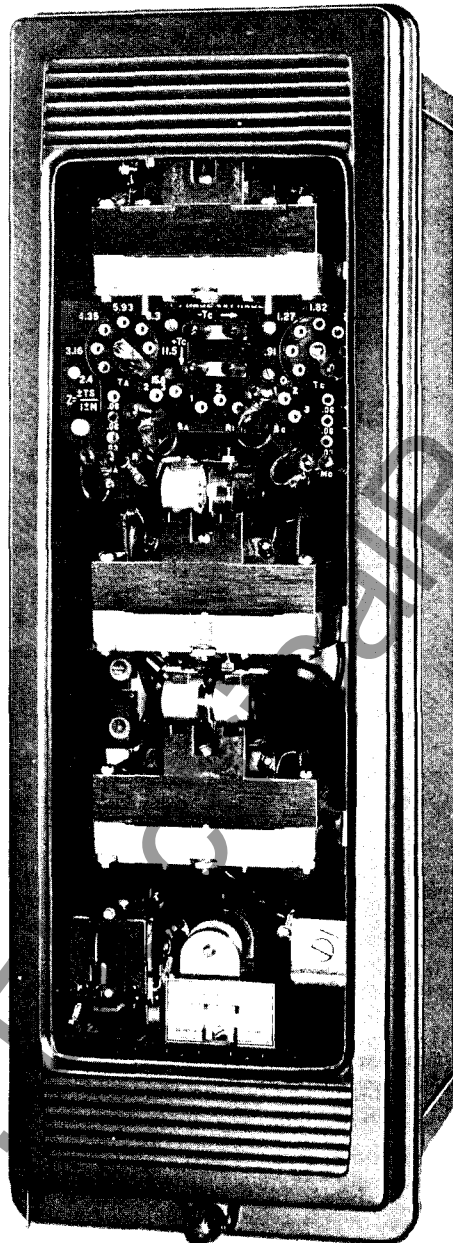


September, 1990  
Supersedes DB 41-745B pages 1-4,  
dated June, 1989  
Mailed to: E, D, C/41-700A

For Use With Delta Connected  
Potential Transformers  
**Device Number: 40**

## Type KLF Generator Field Protection-Loss of Field Relay



The KLF relay is designed to protect a generator from thermal damage due to decrease or loss of field. The relay also protects the power system from instability due to voltage decrease caused by a generator operating at low excitation.

One KLF provides three phase protection. The relay requires single phase current and three phase voltage, and consists basically of an impedance unit, a directional unit, a voltage unit, and a telephone type time delay relay, all mounted in one type FT-41 Flexitest case.

The directional and impedance units operate to sound an alarm during low field excitation conditions; thus enabling a station operator to correct the low excitation condition. The voltage unit can be set to trip the generator when continued low (or loss of) excitation results in low voltage and possible system instability. The KLF can be used on all types of synchronous machines, such as turbo-generators, water wheel generators, or synchronous condensers.

The KLF is designed for circuits using delta connected potential transformers. On circuits with wye connected potential transformers, the type KLF-1 relay is used to increase security during inadvertent loss-of-potential (such as due to a blown potential fuse).

### Further Information

List Prices: PL 41-020  
Technical Data: TD 41-025  
Instructions: IL 41-748  
Renewal Parts: RPD 41-960  
Flexitest Case Dimensions: DB 41-076  
Contactor Switches: DB 41-081  
Type KLF-1 Relay: DB 41-703E  
Silent Sentinel Publication, RPL 72-5,  
"Loss of Field Zone Relaying"  
Other Protective Relays:  
Application Selection Guide, TD 41-016

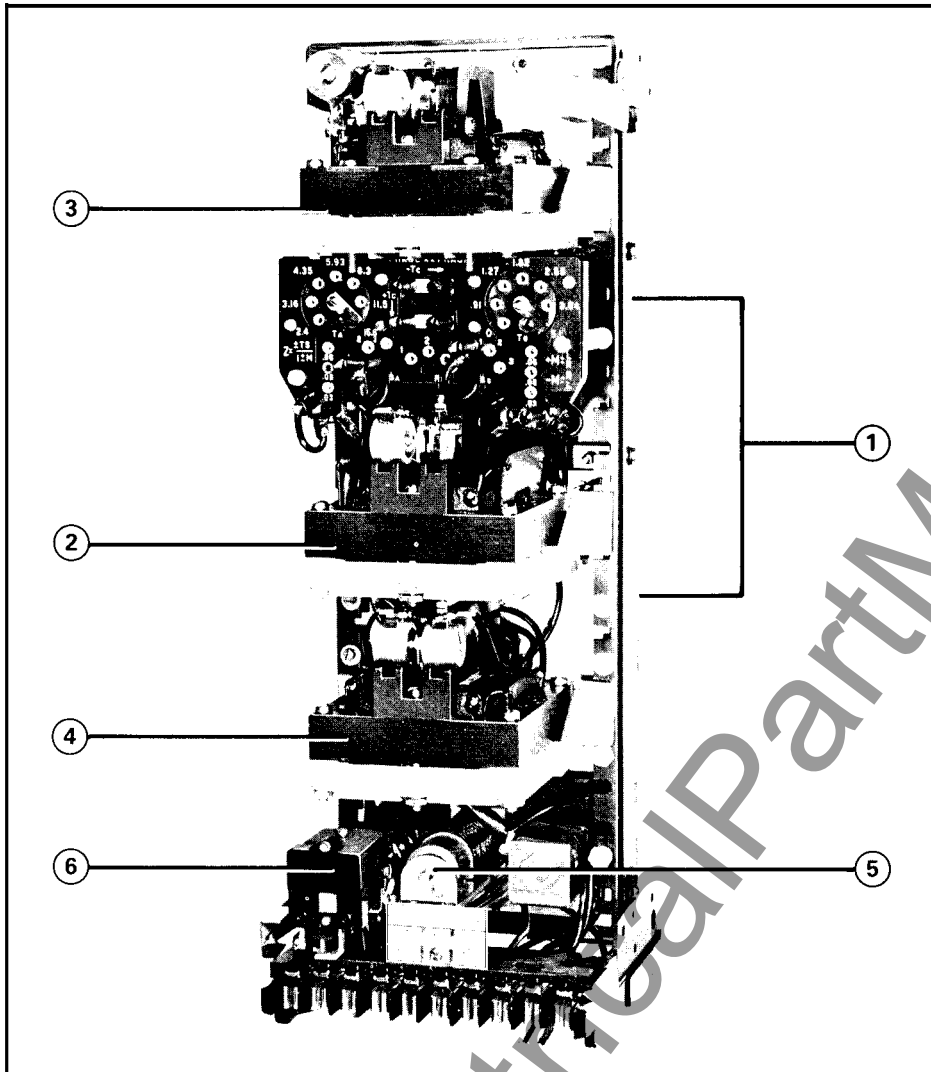


Figure 2: Chassis View KLF Relay

**1 Compensator and Autotransformer**

**Compensator:** The compensators (which are designated  $T_A$  and  $T_C$ ) are two-winding air gap transformers. The primary or current winding of the long-reach-compensator  $T_A$  has seven taps which terminate at this tap block. The primary winding of the short-reach compensator  $T_C$  also has seven taps which terminate at this tap block. A voltage is induced in the secondary which is proportional to the primary tap and current magnitude.

The secondary winding is connected in series with the relay terminal voltage. Thus a voltage which is proportional to the line current is added vectorially to the relay terminal voltage.

**Auto-transformer:** The auto-transformer has three taps on its main winding, S, which are numbered 1, 2, and 3 on the tap block. A tertiary winding M has four taps which may be connected additively or subtractively to modify the S setting by any value from -15 to +15 percent in steps of 3 percent.

The auto-transformer makes it possible to expand the basic ranges of the long and short reach compensators by a multiplier of  $\frac{S}{1 \pm M}$ . Any relay ohm setting can be made within  $\pm 1.5$  percent from 2.08 ohms to 56 ohms for the long reach and from .79 ohms to 18 ohms for the short reach.

**2 Impedance Tripping Unit**

The distance unit is a four pole induction cylinder type unit. The operating torque of the unit is proportional to the product of the voltage quantities applied to the unit and the sine of the phase angle between the applied voltages. The direction of the torque produced depends on the impedance phasor seen by the relay with respect to its characteristic circle.

**3 Directional Unit**

The directional unit is also an induction cylinder unit operating on the interaction between the polarizing circuit flux and the operating circuit flux.

Otherwise the directional unit is similar in construction to the impedance tripping unit.

**4 Undervoltage Unit**

The undervoltage unit is also an induction cylinder unit.

It is similar in its construction to the directional unit.

**5 Time Delay Relay**

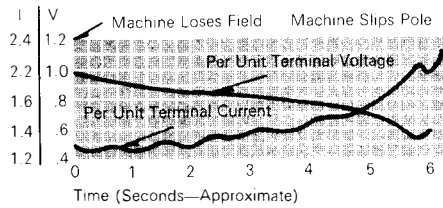
The time delay telephone type relay (X) has a slow drop-out characteristic. In service, the relay is normally energized holding the break contacts open. When energized, the solenoid core attracts an iron-right-angle armature bracket, which in turn opens the break contacts.

**6 Indicating Contactor Switch (ICS)**

The dc Indicating Contactor Switch is a small clapper-type device. A magnet armature, to which leaf-spring mounted contacts are attached, is attracted to the magnetic core upon energization of the switch. When the switch closes, the moving contacts bridge two stationary contacts, completing the trip circuit. Also during this operation two fingers on the armature deflect a spring located on the front of the switch, which allows the operation indicator target to drop. The target is reset from the outside of the case by a push rod located at the bottom of the cover.

**Construction**

The relay consists of two air-gap transformers (compensators), two tapped auto-transformers, one reactor, one cylinder-type distance unit, one directional unit with adjustable resistor, one undervoltage unit with adjustable resistor, telephone type time delay relay, and an Indicating Contactor Switch (ICS).



**Figure 3: Effect on Terminal Voltage and Current**①

① All values are per unit based on Kva rating.

### Application Effects of Loss of Field, Round Rotor Machines

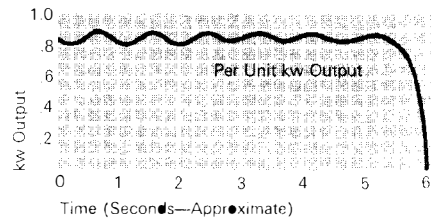
Decrease or loss-of-field excitation on a synchronous generator can result in thermal damage to the generator or can cause system instability due to low voltage conditions. Loss of excitation can be caused by a short in the field leads, flashover of the commutator of the exciter, or by tripping of field breakers.

Absence of field current in the rotor of the generator, reduces the magnetic tie-in between the rotor and the stator. If the same mechanical input is applied to the machine, the rotor accelerates, runs above synchronous speed, and the machine operates as an induction generator.

Instead of supplying inductive reactive power to the system, the machine will draw inductive power from the system through the stator windings. These stator currents induce heavy currents in the rotor teeth and wedges, and will damage the machine if allowed to continue. Most modern generators can safely run above synchronous speeds for 2 or 3 minutes at full load and zero excitation.

Another possible result of loss-of-field is instability of the connected system due to low voltage. A heavily loaded generator may draw enough reactive power from the system to approach the rated kva of the generator. Supplying this large amount of kilovars may often stress the system more than supplying the kilowatts lost by tripping of the generator. The major consideration is determining whether loss-of-field on a machine can cause a sufficiently low system voltage so that instability between sound machines can result. If the system voltage is not reduced excessively, the field excitation can be restored to the machine in trouble, resulting in a minimum system disturbance. If the system voltage is lowered excessively, the machine should be tripped.

Figure 3 illustrates the decrease in the terminal voltage of the generator when the field excitation is reduced to zero. Terminal



**Figure 4: Effect on Kw Output**①

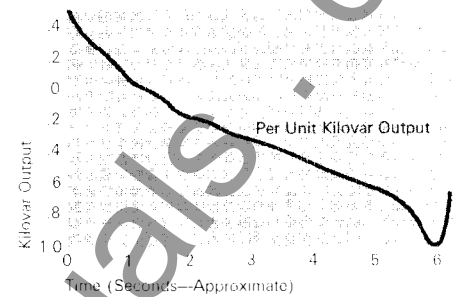
voltage decreased to about 70% of normal voltage in five seconds.

Figure 4 illustrates the kilowatt output of the machine after loss-of-field. Reduction of field does not immediately reduce the flux in the machine to zero, since the machine is a highly inductive circuit. The flux starts to decay (per time constant of the circuit) but with a constant mechanical input, the machine speeds up, creating a greater angle between the machine terminal voltage and the system voltage to maintain a practically constant power output.

Figure 5 illustrates the change in kilovar output of the machine after loss of excitation. The kilovar output reduces to zero and becomes negative; that is, the machine draws lagging reactive power from the system. Thus, up to the time of loss of synchronism (approximately 6 seconds) the system is not particularly in danger. The kilowatt output is practically constant, the kilovar output has changed considerably, the system voltage has decreased. However, when a synchronous machine slips past the first pole, there is an abrupt acceleration of the rotor with a consequent sudden decrease in kilowatts as shown in Figure 4. At the same time a reversal occurs in the induced field current, with a consequent sudden reduction in kilovars into the machine. Reduction of kilovars into the machine causes the terminal voltage at the machine to momentarily rise. (See Figure 3).

The field of the machine which has momentarily lost excitation can be safely reapplied while the machine is operating as an induction generator. Calculations of shaft torques developed, due to field reapplication, indicate that the torques are within design values. Therefore, if loss-of-field is due to an operating error which can be corrected, or if an alternate excitation source is available, the field can be reapplied and the machine will pull into synchronism.

Figure 6 illustrates the locus of the machine terminal impedance vector from rated load and rated power factor position, after loss-of-field excitation. Time values are noted



**Figure 5: Effect on Kilovar Output**①

along the curve trace. As shown in Figure 3, the terminal current increases and terminal voltage decreases with loss of field. Thus, the terminal impedance (V/I, Figure 6) decreases. The impedance unit of the KLF relay is set to close its contact when the impedance at the terminal of the machine is within the capability curve of the protected machine. As the capability curve is a thermal limit, it represents a zone where excessive temperature can occur. The locus of the impedance unit operating curve should be about 10% inside the thermal capability curve of the machine. (See Figure 7).

### Effect of Loss-of-field On Machine Terminal Voltage

Reduced field excitation on the machine results in a drop in terminal voltage at the machine, causing the machine to draw reactive power from the system. The ability of the system to maintain stability is primarily dependent upon the relative size of the generator with respect to the system, and the action of voltage regulators. Voltage regulators tend to minimize the reduction in system voltage and may be able to prevent the system from becoming unstable.

An excessive decay of system voltage indicates that the system will become unstable. Thus, the KLF relay voltage unit is set to close its contact at about 80% of normal operating voltage. Closing of the directional, impedance, and voltage unit contacts will trip the machine off the system.

### Salient-Pole Machine Application

The response of salient-pole machines to loss-of-field is generally similar to that of round-rotor machines. Because of the higher transient reactance of the salient-pole machines, they go out of synchronism faster than the round-rotor types. However, at light loads, a salient-pole machine may not lose synchronism due to the saliency effect. (Refer to Westinghouse "Electrical Transmission and Distribution" reference book, chapter 13, Section III).

If a salient-pole machine loses synchronism because of loss of field, it will accelerate to a high slip. This is due to the fact that the

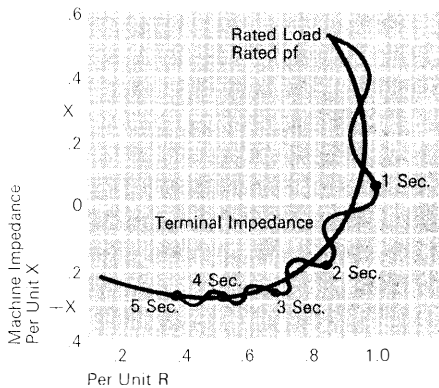


Figure 6: Terminal Impedance (Ohms)

governor is not as fast acting as a round-rotor machine governor, and the salient-pole machine is less efficient as an induction generator than the round-rotor machine.

Therefore, the salient-pole machine must be re-synchronized in the normal manner. The field cannot be simply reapplied as on a round-rotor machine.

**Synchronous Condenser Application**

Synchronous condensers usually operate at low field currents. However, minimum field current and low system voltage should not exist simultaneously. If these two conditions do exist simultaneously, it indicates a failure of the excitation system and the condenser should be disconnected from the system.

The offset impedance unit is set so that it definitely includes the impedance as viewed from the terminals of the machine looking into the system with zero excitation, regardless of system voltage. This impedance is  $-j$  (1/per unit short circuit current). However, the impedance and directional units are not connected to an alarm since normal operation of the condenser may have the D and Z contacts closed.

The undervoltage unit is set to drop out, or trip, when the voltage falls below the minimum safe voltage for normal system conditions. This minimum normal voltage is the machine terminal voltage existing at normal system voltage with the machine operating at maximum under excited rating.

If a voltage below this value exists simultaneously with zero excitation, the condenser will be tripped automatically. However, if the condenser is supplying lagging reactive power to the system, the machine will not be tripped regardless of the voltage because the directional unit contact is open.

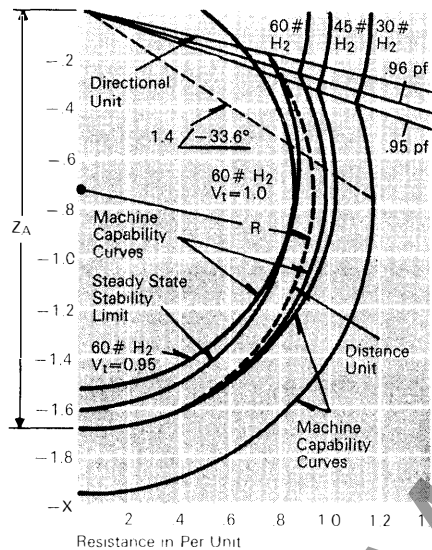


Figure 7: Typical Machine Capacity Curve

**Machine Capacity Limits**

For most applications, the KLF relay is set to operate before the steady state stability, or machine capability limit is exceeded, whichever may govern. To allow for maximum output without an alarm, the impedance unit of the relay is set to permit the machine to operate at maximum hydrogen pressure, and 0.95 per unit voltage, which is the lowest voltage for which the capability curve applies.

Where the maximum capability of the machine cannot be realized without exceeding the steady state stability limit, the distance unit is set to operate before the steady state limit is exceeded (see Figure 7).

A typical machine capacity curve furnished by the generator manufacturer is shown in Figure 8. This curve can be converted to the impedance curve shown in Figure 7. See information under "Relay Settings".

If a minimum excitation limiter is used, the KLF relay curve should be drawn as a circle falling between the steady state stability limit and the MEL impedance circles to avoid unnecessary relay alarms.

As previously mentioned, the KLF relay is designed for operation on all systems using delta connected potential transformers.

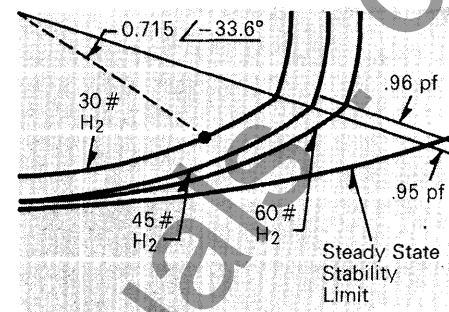


Figure 8: Typical Machine Capacity Curve

185A183

**Burden**

(@ 5 amperes, 60 Hertz

Settings	VA	Angle of Lag
Maximum	18.6	77°
Minimum	3.8	51°

**Potential**

(@ 120 volts, 60 Hertz

Phase A <sub>B</sub> S <sub>A</sub> - S <sub>C</sub>	VA	Angle of Lag	Phase B <sub>C</sub> VA	Angle of Lag
1	18.0	2°	2.6	12°
2	14.4	31°	5.9	38°
3	13.9	39°	6.6	42°

**Dc Circuit**

Rating	Watts (@ Rated Voltage)
125	3.9
250	7.8

**Thermal Ratings**

Potential: 132 volts (line-to-line) continuous

Current: 8 amperes continuous  
200 amperes for one second.

**Shipping Weights and Carton Dimensions**

Case Size	Domestic Shipping Carton	
	Dimensions: Inches	Weight: Lbs. Net Shipping
FT-41	12" x 13" x 21"	24 28

Printed in U.S.A.



December, 1990  
 Supersedes TD 41-020, Type KLF on  
 page 129, dated November, 1987  
 Mailed to: E, D, C/41-700A

For Use With Delta Connected  
 Potential Transformers

# Type KLF Generator Field Protection-Loss of Field Relay

## Generator

Loss of Field, Three Phase (Device Number: 40)

Type	Indicating Contactor Switch <sup>③</sup>	Rating		Range: Ohms		Relay Data				
		Volts Ac	Volts Dc	Amps Ac	Long Reach	Short Reach	Internal Schematic	Style Number	Case Size	
<b>KLF</b> ①	0.2/2.0 amp dc	120 <sup>②</sup>	48	5	2.08-56.0	0.79-18.0	184A958	290B481A13	<b>FT-41</b>	
			125					290B481A09 <sup>⑤</sup>		
			250					290B481A10		
			125					629A834		290B481A14 <sup>④</sup>
			250					290B481A15 <sup>④</sup>		

⑤ Denotes item available from stock.

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

② Delta or open-delta connected potential transformer secondaries.

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.

④ Undervoltage contact shorted out.