LOW-VOLTAGE AIR CIRCUIT BREAKERS

SELECTIVE TRIPPING FOR TYPES DB-15, DB-25, AND DB-50

The new overload tripping devices as incorporated in the DB line of breakers has developed considerable interest recently in the possibilities presented for selective tripping applications in the low-voltage field. Although each specific application requires careful analysis, the following AIEE Conference paper, reprinted with permission of the authors, will illustrate how one such problem was approached and solved.*

SELECTIVE TRIPPING OF POWER STATION AUXILIARIES*

There is probably no other application of "Selective Tripping" in the low-voltage air circuit breaker field, that is more important than its use in conjunction with Power Station Auxiliaries.

Selective tripping, as the name implies, is the selection of the breaker next to the fault as the preference breaker to open and in case of failure of this breaker the progressive tripping of the other breakers in the series, until the fault is cleared.

Reliable direct-acting trip devices of the Selective type obviating the use of current transformers and relays have been the goal of designers and users of low-voltage air circuit breakers, in order to provide an economical installation more in keeping with this class of equipment.

Selective tripping has of course been the practice of power companies and others for years where it involved higher voltage equipment. In fact the whole relay art has for its basis the proper selection of the breaker or breakers to trip in event of a fault.

There are many reasons why, up to the present time, Selective Tripping has not been obtained and practiced in low-voltage station auxiliary circuits. It certainly is not because the operators of power stations did not realize the need but rather is because the proper equipment was not available to do the job, either from an economic or performance standpoint.

LOW-VOLTAGE AIR CIRCUIT BREAKER DEVELOPMENT

A little delving into history will show this to be true. Prior to 1936 the carbon tip brush contact type of breaker was in general use. This breaker did have oil dashpot overload elements that operated on fault currents but under high-current values there was no appreciable time delay in tripping. It was not this feature however, that led to the next step in design but rather the need for breakers that could be metal-enclosed and yet handle higher fault currents. This led to the development of the so-called De-ion® arc chute, butt main contacts, silver tungsten arcing tips and other mechanical improvements which greatly increased the rupturing capacity of the breakers. Manufacturers presented designs ranging in interrupting rating upwards to 100,000 amperes.

Most of these breaker designs depended on very fast tripping, 1½ to 5 cycles, in order to maintain their full interrupting rating. This was certainly not conducive to the application of selective tripping, which at that time required induction time delay relays with their attendant current transformers and d-c shunt trip coils. A reduction of the breaker interrupting rating was also necessary due to the increased tripping time. There were of course attempts made at partial Selective Tripping up to 5 or 6 times the breaker current carrying capacity rating, using oil dashpots or I.T.L. trips as they are known.

Most faults however, were well above these values of current and in a zone where no time delay could be obtained from the trip unit.

The advent of cascading in 1939, in which a normal current interrupting rated breaker backs up a group of smaller rated breakers did not give any impetus to the development of Selective Tripping Devices. It has and does serve a useful purpose, however, in that more economical installations of air circuit breakers are made possible where selective tripping is not desired or needed.

During the war the need was felt very keenly aboard ship for a system of tripping that would insure maximum continuity of service during battle when faults are most likely to occur. To meet this demand the "Ticker" or escapement restraint was added to the trip bar of the Navy counterpart of the standard low-voltage air circuit breaker. This gave the desired time delay to the tripping of the breaker, thereby allowing the feeder on which the fault had occurred to clear the circuit, leaving the rest of the system intact. In 1943, successful tests of this device were first exhibited to the Navy and it was accepted for shipboard use.

MODERN DESIGNED TRIP UNITS

Since the war, manufacturers, upon the continued demand of users, have proceeded with the development of adequate trip units for Selective Tripping. Low-voltage systems (600 volts and under) supplying Power Station Auxiliaries are in the forefront in the application field for this type of equipment.

Many improvements have been incorporated in the new desig of time delay trip units since the original Navy It has required a great deal of research and deve bring this equipment up to its present caliber of perfo

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MODERN DESIGNED TRIP UNITS (Continued)

It was realized after considerable investigation that each trip unit on each pole of a three-phase breaker should have its own time delay trip device and not just a restraint on the trip bar common to all trip units. The reason for this is that the forces imparted to the trip bar for single phase and three-phase faults differ a great deal, resulting in different restraint times for the two different types of faults.

The modern Westinghouse Type DB breaker has been designed to withstand short circuits without derating for a period of time necessary to secure Selective Tripping. They have incorporated in their tripping facilities, individual time delay trip units for each pole. The time delay features are divided into three categories: Long Time Delay, Short Time Delay and Instantaneous.

The current time characteristic of the Long Time Delay part of this trip unit has been designed for motor starting duty and overloads. Adequate protection of cables and transformers is also obtained when the trip units are properly applied and calibrated. The current pick-up can be varied between 80% and 160% of normal current rating.

The Instantaneous Trip operates between one and two cycles when the current goes beyond its setting. The combination of the Long Time Delay and the Instantaneous characteristic in a trip unit is not new, since devices of a similar nature, only not so modern in design, have been supplied for many years.

The distinctive feature of the new unit is the Short Time Delay Device which may be used in place of the Instantaneous Trip. This gives a trip unit with the usual long time delay characteristic plus one of short time delay. The value of current at which the Short Time Delay Device becomes effective can be varied between 4 and 10 times its normal coil rating. It can also be calibrated to function through three different time characteristics designated as time zones 1, 2 and 3. The first zone device functions over a characteristic time current curve that takes longer to trip the breaker than would be the case if an instantaneous trip were used. The second and third zones take longer times to trip than the first zone or instantaneous devices.

In Figures 1 and 2 is shown the relationship between the current time characteristics of Instantaneous, first and second zone tripping devices from an actual application. It is readily seen that a series connection of breakers equipped with trip devices as just described will open selectively to isolate a fault with a minimum loss of load to the system.

Each pole of a three-phase breaker is equipped with a combination of a Long Time Delay and a Short Time Delay Tripping Device or a Long Time Delay and an Instantaneous Tripping Device, depending upon its location in the system. Breakers for motors or other loads are equipped with the Instantaneous Type of Tripping Device while lines and transformer breakers are equipped with those having the Short Time Delay characteristic of either the 1, 2 or 3 zone classification.

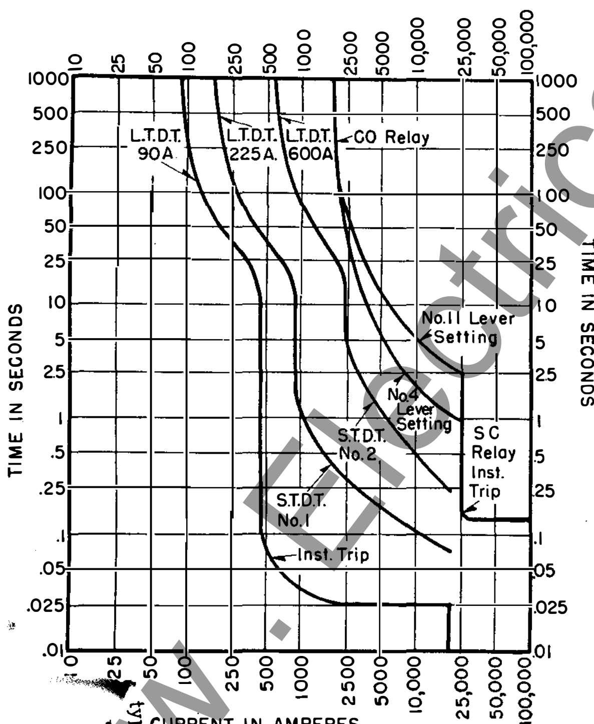

FIG. NO. 1

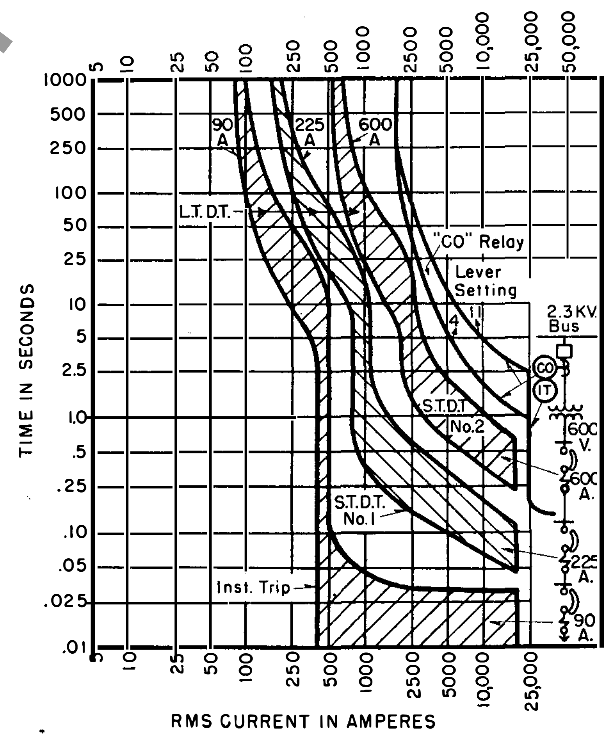

FIG. NO. 2

SWITCHGEAR DEVICES

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BREAKER CHARACTERISTIC CURVES

The current time characteristics of the CO relay, 600-ampere breaker, 225-ampere breaker and the 90-ampere breaker are shown in Figure No. 2. These are average characteristic curves as far as the breakers are concerned and show complete selectivity from overloads to faults of 20,000 amperes rms short circuit current.

In Figure No. 2 the current time curves have been changed to so-called band curves. These together with the single line diagram at the right show the relationship between the breakers in the circuit and their tripping characteristics. A fault anywhere along this series connection of breakers will cause only the breaker just above the fault to trip.

The band curves should have some explanation. These do not represent, as might be assumed, a zone anywhere within which the breaker might trip. Specific conditions must exist for the tripping time to move across the band for a given value of fault current. The bottom edge of the band is what is known as the "Resettable" time delay. Any fault that remains on long enough to reach the lower edge of the band curve, will cause the breaker to trip whether the fault current is interrupted or not by some other breaker below it. In other words, this is a limit beyond which the breaker will not reset but will go on and trip due to inertia of parts and opening of latches. The top part of the band curve is the maximum time the breaker should take to trip under any condition. The factors that cause this upper limit are manufacturing tolerances, temperature effects and mechanical friction variances that accompany different types of maintenance.

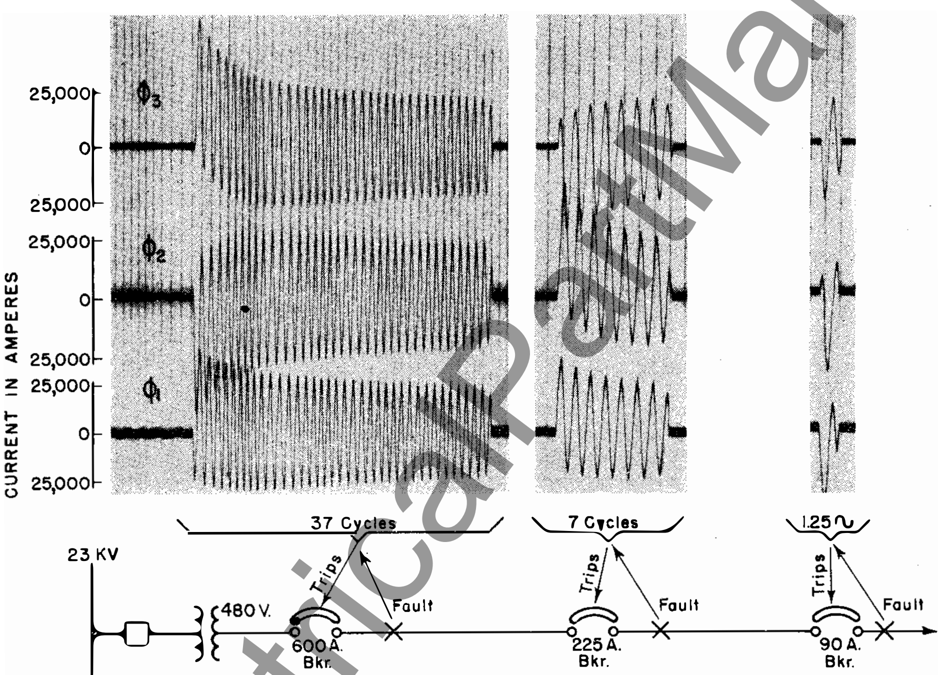

FIG. NO. 4

TESTS

Tests were made in the Westinghouse High Power Laboratory on the Group D breakers and oscillographs taken. Figure No. 4 shows the results of the maximum short circuit current shots in oscillograph form, with their relationship to the location of the faults and the breakers in the circuit.

Field tests made at the time of installation covered the calibration of the trip units of all breakers in Groups A-B-C and D. The results were within the limits shown on the curves indicating that selectivity could be expected under operating conditions from the breakers in all of the groups.

CONCLUSIONS

The advancements that have been made in the field of Selective Tripping have made it possible to place the protection of low-voltage station auxiliary circuits in the same class as the transmission circuits on the main power system. This has been done without derating of breakers, increasing the size of equipment, or the use of relays for the low voltage breakers. This method also provides back-up protection, a feature always desirable in any system.

The integral trip on each breaker pole, with Long Time, Short Time, and Instantaneous characteristics is the most economical and dependable protection available for this type of equipment. Laboratory tests, field tests, and operating experience, show that this comparatively new method of obtaining Selective Tripping is a successful one. This method of Selective Tripping is applicable to power station low-voltage auxiliary systems and other systems of like nature.

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APPLICATION OF SELECTIVE TRIPPING

In the C. R. Huntley Station No. 2 of the Buffalo Niagara Electric Corporation, the 600-volt station auxiliary system has been equipped with selectively tripped air circuit breakers. The single line diagram of this 600-volt, 60-cycle system is shown in Figure No. 3.

This is a double ended fed substation, the transformers being energized from the 2300-volt, 60-cycle station service. Since there are no breakers in the secondary leads of the transformers, the Type CO induction disc overcurrent relays protecting the 2300-volt primary breaker have been included in the selective tripping scheme and coordinated with the tripping characteristics of the 600-volt air circuit breakers.

These CO relays act as back-up protection to the entire 600-volt system, as well as the protective means against transformer faults. The setting on the relay is such that it will function after a time delay for faults anywhere in the 600-volt system. The time delay is sufficient to allow normal clearing of 600-volt system faults by the proper low-voltage air breaker without opening the 2300-volt primary breaker.

The Instantaneous overcurrent relay in series with the CO relay functions to trip the 2300-volt breaker on transformer primary faults without any intentional time delay. The reduction in 600-volt fault current due to the impedance of the transformer prevents the Instantaneous relay from operating on 600-volt system faults.

SELECTIVE TRIPPING GROUPS

In Figure No. 3 is shown four Selective Tripping groups which have been "roped" off on the diagram and they are designated as Groups A-B-C-D. Within each of these groups the breakers are selective with one another. In case of a fault the next breaker toward the source of supply will trip. Any parallel circuits will be left intact to continue carrying load.

Since Group D has the most breakers in series, selective with one another, it has been chosen for detail analysis.

The first breaker in the series of breakers in Group D is the 2400-volt primary breaker under the tripping control of the CO relay. This has already been discussed. The second breaker is the 600-ampere DB-25 which connects bus 644 with remote bus 646. The third breaker is a 225-ampere bus tie breaker connecting busses 646 to 645. The fourth breaker is any of the breakers on bus 645. The 90-ampere breaker being the highest current rated breaker on this bus, it was chosen to use in the selective tripping analysis. If this breaker is selective then any smaller current rated one will also be selective.

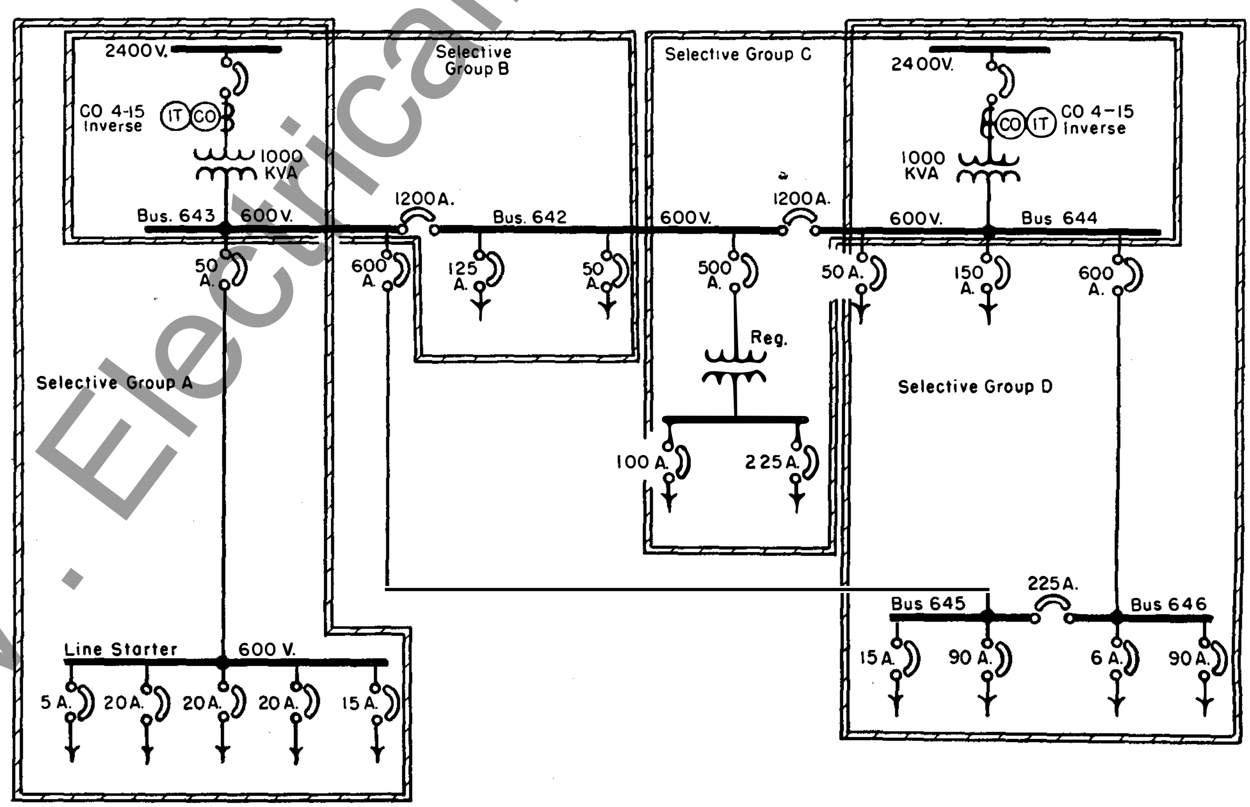

FIG. NO. 3