$$\frac{\bar{V}_1}{\bar{V}_2} = \sqrt{\frac{a^2+b^2}{c^2+d^2}} \angle \theta_1 - \theta_2$$

$$\text{real}\left[\frac{\bar{V}_1}{\bar{V}_2}\right] = \sqrt{\frac{a^2+b^2}{c^2+d^2}} \cos(\theta_1 - \theta_2)$$

$$\text{real} = \left(\frac{a+jb}{c+jd}\right) = \frac{ac+bd}{c^2+d^2} = \sqrt{\frac{a^2+b^2}{c^2+d^2}} \cos(\theta_1 - \theta_2)$$

For phase comparison we have $\cos\theta \geq 0$, then

$$\cos(\theta_1 - \theta_2) = \frac{ac+bd}{c^2+d^2} \sqrt{\frac{a^2+b^2}{c^2+d^2}} \geq 0$$

Which results in

$$\cos(\theta_1 - \theta_2) = \frac{ac+bd}{\sqrt{(a^2+b^2)(c^2+d^2)}} \geq 0$$

Substituting we get

$$k_1 k_2 |\bar{Z}_L|^2 + |\bar{Z}_L| \left\{ k_1 |\bar{Z}_2| \cos(\psi_2 - \phi_L) + k_2 |\bar{Z}_1| \cos (\psi_1 - \phi_L) \right\} + |\bar{Z}_1||\bar{Z}_2| \cos(\psi_1 - \psi_2) \geq 0$$

The above general ± 90 phase comparitor, assuming k_1, k_2, Z_1, Z_2 are different relay characteristics.

OHM RELAY

make $k_1 = -k$, $k_2 = 0$, $Z_1 = Z_2 = Z$; $\psi_1 = \psi_2 = \psi$

substituting we get...

$$-k|Z_L||Z|\cos(\psi - \phi_L) + |Z|^2 \geq 0$$

$$|Z_L|\cos(\psi - \phi_L) \leq \frac{|Z|}{k}$$

This give characteristic of the ohm relay in phase comparson mode. Plotting X_L verses R_L gives the following.

MHO RELAY

choose $k_1 = k$, $k_2 = 0$, $Z_1 = 0$, $Z_2 = |Z|\angle\psi$

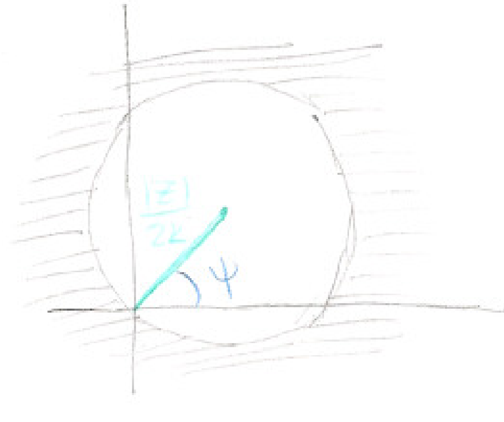
substituting we get...

$$-k^2|Z_L|^2 + k|Z_L||Z|\cos(\psi - \phi_L) \geq 0$$

In terms of R_L and X_L, we have

$$\left(R_L - \frac{|Z|\cos\psi}{2k}\right)^2 + \left(X_L - \frac{|Z|\sin\psi}{2k}\right)^2 \leq \frac{|Z|^2}{4k^2}$$

The above X_L, R_L plot is...



GENERATOR PROTECTION

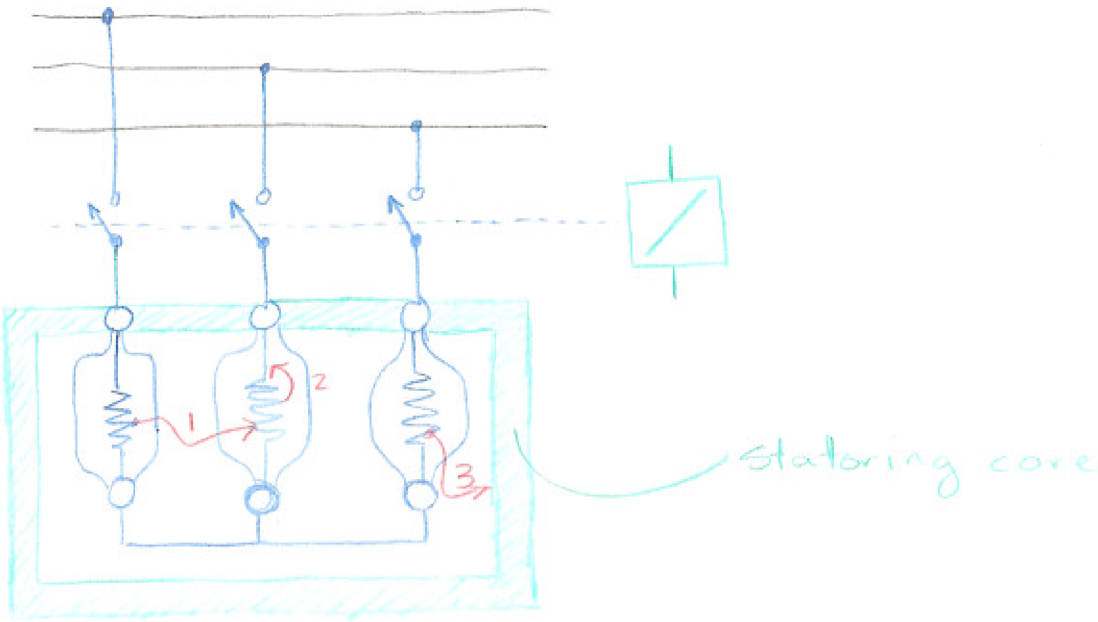
There are a number of abnormal conditions that may occur with rotating equipment which include:

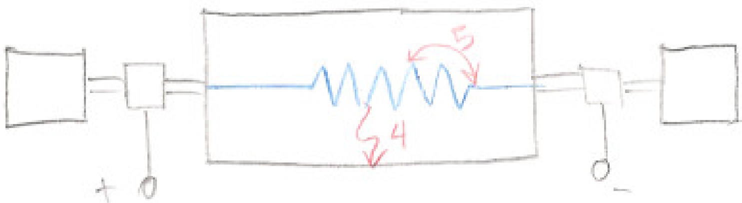
* Faults in windings
* Loss of excitation
* Motoring of generators
* Overload
* Overheading
* Overspeed
* Unbalanced operation
* Out of step operation

Several of these conditions can be corrected while the unit is in service and should be detected and signalled by alarms. Faults, however, require prompt tripping and are a result of insulation breakdown or flashovers that occur across the insulation at some point. The result of a fault is a conducting path between points that are normally of different potenial.

If the path has a high resistance, then the fault is accompanied by a noticable voltage change in the affected area. If on the other hand the path has a low resistance, A large current will result which can cause serious damage. The figure shown below shows various types of faults that may occur in an insulation system of a generator winding. The faults shown are identified as:

* Interphase short cct.
* Interturn fault
* Stator earth fault
* Rotor earth fault
* Interturn fault in rotor





A short cct. Between parts of different phase of the winding, such as faults 1 and 2 above result in sever current with machines.