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POWER FACTOR OPTIMIZATION OF INDIVIDUAL INDUCTIVE EQUIPMENT

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ABSTRACT:

The Optimization Sizing System, utility patent number 5,440,442, August 8, 1995, was developed to optimize power factor, whereby the required capacitance is quickly and easily determined to size motors individually in their existing working condition, thus reducing costs with less sizing errors and to determine the proper application of the compensators. Once each load is sized, the compensators are custom designed for that particular electrical load and installed on the load side of the switching device.

1. INTRODUCTION

The Optimization Sizing System provides a simple and accurate way for measuring the power quality of individual inductive loads (motors). This system consists of three units for sizing, a SINGLE PHASE UNIT which we call a US1, sizes all single phase equipment, a THREE PHASE UNIT we call US2, sizes motors from fractional motors up to 65hp, and a THREE PHASE UNIT which we call US3, sizes motors from 65hp up to 300hp. All Optimizers size up to 600 volts. All have five switches and sizing is accomplished by turning ON one switch or a combination of switches. This system has a possible 93 combinations to optimize the power quality of inductive motors. After sizing is completed, a precise analysis, estimated savings, estimated return on investment and system cost is prepared for the customer. There are three models of sizing units for applications as shown below:

MODEL #	PHASE	APPLICATION	50/60 hertz
US1	SINGLE PHASE	FRACTIONAL TO 5HP, UP TO 600V	
US2	THREE PHASE	FRACTIONAL TO 65HP, UP TO 600V	
US3	THREE PHASE	65HP TO 300HP, UP TO 600V	

Optimization Sizing Units

There are several advantages to increasing the lagging power factor (pf) on the electrical supply of a motor. Most loads in modern electrical distribution systems are inductive. Examples include: air conditioners, heat pumps, refrigeration equipment and chillers, ammonia systems, conveyers, irrigation pumps, pool pumps, etc. Advantages of individual power quality at the load are: Compensators will not cause problems on the line during light load conditions, Motor always operates with compensators, Improved motor life, Motor and compensators can easily be relocated together, Reduced line losses, Increased system capacity, Greater energy savings and Individual surge protection. Power quality is the ratio of working power (KW) to perform the actual work of creating heat, light, motion, machine output, etc. to reactive power (KVAR) to sustain the electromagnetic field. Apparent power is measured in kilovolt-amperes (KVA). It measures how effectively electrical power is being used. A high power factor signals efficient utilization of electrical power, while a low power factor indicates poor utilization of electrical power.

These two powers are related by:

When apparent power (KVA) is greater than working power (KW), the utility must supply the excess reactive current plus the working current. Compensators act as reactive generators. By providing the reactive current, they reduce the total amount of current your system must draw from the utility. Low power factor results when motors are operated at less than full load. By improving the power factor of a squirrel cage induction motor from .80 to .95, substantial energy savings can be realized, as the following analysis indicates. Voltage = current x resistance (V = IR) and by algebraic manipulation, *I = V/R* and *R = V/I*. Real power (*P*) is the *time rate of energy consumption* and equals voltage times current when both quantities are in phase or have unity power factor (PF = 1). Thus, power in watts equals volts times amps times cos *0*.

P = V(I) @ PF =1

POWER = VI = (IR)I =IR2

$$\textbf{CURRENT (I)} = \frac{\textbf{VOLTAMPS}}{\textbf{VOLTAGE}}, \quad \textbf{OR, } I = \frac{\textbf{VA}}{\textbf{V}} \quad \textbf{WHERE A} = \textbf{CURRENT IN AMPERES}$$

$$\textbf{VOLTAMPS (VA)} = \frac{\textbf{WATTS}}{\textbf{PF}}, \quad \textbf{OR VA} = \frac{\textbf{W}}{\textbf{PF}}$$

$$I = \frac{VA}{V} = \frac{W}{V(PF)} = \frac{WATTS}{V(PF)}$$

THUS

$$I(0.8PF) = \frac{W}{V(0.8)} = \frac{1.25\,W}{V}, \quad \textbf{OR, } I(0.8PF) = 1.25 \textbf{ AT UNITY POWER FACTOR}$$

The current at 0.8PF has been increased by 1.25 times the current at unity power factor

(PF = 1).

$$\text{Thus, the power @ (0.8PF)} = \left(\frac{I}{.8}\right)^2 R = (1.25I)^2 R = 1.5625I^2 R$$

$$\text{and, power @ 0.95PF} = \left(\frac{I}{.95}\right)^2 R = (1.0526I)^2 R = 1.108I^2 R$$

The difference in power consumed at .95 PF versus 0.8 PF equals

$$\frac{(1.108 - 1.5625)}{1.5625} \text{ x } 100 = -29.088\%, \text{ or } 29.1\% \text{ less energy used}$$

Another useful formula is the following: Percentage reduction of power loss equals
100- [100(0.8/0.95)2 = 100 - [100(0.84211)2 = 100 - [100(.70914)] = 100 - 70.914 = 29.1%, which correlates with the preceding solution derived from another approach.

While real power is constant, system losses increase as power factor declines,

POWER FACTOR	REAL POWER	REACTIVE POWER	APPARENT POWER	GRID LOSS
1	1	0	1	1
0.95	1	0.33	1.05	1.1
0.9	1	0.49	1.11	1.23
0.85	1	0.62	1.18	1.39
0.8	1	0.75	1.25	1.56
0.7	1	1.02	1.43	2.04
0.6	1	1.33	1.67	2.79
0.5	1	1.73	2	4.04

Mathematical calculations and tests conducted at leading test labs (EPA,NASA,Institute of standards and technology) confirm that regardless of the loading of a motor, optimizing for line losses will render about the same savings per hour in wattage in a given circuit. Low voltage, resulting from excessive current draw, causes motors to be sluggish and overheat. As power efficiency decreases, total line current increases, causing further voltage drop. Losses caused by poor power factor are due to reactive current flowing in the system. These are watt-related charges and can be eliminated through installing capacitive devices. Power losses (watts) in a distribution system are calculated by squaring the current and multiplying it by the circuit resistance (I2R).

To calculate loss reduction:

(Original efficiency)2

% reduction losses = 100 - 100x (New efficiency)

"I2" stands for the electrical current that must pass through these conductors (squared). "R" stands for the resistance in these electrical conductors. I2R = (I x I) x R equals the power lost in the system due to resistance (which is lost in the form of heat.) The resistance of the conductors remains the constant, only affected slightly by temperature.The currents of an electrical system are the sum total of all feeders to all panels, sub panels and all branches to all loads. When we add another electrical load regardless how large or small, we increase the total current of the system. So it follows that the more current in a system (with conductors of the same size) the more line losses (watts). To reduce line losses we must reduce current. By adding properly sized compensators to each individual inductive load, you reduce the line losses and
thus reduce wattage by up to 12%.

Conclusion

The importance of power factor and its effect upon both capacity and voltage regulation is deserving of the most careful consideration as with all electrical apparatus, in which an inherent phase difference exists between the pressure and the current, as for instance in induction motors. The common belief is that any decrease in power factor from unity value does not demand any increase of mechanical output. This is not true, since all internal alternators and line losses, manifest themselves as heat, the wasted energy to produce this heat is being supplied by the prime mover. There are two ways to reduce line losses: (1) by increasing the size of the conductors, (2) by reducing the electrical current that flows through them using compensators.

The Optimization sizing units provide an exact approximation of the capacitance required to optimize the power factor to unity in an inductive circuit with less sizing errors. Methods exist to determine the nominal capacitance required for motor circuits, but in our extensive field testing, the name plate information is not the true values of the inductive equipment in their existing working conditions. These methods (engineering analysis) consider the capacitance effects imposed on other loads and equipment throughout a facilities electrical system. The Optimization sizing unit does not circumvent the need to properly engineer the total electrical power system supplying inductive loads, but the sizing analysis can provide useful information for these engineering purposes.

Benefits:

. Giving field data on the loads to facilities managers not available to them before.
. Gives the facilities manager the option to replace the load or retrofit the load.
. Certification of loads purchased by facilities personnel of the loads high efficiency rating, as stated by the manufacturer.
. Delivers consistent and more reliable results than current technology.
. Eliminates many labor-intensive functions required by other methods.
. Provides an instantaneous and accurate analysis.
. Provides an easily portable system for performing accurate analysis in the field.
. Reduces the retrofit costs.

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EQUIPMENT REQUIRED FOR SIZING:

ACME POWER FACTOR METER
US1, US2, OR US3 OPTIMIZATION SIZING UNIT
BLACK INDELIBLE MARKER
ENGINEERING SURVEY SHEETS
PEN AND/OR PENCIL
SCREWDRIVER
DRAWING PAD
PORTABLE DRILL

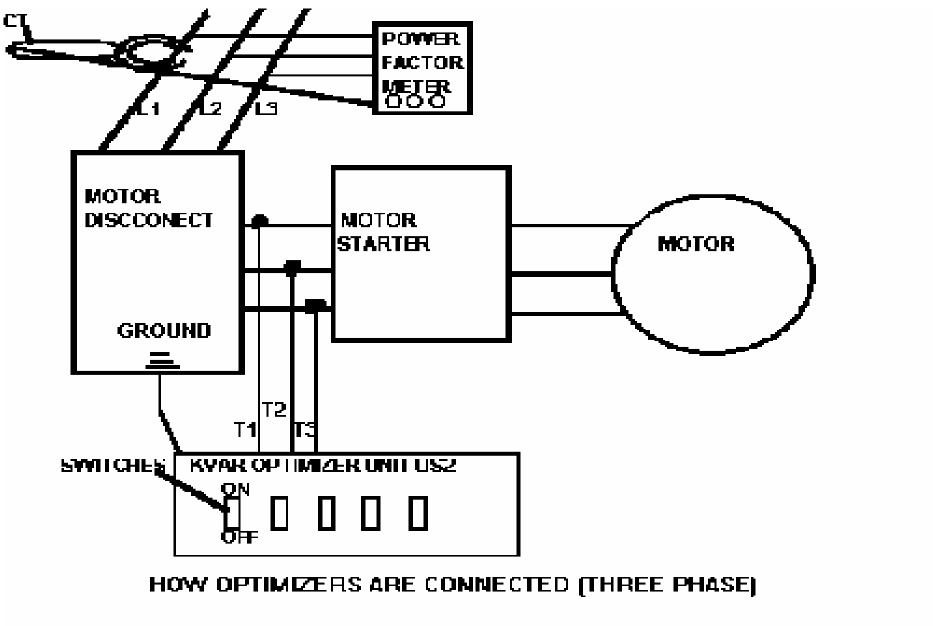

Figure 1
Optimization Sizing Unit locations

1. In the field we use the above equipment along with our survey sheet (enclosed).
2. We record the voltage, amperage, phase, and power quality before sizing.
3. We then add the capacitance, one switch or combination of switches until we have the power quality to unity.
4. We then record the voltage, amperage, lead amps and power quality after sizing.