Westinghouse

Ground Fault Protection With Westinghouse Amptector® Static Trip On Type DS Or Type DB Air Circuit Breakers

Distribution Systems
The power distribution in three phase low voltage systems can be three or four wire distribution. The three wire distribution can be served from either delta or wye sources, but the four wire distribution is obtained from wye source only. Fig. No. 1 shows three wire distribution with delta source and Fig. No. 2 shows three wire distribution with wye source. It is significant on Fig. No. 2, that the wye connection of a transformer secondary does not necessarily mean four wire distribution in switchgear. This is worthwhile to note because four wire distribution is quite frequently assumed when the transformer secondary is wye connected. The low voltage system is three phase four wire distribution only if a fourth wire is carried through the switchgear and single phase loads are connected to feeder breakers. This fourth wire is the neutral bus. The neutral bus is connected to the neutral of the wye connected transformer secondary as shown on Fig. No. 3. The standard neutral bus capacity is one half of the phase bus current carrying capacity but full capacity neutral busses are also available on request.

Three or four wire systems can be grounded or ungrounded in service. Generally where the source is delta connected it is ungrounded, but in some very rare cases it is grounded at one corner of the delta or at some other point. When the source is wye connected it can be grounded or ungrounded and when grounded the grounding is at the neutral. When low voltage systems are grounded they are generally solidly grounded. However occasionally the grounding is through a resistor. Three and four wire solidly grounded systems are shown on Fig. No. 4 and 5. At present the new installations are mostly solidly grounded or ungrounded low voltage systems with a definite trend toward the increase of the solidly grounded systems. An ungrounded low voltage system is a good operating system if it is equipped with a ground detection device and if the operators and maintenance crew are trained to locate the initial ground and clear it as soon as practical. The grounded neutral system results in a ground current as soon as any ground occurs on a phase conductor and if the current exceeds the setting of the protective device it will operate and isolate the fault.

Need For Ground Fault Protection
If the magnitude of all ground currents would be large enough to operate the short delay or instantaneous elements of the phase overcurrent trip devices there would be no problem in solidly grounded systems. Unfortunately this is not the case, because low magnitude ground currents are quite common. Low level ground currents can exist if the ground is in the winding of a motor or a transformer or if it is a high impedance ground. Low level ground currents may also be due to an arcing type ground. The arcing type grounds are the source of the most severe damages to electrical equipment. The lower limit of the arcing ground currents is unpredictable and the magnitude may be considerably below the setting of the breaker phase overcurrent trip devices.

Since the breaker phase overcurrent trip devices cannot provide fast protection against low magnitude ground faults there is a need for an additional protective device. This additional device is not to operate on normal overloads and it is to be sensitive and fast enough to protect against low magnitude grounds. It is also important that this additional ground protecting device be simple and reliable. The Westinghouse Amptector solid-state tripping system including an optional "ground element" will assure good ground fault protection.

The Ground Element
The ground element of the solid-state trip is part of the Amptector and is in addition to the usual phase protection. The ground element will trip the breaker with time delay when 1.0 ampere or more of input current is applied to its terminals. The ground element is equipped with a continuously adjustable time delay with calibrated marks at 0.22 – 0.35 – 0.5 seconds. The above mentioned input current can be provided by:

(a) Residual connection of phase sensors with residual current connecting to ground element terminals. This is the Westinghouse East Pittsburgh Low-Voltage Switchgear standard ground protection system. Based on the above mentioned 1.0 ampere pickup this assures a ground tripping sensitivity of 20 percent of sensor rating. The standard ground element pickup is non-adjustable and it provides good ground protection for normal applications. However for special applications 40 – 60 and 80 percent of phase sensor rating pickup points can be furnished.

(b) External ground sensing current transformer directly connected to ground element terminals. This is one of the unique features of the Westinghouse Amptector. This means that this external ground sensor will trip the breaker on grounds without the use of external relay and without the application of a breaker shunt trip and external power source. The lower the CT ratio the more sensitive the ground fault protection.

Ground Fault Protection Application and Coordination
In well designed systems the continuity of service is very important. For reliable service continuity selective tripping is applied between main tie and feeder breakers and the downstream protecting devices for phase to phase faults. Similar selective tripping is desirable when breakers trip on grounds. The application of ground protection on main breakers only may assure good ground protection, however it will not provide good service continuity because the main breaker will trip on grounds which should have been cleared by feeder breakers. When the switchgear itself feeds the loads directly the applied ground protection must be such that on a load circuit ground the associated feeder breaker will trip first. Therefore for proper protection and for good service continuity main tie and feeder breakers all should be equipped with ground protection. Ground protection is not required for non-automatic tie breakers having no phase overcurrent protection.

The necessary coordinated tripping is not easily accomplished when the switchgear feeds into downstream sub-distribution panels which do not have ground protection. If full selective tripping is required the downstream protecting devices should also be equipped with ground protection. If not, the system designer will face a coordination problem in obtaining selectivity between the low pickup and fast tripping switchgear breaker ground elements and phase overcurrent protective devices. This is a very difficult problem because of the time-current tripping characteristic of the phase overcurrent protective devices. When such coordination is desired the ground element pickup could be increased in order to "desensitize" the standard 20 percent ground fault pickup. Taps at 40 – 60 – 80 percent of sensor rating can be used. It is obvious that when the ground element pickup is set for example at 80 percent valuable protection is lost for low magnitude arcing ground currents. If higher ground element pickup is

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Ground Fault Protection Application and Coordination, Continued
attempted to achieve coordination with fairly large sized downstream phase devices the ground protection setting approaches the characteristic of a short time phase element and the ground protection will lose its true meaning and not provide the expected protection.

In view of the above it is evident that properly applied ground protection requires ground elements as far down the system to the loads as practical. For best results downstream molded case breakers should have individual ground protection. This would result in excellent ground protection because ground elements of switchgear and downstream breakers having similar tripping characteristic can be coordinated.

Coordination between switchgear breaker ground elements and downstream branch circuit fuses is not practical. This is due to the basic fact that the blowing of one phase fuse will not clear a ground on a three phase system. The other two phase fuses will let the load "single-phase" and also continue to feed the ground through the load as shown in figure 6.

The following provides guidelines for ground fault protection.

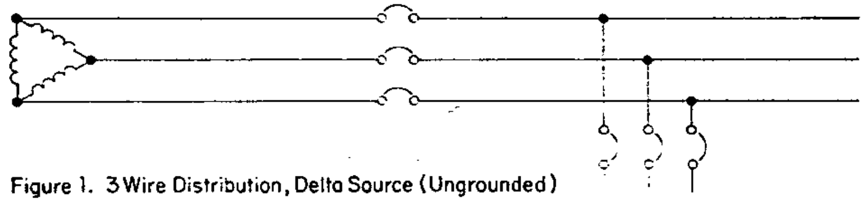


Figure 1. 3 Wire Distribution, Delta Source (Ungrounded)

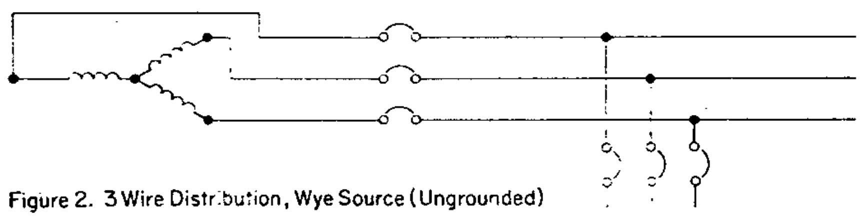


Figure 2. 3 Wire Distribution, Wye Source (Ungrounded)

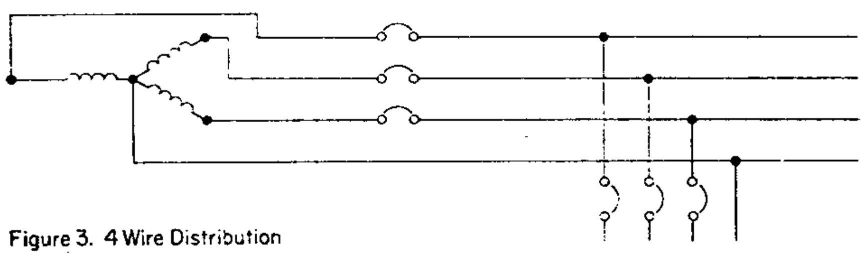


Figure 3. 4 Wire Distribution

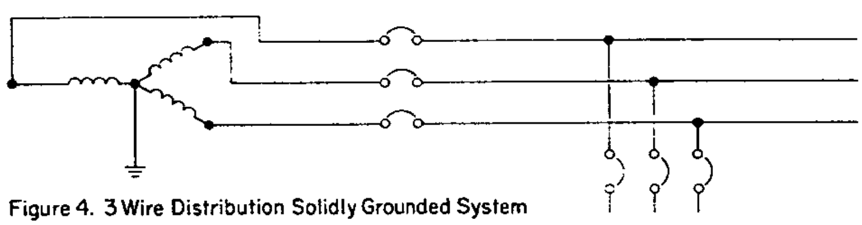


Figure 4. 3 Wire Distribution Solidly Grounded System

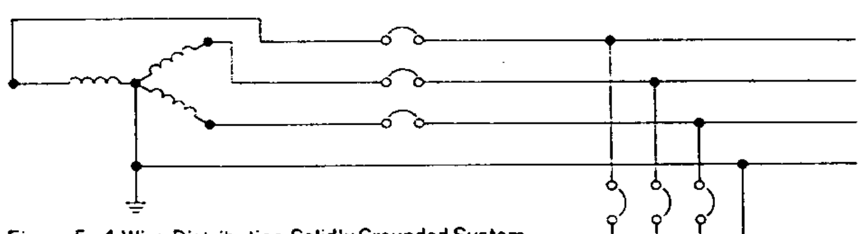


Figure 5. 4 Wire Distribution Solidly Grounded System

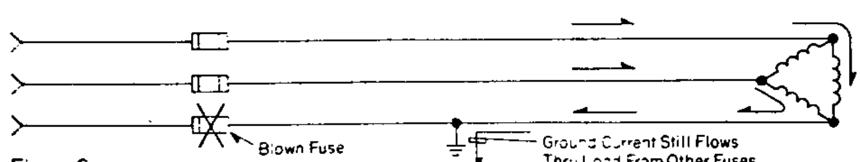
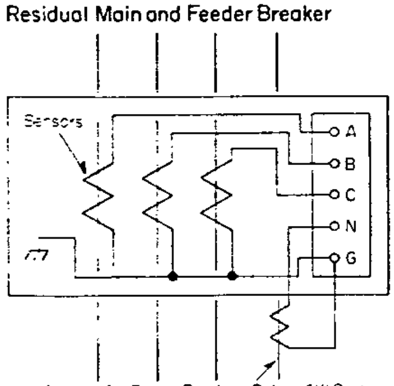


Figure 6.

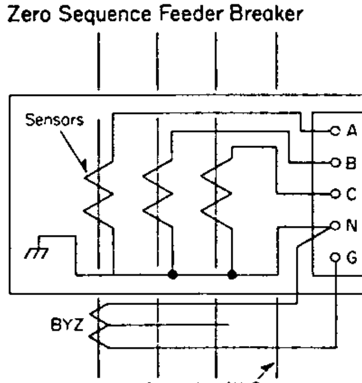
Ground Fault Protection With Westinghouse Amptector® Static Trip On Type DS Or Type DB Air Circuit Breakers

System	Advantages	Disadvantages	Equipment Available for Protection			
			Main Breaker	Tie Breaker	Fdr. Breaker	Notes
Un-grounded (3 Wire)	Minimum disturbance to service continuity. Currents for the majority of grounds will be limited to capacitance charging current of the system. Can operate with the first ground until it is removed during a regular shutdown.	When ground detector shows that a ground exists corrective action must be taken at the earliest possible shutdown. However, experience indicates that this attention is not always possible. Therefore most ungrounded systems operate with one phase grounded through the first uncleared ground. A ground on another part of the system, due to fault impedance, would probably result in low values of current which would not operate a breaker phase trip, and would produce fire damage.	Lamp type ground detector or ground detecting voltmeters without or with pts. If pts. are used a ground alarm relay can be added for remote or local alarm.			With proper maintenance this system would result in the minimum disturbance to service continuity.
	Ground protection for an ungrounded system		Amptector 'DS' ground 3W protection, 20% of sensor rating pick-up, .50 sec. time delay. See SK #1 & #6	Amptector 'DS' ground 3W protection 20% of sensor rating pick-up .35 sec. time delay.	Amptector 'DS' ground 3W protection 20% of sensor rating pick-up .22 sec. time delay. See SK #1 & #6	Ground fault protection on this ungrounded system would trip the breaker when the second ground occurs and current exceeds the 20% pick-up rating.
Solid Grounded	Psychologically safer. Practically results in good continuity of service. Isolation of faults automatic through ground protection system no overvoltages due to ferroresonance or switching.	Probability of very high ground current and extensive damage however, normally these high currents are not obtained. Grounds are automatically isolated and continuity of service is interrupted.	Amptector 'DS' standard residual ground protection in 3W systems and source neutral C.T. feeding into Amptector in 4 wire systems. 20% of sensor rating pickup, .50 sec. time delay See SK. #1, #3, & #6.	Amptector 'DS' ground 3W or 4W (as required) fault protection. 20% of sensor rating pick-up .35 sec. time delay	Amptector 'DS' ground 3W or 4W (as required) fault protection. 20% of sensor rating pick-up .21 sec. time delay or BYZ current transformer feeding into above amptector with 10 amp primary pick-up See SK #1, #2 & #6	This is the most common system in use today and as long as it is not necessary to coordinate with phase devices down the line it will give very good main bus and feeder protection.
High Resistance Grounded (3 Wire)	Ground fault current is limited. Ungrounding can result in high voltages during switching and this is corrected by high resistance grounding.	Very sensitive detection is required to detect the limited fault current. Since overvoltage due to switching isn't prevalent on ungrounded low voltage systems high resistance grounding is not required.	Same as for ungrounded except if ground alarm relay is used connect relay across grounding resistor.	Same as for ungrounded.	Same as for ungrounded.	This system is very seldom used and is not recommended.

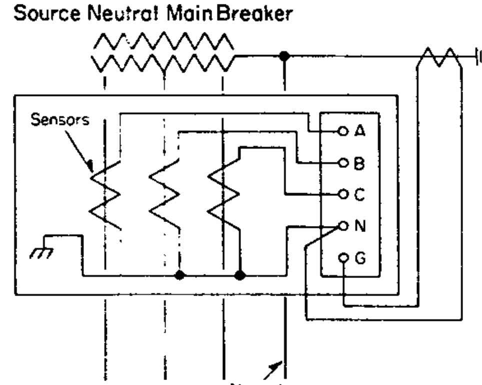
Sketch 1. (*)
Residual Main and Feeder Breaker



Sketch 2.
Zero Sequence Feeder Breaker



Sketch 3.
Source Neutral Main Breaker



(* Apply in 3 Wire Systems for Main Breaker and in 3 or 4 Wire Systems for Feeder Breakers

Note: For double ended secondary unit substations ground fault protection should be as indicated on sketches #4 and #5 however for this type application the East Pittsburgh Works Low-Voltage Switchgear Department should be consulted for the actual bill of material to be used. The application becomes rather complex if single phase to neutral loads are being served.

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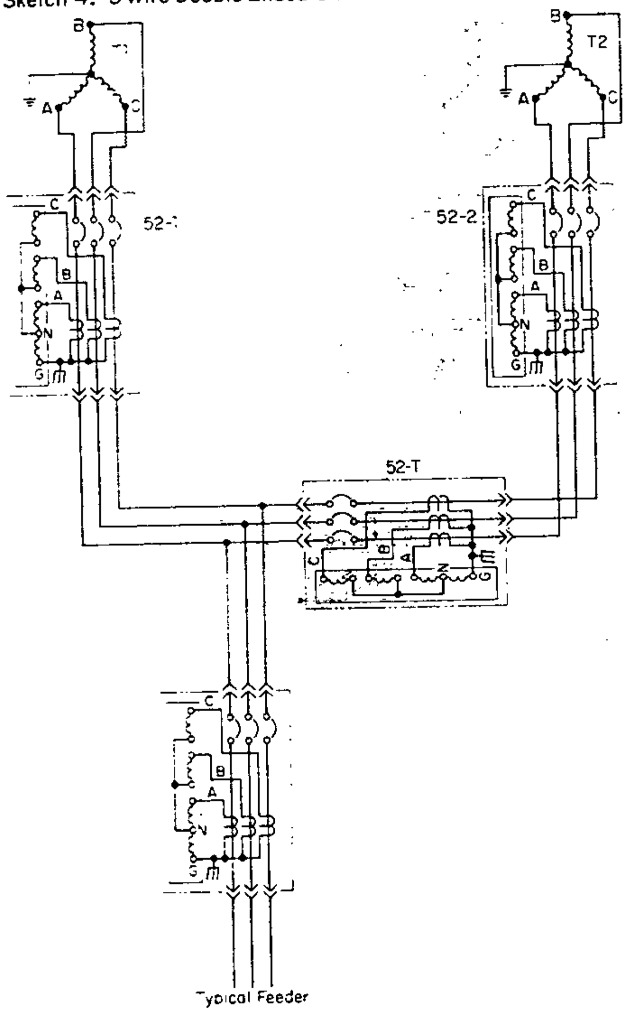
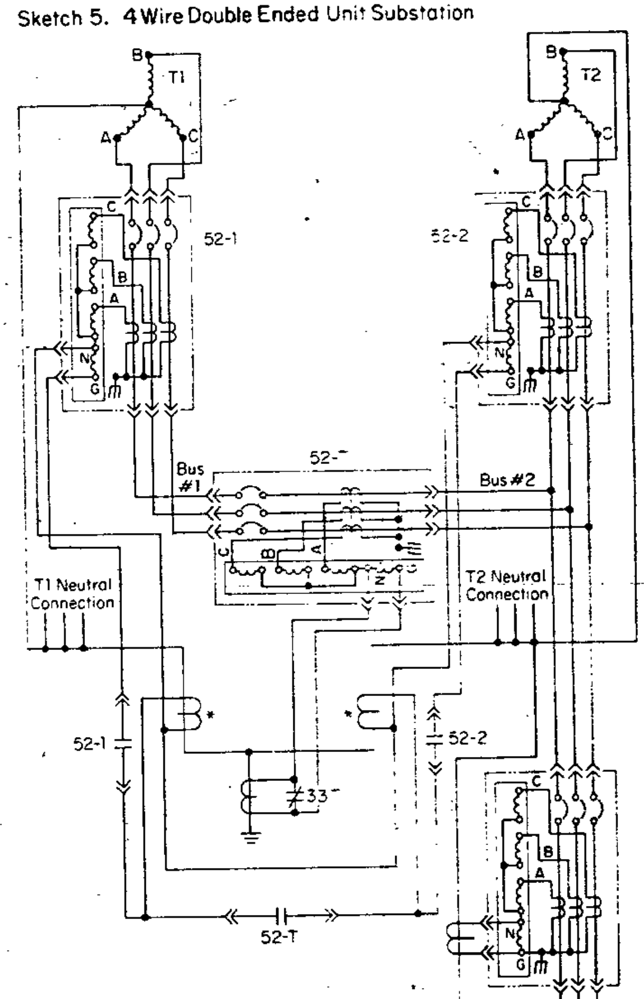
Sketch 4. 3 Wire Double Ended Unit Substation



Sketch 5. 4 Wire Double Ended Unit Substation



*These CTS are to Have Identical Ra...

Sketch 6.