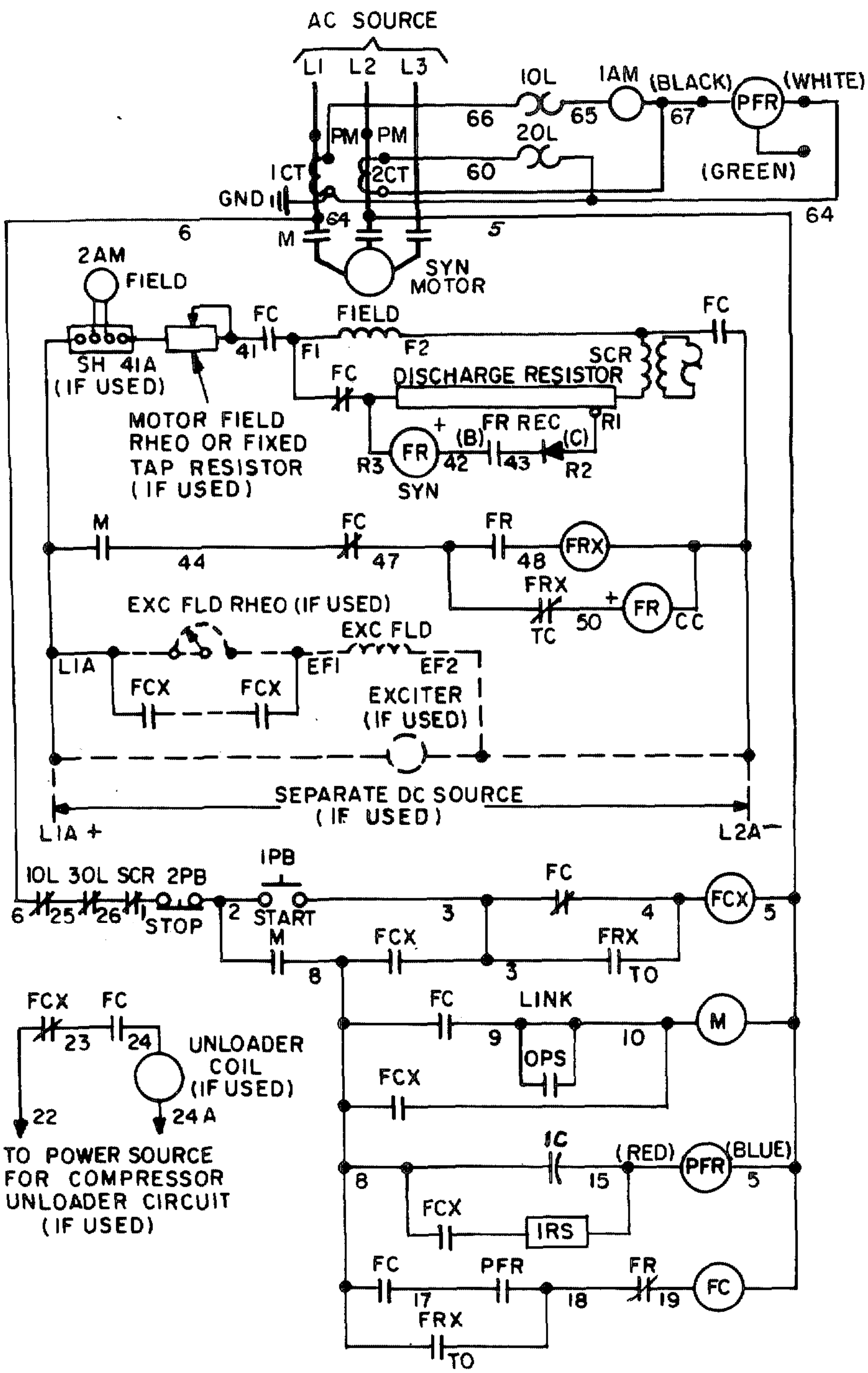
STARTING AND FIELD APPLICATION (Refer to Fig. 2)

Pressing the START button will pick up relay FCX and, in turn, the main line contactor through contacts 3-8 and 8-10. The seal circuit for FCX will thus be established through M contact 2-8, FCX contact 8-3, and FC contact 3-4; and the M contactor will also be sealed in, so that the START button may be released.

When contactor M closes, relay FR closing coil (CC) will be energized through M contact L1A-44, FC contact 44-47, and FRX contact 47-50. Relay FR will pick up at a relatively low voltage through its closing coil, thus closing its contact 42-43 and opening contact 18-19 to prevent the field contactor FC from closing. Induced field current flowing through the motor field-discharge resistor causes a voltage of 100-125 volts to appear across R2-R3, which will hold the FR relay in. This voltage across R2-R3 can be reduced to 60 volts for certain motors so that voltage at zero speed will not be excessive and burn out diodes of half-wave rectifier (FR). With FR synchronous coil (SYN) resistance of 50 ohms, maximum current through coil should be limited to 4 amperes through charging taps or discharge resistor.

Relay FR contact 47-48 will close the circuit to the FRX coil 48-L2A. This device is set for a pick-up voltage high enough to synchronize the motor, and when exciter voltage builds up to this value, relay FRX will pick up, opening its contact 47-50 and de-energizing the FR closing coil. Thus, the field contactor cannot close until the proper dc voltage is available to pull the machine into step.

The FR relay is held in through its synchronizing coil until the time of succeeding blocked-out half waves of induced field current equals or exceeds the time drop-out setting of FR (see Figs. 3 and 4). When the proper rotor speed has been reached, relay FR will drop out, closing its contact 18-19. The FC (field contactor) coil 19-5 will then be energized through relay FRX contact 8-18 and relay FR contacts 18-19. FC picks up and dc excitation is applied to the motor field which now pulls into synchronism. Dropping out the FR relay will open its contact 47-48, de-energizing the FRX relay coil, but FRX is a time-opening device and its contact 8-18 will hold contactor FC closed (bypassing PFR contact 17-18) for a time long enough to allow the motor stator current to settle down after synchronizing. Relay FRX also seals in relay FCX through its contact 3-4, thus FCX has the same drop-out time as FRX.



AM	Ammeter	M	Line Contactor	RS	Resistor
1C-2C	Phase Shift Capacitors	OL	Stator Thermal Overload Relay (Hand Reset)	REC	Rectifier
CC	Closing Coil	OPS	Oil Pressure Switch (Remote)	SCR	Squirrel Cage Protective Relay (Hand Reset)
CT	Current Transformer	PB	Pushbutton	SH	Shunt
FC	Field Contactor	PFR	Power-factor Field-removal Relay	SYN	Synchronizing Coil
FCX	Aux. Relay to FC	PM	Polarity Mark	TC	Time Closing
FR	Field-applying Relay			TO	Time Opening
FRX	Aux. Relay to FR				

Fig. 2. Elementary diagram of typical full-voltage, low-voltage starter (Two-line connection of PFR)

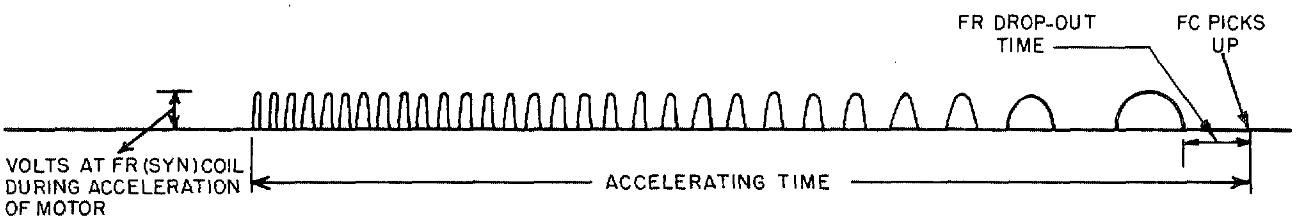


Fig. 3. Voltage on FR (synchronizing) coil during starting

At the end of this time, relay FCX opens, contact 22-23 closes energizing the automatic unloader which would allow a compressor to begin pumping; contact 8-10 opens which transfers the seal circuit of contactor M to FC contact 8-9 and oil-pressure switch OPS (9-10). The contacts of relay FCX, which are connected across the exciter rheostat open to insert resistance in the exciter-field circuit, reducing the exciter voltage to its normal operating value.

If, during normal running of the motor in synchronism, excessive mechanical load is applied to the motor, the relay PFR will drop out, opening its contacts 17-18, and removing field by dropping out contactor FC. On most applications it is also desirable to remove the motor from the line, and this is accomplished by control contacts 8-9 on FC which drop out line contactor M. If for some special reason, and on motors which are so designed and protected to permit it, the user may connect jumpers across contacts 8-9 on FC and across contacts 8-3 on FCX, to cause the motor to resynchronize automatically after pull-out. This latter connection is not recommended for normal applications, however, and the user should be cautioned to use it only where all factors implicit against it are known and accounted for in other ways.

PROTECTION

PULL-OUT PROTECTION

After a synchronous motor has been started and is running with field on, it will remain at constant speed unless excessive load is applied to the shaft. If the negative torque of the excessive load exceeds the ability of the motor to produce positive torque, then the motor cannot remain at constant speed and will "pull-out" of synchronism. This "slipping" can be the cause of damage to the motor, shaft, couplings, load and power system due to the high values of pulsating torque and power-system disturbance produced during each pole "slip." It is thus highly essential that the synchronous-motor controller respond as rapidly as possible to this pull-out condition so as to remove field and prevent pulsations.

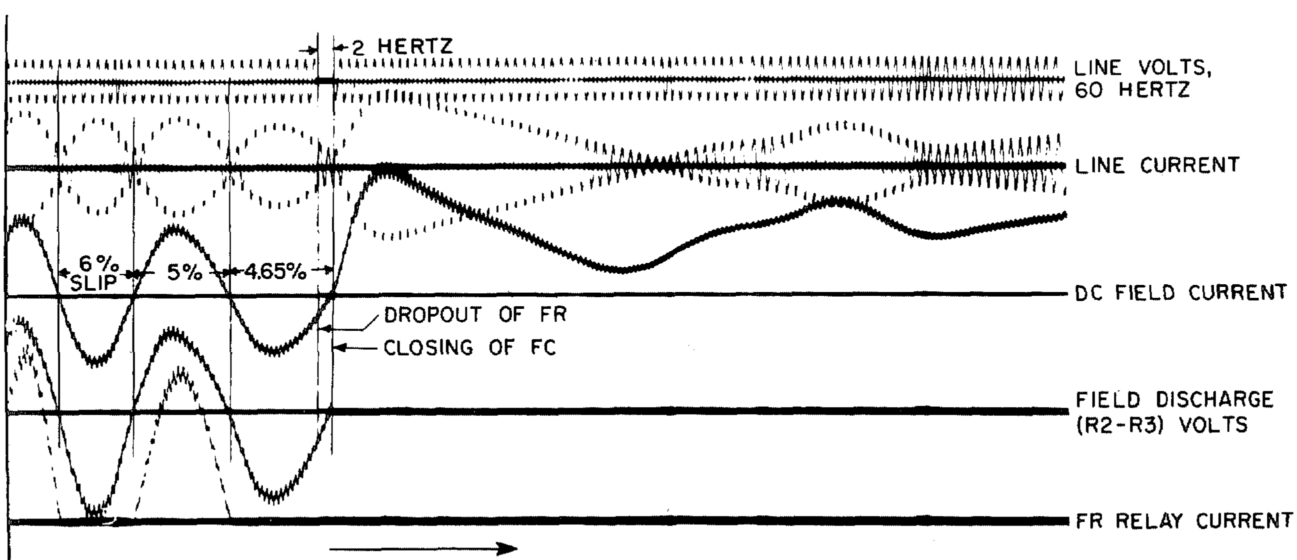


Fig. 4. Field application from five-percent slip, with motor accelerating

The controller utilizes the phenomena of line power-factor change, occurring when the motor approaches pull-out, to operate a relay which responds to lagging power factor. This relay, PFR (Power-factor Field-removal Relay), provides pull-out protection and is described more completely in "STALL PROTECTION".

STALL PROTECTION

When a synchronous motor is subjected to a condition causing sudden stall, occurring within approximately 1/10 second, the PFR relay does not respond rapidly enough to cause motor shutdown. For those loads and drive conditions whereon a 1/10-second (or less) stall is a likely possibility, an auxiliary system of protection is recommended. This consists of an instantaneous overcurrent relay with pickup setting adjusted so the relay operates at a value somewhat above motor armature current at first slip cycle on pull-out, but below motor armature current at stall (locked rotor). This allows the PFR relay to operate on overloads causing pull-out but not stall; and yet the motor is protected against sudden stall should it occur. As seen from Fig. 5, this overcurrent relay coil is included in one C.T. secondary, and its contacts are arranged so as to drop out field contactor FC in the same manner as PFR, such that if PFR does not operate, then SPR will remove field, and accordingly shut down the motor. During starting, SPR picks up on the high starting current of the motor, but its normally closed contacts are bypassed by relay FRX until the motor synchronizes; the starting current then reduces, and SPR drops out, completing the circuit to field contactor FC during normal running.

POWER-FACTOR FIELD-REMOVAL RELAY (PFR)

NOTE: *There are two starter diagrams applicable to synchronous motor control described in this instruction, Fig. 2 and Fig. 10. The only difference being the manner in which relay PFR is connected. This difference will be described below.*

RELAY PROTECTION

The power-factor field-removal relay DS2820-1751 is a device for detecting undesirable retrograding motion of the synchronous-motor salient-field pole with respect to its armature pole, and for its operation relies upon the increase in reactive current drawn from the power supply during such retrograding motion. In other words, the relay is used to detect "out-of-step operation." Note that "out-of-step operation" is a term applicable to the synchronous machine, and implies that the field is energized. With the field not energized, the machine is not synchronous.

The relay is a simply constructed electromagnet and armature device arranged to pick up when the coil-produced flux is of sufficient magnitude to overcome spring tension and close a set of contacts. The coil differs from that of the conventional relay however, in that it contains two windings, each with its own leads, on a common core so that flux produced by one coil can be added to or subtracted from that of the other coil. The vector sum of the ampere-turns or flux of the two coils will then determine pickup or drop-out of the relay.

To pick up the relay, sufficient amperes from a potential source are put through coil A (see Fig. 6). After pickup, the amperes are decreased in coil A by insertion of external impedance, and this makes it possible to drop out the relay with a relatively small amount of amperes of opposite polarity in coil B; or, coil B can buck out coil A, to drop out the relay under conditions of a specific value of current in coil B.

If the synchronous motor is overloaded for some reason and its field pole shifts backward with respect to its armature or stator pole, flux in coil A remains unchanged, but a decrease in power factor occurs (see Fig. 8) which produces a shift in re-

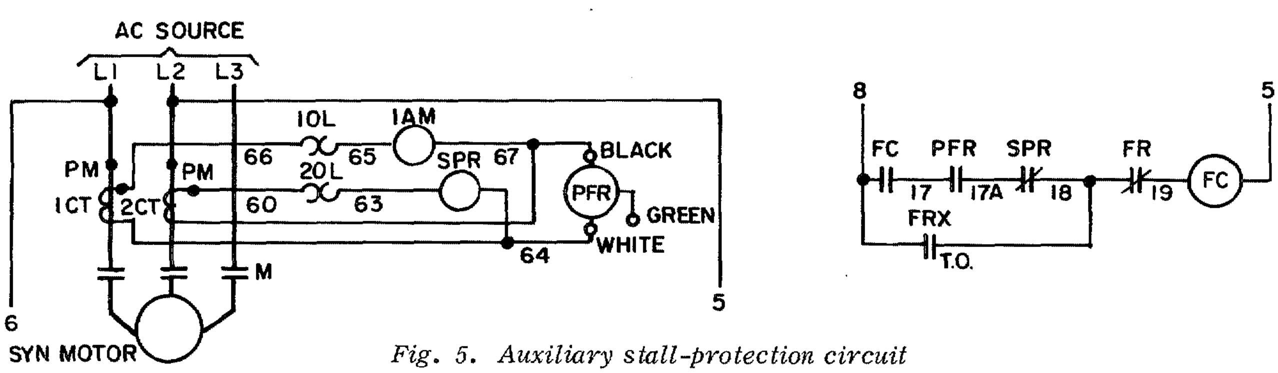


Fig. 5. Auxiliary stall-protection circuit

lationship of coil B current with respect to voltage, and consequently a corresponding net shift with respect to coil A current.

Coil B current now bucks coil A current sufficiently to drop out the relay, which, in turn, removes field and shuts down the motor.

NOTE: *The GREEN lead from the current coil of the PFR relay may be connected at the factory in place of the WHITE lead. This is for unusual motor characteristics requiring fewer ampere turns in the relay to permit wider load swings before pull-out.*

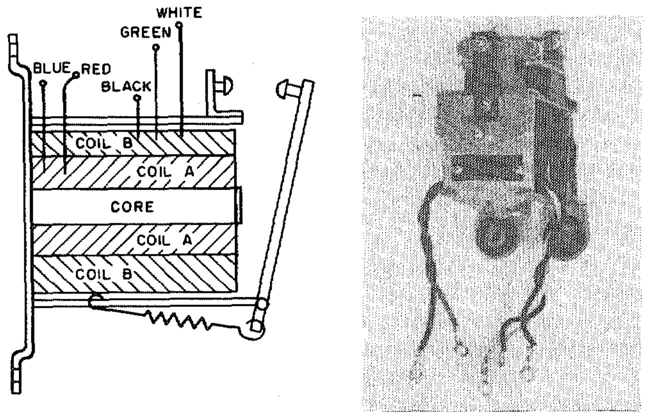


Fig. 6. PFR relay

TWO-LINE CONNECTION OF PFR
(Not Sensitive to Phase Rotation)

To make it possible for the PFR relay to function satisfactorily regardless of power-system phase-sequence rotation, and to make it unnecessary to check system phase rotation at installation, a more recently devised scheme for connecting PFR has been utilized on some starters. This scheme is shown on the starter diagram Fig. 2, and utilizes only two of the three power lines for both voltage and current to obtain an indication of lagging power factor. The current from the two lines is combined vectorially so as to give a directional orientation parallel to the voltage. If the two lines are reversed for any reason, inadvertently or otherwise, the voltage and current are maintained directionally equal, and relay function is not jeopardized. A phase-shifting capacitor is applied in the relay voltage-coil circuit to make voltage-coil flux appear approximately at right angles to the current-coil flux.

Combining the currents of the two lines for use with the relay requires two current transformers with secondaries available for interconnection. Refer to Fig. 7. The current from C.T. in line 2 is reversed (180 degrees) and added to the current from C.T. in line 1, which gives a resultant parallel to the voltage between the same two lines (1 and 2). Voltage must then be from 2 to 1 to make relay fluxes add. Since the relay is designed to drop out on lagging power factor (motor pull-out), a decrease in total relay flux is required when the line current lags the line voltage. Under this condition, then, current flux must oppose voltage flux, total opposition meaning 180-degree angular separation. But since a change from normal load (resistive) to a fully inductive load (pull-out) would mean only a 90-degree separation, an initial fixed separation of 90-degrees leading is introduced by a capacitor in series with the relay voltage coil. (Some coil resistance reduces the angle to an actual 83 degrees.)

Vector representation of current and voltage is shown in Fig. 8. It can be seen that for either direction of system phase rotation, current-coil flux will oppose voltage-coil flux when the motor appears to the relay as an inductance (during pull-out). The PFR connected in this manner will operate correctly regardless of power-system phase rotation and, therefore, no test for this rotation is required either at installation or subsequently if phase rotation should be changed for controls employing these connections.

TABLE I
PFR RELAY COMPONENTS

VOLTS	FREQUENCY	RELAY CAT. NO.	CAPACITOR 1C	RESISTOR 1RS
115	60	DS28201751AD2	(1) 68A7052P3A20 (1) 68A7052P4A20 Connect in parallel (7 MFD)	(ohms) (110) 68A7020P110D
230	60	DS28201751AD3	23F1054G202 (2 MFD)	(400) 68A7020P400D
460	60	DS28201751AD4	23F473G102 (0.5 MFD)	(1800) 68A7020P180E
575	60	DS28201751AD5		(2700) 68A7020P270E

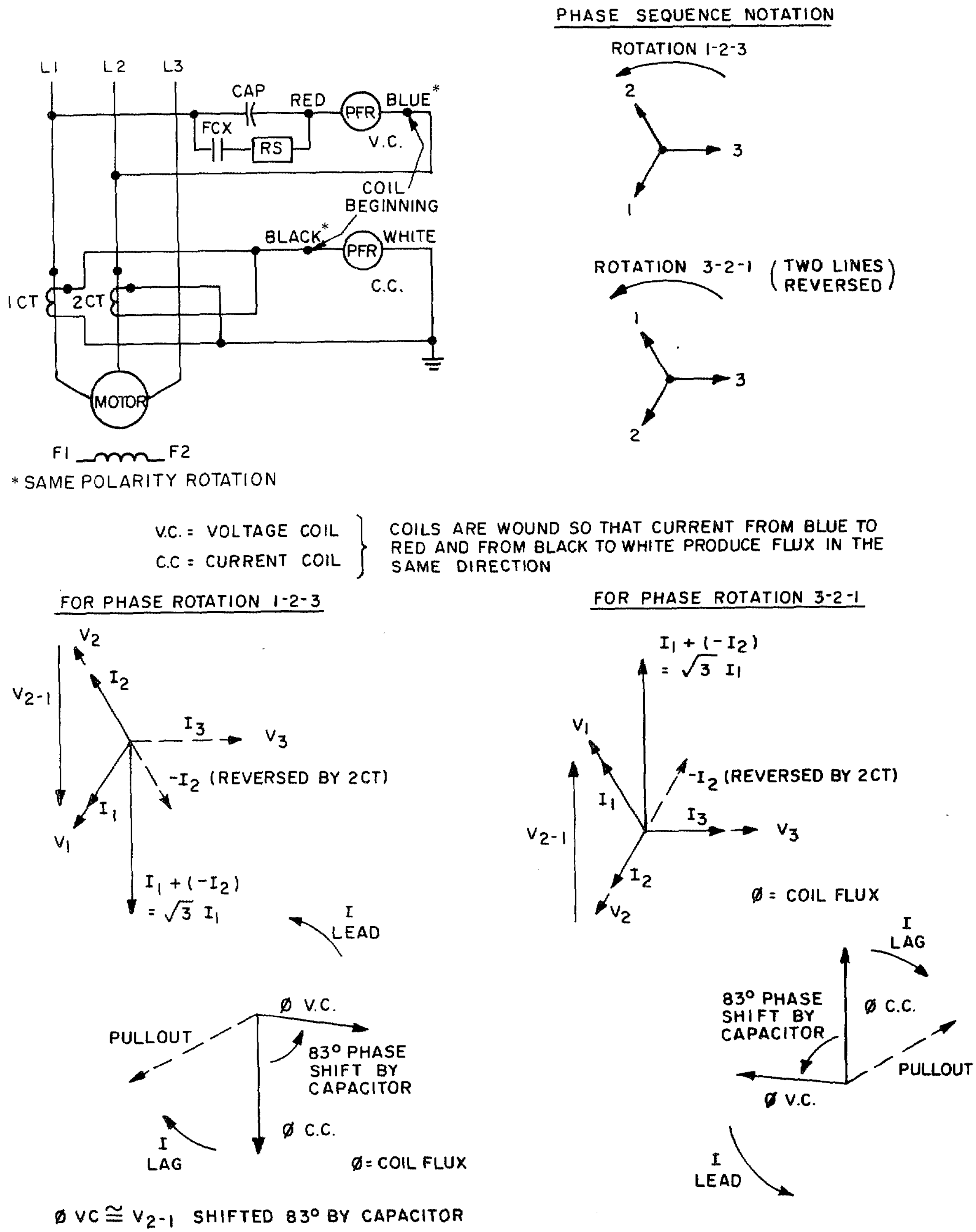


Fig. 7. Vector representation of relay PFR operation

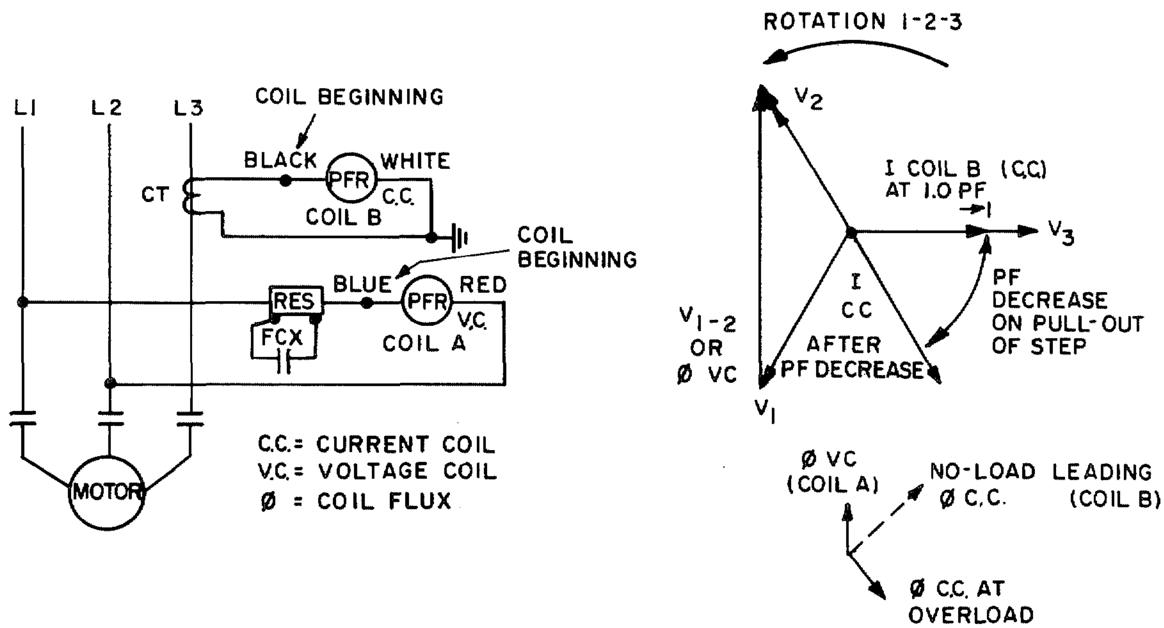


Fig. 8. PFR current-voltage relationship

THREE-LINE CONNECTION OF PFR

Older starters have PFR connected as shown in Figs. 8 and 10.

From the figures it can be seen that phase rotation 1 - 2 - 3 is assumed for proper operation of the relay upon a decrease in line power factor. Phase rotation of the power system is not always known however, and is never easily determined and correlated with the relay voltage-coil connections.

If phase rotation happened to be 2 - 1 - 3, the vector diagram would be as shown in Fig. 9.

It can be seen that a shift of current in coil B for decreasing power factor would thus add to current in coil A, causing an increase of relay flux rather than a decrease. Under this condition of phase rotation, the relay would not drop out to cause field removal for out-of-step operation of the motor.

Some method of phase rotation check for the voltage coil connection is thus necessary when the PFR is connected as shown in Fig. 10.

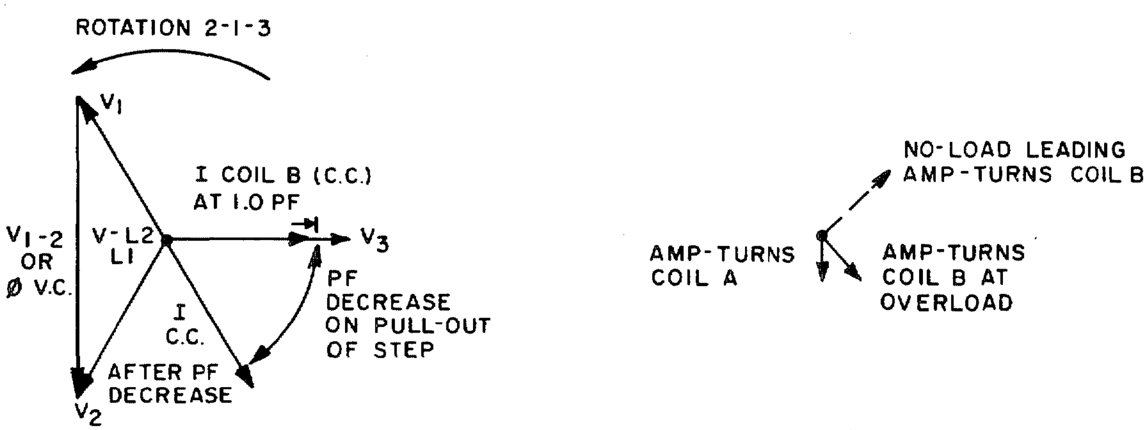
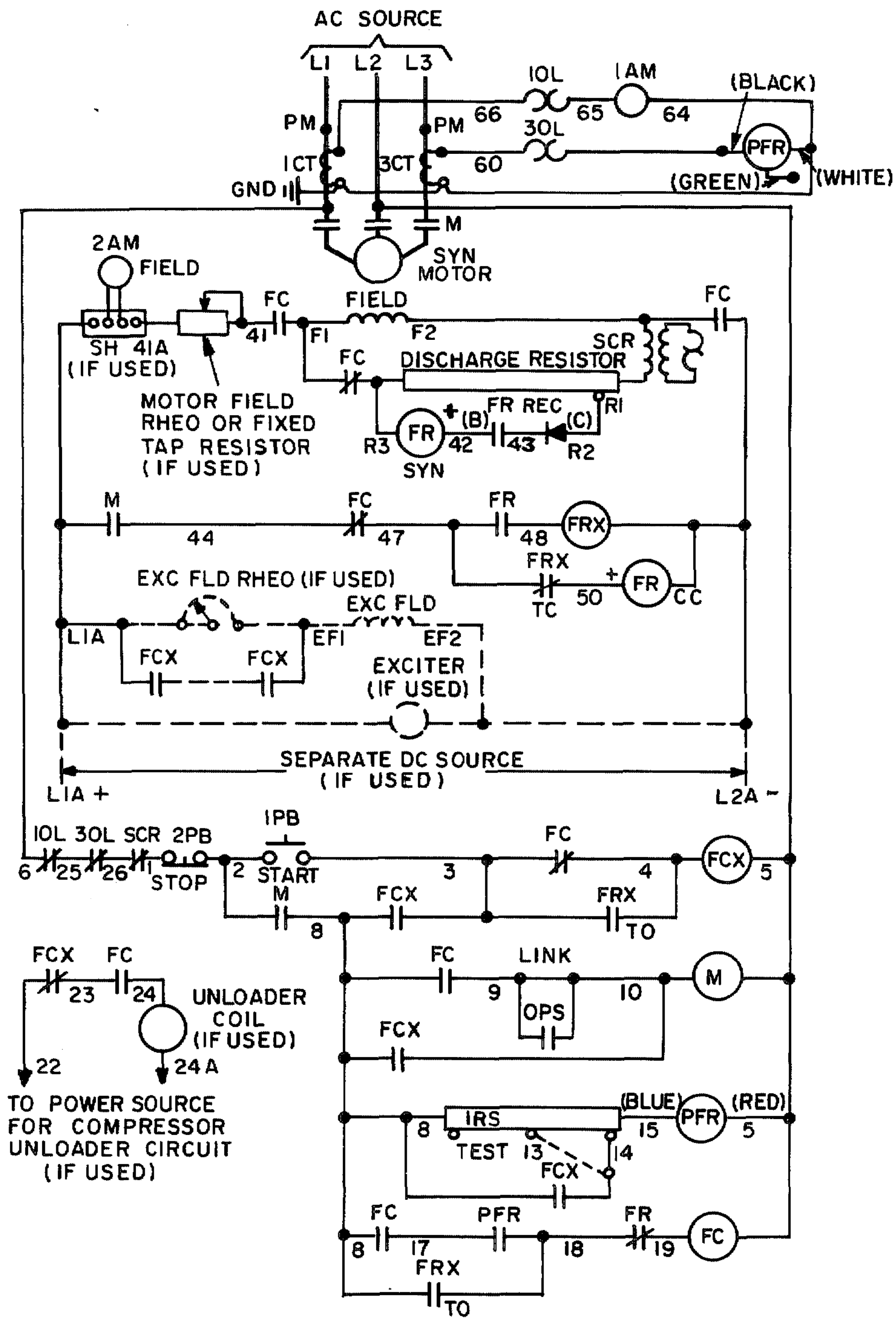


Fig. 9. PFR current-voltage relationships with reversed phase sequence



AM	Ammeter	OL	Stator Thermal Overload Relay (Hand Reset)	RS	Resistor
CC	Closing Coil	OPS	Oil Pressure Switch	REC	Rectifier
CT	Current Transformer	PB	Pushbutton	SCR	Squirrel Cage Protective Relay (Hand Reset)
FC	Field Contactor	PFR	Power-factor Field-removal Relay (PFR Current Coil in Third Phase)	SH	Shunt
FCX	Aux. Relay to FC	PM	Polarity Mark	SYN	Synchronizing Coil
FR	Field-applying Relay			TC	Time Closing
FRX	Aux. Relay to FR			TO	Time Opening
M	Line Contactor				

Fig. 10. Elementary diagram of typical full-voltage, low-voltage starter (Three-line connection of PFR)

TEST FOR CORRECT CONNECTION OF PFR

From the foregoing description of relay operation, it is evident that on three-phase systems, incorrect connections, due to reversed potential coil, reversed current coil, or phase sequence other than 1 - 2 - 3, can be corrected merely by reversing the relay voltage-coil connection.

To determine whether or not the relay voltage coil is connected for proper relay operation, a test must be made by observing the relay performance during initial start-up of the motor. At the time of manufacture, the lead from the FCX relay contact is connected to terminal 14 on 1RS (See Fig. 10). To make the test, this lead should be moved to terminal 13, and the motor and starter made ready for starting.

During starting, the power factor of the motor is severely lagging and the current is relatively high, which is similar to the condition of motor pull-out. Moving the lead on 1RS to terminal 13 introduces more resistance into the PFR voltage-coil circuit to somewhat overcome the shorting effect of relay FCX and make the voltage-coil flux sufficiently low to allow the lagging current-coil flux occurring during motor starting to prevent relay pickup. As noted from Figs. 8 and 9, lagging current-coil flux will drop out the relay if the voltage-coil is correctly connected, but this same current will tend to hold in the relay (by adding flux to the voltage coil) if improperly connected. This test made during starting is to observe whether the relay is held open by the high-lagging starting current.

At the instant of starting, the PFR voltage-coil will be energized as soon as relay FCX picks up. This may be somewhat ahead of the time current begins to flow in the PFR current coil, due to the time required for the line contactor to close, and since the drop-out flux must be lower than the pickup flux, it will be necessary to manually hold the relay open (to prevent pickup) at the instant of pushing the START button, and then quickly release it as current flows in the relay current coil. This is done by using a string looped around the relay contact arm as shown in Fig. 11. If the relay voltage coil is correctly connected, the relay will not pickup during motor starting. If improperly connected, the relay will instantly pickup upon release of the string but before the motor synchronizes.

Synchronizing would be noted by the closing of contactor FC. If the relay does pickup during this test, then coil leads 5 and 15 (blue and red) should be reversed and the test repeated. If the test proves satisfactory, then return the lead on resistor 1RS to terminal 14.

ALTERNATE TEST

An alternate test that can be made is to measure the voltage across the voltage coil of the PFR relay between points 15 and 5. When the current and voltage coils are aiding, the total flux in the relay core will be high. Therefore, the voltage drop across the voltage coil will be higher than when they are opposing.

A synchronous motor at no-load and normal or rated excitation will be operating at a leading power factor. This is shown by the dotted arrows in Fig. 8 with the correct connections, and as shown in Fig. 9 with the wrong connections.

Therefore, at no-load leading power factor, or even under load at a leading power factor, the voltage across the voltage-coil points 15 and 5 will be higher with normal connections than with the reversed or incorrect connections. The magnitude of the voltage difference will depend upon the magnitude of the leading component of the current.

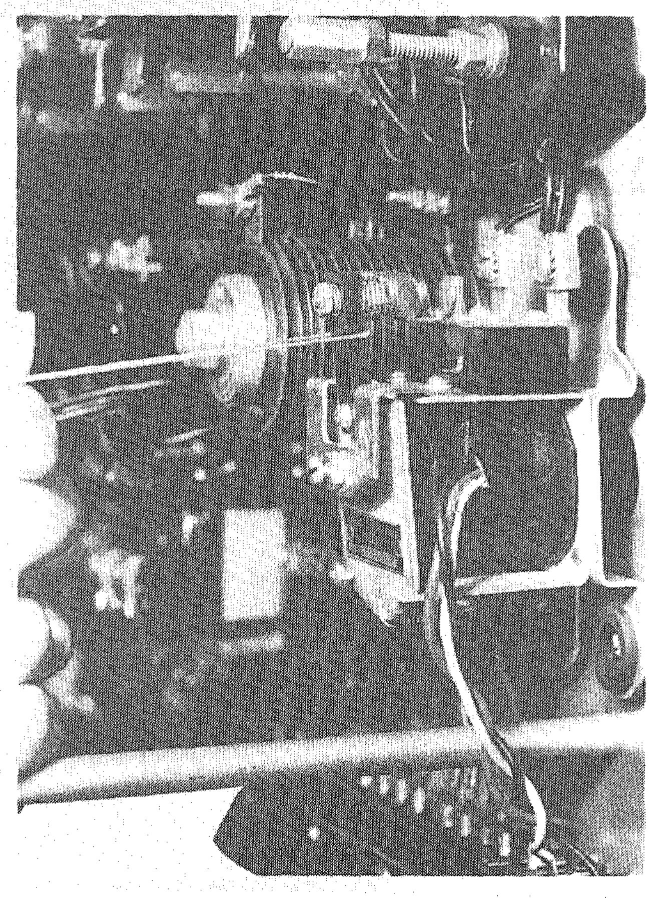


Fig. 11. To check polarity of PFR relay

FIELD-APPLYING RELAY (FR) AND AUXILIARY RELAY (FRX)

The field-applying relay FR and its auxiliary FRX are similar devices except for coils. Sliding bimetal shims. by which the amount of magnetic material in the air gap may be changed, provides adjustment of time drop-out. The field-applying relay FR has two coils; the first or closing coil (c.c.) is a dc coil operating on the excitation voltage; the second or synchronizing coil (SYN) operates from a tap in the discharge resistor through a half-wave rectifier. Description of over-all function of these two devices is included under OPERATION on Page 2 and the diagram Fig. 2.

Relay FRX is set to pick up at a voltage high enough for synchronizing and thus provides a dc voltage check to prevent closure of FC unless sufficient excitation voltage is available. To prevent the motor from starting, however, a dc voltage-check relay must be added to the order. Unless a voltage-check relay is added to the order for the starter. the motor will start and run without synchronization until it is shut down by the protective relay SCR. A voltage-check relay is, therefore, recommended as protection against starting without excitation voltage being available. It is very important that field voltage be connected to the starter with positive and negative leads arranged as shown in Fig. 2. If negative (-) dc is connected to L1A instead of positive (+), the FR relay will not function correctly. As noted above, the FR relay has two coils, one of which is used for closing and takes its voltage source from the excitation supply. The flux established in the relay core by this source to close the relay must be directionally the same as that from the synchronizing coil so as to hold the relay in. If the polarities of either of the two coils is reversed with respect to the other, then relay FR will pick up but immediately drop out if the synchronizing coil flux is polarized in such a way as to oppose the closing coil flux. This will result in the relay "chattering" during starting and false closing of contactor FC.

Table II page 12, gives the time drop-out settings of relay FR when tested from a separate dc source, applying rated excitation to the closing coil, to synchronize from a given constant slip.

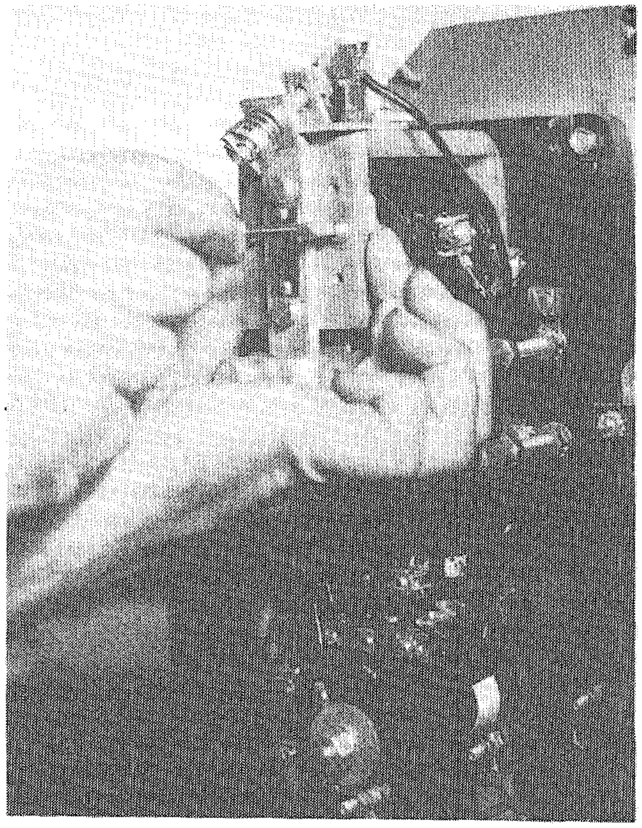


Fig. 13. Adjustment of shim for timing

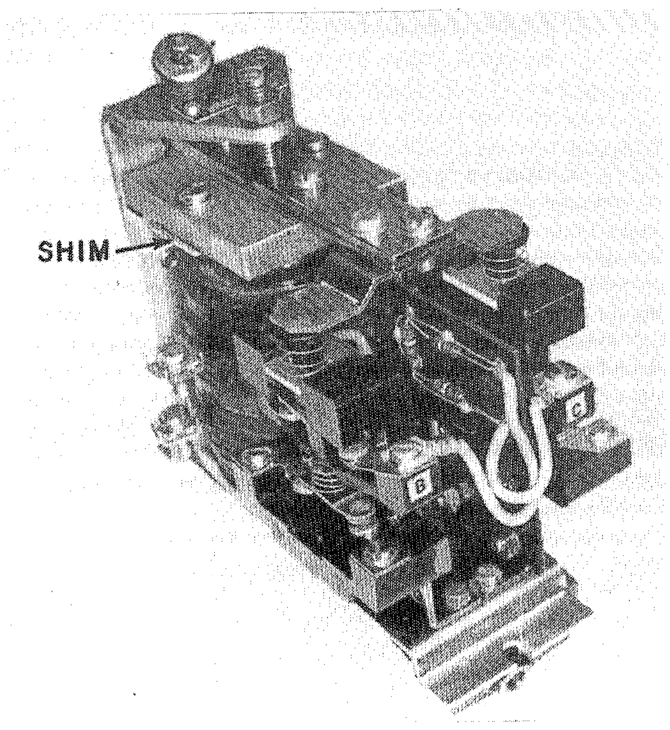


Fig. 12. FR relay DS2820C100L

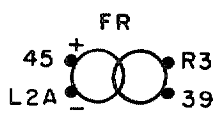


Fig. 14. FR relay coil connection terminals

TABLE II

FR RELAY TIME DROP-OUT SETTINGS

Slip Setting Desired for Synchro-nizing	Relay FR Time Setting in Seconds			
	25 Hertz	40 Hertz	50 Hertz	60 Hertz
1%	2.20	1.50	1.20	1.00
2%	1.16	0.74	0.62	0.53
3%	0.76	0.52	0.44	0.37
4%	0.61	0.41	0.34	0.29
5%	0.50	0.34	0.28	0.24

Unless otherwise specified on the order, standard, general-purpose starters will be shipped from the factory with the FR relay set to apply dc field excitation at approximately five-percent slip. If, due to special operating conditions, it is found that the field should be applied at a speed other than that set originally, the timing of the FR relay drop-out may be changed by shifting the location of the shim. In order to obtain a setting for one-percent slip at 25 and 40 Hertz, it may be necessary to "back off" on the armature-spring adjusting nut as well as shifting the shim.

To shift the position of the shim on the FR relay, loosen the two screws in the armature of the relay and slide the shim either up or down, depending upon the change in time required. Sliding the shim up decreases the time required to drop out, while sliding the shim down increases the time required to drop out. After the desired time drop-out is obtained, the shim should be locked in the proper position by tightening the two screws in the relay armature.

The contact gap on the FR relay (normally closed contact) should be 1/8 inch and the wipe on bridge of contact bar should be 1/16 inch, while the contact gap on the FRX relay (normally closed contact) should be 1/4 inch and the wipe on bridge of contact bar should be 1/16 inch. The FRX relay should be set to drop out at 1.5 seconds.

NOTE: *For special applications of high-inertia-load synchronizing, where unusually long period of rotor oscillations occur, a longer time setting of FRX may be required.*

Voltage on FR Synchronizing Coil

The tap on the discharge resistor, R2 to R3, is selected so that with the machine operating as an induction motor at 95-percent speed, the tap voltage, applied to the FR synchronizing-coil circuit will be in the range of 100 to 125 volts. For speeds above 95 percent, this tap voltage will vary directly with slip.

TROUBLE-SHOOTING NOTES

TYPE OF TROUBLE	PROBABLE CAUSES	RECOMMENDED SOLUTION
Motor starts but shuts down after accelerating to rated speed.	1. If the motor is very lightly loaded it may accelerate to rated speed and pull into synchronism by the action of residual flux in the field poles; the acceleration being so rapid that field-applying relay FR does not respond to time the induced field frequency. FR then drops out after the motor has pulled into step, FC closes and applies excitation, and if the residual flux is in opposition to this applied flux, then the motor will slip a pole, causing relay PFR to operate and shut down the motor.	1. There are two possible solutions. First, reduce the time setting of relay FR (see Page 12) to the point where it will accurately respond to the last negative half cycle of induced field current. This will apply field at an appropriate time and prevent synchronizing on residual flux. Second, increase the drop-out time of relay FRX to keep relay PFR from being operative until the motor has slipped back into proper alignment when field is applied.

TROUBLE-SHOOTING NOTES (CONT'D)

TYPE OF TROUBLE	PROBABLE CAUSES	RECOMMENDED SOLUTION
Motor starts but shuts down after accelerating to rated speed. (cont'd)	2. If the starter is equipped with a field-current loss relay (FLR), the build-up of field current in some motors may be too slow to pick up FLR before FCX drops out. This causes shut-down just at synchronization.	2. Increase the time drop-out of relay FRX to allow for the period of field current build-up required to pick up FLR. In some cases, this may require a special FRX relay to obtain a long time delay.
	3. Relay FR could be incorrectly adjusted so that FC picks up before motor reaches optimum speed for pull-in. This causes pole slipping and relay PFR causes shutdown.	3. Increase drop-out time of FR to allow motor to reach a higher speed. See Table II on Page 12 for FR adjustment.
	4. Relay FRX set for too short a time. Motor line current and power factor do not stabilize and relay PFR causes shutdown.	4. Increase time drop-out of FRX.
	5. If drive includes an oil pressure switch (OPS), it may not be operating correctly.	5. Check connections to OPS and see that it is operating properly.
	6. Relay SCR trips because of high induced-field current or prolonged acceleration time.	6. Measure induced field current and other values as shown in GEH-1944. The relay trip time may be increased 20-25 percent by following instruction in GEH-1944.
Relay FR "chatters" during starting and picks up FC too soon.	1. Incorrect polarity of excitation voltage, or incorrect connection of FR SYN coil.	1. Reverse leads L1A and L2A from exciter. See Page 11 for further explanation.
	2. Incorrect induced-field voltage.	2. Check voltage between R2 and R3 on FDRS (should be 100 to 150 volts). See OPERATION, page 2.
Field current too high or too low based on motor nameplate rating.	1. Excitation voltage source needs adjustment.	1. Adjust exciter field rheostat or motor field rheostat when used. If excitation is from a dc fixed bus, then a tapped resistor in series with the motor field must be adjusted by changing taps. If excitation is from a rectifier exciter, then adjust taps on the exciter transformer to raise or lower output voltage.

TROUBLE-SHOOTING NOTES (CONT'D)

TYPE OF TROUBLE	PROBABLE CAUSES	RECOMMENDED SOLUTION
Motor shuts down when another motor on same power bus is started.	1. This trouble usually occurs when both motors have static exciters connected to the motor main-power bus. Starting the second motor causes a drop in bus voltage as well as excitation voltage, but as the newly started motor synchronizes, the bus voltage returns to normal. During the drop in voltage, the field current of the first motor is reduced and may in itself cause enough loss of torque to pull the motor out of step. If the drop in voltage itself does not cause pull-out, then lagging power factor which occurs on restoration of voltage may cause PFR to drop out.	1. First, determine amount of voltage drop on both motor and exciter. If this voltage drop is of a value to cause less than pullout torque, then the only solution is to install some means of maintaining either excitation voltage or line voltage or both (remember torque decreases as square of voltage when excitation is same source as line; 15-percent drop in voltage would be 28-percent reduction in torque). If voltage drop is not of a value low enough to cause less than pull-out torque, then the cause of shutdown is probably due to a transient power-factor swing occuring on restoration of voltage, which causes PFR to operate. This can be corrected by interwiring FCX contacts between starters to short out 1C (or 1RS) if either motor is started; this keeps PFR picked up.
	2. Power-factor relay sensitivity too high.	2. Reduce the PFR relay sensitivity by interchanging green and white leads. This solution may be used if the maximum full-voltage armature current on the first slip cycle on pull-out will produce 8 amps in the relay current coil (check motor data).
Motor won't start when START button is pushed.	1. Overload devices not reset.	1. Push reset buttons on 1OL, 2OL, 3OL, and SCR.
	2. If starter is equipped with a dc voltage-check relay, VCR, it may not be picked up from lack of excitation voltage.	2. Use voltmeter and check availability of excitation voltage and whether it is up to rated value. Also check that exciter leads are connected to starter.
Motor starts and runs but does not synchronize (that is, FC does not pick up)	1. Relay FR set for too long a time and does not drop out at slip frequency.	1. Readjust FR for a shorter time.
	2. Load too heavy for motor to accelerate to pull-in speed.	2. Check condition of load.

TROUBLE-SHOOTING NOTES (CONT'D)

TYPE OF TROUBLE	PROBABLE CAUSES	RECOMMENDED SOLUTION
Motor shuts down while running with normal load.	1. Momentary loss of voltage on power system, causing line and field contactors to drop out.	1. Pushing START button will restart motor of course, but if this condition is frequent, a time-delay undervoltage relay should be installed, arranged to allow resynchronizing without shutdown, provided motor and load are suitable for this arrangement.
	2. A line-to-ground fault on one line of the power system (such as a lightning stroke) will cause loss of voltage on that phase and reversal of current from the motor. This will cause PFR to operate and shut down the motor if the three-line connection for PFR is used.	2. Change PFR to two-line connection as shown in Fig. 2. This requires a change in coil for PFR also. Alternately, change PFR to special connection using two potential transformers as shown on Drive Systems Dept. Drawing 194A2062.
	3. Transient load torque on motor shaft, not high enough to cause pull-out, but drops out PFR. PFR too sensitive for motor design.	3. Reduce PFR sensitivity by interchanging green and white leads. This solution may be used only if the maximum full-voltage armature current on the first slip cycle at pull-out will produce 8 amps in the relay current coil (check motor data).

RENEWAL PARTS

When ordering renewal parts, address the nearest General Electric Sales Office or Distributor, specifying the quantity required, the catalog number and description of each part. Also give the complete nameplate rating of the equipment.