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SINGLE PHASE AUTO-RECLOSING AND SECONDARY ARC CONSIDERATIONS

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Single Phase to Ground (SLG) is the most common fault in power transmission systems. Single phase auto reclosing is used to improve system stability, power transfer, reliability, and availability of a transmission line during a single phase to ground fault [1].

Soon after the fault, the two line end breakers will open (faulted phase only in this case) to isolate the fault. However, the other line (un-faulted phases) are still energized. There is inductive and capacitive coupling between the faulted line and the healthy phases, as well as between other conductors of parallel circuits (i.e. double circuit lines). This coupling has two effects [1]:

1. It feeds and maintains the fault arc.
2. As the arc current becomes zero, the coupling causes a recovery voltage across the arc path. If the rate of rise of recovery voltage is too great, it will reignite the arc.

The arc on the faulted phase after the two line end breakers open is the secondary arc. Recovery voltage is the voltage across the fault path after the extinction of the secondary fault arc and before re-closure of the circuit breakers.

Auto re-closing will be successful only if the secondary arc has been fully extinguished by the time the breakers are re-closed. The duration of the secondary arc depends on many factors. The main factors are:
arc current, recovery voltage, arc length, as well as external factors, such as wind. When transmission lines are compensated with line end reactors, the secondary arc extinction can be improved by placing a suitably sized neutral grounding reactor (NGR) on the neutral of the line reactors [1]-[3].

DAR Engineering has designed a number of NGR's for EHV transmission lines in the Gulf region. Once the NGR parameters are determined, detailed electromagnetic transient simulations are carried out on PSCAD®/EMTDC™ to verify the insulation requirements of the NGR and to estimate the secondary arc extinction times under different system operating conditions. Such information is essential to properly design the single phase auto re-close relay settings.

The Line End and Neutral Grounding Reactors (NGR) in EHV Transmission Lines The NGR is used to cancel the capacitive component of the secondary arc current [1]. In order to cancel the capacitive current, the inductive and capacitive branches must resonate. Installation of this reactor is effective when lines are transposed.

Estimation of NGR based on the 'Shunt Compensation Degree' The NGR value can be estimated based on the following design equations (see [2] for details):

$$Xn = \frac{B1 - B0}{3F \cdot B1 \cdot (B0 - (1-F) - B1)}$$

Where:
B1: positive sequence line susceptance (Siemens);
B0: zero sequence line susceptance (Siemens);

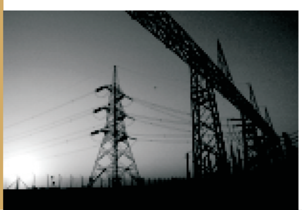
$$F = \frac{Br}{B1} = \frac{1}{B1 \cdot Xr}$$: shunt compensation degree.

Xr: equivalent reactance of the line reactor.
Xn: equivalent reactance of the NGR
Note 1: B1 and B0 are known from transmission line characteristics and are outputs from the PSCAD line constants program.

Estimation of NGR based on the Basic Insulation Level (BIL) requirements BIL is also a consideration when selecting the NGR. Because the higher neutral BIL level requires special design and more insulation for the line reactor, the cost of the line reactor and neutral reactor increases. If this is the NGR design criteria, the minimum acceptable BIL for the neutral point can be calculated by [4]:

$$BIL\_N = \frac{Xn}{Xn + Xr} \cdot BIL\_Ph$$

Where:
BIL_N: Basic Impulse Insulation Level for the NGR.
BIL_Ph: Basic Impulse Insulation Level of the phase.
For a 400 kV system, the BIL of the neutral point of the line reactor typically is less than 350 kV.



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