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News to Use

Design Requirements Manual

The formulae $\frac{\partial \rho U_i}{\partial t}+\frac{\partial}{\partial x_j}(\rho U_i U_j)=-\frac{\partial P}{\partial x_i}+\frac{\partial}{\partial x_j}\left(\mu\frac{\partial U_i}{\partial x_j}\right)+g_i(\rho-\rho_0)$ *for building* $\frac{\partial}{\partial x_j}(\rho\overline{U_i}\overline{U_j})=-\frac{\partial \bar{P}}{\partial x_i}+\frac{\partial}{\partial x_j}\left(\mu\frac{\partial \overline{U_i}}{\partial x_j}-\rho\overline{u_i'u_j'}\right)+g_i(\rho-\rho_0)$ *state of the art* $\frac{\partial}{\partial x_i}(\rho\overline{U_i}\overline{H})=\frac{\partial}{\partial x_i}\left(\lambda\frac{\partial \overline{T}}{\partial x_i}-\rho\overline{u_i'h'}\right)$ *biomedical research facilities.*

'Design Requirements Manual (DRM) News to Use' is a monthly ORF publication featuring salient technical information that should be applied to the design of NIH biomedical research laboratories and animal facilities. NIH Project Officers, A/E's and other consultants to the NIH, who develop intramural, extramural and American Recovery and Reinvestment Act (ARRA) projects will benefit from 'News to Use'.

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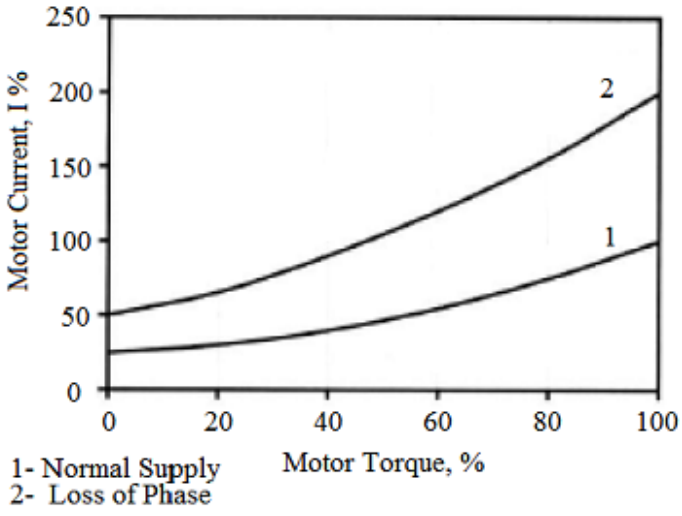
Single Phase Protection

The single phase condition occurs when one of the phase wires in three phase systems doesn't supply power to the load. This usually happens due to blown fuse, loose connection, defective circuit breaker and line to ground fault not cleared or detected. In a three phase motor, loss of a phase while motor is running will result in an increased current flow in the operating phases since motor will continue to run. Similarly, loss of a phase at the primary side of the three phase transformer will result in an increased current flow as well as unbalanced voltage at the secondary. Protection devices sized at the rated full load current flow may not detect loss of a phase in a lightly loaded system. Engineers must evaluate system operating conditions to specify proper single phase protection system.

Single Phase Operation of Motor: Loss of a phase can occur during both startup and running conditions. If a three phase motor is started with one phase wire open, motor will not start as the pulsating current will not create enough starting torque for the motor to start. If the motor loses a phase while running, speed of the motor will decrease and current supply increase sharply. Figure below shows motor current flow for different load conditions:

Figure 1. Torque vs. Current



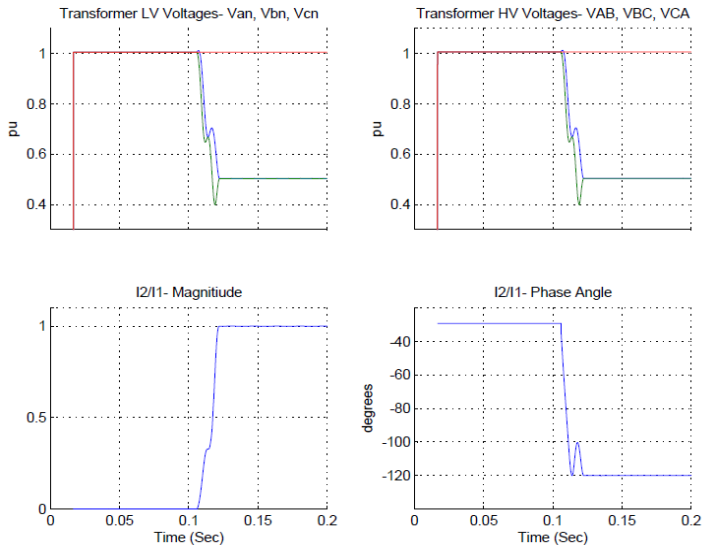
Under full load conditions, motor overcurrent protection will protect the motor since current flow in the operating phase far exceeds full load current, preventing possible motor burnout.

As seen from the graph above, under small load conditions, motor current is smaller than the rated full load current. Therefore, overload protection based on full load operation may not protect the lightly loaded motor.

Further details on this month's topic are available on the DRM website:
Design Requirements Manual
DRM Chapter 10, Section 3 Normal Power

Single Phase Operation of Transformer ($\nabla - Yg$): Loss of a phase at the primary side of the three phase transformer will result in both current and voltage unbalance at both primary and secondary side of the transformer. Figures below shows both primary and secondary voltages, current for loss of phase in a three phase transformer with delta primary and Y grounded secondary:

Figure 2. Voltage/Current – Three Phase Transformer



As stated above, voltage unbalance can have deleterious effects on three phase motors. Therefore, single phase protection is usually required to protect electrical systems from permanent damage of equipment, fire hazards, and loss of personnel safety.

Single Phase Protection Schemes: There are many ways to provide single phase protection. One option is to provide a relay at each phase and interrupt the circuit when current flow in one of the phases is reduced to zero. The disadvantage of this scheme is that relays need to be shunted during the startup. Another option includes sensing voltages and phase angles on each of the three phases to detect single phasing. Modern day microprocessor based relays can provide enhanced protection by sensing currents, voltages and phase angles.

Protection of three phase motors from single phase operations is critical to ensure safety of operation. The NIH Design Requirement Manual (DRM) requires that all three phase motors shall be provided with single phase protection. Thermal overload protection and overcurrent devices may not always provide adequate single phase protection. Therefore, engineers must consider actual operating conditions to specify appropriate single phase protection mechanism.