# High Voltage Busbar Protection

An Online Continuing Education Course for Engineers

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# High Voltage Busbar Protection

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The protection arrangement for an electrical system should cover the whole system against all possible faults. Line protection concepts, such as overcurrent and distance arrangements, satisfy this requirement, even though short circuits in the busbar zone are cleared after a specified time delay. But in that case, unit protection is used for feeders and plants; the busbars are not inherently protected. Busbars have typically been left without dedicated protection, for the following reasons:

- the busbars and switchgear are highly reliable
- it was believed that inadvertent operation of busbar protection might cause cascade tripping
- it was believed that electrical system protection or backup protection would give adequate bus protection if necessary.

Although the risk of a short circuit happening on modern metal clad equipment is insignificant, it cannot be completely dismissed. The damage resulting from even one short circuit could be huge, up to the overall loss of the substation by fire. Severe damage or destruction could conceivably end in widespread and prolonged supply disruption.

Typically, electrical system relay protection will not – over time – give the needed cover. Such protection may be sufficient for small distribution substations, but not for vital substations. Even if distance protection is used for all utility feeders, the busbar will be located in the second protection zone, so a bus short circuit will be slowly cleared, and the voltage dip that results may not be permissible.

In the case of outdoor switchgear, the situation is less clear. Even though the likelihood of a short circuit is greater, the risk of widespread damage is lower. In principle, busbar protection is needed when the system protection does not protect the busbars, or when high-speed, short-circuit current clearance is needed to keep the power system stable. Unit busbar protection meets those requirements. Also, if busbar sections are separated, only one section needs to be isolated to clear a fault. Busbar protection is actually the strongest when bus sections are separated.



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## Busbar Faults

Most bus faults involve one phase and ground. Although faults have many causes, a great number are interphase clear of ground. In fact, a large percentage of busbar faults are caused by human error, rather than the failure of switchgear components. With totally phase-segregated, metal-clad equipment, only ground faults are possible, and a protection configuration needs to have only ground fault sensitivity. In other situations, an ability to react to phase faults that do not involve ground is an advantage, even though the phase fault sensitivity does not need to be high.

## Protections Requirements

Though not fundamentally different from other circuit protection, the key busbar position increases the emphasis placed on basic speed and stability requirements. The special characteristics of busbar protection are elaborated in the sections that follow.

## Speed

Busbar protection is mainly concerned with:

- limiting consequential damage
- clearing busbar faults in less time than backup line protection would take while keeping the system stable.

Some early busbar protection configurations applied a low-impedance differential system that had a relatively long operation time – up to 0.5 second. Most modern configurations employ a differential system using either low-impedance biased or high-impedance unbiased relays, capable of tripping within one cycle at a very moderate multiple of the fault setting. The operating time of any tripping-protection relays must be added to that, but an overall tripping time of less than two cycles can be accomplished. With high-speed circuit breakers, total fault clearance may be obtained in roughly 0.1 second. When a frame-ground system is applied, the operating speed is similar.

## Stability

Bus protection stability is critical. Although the rate of fault incidence is low, unless the stability of the protection is absolute, installing bus protection could subject the power system to an increased degree of disturbance. The chance of maloperation has led to


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hesitation in using bus protection and to the installation of some very complex configurations.

A better understanding of the differential system response to transient currents allows such systems to be used with their fundamental stability trusted. Even with a stable protection configuration, dangers still exist for a number of reasons, including:

- an unbalance created by the interruption of the current transformer secondary circuit. Depending on the circuit load relative values and effective setting, it might start tripping on load. Certainly, it would start tripping during a through a fault, generating substantial fault current in the analyzed circuit.
- a mechanical shock of sufficient severity may start operation, even though the likelihood of that happening with modern numerical configurations is low
- accidental interference with the protection relay, developing from a mistake during maintenance testing, could lead to tripping.

To keep the high order of integrity required for busbar protection, it is an almost constant practice to make tripping depend on two separate measurements of fault quantities. Also, if the tripping of all the breakers within a zone is derived from common measuring relays, two separate elements must operate at each stage to complete a tripping process.

The two measurements may be completed by two similar differential systems or by one differential system that can be checked by a frame-ground system, by ground-fault relays energized by current transformers in the transformer neutral-ground conductors, or by voltage- or overcurrent-protection relays. Optionally, a frame-ground system may be checked by ground-fault protection relays. If two systems of the unit or other similar type are applied, they should be energized by different current transformers in high-impedance, unbiased-differential configurations. The duplicate ring CT cores may be installed on a common primary conductor, but independence must be kept throughout the secondary circuit. In low-impedance, biased-differential configurations that cater to different ratio CTs, the arrangement can be energized from either one or two different sets of main current transformers. The criteria of double-feature operation before tripping can be kept by the provision of two sets of ratio-matching interposing CTs per circuit. When multi-contact tripping relays are applied, they are also duplicated – one being energized from each discriminating protection relay. The contacts of the tripping protection relay are then series-connected in pairs to give tripping outputs. Separate tripping relays, each controlling only one breaker, are typically preferred. The importance of such protection relays is no more than that of normal circuit protection, so


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no duplication is needed at this stage. Not least among the benefits of using separate tripping relays is the simplification of trip-circuit wiring, compared to taking all related trip circuits with a given bus section through a common multi-contact tripping relay.

In double busbar systems, a different protection configuration is used for each section of each busbar, and a complete check system covers all sections of both busbars. The separate zones are made to overlap the busbar section switches so that a fault on the section switch trips both of the adjacent zones. This has been avoided in the past by providing the section switch with a time advantage. The section switch is operated first, and the remaining breakers are delayed by 0.5 second. Only the zone on the section switch's faulty side will remain operating and trip; the other zone will reset and retain that section in service. This gain, applicable only to very rare section switch faults, comes at the expense of seriously delaying the bus protection for all other faults. For that reason, this pattern is not typically favored. There are numerous possible combinations, but the basic principle is that no single accidental incident of a secondary nature should be able to cause an unnecessary bus section trip.

Security against maloperation is possible only by increasing the number of devices needed to function and complete an operation. This inevitably raises the statistical risk that a tripping operation due to a fault may fail. Aside from consequential damage, such a failure may end in greater power system disruption than an unwanted trip would cause. The relative failure risk of this kind may be small, but it's worthwhile to guard against it. Stability and operation security is accomplished by supplying three independent channels – say X, Y, and Z – whose outputs are organized in a "two-out-of-three" voting scheme, as illustrated in Figure 1.

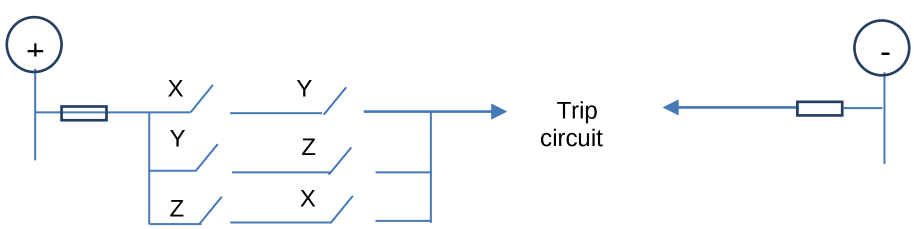


Figure 1. Two-out-of-three zone arrangement


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## Protection System Types

A number of busbar protection arrangements have been prepared:

- system protection used to cover busbars
- frame-ground protection
- directional blocking protection
- phase comparison protection
- differential protection.

Of those, system protection used to cover busbars is only appropriate for small substations. Phase comparison protection is typically seen only as a supervision check device within biased-differential numerical configurations. Directional blocking protection is getting higher acceptance when implemented as IEC 61850 GOOSE-based configuration using overcurrent protection relays. Early configurations of busbar biased-differential protection, such as versions of "Translay" protection and of a configuration using harmonic restraint, were replaced by unbiased high-impedance differential protection. The relative simplicity of the latter – and more importantly the relative simplicity with which its performance can be computed – have ensured its success. However, in the 1980s the developments in semiconductor technology, coupled with a more pressing need to be able to use different ratio CTs, led to the reintroduction of biased configurations, typically using static relay arrangements, especially for the most extensive and onerous applications. Frame-ground protection systems have been in service for many years, mainly related to smaller busbar protection configurations at distribution voltages and for metal clad busbars, for example, SF6 insulated busbars. Nevertheless, it has been common to use an additional unit protection configuration to provide two different fault-detection methods.

## System Protection Configurations

System protection that involves overcurrent or distance configurations will inherently provide protective cover to the busbars. Overcurrent protection is only used for rather simple distribution networks, or as backup protection, set to provide a significant time delay. Distance protection will give cover for busbar faults with its second and possibly subsequent zones. In both situations, busbar protection is slow and useful only for limiting the consequential damage. The only exception is a mesh-connected substation in which the current transformers are installed at the circuit breakers. In that case, the busbars are included in sections in the main circuit protection individual zones, whether


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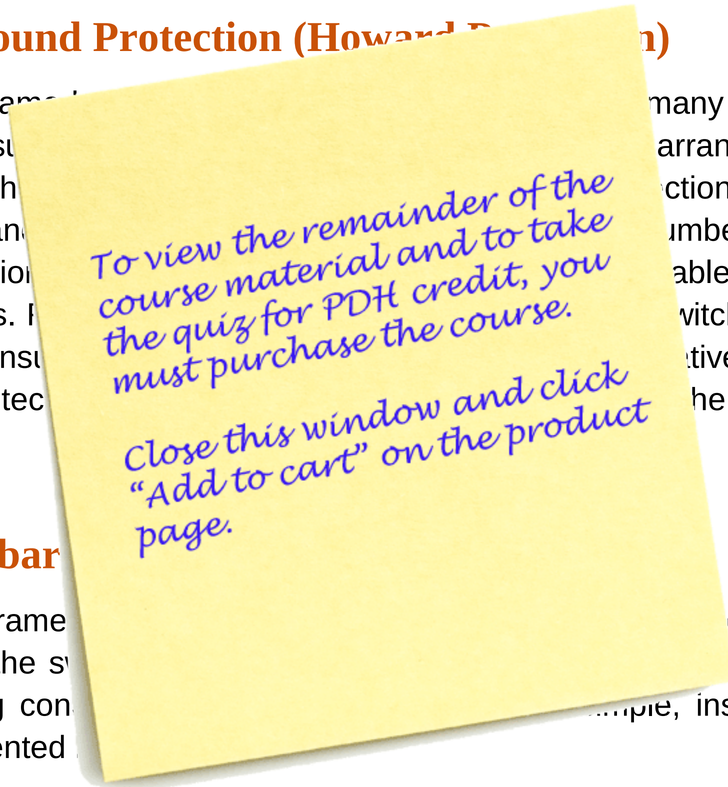
it is of unit type or not. In special situations when the current transformers are installed on the line side of the mesh, the circuit protection will not include the busbars in the instantaneous zone, and separate busbar protection, known as mesh-corner protection, is typically applied.

## Frame-Ground Protection (Howard P... n)

In the past, fra... many different cases. A few variations of su... arrangements with different capabilities. Th... ctions have thus been kept for historical an... umber of configurations are still in operatio... able solution in particular circumstances. F... witchboard frame and give cable gland insu... tive configurations using numerical protec... he use of frame-leakage systems.




## Single-Busbar ...

Single zone frame... ent of the fault current flowing from the s... sformer is installed on the grounding con... mple, instantaneous protection relay as presented ...



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