Lecture 27
EE5210

EXAMPLE →

ASSUME IMPEDANCE = X Ω.

IN ZERO SEQUENCE NETWORK = 3X Ω

(∵ ALL ZERO SEQUENCE CURRENTS ARE IN PHASE) $I_{a0} = I_{b0} = I_{c0}$

PU. CURRENT = $\frac{100 \times 1000A}{\sqrt{3} * 13.8}$

= 4183.7 A

10 A = $\frac{10}{4183.7A}$ = 0.0024 pu

EXAMPLE

$$I_A = \frac{3 \times (1)}{j(0.273 + 3X)}$$

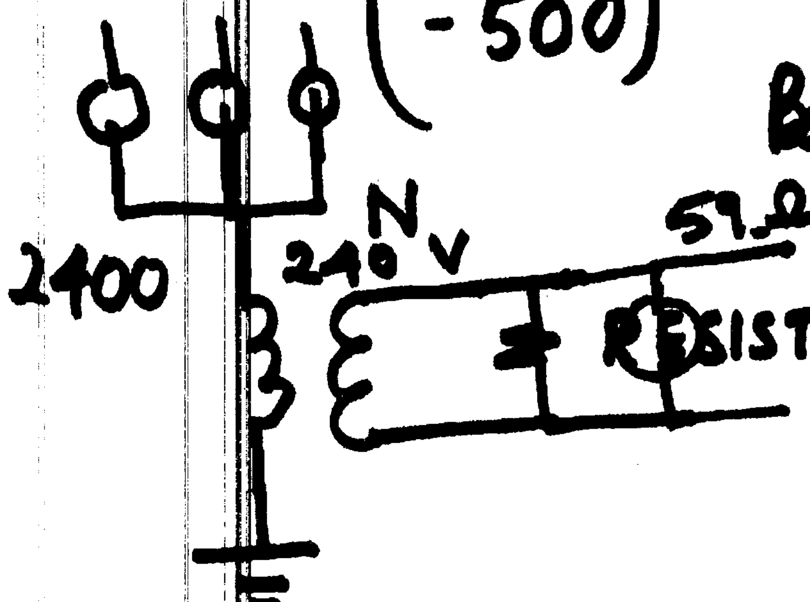
$$= 0.0024 \text{ pu}$$

$$3X = 3 / 0.0024 - 0.273 \text{ pu}$$

$$X = 416.57 \text{ pu}$$

$$R \simeq \begin{pmatrix} 400 \\ -500 \end{pmatrix} \text{ pu}$$

$$\text{Base } \Omega = \frac{(13.8)^2}{100} = 1.9\ \Omega.$$



RESISTANCE = 8 Ω

6

ese sources and their interconnections to n technical requirements for these inter- ictices, operating procedures, and design igh quality of service and of safety for stomers, general public), and protection cooperation is very important between sign, construction, and operation of the

nsidered are as follows:

phase or ground faults in the stator and

: rotor and loss of field excitation
operational hazards
r; generator motoring (32)
r hertz protection (24)
tion: nonsynchronized connection (67)
: breaker pole flashover (61)

tion for large steam turbines
ency (81)
d overvoltage (59)
: out of step
llations

ONS AND

ors are as follows:
eral) each through a circuit breaker to . 8.2: Usually they are wye-grounded grounded, or are delta-connected. They ower system or to the power system r.

ility, industrial, or IPP generators is IPP generators under- and overvoltage are mandatory toward disconnecting separate transfer trip channel from the ed to assure that the IPP unit is not to restore service. This is important

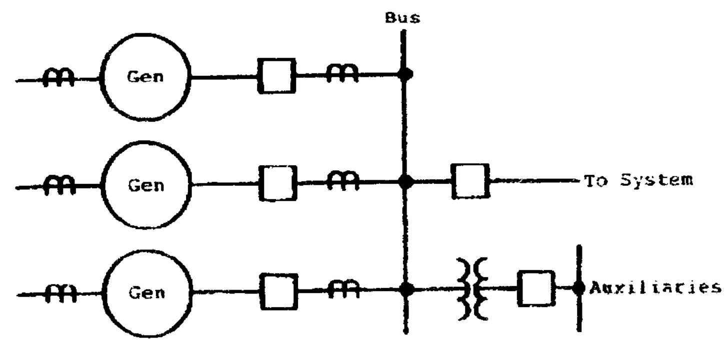
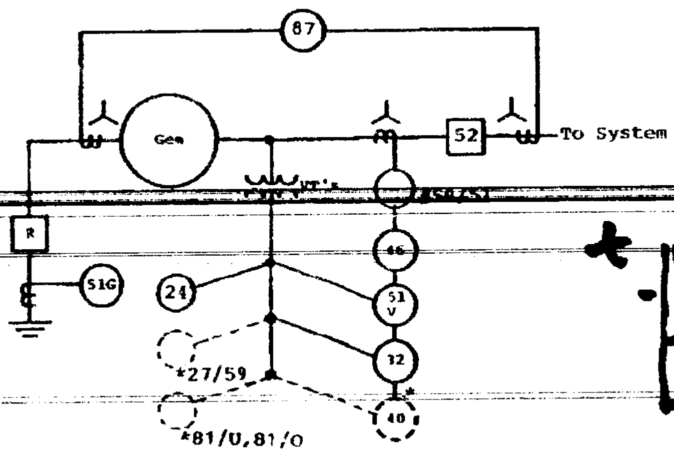


FIGURE 8.2 Direct-connected generator units (one or more) to a common system bus.

where the IPP and industrial generation may be islanded and able to supply the utility loads in the island.

2. *Unit connected,* in which the generator is connected directly to an associated power transformer without a circuit breaker between, as shown in Fig. 8.4. This is the common connection for the large generators in util-



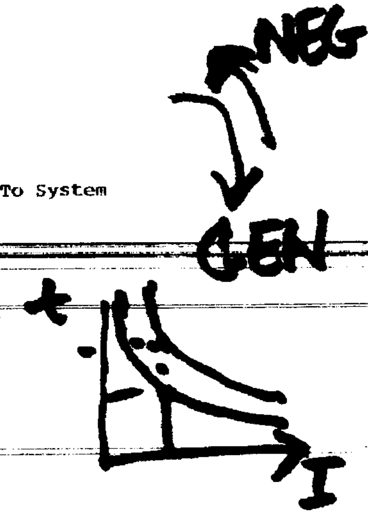


FIGURE 8.3 Typical protection for a direct-connected generator. (*) Dotted relays are optional except 29/57 under- or overvoltage and 81 under- or overvoltage mandatory for nonutility generators connected to a utility; (#50) not always applicable.

7

[redacted]

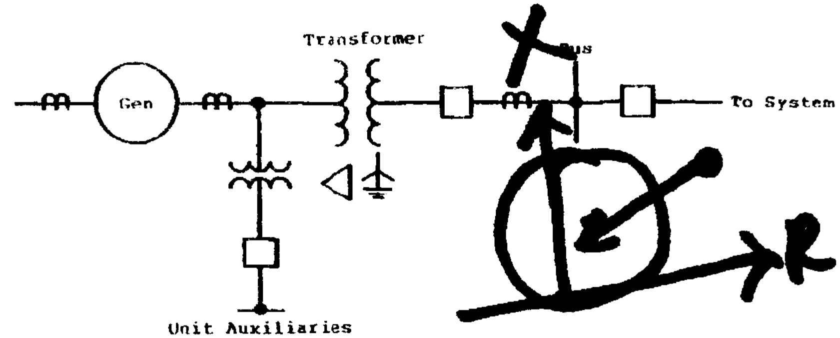
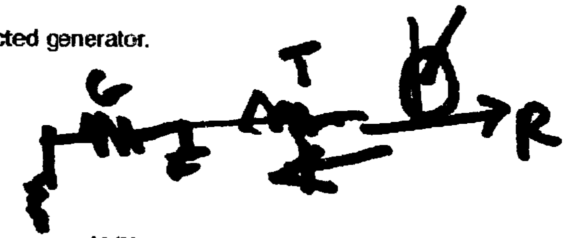


FIGURE 8.4 Unit-connected generator.



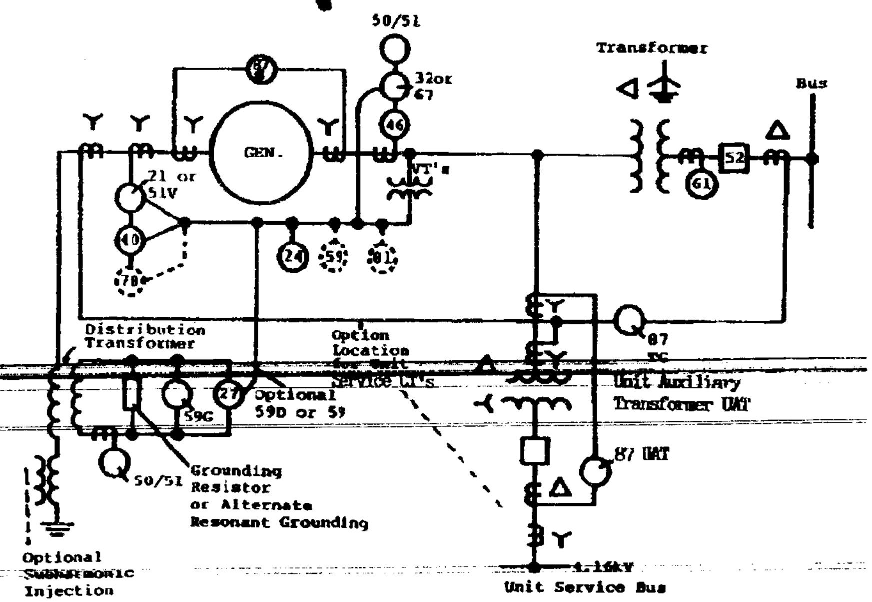


FIGURE 8.5 Typical protection for a unit generator and for large generators in utility systems.

8

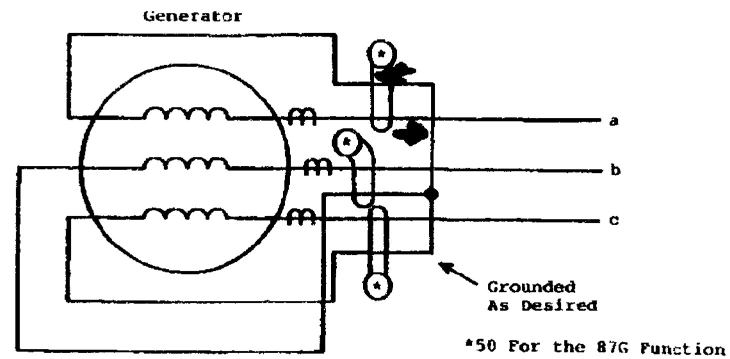


FIGURE 8.6 Differential protection for small generator units with flux summation current transformers and an instantaneous overcurrent (50) relay.

side of the breaker and the generator neutral side leads are carried to that point. This is seldom practical, so other protection must be provided for this area between the flux summation CT and the breaker. In general, this scheme (see Fig. 8.6) is more sensitive as long as the generator CT ratio is greater than 150:5 to 200:5. If the flux summation CT is not applicable and differential protection is desired, the scheme of Fig. 8.7 can be used.

8.3.2 Multi-CT Differential Protection (87) for All Size Generators

The basic principles of this protection were covered in Section 6.2. It is widely used to provide fast and very sensitive protection for the generator and associated circuits. The 87 relays are connected to two sets of current transformers; one set in the neutral leads, the other in the line side. For generators with associated breakers, the line-side CTs are usually associated with the breaker, as shown in Figs. 8.2 and 8.3.

For unit generators the line-side CTs are usually quite close to the generator, basically at the generator terminals. Typical connections for the three-phase units are shown in Fig. 8.7 for both wye- and delta-connected generators.

If current transformers are available at each end of the windings for the delta-connected generators of Fig. 8.7b, differential relays can be applied for winding protection. The connections would be similar to those shown in Fig. 8.7a. However, this would not provide protection for the junction points or the phase circuits that are within the protective zone (see Fig. 8.7b).

9

TURN-TO-TURN FAULT

——— a

——— b

——— c

rounded
s Desired

For the 87G Function

generator units with flux sum-
eous overcurrent (50) relay.

l side leads are carried to that ction must be provided for this breaker. In general, this scheme e generator CT ratio is greater CT is not applicable and differ- g. 8.7 can be used.

n (87) for All

covered in Section 6.2. It is ve protection for the generator onnected to two sets of current he other in the line side. For side CTs are usually associated 3.3.
are usually quite close to the ls. Typical connections for the oth wye- and delta-connected

each end of the windings for ifferential relays can be applied ld be similar to those shown in otection for the junction points ctive zone (see Fig. 8.7b)

C800

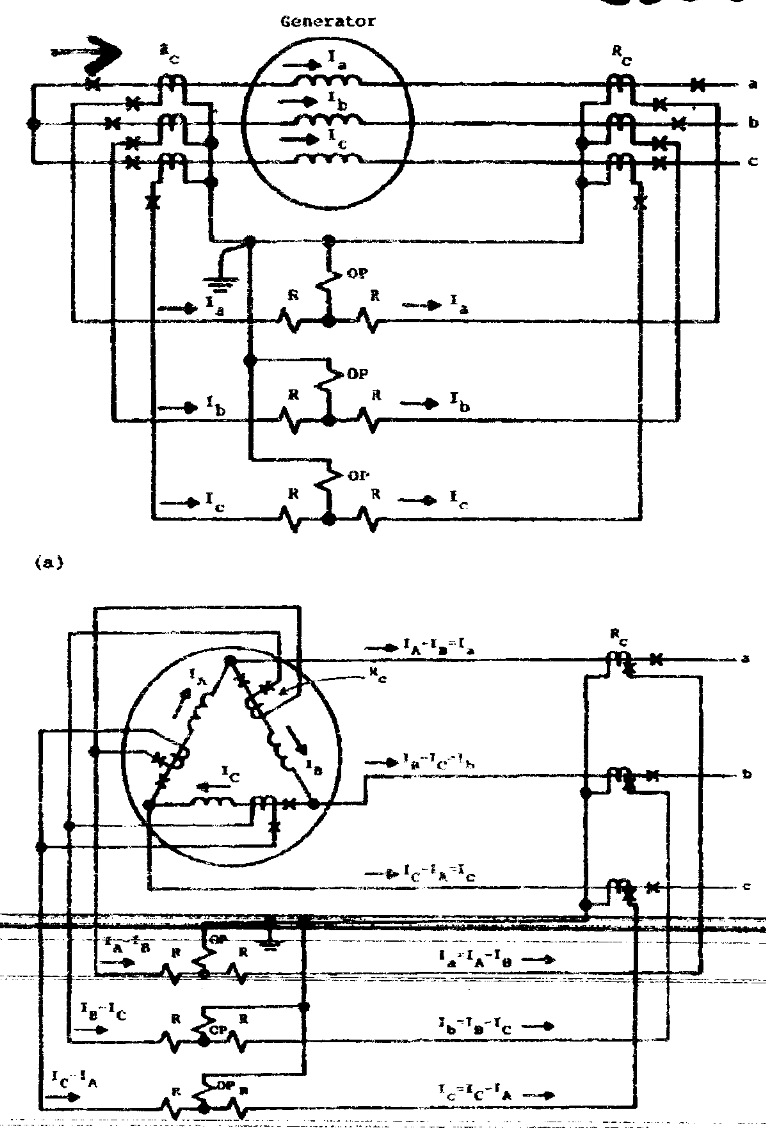


FIGURE 8.7 Typical differential (87) connections for the protection of wye- and delta-connected generators: (a) wye-connected generator; (b) delta-connected generator.

CT RATIOS / MISOPERATIONS

CONTINUOUS UNBALANCE CURRENT CAPABILITY

A generator shall be capable of withstanding, without injury, the effects of a continuous current unbalance corresponding to a negative-phase-sequence current I_2 of the following values, providing the rated kVA is not exceeded and the maximum current does not exceed 105 percent of rated current in any phase. (Negative-phase-sequence current is expressed as a percentage of rated stator current).

Type of Generator	Permissible I_2 (percent)
Salient Pole	
With connected amortisseur windings	10
With non-connected amortisseur windings	5
Cylindrical Rotor	
Indirectly cooled	10
Directly cooled - to 960 MVA	8
961 to 1200 MVA	6
1201 to 1500 MVA	5

These values also express the negative-phase-sequence current capability at reduced generator kVA capabilities.

UNBALANCED FAULT CAPABILITY

Negative sequence current is expressed in per unit of rated current and time is in seconds.

Type of Generator	Permissible I_2^2t
Salient pole generator	40
Synchronous condenser	30
Cylindrical rotor generators	
Indirectly cooled	20
Directly cooled (0-800 MVA)	10
Directly cooled (801-1600 MVA)	see curve below

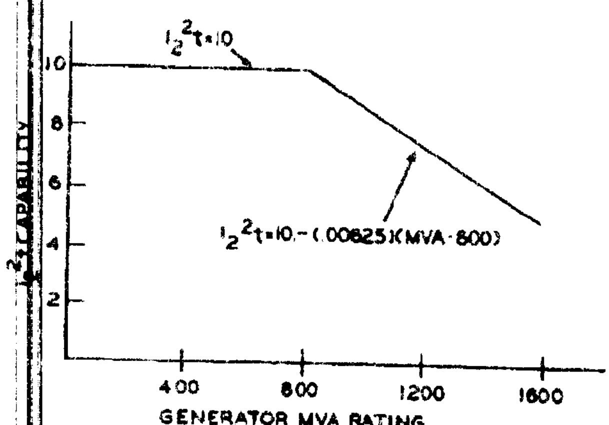


Fig 4.5.2-1
Continuous and Short-Time Unbalanced Current Capability of Generators (from ANSI C50.13-1977 [1])

current may be above relay pickup and the magnitudes of the harmonics may not be sufficient to provide adequate restraint.

Three approaches have been used to prevent such operations. One approach uses a volts/Hz relay to block tripping of or to desensitize the transformer differential relay when the volts/Hz exceeds a specified level.

The second approach uses a modified differential scheme which extracts and utilizes a third harmonic exciting current from the transformer delta winding to restrain the relay from operating during an overexcitation condition. It should be recognized that the first two approaches somewhat degrade the differential protection.

The third approach utilizes a differential relay that restrains on the fifth harmonic as well as the second harmonic. The fifth is the lowest harmonic flowing from the delta windings under balanced conditions.

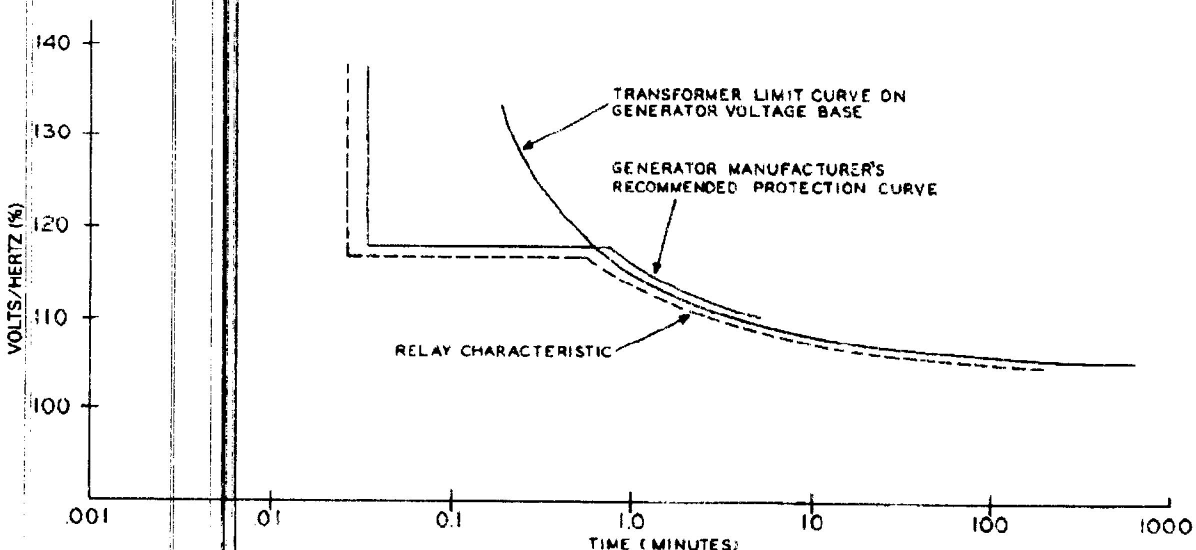
4.5.4.4 Tripping. This protection is generally connected to trip the main generator breaker(s) and the field breaker(s) and transfer auxiliaries if necessary. Again, this permits fast resynchronization of the generator if the overexcitation condition can be remedied quickly. When a unit is off-line, alarm and inhibit circuits may be required to prevent an operator from exceeding safe levels of excitation when preparing a unit for synchronizing. See the caution in 4.5.1.4.

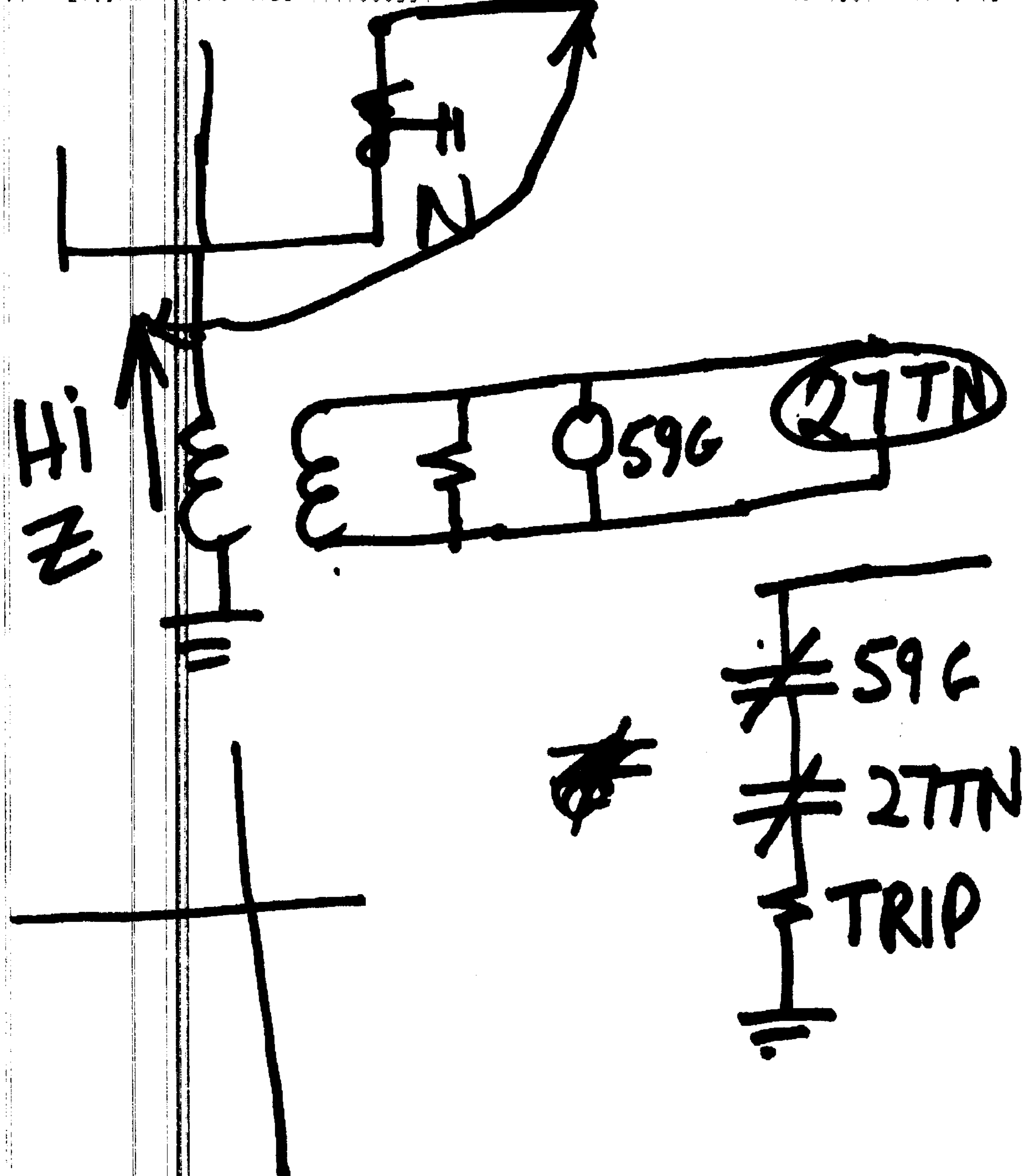
4.5.5 Anti-Motoring. Motoring of a generator occurs when for some reason the energy supply to the prime mover is cut off while the generator is still on line. When this occurs, the generator will act as a synchronous motor and drive the prime mover. While this condition is defined as generator motoring, the primary concern is the protection of the prime mover which can be damaged during a motoring condition.

4.5.5.1 General Considerations. Motoring causes many undesirable conditions. For example, in a steam turbine, the rotation of the turbine rotor and blades in a steam environment causes idling or windage losses. Since windage loss is a function of the diameter of rotor disc and blade length, this loss will usually be greatest in the exhaust end of the turbine. Windage loss is also directly proportional to the density of enclosing steam. Thus, any situation in which the steam density is high will cause dangerous windage losses. For example, if vacuum is lost on the unit, the density of the exhaust steam will increase and cause the windage losses to be many times greater than normal. Also, when high density steam is entrapped between the throttle valve and the interceptor valve in reheat units, the windage losses in the high pressure turbine are very high.

Windage loss energy is dissipated as heat. The steam flow through a turbine has a two-fold purpose — to give up energy to cause rotation of

Fig 4.5.4-2
Example of Inverse Volts/Hertz Setting





Hi
N
Hi
Z
59G
27TN
59G
27TN
TRIP

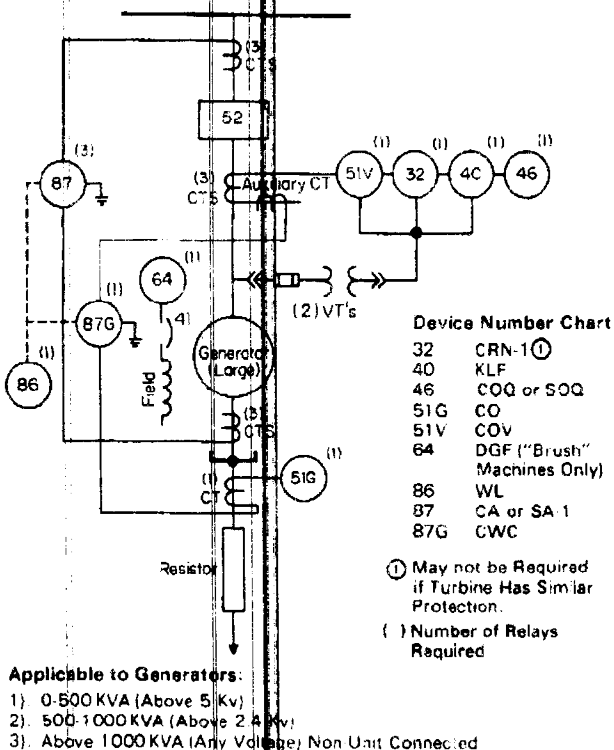


Figure 6-24: Recommended Protection for Large Generators Used in Industrial Plants.

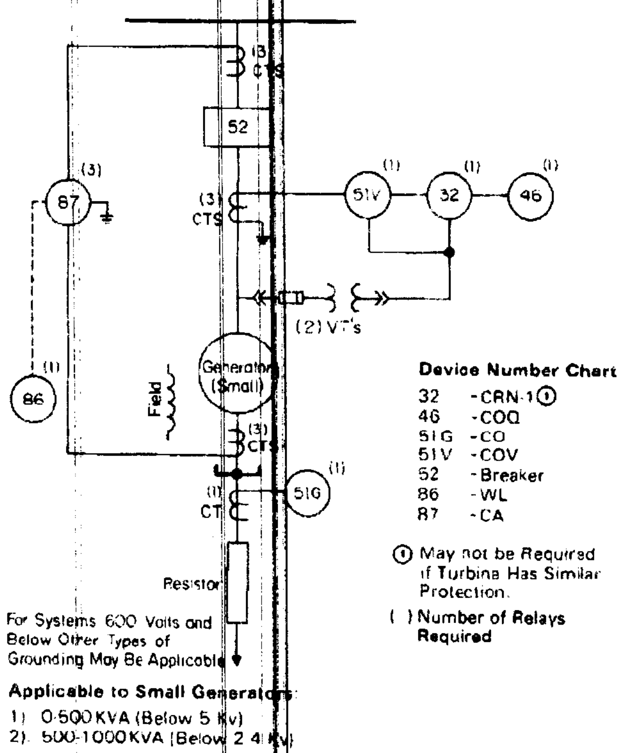


Figure 6-25: Recommended Protection for Small Generators as Used in Industrial Plants.

XVI. BUS TRANSFER SYSTEMS FOR STATION AUXILIARIES

Automatic transfer of highly essential station auxiliary loads such as boiler feed pumps and induced draft fans is common practice. Paralleling the normal and emergency sources is not generally recommended, however, because the higher breaker interrupting duties involved can cause problems, as can circulating currents between systems. The transfer scheme requires interlocks to prevent paralleling of the supply sources. Transfers should not be made if voltage in the alternate supply is not satisfactory or the load circuits are faulted. Also, supply breaker tripping should be delayed long enough to permit fault sectionalizing in the load circuits. An example of a transfer scheme using type CP polyphase voltage relays is shown in Figure 6-26.

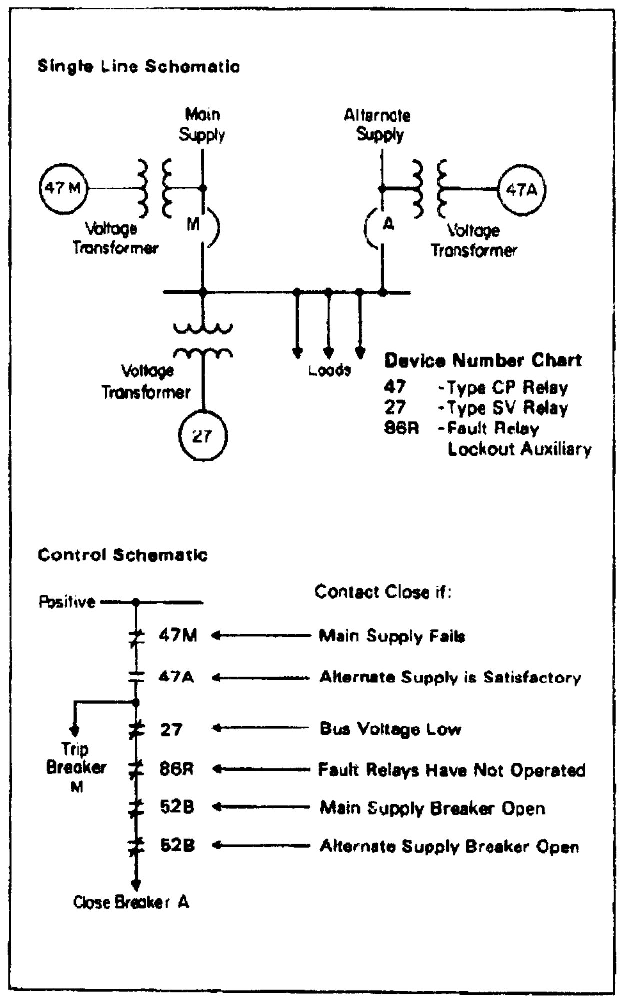


Figure 6-26: Bus Transfer Scheme Utilizing Polyphase Voltage Relays.

The SC relay (or SV for the CV-8) is recommended as supplementary protection in several areas indicated by an asterisk in Table 6-III. Use of this relay is optional in the A and B classifications and will depend on the need for additional sensitivity. The SC current relay has a flat characteristic, and increases slightly in sensitivity as the operating frequency drops. When an SC relay is operated on dc, it picks up at approximately 15 percent below its normal 60-Hz pickup. The pickup of the SV voltage relay is almost directly proportional to frequency; its sensitivity at 15 Hz is thus 4 times the sensitivity at 60 Hz. For this reason, the SV relay provides excellent backup protection for 60-Hz voltage relays that lose their sensitivity at low frequencies.

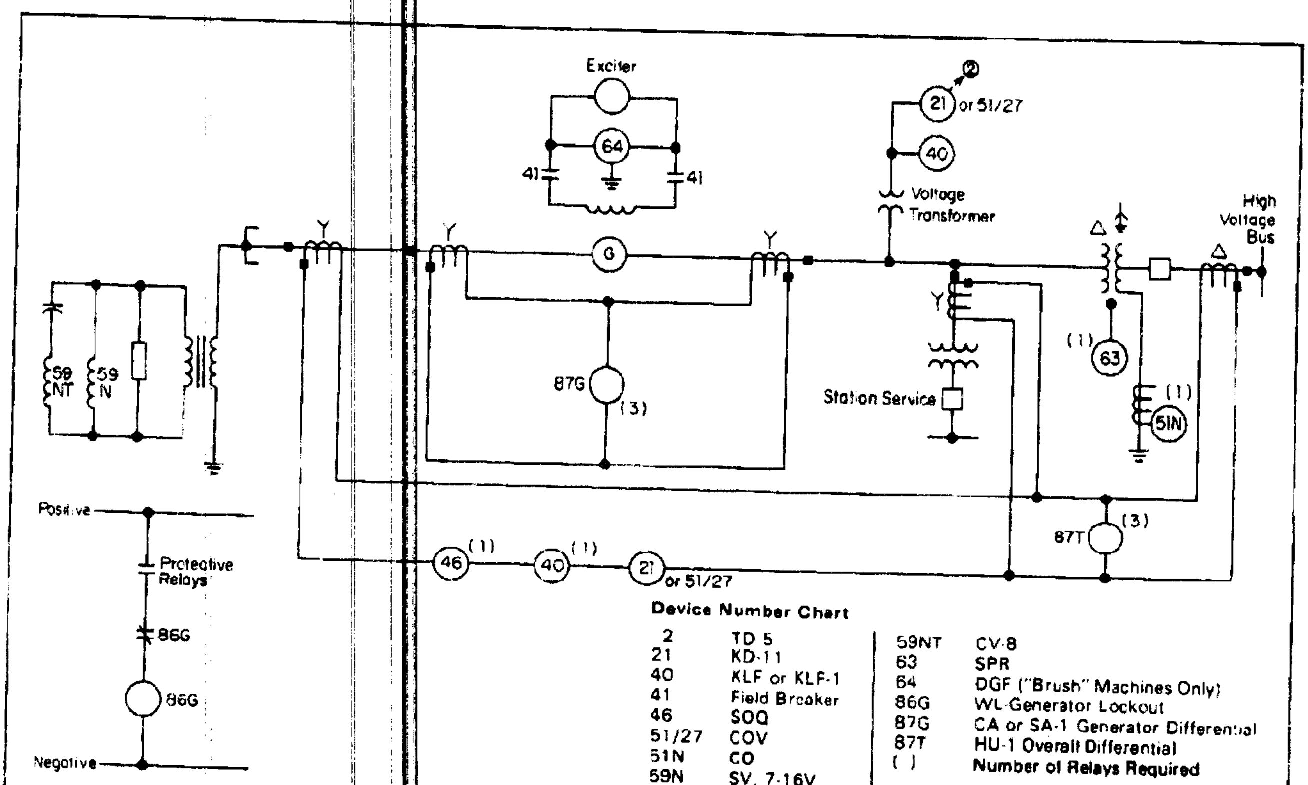
With one exception, the relays listed in Table 6-III will neither overheat nor operate incorrectly if left in the circuits when the generator is operated at reduced frequencies. The KLF and KLF-1 relays, when used in a cross-compound configuration, must have their trip incapacitated during start-up.

XIV. RECOMMENDED PROTECTION

Figures 6-22 and 6-23 show the recommended protection for large tandem-compound and cross-compound, unit-connected turbine generators. Figures 6-24 and 6-25 show the recommended protection for machines that are not unit connected. Generally, such generators are used in industrial applications.

XV. OUT-OF-STEP PROTECTION

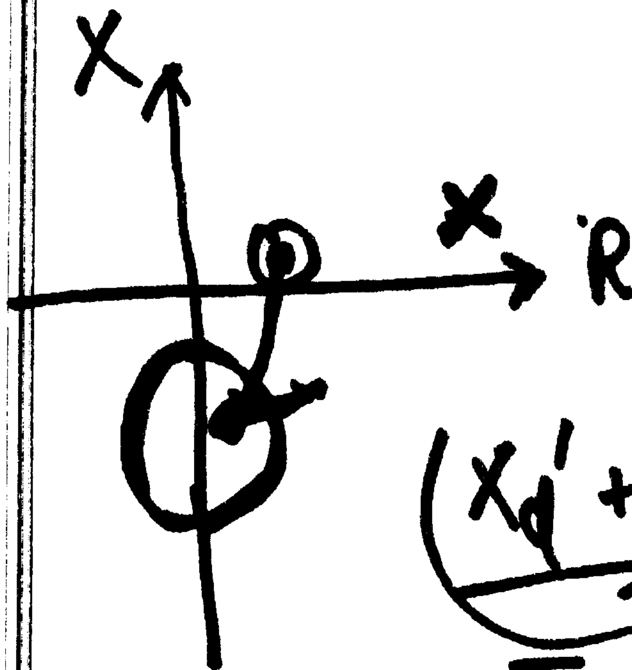
As generator impedances become larger in proportion to the system, the electrical center will be closer to the generator. This condition intensifies the need for out-of-step detection as part of the generator relaying complement. Such relaying schemes are described in Chapter 19, System Stability and Out-of-Step Relaying.



Device Number Chart

2	TD 5	59NT	CV-8
21	KD-11	63	SPR
40	KLF or KLF-1	64	DGF ("Brush" Machines Only)
41	Field Breaker	86G	WL-Generator Lockout
46	SOQ	87G	CA or SA-1 Generator Differential
51/27	COV	87T	HU-1 Overall Differential
51N	CO	( )	Number of Relays Required
59N	SV, 7-16V		

Figure 6-22: Overall Protection for a Tandem-Compound Unit Connected Generator.



$$\left(\frac{X_q' + X_d'}{2}\right)$$

RELUCTANCE TORQUE

$$(X_d - X_q)$$