machine (commonly termed a two-pole machine) rotates 3600 rev/min at zero slip. An equation for synchronous speed in SI units is

$$\omega = \frac{2\pi Hz}{n} \tag{13-1a}$$

where $\omega$ is radians per second, $Hz$ is current frequency in cycles per second, and $n$ is the number of poles (which is twice the number of pole pairs). In U.S. customary units,

$$\omega = \frac{120Hz}{n} \tag{13-1b}$$

where $\omega$ is revolutions per minute and the other terms are as defined above.

Preferred motor speeds for pumping station equipment depend on the characteristics of the driven equipment as well as the overall costs—in particular, the life-cycle costs of the various practical alternative speeds. As a general recommendation, the following guidelines apply to pumping station equipment:

- Blowers and fans: use 1800- or 3600-rev/min motors with speed increaser gears when higher speeds are required. Note, however, that high speed produces a high noise level and 3600-rpm fans do not last nearly as long as 1200-rpm or 1800-rpm fans.
- Water, wastewater, or sludge pumping: use 900-, 1200-, or 1800-rev/min motors for medium to small pumps and speeds up to 600 rev/min or less for special, low-head, large pumps. Motors that run at 1800- and 1200-rpm are usually stock items, while 900-rpm and slower motors are not.
- Progressing cavity screw pumps: use 900-rev/min motors (or less). Consider connecting the motor to the pump through a belt or gear speed reducer.

Note that European motors are designed for 50 Hz. Operating these machines on 60 Hz will probably cause them to overheat. Likewise, do not operate a 60-Hz motor on a 50-Hz system unless the manufacturer specifically warrants the motor at the reduced frequency at some specific voltage and load.

## 13-7. Motor Voltage

Typical distribution system voltages are given in Table 8-6 as single-phase (120 or 240 V) and three-phase (208, 240, 480, 600, 2400, 4160, or 12,000 V). These voltages are the levels that the utility attempts to maintain at its point of service.

Voltage drops occur in the user's electrical system, and these are divided into two parts according to the NEC. The first drop is in the feeders and includes the service switchgear and the cables delivering electrical energy to local distribution centers, which are typically motor control centers (MCCs) in pumping stations. The second voltage drop cited in the NEC is in the branch circuit, which includes all of the power wiring between the circuit protective equipment (typically the MCC) and the motor. A 5% voltage drop is allowable in the total system and a maximum drop of 3% in either the feeder or the branch circuit is recommended by the NEC. For example, on a system rated at 480 V line-to-line, a 5% drop is 24 V and the net voltage delivered is 456 V line-to-line (at the full rated load). The designer may divide the drop in accordance with the NEC rules or choose to put in cables heavy enough to make the drop somewhat less. It is good design practice to keep the total calculated drop and the individual parts of that drop well below the specified levels discussed. At light loads, the terminal voltage at the motor is likely to approach the service voltage or to be approximately 480 V. The motor manufacturer usually rates the motor (full-load current and horsepower) at 460 V with a ±10% tolerance at full load. Thus, the motor guarantee would be valid at 506 V, but the life of the motor at 506 V may be shortened. A motor rated with a service factor may not be guaranteed at a voltage other than the nameplate voltage.

Typical rated voltages for motors are 115 or 230 V (single-phase), and 200, 230/460, 460, 575, 2300, and 4000 V (three-phase). The supply voltage for a very small pumping station may be 240 V, three-phase, three-wire from a utility delta-connected system, and a 120/240-V supply can be provided from a center tap between two phases on the utility's transformer. Sometimes the utility may supply a 208Y/120-V, three-phase, four-wire system, particularly if the pumping station is located in a network area having this supply. It is also frequently available where an individual transformer is required for the pumping station. This multivoltage system is preferable to a 240-V, three-phase system because it enables the load to be balanced on all three phases. Pumping stations of medium size—for example, 75 to 600 kW (100 to 800 hp)—need a full 480-V supply and usually derive their own 120-V circuits for lighting, small power outlets, and control devices from dry-type transformers located in the station.

Ordinarily, the service for a large station is most economical at the highest voltage available, and large pumping stations require 4160-V service. Because motors are usually rated at 4000 V maximum,