



High Voltage Busbar Protection

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Course Author: Velmir Lackovic

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HIGH VOLTAGE BUSBAR PROTECTION

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 certain time delay. But in the case, unit protection is used for feeders and plants, the busbars are not inherently protected. Busbars have typically been left without dedicated protection, from 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 back-up protection would give adequate bus protection if necessary

It is a fact that the risk of a short circuit happening on modern metal clad equipment is insignificant, but it cannot be completely dismissed. Nevertheless, the damage resulting from one short circuit may be huge, up to the overall loss of the substation by fire. Severe damage or destruction would possibly end in widespread and prolonged supply disruption.

Eventually, electrical system relay protection typically, will not 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 of all the distance protections, so a bus short circuit will be slowly cleared, and the resultant voltage dip may not be permissible.

In the case of outdoor switchgear, the situation is less clear since. 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, in order to keep power system stability, high-speed short circuit current clearance is needed. Unit busbar protection meets these requirements. Also, in the case busbars 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.

BUSBAR FAULTS

Most of the bus faults involve one phase and ground, but faults are caused by many causes and a great number are interphase clear of ground. In fact, a great proportion 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.

PROTECTION REQUIREMENTS

Even though not fundamentally different from other circuit protection, the key busbar position increases the emphasis placed on the basic requirements of speed and stability. The special characteristics of busbar protection are elaborated below.

SPEED

Busbar protection is mainly concerned with:

- limitation of consequential damage
- busbar fault clearance in less time than could be accomplished by back-up line protection, with the object of keeping system stability

Some early busbar protection configurations applied a low impedance differential system that has a relatively long operation time, of up to 0.5 seconds. The foundation of most modern configurations is a differential system using either low impedance biased or high impedance unbiased relays. They are capable of tripping in a time of the order of one cycle at a very moderate multiple of fault setting. Operating time of any tripping protection relays must be added to this time, however 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 seconds. When a frame-ground system is applied, the operating speed is similar.

STABILITY

Bus protection stability is of critical importance. Keeping in mind the fault incidence low rate, it is evident that unless the stability of the protection is absolute, the disturbance degree to which the power system is likely to be subjected may be increased by the installation of bus protection. The chance of incorrect operation has led to hesitation in using bus protection and has also led to installation of some very complex configurations. Increased understanding of the differential system response to transient currents allows such systems to be used with trust in their fundamental stability. Notwithstanding, the overall stability of an adequately used protection configuration, dangers exist in reality for a number of reasons. These reasons include:

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

In order 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 have to be operated at each stage to complete a tripping process.

The two measurements may be completed by two similar differential systems, or one differential system may 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 the case of 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 the case of low impedance, biased differential configurations that cater for 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, these 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 then no more than that of normal circuit protection, so no duplication is needed at this stage. Not least among the benefits of using separate tripping relays is the simplification of trip circuit wiring, in comparison with taking all trip circuits related 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. Complete check system is also provided, covering 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 the adjacent zones. This has been avoided in the past by providing the section switch a time advantage. The section switch is operated first and the remaining breakers are delayed by 0.5 seconds. Only the zone on the section switch faulty side will remain operated and trip, the other zone resetting and retaining that section in service. This gain, applicable only to very rare section switch faults, is got at the expense of seriously delaying the bus protection for all other faults. Therefore, 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 is able to cause an unnecessary bus section trip.

Security against maloperation is only accomplished by increasing the number of devices that are needed to function to complete an operation. This inevitably increases the statistical risk that a tripping operation due to a fault may fail. Such a failure, leaving aside the question of consequential damage, may end in power system disruption to an extent greater than would be caused by an unwanted trip. The relative failure risk of this kind may be small, but it has been worthwhile to provide a guard in this respect as well. Stability and operation security is obtained by supplying three independent channels (say X, Y and Z) whose outputs are organized in a 'two-out-of three' voting scheme, as presented in Figure 1.

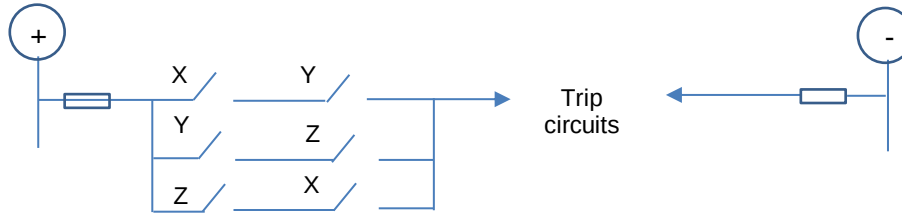


Figure 1. Two out of zone three arrangement

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 these, 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 also 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 1980's the developments in semiconductor technology, coupled with a more pressing need to be able to use different ratio CTs, led to the re-introduction 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 with smaller busbar protection configurations at distribution voltages and for metal clad busbars (e.g. SF6 insulated busbars). Nevertheless, it has often been common for a unit protection configuration to be used in addition. It is used to provide two different fault detection methods.



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