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For Use With Wye Connected Potential Transformers
Device Number: 40

Type KLF-1 Generator Field Protection Loss of Field Relay

Type KLF-1

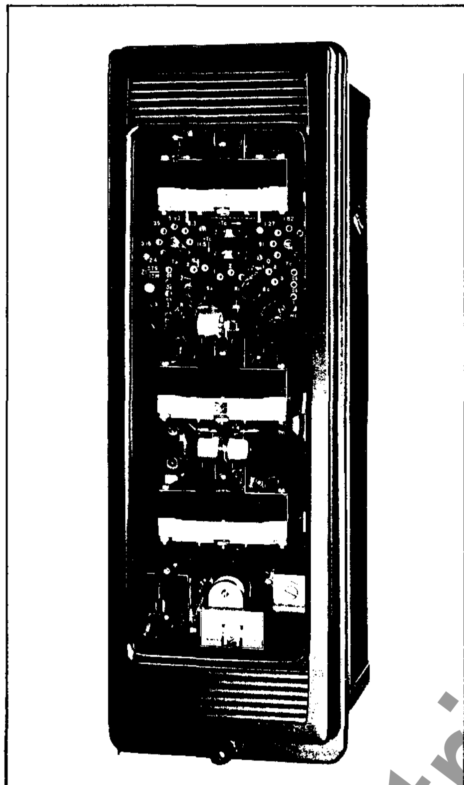


Fig. 1

The KLF-1 relay is designed to protect a generator from thermal damage due to decrease or loss of field, and also to protect the power system from instability due to voltage decrease caused by a generator operating at low excitation. One KLF-1 provides three phase protection. It 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-1 can be used on all types of synchronous machines, such as turbo-generators, water wheel generators, or synchronous condensers.

It is designed for circuits using wye connected potential transformers. By connecting the directional, impedance and voltage units to sequence phase-to-neutral potentials, this relay is not suceptible to incorrect tripping due to loss-of-potential on one phase. On circuits with delta connected potential transformers, the type KLF relay is used (see Descriptive Bulletin 41-745B).

Construction

The KLF-1 relay utilizes the modern design concepts of the K-Dar compensator line of relays. A chassis view of the KLF-1 is shown by figure 1.

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

(1) Compensator and Autotransformer

Compensator: The compensators (which are designated T_A and T_C) are two-winding gap transformers. The primary or current of the long-reach compensator T_A has seven taps which terminate at the tap block (see figure 1). 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. This proportionality is established by the cross sectional area of the laminated steel core, the length of an air gap which is located in the center of the coil, and the tightness of the laminations.

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.

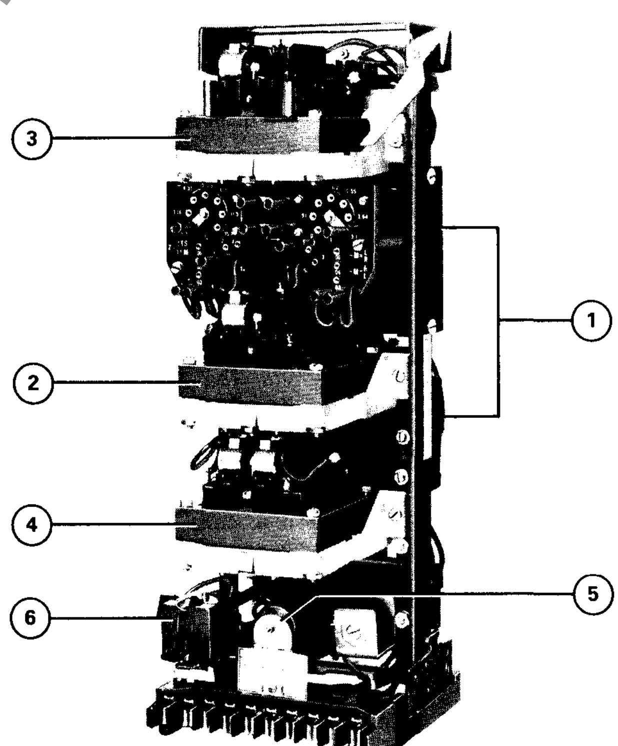


Fig. 2

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 ±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) Distance 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 so produced depends on the fault location with respect to the balance point setting.

Mechanically, the cylinder unit is composed of four basic components: a die-cast aluminum frame, an electromagnet, a moving element assembly, and a molded bridge. The frame serves as a mounting structure for the magnetic core.

The electromagnet has two sets of two series connected coils mounted diametrically opposite one another to excite each set of poles.

The moving element assembly consists of a spiral spring, contact carrying member, and an aluminum cylinder assembled to a molded hub which holds the shaft. The hub to which the moving contact arm is clamped has a wedge-and-cam construction, to provide low-bounce contact action. Optimum contact action is obtained when a force of 4 to 10 grams pressure applied to the face of the moving contact will make the arm slip one-fourth of its total free travel. Free travel is the angle through which the hub will slip from the condition of reset to the point where the clamp projection begins to ride up on the wedges. The free travel can vary between 15° to 20°.

The shaft has removable top and bottom jewel bearings. The shaft rides between the bottom pin bearing and the upper pin bearing with the cylinder rotating in an air gap formed by the electromagnet and the magnetic core. The stops are an integral part of the bridge.

The bridge is secured to the electromagnet and the frame by two mounting screws. In addition to holding the upper pin bearing, the bridge is used for mounting the adjustable stationary contact housing. This stationary contact has .002 to .006 inch follow which is set at the factory by means of the adjusting screw. The stationary contact housing is held in position by a spring type clamp. The spring adjuster is located on the underside of the bridge and is attached to the moving contact arm by a spiral spring. The spring adjuster is also held in place by a spring type clamp.

When contacts close, the electrical connection is made through the stationary contact housing clamp, to the moving contact, through the spiral spring and out to the spring adjuster clamp.

(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.

Mechanically, it is composed of the same basic components as the distance unit.

The electromagnet has two series-connected polarizing coils mounted diametrically opposite one another and two series-connected operating coils mounted diametrically opposite one another; two magnetic adjusting plugs; upper and lower adjusting plug clips, and two locating pins.

The moving element assembly consists of a spiral spring, contact carrying member, and aluminum cylinder assembled to a molded hub which holds the shaft. Otherwise the directional unit is similar in construction to the distance unit.

(4) Undervoltage Unit

The voltage unit is also an induction cylinder unit.

The electromagnet has two pairs of voltage coils. Each pair of diametrically opposed coils is connected in series. In addition one pair is in series with a parallel R-C combination. The adjustable resistor serves not only to shift the phase angle of the one flux with respect to the other to produce torque, but it also provides a pickup adjustment.

Otherwise the undervoltage unit 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 armature bracket, which in turn opens the break contacts.

(6) Indicating Contactor Switch (ICS)

The d-c 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.

Applications

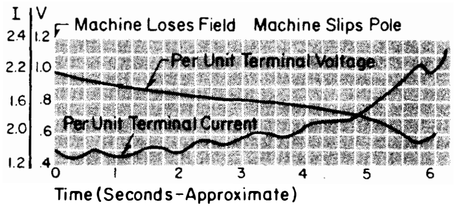
Effect of Loss-of-field – Wound Rotor Machines

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 in induction generator.

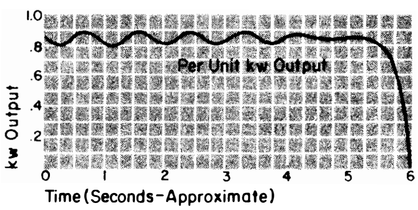
Instead of supplying inductive reactive power to the system, the machine will draw inductive power from the system through the stator windings. These stator currents induce heavy currents in the rotor teeth and wedges, and will damage the machine if allowed to continue. Most modern generators can safely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



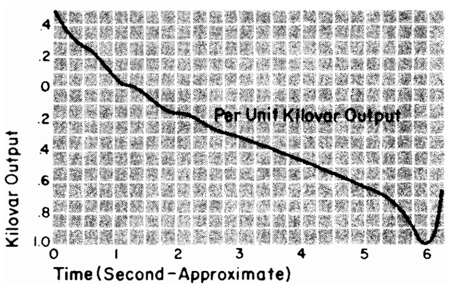
All values are per unit based on KVA Rating

Fig. 3: Effect on Terminal Voltage and Current



All values are per unit based on KVA Rating

Fig. 4: Effect on KW Output



All values are per unit based on KVA Rating

Fig. 5: Effect on Kilovar Output

Figure 3 illustrates the decrease in the terminal voltage of the generator when the field excitation is reduced to zero. Terminal 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 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-1 relay is set to close its contact when the impedance unit of the KLF-1 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 unit, 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, page 4).

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-1 relay voltage unit is set to close its contact at about 80% of normal operating voltage. Closing of the directional, impedance, and the voltage unit contact 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 looses synchronism because of loss-of-field, it will accelerate to a high slip. This is due to the fact that the 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.

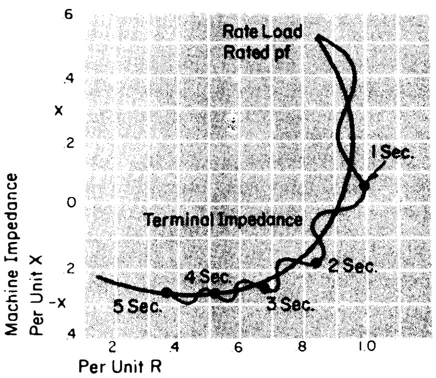
The offset impedance unit is set so that it definitely includes the impedance as viewed from the terminals of the machine looking into the system with zero excitation, regardless of system voltage. This impedance is -j (1/per unit short circuit current.) However, the impedance and directional units are 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.

Machine Capability Limits

For most applications, the KLF-1 relay is set to operate before the steady state stability, or machine capability limit is exceeded, whichever may govern. To allow for maxi-



All values are per unit based on KVA Rating

Fig. 6: Terminal Impedance (Ohms)

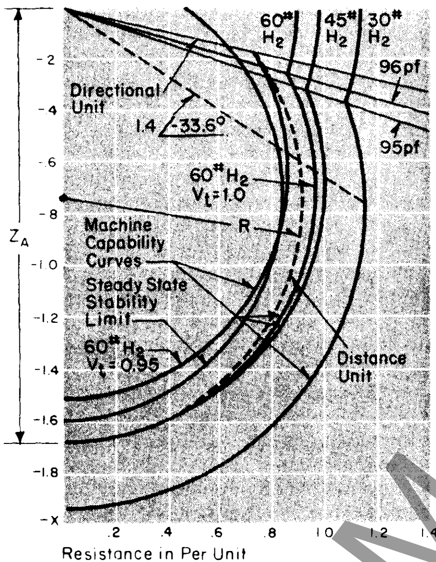


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Fig. 7: Typical Machine Capability Curve

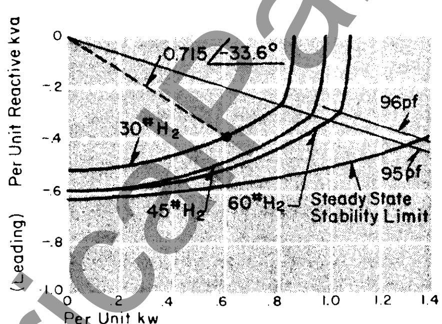

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Fig. 8: Typical Machine Capability Curve

mum 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 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-1 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-1 relay is designed for operation on all systems using wye connected potential transformers, which is the scheme most commonly used. A feature of the KLF-1 is its security against false tripping under conditions of loss of relay potential in any or all phases. It is also immune to false operation under short circuit conditions between phases at the relay terminals.

Potential

@ 69 volts (phase-to-neutral), 60 cycles

Phase 1: S = 1, 6.1 volt-amperes at 9° current lag
Phase 2: S = 2, 1.5 volt-amperes at 9° current lag
Phase 3: S = 3, 0.7 volt-amperes at 9° current lag
Phase 2: 3.18 volt-amperes at 48° current lag
Phase 3: 2.76 volt-amperes at 43° current lag

D-c Circuit Rating	Watts @ Rated Voltage
125	3.9
250	7.8

Thermal Ratings

Potential: 75 volts (line-to-neutral) continuous

Current: 8 amperes continuous
200 amperes for one second.

Shipping Weights and Carton Dimensions

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

Further Information

List Prices: PL 41-020
Technical Data: TD 41-025
Instructions: IL 41-748.1
Renewal Parts: RPD 41-961
Flexitest Case Dimensions: DB 41-076
Contactor Switches: DB 41-081
Type KLF Relay: DB 41-702E
Other Protective Relays:
Application Selector Guide, TD 41-016

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