Motor Protection

- 3-phase motors
- Induction motors
  - line fed
- Adjustable Speed Drives
  - Drive has own protection
- Synchronous motors
  - Protection scheme mostly similar to synch generator
Induction motor circuit

Standard positive sequence equivalent circuit

Protection based on thermal limits

Negative seq.
Startup ($s = 1$)

Rotor current frequency = stator frequency

- Heating from $I^2R$ in rotor

- Higher $R$ at startup
- Higher current at startup
- Start up (or stall)
- No cooling
- Inertia impacts starting time
- Acceleration $\rightarrow$ heating
- Less cooling at start up
Modern motor relay have thermal models for motors

2 thermal models

1) Startup / locked rotor model
   - uses measured current
   - If $I_i > 2.5 \times I_{nom}$ changes to this model
     $u$ — temperature rise above ambient

   - heat dissipation (rejected by cooling)
   - open at startup

   ![Diagram of heat source and heat storage capacity]
Start up

\[ \frac{R_1}{R_0} (I_1^2 + I_2^2) \]

\[ \text{pos} \quad \text{neg} \]

\[ \frac{R_1}{R_0} \]

\[ R_r \equiv \text{rotor resistance under start up} \]

\[ R_o \equiv \text{Rotor resistance at rated speed} \]
plot of $u$ vs time for normal start up

Switch models when $L < 2.5$ mm
Run model

\[ I_2^2 (T_A - T_0) \]

Threshold

\[ I_2 \]

assuming an effect of \( I_2 \) on heating

\[ \frac{z_2^2 + 5I_2^2}{I_2} \]
Other concerns with motor protection

- faults
  - in the motor itself
- on the system
  - voltage sag
    - draws more current
      - slow down
      - stalls
- motor bus transfer
- power system impact of higher Q draw
Actual - Fault Induced Delayed Voltage Recovery FIDVR
Fast Bus (<1 cycle) Transfer (static transfer)

- In phase Transfer
- Residual voltage Transfer ≤ 30%

Bus Tie Breaker