Pump ED 101

Power Factor – A Tale of Two Currents - Part 3 Capacitor Installation

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Capacitor Installation Options

Last month we learned that a capacitor's current is totally out of phase with that of a motor's magnetizing current. This allows it to store current when the magnetic field collapses and return it to the stator when the magnetic field is building. The net effect is a much improved motor PF. There are two different ways of improving power factor with capacitors. One is static and the other is bulk. Static correction involves using capacitors to correct a single load and they can be installed at several locations. Static correction can be the most effective method but it can also be the most expensive. Bulk correction uses a bank of capacitors that improve power factor for various portions of a facility and they can be switched in and out of the circuit depending upon the monitored power factor.

Capacitor Location Options

Where a static capacitor or capacitor bank is installed has a major effect on where PF is improved. Capacitors provide "upstream" correction only and relieve all upstream wiring and components of the current required to create a magnetic field in an inductive device. All wiring and electrical components that are "downstream" of the installation still must be sized to carry both the load and magnetizing currents.

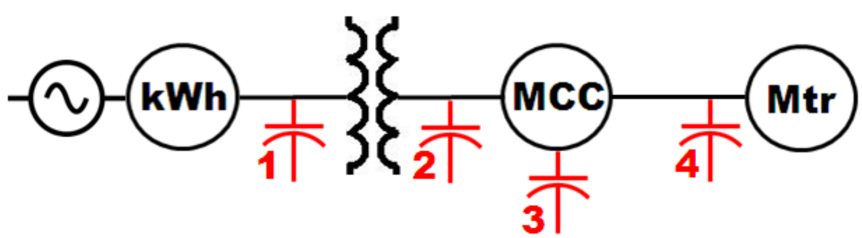

Figure 1 is a simplified sketch of a plant electrical system which I will use to show the effect of capacitor location. On the left is the utility entrance and its kWh meter. Next is a transformer that provides the plant's supply voltage. To the right of the transformer is a motor control center (MCC) that is used to operate AC motor driven equipment. On the far right is a single AC motor. The red capacitor symbols (1 through 4) show the possible locations for capacitor installation. In real life this diagram would be much more complex. There could be multiple transformers and branch circuits feeding various portions of the plant. Also there could be several MCC's and dozens of AC motors.

Location 1 - The plant could install a capacitor bank at location 1 if the utility is charging a penalty. This would relieve the utility of supplying the magnetizing current to the plant and make it available for sale to other customers. Typically, the bank would be operated by a PF controller that would switch individual capacitors on and off based upon the measured PF of the entire plant. This would eliminate the penalty but will not change the PF downstream of the bank.

Location 2 – The capacitor bank could also be installed at location 2 which is the secondary side of the plant's transformer. This location will still relieve the utility while increasing the transformer's capacity. For example, an 800kW transformer can provide 640kW of useful power at a PF of 80. If PF is increased to 95, it could provide 760kW or about 19 percent more. This bank would also be operated with a controller that switches capacitors on and off as needed.

Location 3 – The capacitor bank from location 2 could also be installed just prior to the MCC. This would reduce the load on the wiring from the transformer to the MCC. Individual (static) capacitors can also be installed at the input or output of each motor controller at the MCC. Either location will eliminate the need for a capacitor bank and its associated controls while reducing the load from the transformer to the MCC. If the capacitors are installed on the input side of the controller, a separate contactor is often required to automatically remove them from the circuit when the motor is off. If the capacitors are installed on the output side of the controller, several control panel components can potentially be downsized on new installations.

Location 4 – Static installation at the motor is the most efficient location. All upstream wiring and electrical components are relieved of the magnetizing current portion of the load required by that motor. If the installation is for a previously installed motor, it can also be more costly as the panel overload device will usually require replacement. Never connect a capacitor downstream of a VFD or solid state soft starter. When installed upstream contact the manufacturer for the required distance.

PF changes when the line voltage varies from the nameplate voltage. PF increases by about 3% when a 460 V motor operates at 440 V. When operated at 480 V, PF decreases by about 5%. The decrease is nearly directly proportional to the voltage increase. Lightly loaded motors also decrease PF. At three quarters load PF is reduced by about 5%. At one half load it is reduced by as much as 12%. Although our focus has been on induction motors, they are not the only source of low PF in the industrial sector. Fluorescent and mercury vapor lighting systems exhibit a very low PF in the range of 0.4 to 0.6. Arc and resistance welding machines also have a PF in the same range. On average, a typical industrial plant will have an uncorrected PF of 0.75 to 0.8. Increasing PF to 0.95 can eliminate utility penalties and increase the efficiency of a plant's electrical grid.

The industrial sector is not the only contributor to low power factor. Large commercial facilities such as hotels and malls can have large inductive loads. Do not forget the residential sector either. Homes have many small motors that power, washers, dryers, refrigerators, air conditioners, heating systems and other devices. Although most are fractional horsepower, they typically have a very low power factor (0.6 to 0.7). When running together they may produce from one to two horsepower. Multiply that by several thousand homes and power factor becomes a big problem for the utility. That is why utilities have their own power factor correction facilities spread throughout their distribution system.

Below are three links to more information on PF correction. The first two cover larger installations and the third covers correction for a single motor. They will also help you determine if PF correction is worth the investment. There are many more available online.

Power Factor in Electrical Energy Management
http://www.pdhonline.org/courses/e144/e144content.pdf

Power Factor Correction: A Guide for the Plant Engineer
http://www.eaton.com/ecm/groups/public/@pub/@electrical/documents/content/sa02607001e.pdf

The Cowern Papers
http://www.pumped101.com/index.html#cowern

Joe Evans is responsible for customer and employee education at PumpTech Inc, a pump & packaged systems manufacturer & distributor with branches throughout the Pacific Northwest. He can be reached via his website www.PumpEd101.com. If there are topics that you would like to see discussed in future columns, drop him an email.