Discrimination don't leave it too late!

Discrimination, or Protection system coordination is an important aspect of an electrical system design that is often overlooked. The ideal time to complete a discrimination study is before ordering the switchboard and panel board circuit breakers. However the switchboards and panelboards are generally selected based on cost with no regard to the circuit breaker characteristics. Accordingly discrimination problems generally get solved retroactively rather than pro-actively.

If all parties involved with the electrical system design and implementation are cognizant of potential discrimination problems, and review their work with this in mind, most discrimination problems can be overcome with minimum impact on either schedules or equipment costs.

1. What's the point of a discrimination study anyway? The intent of the discrimination study is to demonstrate that:
    - Electrical equipment is satisfactorily protected by the system protection equipment (circuit breakers, relays etc)
    - The protective devices have compatible characteristics to ensure that protective equipment closest to a fault, operate first
    - Electrical equipment not involved with the fault, remain in service.

2. Who should do it?

    There is an argument that the switchboard manufacturer is in the best position to undertake the discrimination study. However as the work involves the complete electrical system, it can equally be argued that it must be addressed by the overall electrical systems design engineer. There is no doubt that the switchboard manufacturer and also the panel board supplier must be aware of the discrimination requirements, however the systems designer is responsible for the overall protective features of the system so he should coordinate the work or at least, approve the study results.

    The discrimination study is closely related to the system short-circuit study and electrical load analysis. The load analysis is used to determine how many generators and what equipment is running under specific operating conditions. The short-circuit study is used to determine the level of short-circuit current at specific parts of the electrical system. Information from these studies must be

considered when addressing discrimination or considering the relevance of a lack of discrimination.

There is no doubt that cognizance of system discrimination by all parties involved in implementing the electrical system is beneficial to the shipyard and vessel owner. The most important step however is for the system designer to review discrimination when configuring the one line diagram. Although circuit breaker details are not available at that time, and a thorough discrimination study cannot be completed, it is possible to foresee major potential problem areas and address these in the design drawings. Many discrimination problems can be overcome by changing the system configuration, or in the least, by specifying suitable interlocking and protection settings.

3. Where do I start?

There are two major characteristics involved in a discrimination study. These are the equipment thermal damage characteristics, principally that of the generator, and the circuit breaker time-current operating characteristics. If fuses are used, discrimination should be reviewed through their "I2t" characteristics or "energy let-through" curves.

The starting point of the study is the main generator thermal damage characteristic.

The thermal damage characteristic is usually provided as a time/current curve similar to that shown on Figure 1. The characteristic provides information on the length of time a generator can withstand a particular level of fault current, without causing major damage. Obviously the higher the current, the shorter the time the current can be withstood by the generator.

The typical thermal damage characteristic shown in figure 1 is drawn in accordance with the NEMA MG1 standard. This illustrates that fault currents of approximately 300% must be cleared within about 3 seconds.

When this information is applied to a marine system discrimination study for generator protection purposes, it is important to re-adjust the thermal damage characteristic in accordance with the applicable generator's marine rating. For example, if the thermal damage characteristic assumes that the generator is rated in accordance with the MG 1 for ambient temperature, insulation class and temperature rise, it must be re-drawn for the higher ambient and lower insulation class temperature rise that is applicable to a marine system. In general this will have the effect of lowering the available power rating from the generator and consequently changing the "line current" scale on the thermal damage characteristic. The "net" effect on the discrimination curves is to move the thermal damage characteristic to the right.

4. How much of the electrical system must be reviewed?

   Discrimination curves must be prepared for all conditions of power generation from the minimum number of units on line up to the maximum. There are several software programs available to assist in drawing up these curves but it should be remembered that these programs are tools to be used by the engineer, and do not provide the solution. Most programs will however automatically re-calculate the circuit breaker characteristics to account for different generator combinations.

5. So what happens once I have the correct thermal withstand characteristics?

   Having obtained the correct generator thermal damage characteristic, it is now necessary to add the generator circuit breaker characteristic and generator short-circuit current decrement characteristic. Obviously to provide protection, on a time-current curve, the generator circuit breaker must fall to the left of the generator thermal damage curve. Figure 2 illustrates typical characteristics.

   Care must be taken when adding the generator short-circuit current characteristic. The SCC must be drawn for a fault at the point of interest on the system. For generator protection this is reasonably obvious and is the short-circuit current at the main switchboard, appropriate to the number of generators on line. For locations further down the system, the short-circuit current must be calculated separately at each point under consideration.

   It should be understood that most methods of short-circuit current

calculation over estimate the probable short-circuit current and this may lead to false conclusions being drawn from the discrimination curves.

In figure 2, the SCC decrement curve indicates that the generator circuit breaker will trip in about 0.1 seconds at point A. It is probable that the actual value of short-circuit current will be less than the calculated value. It is certain however that once under the control of the generator's automatic voltage regulator, the short-circuit current will be constant, i.e. after about 1 - 2 seconds.

Dependent on the method of calculation, the sub-transient and transient short-circuit current could be some 15 - 20% less than that calculated. The fault current path may be more resistive than assumed in the calculations. Consequently the generator circuit breaker may not operate until point B i.e. 10 - 11 seconds. It must be ascertained that not only the generator, but also the switchboard can withstand the prospective level of current for the time appropriate to point B.

Although the current resulting from the short-circuit fault may not cause permanent equipment damage, the fault remains on the system until cleared by the generator circuit breaker. Throughout this time the system is in danger from fire and subsequent extensive damage. A good rule of thumb is to clear a main busbar short-circuit fault within 2 - 3 seconds.

6. Can I still get discrimination although my feeder breakers are larger than the generator breakers?

   For large systems where multiple generators are used, the situation when a feeder circuit breaker has a larger rating than the generator circuit breaker is quite common.

   In such cases consideration must be given to system operation. For example, when the feeder is required, what would be the

minimum number of generators on line at that time? Is it reasonable to interlock the feeder circuit breaker to ensure that the necessary minimum number of generators to achieve both discrimination and operation considerations are on linen before the feeder can be closed? For example, a large Bow Thruster may need 2 or 3 generators on line for full power operation. In this case, interlocking the Bow Thruster breaker with the generator circuit breakers is an obvious solution.

Of course, the "Bow Thruster interlock" solution described above cannot be applied in all circumstances. For example a feeder supplying say a forward switchboard. In this case the first task would be to examine the loads on the forward switchboard and determine which loads must be supplied when only one generator is available, for example an anchor windlass, lighting. The first option should be to remove these loads from the forward switchboard and connect them to other parts of the system. If this approach is taken to its logical conclusion, it may result in removal of the forward switchboard and hence there is an economic and practical limit to this approach.

Another solution is to install simple overcurrent relays in the feeder circuit. The relays are set at a low value to provide discrimination when only one generator is connected. When two or more are on line, the relays are disconnected assuming that satisfactory discrimination can be achieved through the circuit breaker characteristics.

7. Are there any other common situations I need to be aware of?

Another common problem is discrimination between a "main-emergency" switchboard tie breaker and the emergency switchboard feeder circuit breakers. For systems using multiple parallel connected generators having a high fault current at the emergency switchboard, a fault on the terminals of an emergency switchboard feeder circuit breaker may cause operation of the tie circuit breaker with consequent loss of the whole emergency switchboard. In such cases it may be useful to use circuit breakers with a high instantaneous trip setting but with a short time delay in the fault current zone.

It is not necessary to draw discrimination curves for every circuit on the system. It is however desirable to draw curves that are illustrative of the system design choosing examples from the one line diagram that illustrate "worst" case situations. It should be noted that all circuit breaker curves have maximum and minimum

values associated with them. The maximum and minimum values also have tolerances. Therefore it is important to ensure that there is sufficient distance (time and current) between different circuit breaker curves to be assured that discrimination will be achieved.

When molded case circuit breakers are used, it is often difficult to achieve discrimination between motor control center, and distribution panel outgoing circuit breakers with the MCC or panel feeder circuit breaker. A solution to this problem could be to install high current rated fuses on the outgoing circuits. In general, under short-circuit conditions, the fuses operate much faster than the panel supply circuit breaker thereby providing discrimination in the instantaneous zone.

Circuits supplying distribution transformers also require careful consideration. In many cases if a fault occurs on a panel or switchboard fed from the transformer secondary, the resulting fault current in the transformer primary may cause the primary circuit breaker to open in its instantaneous zone. In such cases the primary circuit breaker instantaneous setting should be increased, but not to such a high value that the transformer becomes unprotected. This condition can be checked against the transformer thermal damage characteristic.

8. These seems complicated - where can I get help?

   DC Maritime Technologies Inc. has completed many discrimination studies on marine electrical systems. Although the final study cannot be completed until the circuit breakers are chosen and their tripping characteristics obtained, it is DCMT's practice to review the electrical design with a view to discrimination, early in the conceptual design process. DCMT's one line diagrams include information on circuit breaker interlocking and protective device settings, with a view to reducing prospective discrimination issues to a minimum. It is still necessary however for the switchboard and panelboard manufacturers to check the characteristics of the circuit breakers they intend to supply, as it is these characteristics that ultimately determine the adequacy of the protection provided.