A PRELIMINARY ANALYSIS OF SYSTEM COORDINATION RELATED TO CIRCUIT PROTECTION AND FEEDER SIZE

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SCOPE

The purpose of this study is to correlate circuit-protective device coordination with the sizing of feeders to determine the optimum conductor size for 12 kv circuits.

SINGLE-LINE DIAGRAM

The attached single-line diagram, Figure 1, shows the basic elements that are considered in this study. The coordination curves include only that portion of the system from the 12 kv bus in the Project Master Substation through the 480 volt control-center feeder-breaker.

The transformer capacities and circuit-breaker current-ratings indicate the range of sizes for which coordination curves are plotted. Transformer-primary fuses are used in order to connect various size transformers to the same feeder and provide the protection required by code.

COORDINATION CURVES

There are four coordination curves shown in this report, Figures 2 through 5. They are representative of the coordination of protective devices that might be expected for unit-substations of 500, 750, 1,000 and 2,000 kva. The final curves will probably vary from these to a minor degree due to certain assumptions that have been made.

PG&E indicate a short-circuit level of 2860 mva as an estimated value, for the reasonable future, at the Project Master Substation. On this basis, the capability at the 12 kv bus is 270 mva. Additional reactance would be required in the Master Substation transformers ~~in order~~ to make possible the use of 250 rather than 500 mva switchgear. This may represent a savings in total cost.

However, for the purpose of this study, 270 mva was used to determine the minimum 12 kv conductor size capable of withstanding this short-circuit current for the time required to clear a fault.

The short-circuit capacity at the primary of the 480 volt unit-substation was assumed to be reduced to 250 mva. This is possible by the method previously mentioned or by the use of reactors in the 12 kv feeders. Under this condition, low-voltage switchgear breakers with an interrupting capacity of 25,000 amperes could be used with unit-substations up through 1,000 kva. These breakers are the minimum reasonable size for 480 volt feeder service.

The major problem at 480 volts is to keep from exceeding the interrupting capacity of available molded-case circuit-breakers. This also holds true down through the 120/208 volt level.

A short-circuit current of 47,000 amperes asymmetrical is possible at 480 volts for a 2,000 kva unit-substation, with 250 mva primary contribution. For the reasons previously mentioned, the maximum short-circuit was assumed limited to 25,000 amperes for all 480 volt substations. In the case of the 2,000 kva substation, additional reactance will be required in these circuits.

A 225 ampere molded-case breaker was selected as the reasonable maximum size that would be used in a control-center or power-panel. This size is suitable for a 100 horsepower motor or a 150 kva transformer. This establishes a maximum condition at the 480 volt level which in turn is reflected in the setting of the 12 kv relay.

CABLE SIZE

A 400 amp relay setting for the 12 kv feeder-breaker is the minimum that will satisfy the coordination requirements for a 2,000 kva substation. This would be the largest 480 volt substation considered. With the relay set at 400 amps, a feeder is capable of supplying a load of 8,320 kva.

The group of curves plotted to show cable current-carrying capacities in underground ducts, Figure 6, takes into consideration cable thermal capacities. From the 75° C. curves it can be seen that two 500 MCM cables in parallel will satisfy the 400 amp relay setting of the 12 kv feeder-breaker. This size cable is the largest that should be considered from the standpoint of ease of handling and for termination requirements.

DUCTBANKS

The most economical ductbank from the standpoint of construction and heat dissipation is three ducts wide. The sketch, Figure 7, showing typical ductbank dimensions indicates the minimum depth of excavation required to construct a manhole. In line with this, a twenty-one duct bank appears to be compatible.

From the curves for cable current-carrying capacities, a twenty-one duct bank goes hand-in-hand with the parallel 500 MCM feeders previously mentioned. The use of a maximum ductbank of 3 by 7 ducts also keeps excavation to a reasonable minimum depth.

CONCLUSIONS

Further studies will be required to determine the most economical method of reducing the short-circuit levels to the values assumed in this study. The cost of additional reactance in transformers and/or feeder reactors must be weighed against the availability and cost of higher interrupting-capacity circuit-breakers.

Undoubtedly, when the time comes to determine the actual loads connected to the 12 kv feeders, not all circuits will be loaded to the 8,320 kva capability. Some loads may require individual feeders for operational reasons. However, for economy, as many feeders as possible should be loaded to their full capability.