ELECTRICAL POWER QUALITY AND CONSUMPTION IN GINNING

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Abstract

The paper is to inform, demonstrate and educate the ginners of cotton on the cost of electrical power consumed in their plant. It will define what utilities charge and desire from its customers. It will illustrate options and steps a ginner of cotton may take to reduce electrical energy cost and better control the continuous process of ginning cotton. The theory is to provide an electrical system that presents connected horsepower as apparent horsepower. It will define the devices used to produce the presentation of power to the utility by a gin facility. This will convey the meaning of power quality to the utilities and to the gin. The resulting theory will reduce power consumption at the ginning facility. Reduced electrical demand and power factors that are well beyond utilities requirements.

What is Power Quality?

In a perfect world, an electrical device should receive electrical energy from an A/C source that delivers a sinusoidal output voltage of proper frequency and nominal value with no aberrations or distortion. This would be perfect power quality.

In understandable terms, the incoming power is 480 volts at 60 cycles. The incoming power should be steady (sinusoidal output voltage of proper frequency). The power should not go low or high, for extended periods, making electrical and electronic devices used in ginning die a premature death.

What are aberration and distortions:

- Sudden voltage variations
- Phase imbalances
- Momentary interruptions
- Frequency deviations (Frequency is also known as cycles, and Hertz)
- Electrical Noise

With deregulation of the electrical utilities industry, voltage variations, phase imbalances, momentary interruptions and frequency deviations should become less common. This may or may not be true. The problem most commonly found in power studies, conducted by a prominent electrical device manufacturer, is low voltage. With high speed recording devices power interruptions are common. These happen at a speed of less than .5 hertz. In a 60 hertz system this equates to less than 1/120 of a second. They are never seen but tax the lives of many components used in gins, computers, temperature controllers, close circuit viewing systems and programmable logic controllers.

It is commonly believe that the most prevalent electrical problem that exists in gins is Electrical Noise.

Electrical Noise

Electrical noise can be defined as any form of electromagnetic energy other than the desired signal and its harmonic components. Some of the components that make up the term Electrical Noise are Transient, Surge, EMI (electromagnetic interference), and RFI (radio frequency interference).

Transient is commonly used synonymous with noise, although the term is most often associated with momentary amplitude changes in voltage and/or current. Transients result from an intentional or unintentional change in the operating state of a circuit.

Surge is a term for either high voltage noise or long duration transients.

EMI is the impairment of a desired electromagnetic signal by and electromagnetic disturbance (such as the electrical noise created by the energizing of a large starter of solenoid).

RFI is noise related to radio frequency ranges of 10 kHz to 30 MHz. This commonly created by hand held two way radio systems. This noise has a negative effect on most low voltage signals in a gin. Some of the devices affected in a gin are thermocouple signals, 0-10vdc signals used by potentiometers and closed circuit television systems.

Noise will appear in an electrical system in two forms, Common Mode Noise and Normal Mode Noise.

Common Mode Noise appears between the ground and the line and/or the neutral current-carrying conductors. The word "common" indicates that the noise signal on each of the current-carrying conductors are in phase and equal in magnitude, therefore a voltage signal is generated between these conductors by noise.

Normal Mode Noise appears between the line and neutral current-carrying conductors. Normal-mode noise is also known as transverse-mode noise, differential mode noise, metallic-mode noise, or as symmetrical RFI.

Of the two types of noise, common-mode noise is the more troublesome
since it is more prevalent than normal-mode noise. This is because noise is almost always transmitted through a distribution transformer as common-mode noise, regardless

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of whether it was generated in the common-mode or in the normal-mode.

Electrical noise could originate from natural phenomena or made-made sources. Lighting, industrial machinery, electronic switching devices and static electricity can produce electrical noise.

Lighting can produce high-amplitude, high frequency noise surges that contain enough energy to destroy electronic components found commonly in the cotton processing industry.

IEEE C62.41-1980 shows voltage, current levels that can reach 6000 volts and 500 amps. Addition information can be found in IEEE Guide for Surge Voltages on Lightning.

Power Factor Correction Capacitors that exist on electrical utility lines and in industrial power systems compensate for the lagging power factor of induction motors. The capacitor banks are switched in and out to achieve unity power factor. The switching of these devices result in damped oscillations involving lower currents and voltage surges than those induced by lighting but for longer duration.

How to Prevent Damage by Common-Mode Electrical Noise

Grounding

The ginning industry must realize the importance of grounding. Most ginning facilities are mixtures of evolving technologies. In most plant expansions the electrical system in not considered from the quality stand point, only from the connected horsepower standpoint. The system grounding may occur as an afterthought, or may not occur at all.

Electrical noise has been shown to occur predominantly in the common mode. This is especially true for high voltage surges caused by lighting or power switching. A lighting surge will appear at a service entrance. Lighting could easily induce a 3,000 amperes transient into a power line. When this surge reaches the building, the building ground at the service entrance could rise to 60,000 volts. In order to protect your ginning plant, it is important to establish a low-resistance earth ground at the service entrance.

The National Electrical Code Article 250, Part 4 specifies that the ground at the building service entrance should have a resistance to ground of 25 ohm's or less. The IEEE Green Book-Recommended Practice for Grounding, ANSI/IEEE Standard 142-1982, Section 4.1 recommence that the ground resistance be even less-under 5 ohms. Grounding conductors are a major player in proper ground techniques. Make sure the total ground system minimizes overall impedance.

If your gin is subject to electrical noise due to lightning, a lightning arrester at the building service entrance is recommended. The best method of providing a ground path for protective devices is to include an extra conductor in the conduit, with the current carrying conductors, that is meant to carry the transient current to ground. The extra conductor should extend to the earth connection at the service entrance. The use of downstream power conditioners, in conjunction with a service entrance lighting arrester, can protect sensitive electronic equipment from lighting and high voltage disturbances. These devices many times are destroyed by a lighting strike. They may lose there filtering capabilities after repeated attacks from transients. This will provide protection from high voltage generated outside of the plant. There are high voltages that occasionally occur in the distribution system as a result of power switching inside the gin. (Power Factor Correction Capacitors, Large across-line motor starter, Solid state motor starters) An effective method of limiting this noise, especially common-mode voltage differentials, is to bond all the ground conductors.

Central Grounding Point

There should be only one connecting point between the grounding system and the earth ground. Every equipment cabinet must have a ground bus that connects to the earth ground bus bar in the power panel. The cabinet ground bar should be bonded directly and securely to the cabinet. Connect the cabinet ground to the ground to the ground bus bar in the power panel using 6 gauge or larger wire and ring connectors. The wire should have green insulation and be routed through the same conduit as the current carrying conductors. Try and keep all ground conductors as short as possible.

Never Connect Grounds in Series

Connect electrical equipment and cabinet's ground leads in a star, with individual ground wires going to the system ground. Never connect ground conductors in series (daisy-chained). This approach makes noise signal additive, turning several low-level noise signal into one large noise signal.

Sometimes the term ground is used interchangeably with common or return. This is incorrect. Although commons or returns may connect to earth ground at some point, do not use them as chassis or cabinet ground connections.

Shields

Use shielded cable for low-level analog signal cables. Shield cable is particularly effective in reducing electrostatic coupling between parallel cables running together in a conduit. Shielded cable also provides protection from electromagnetic noise in the RF range. Connect shield drain wire to ground at the device end. Keep this convention regarding shields throughout the plant. Keep exposed ends of low voltage cables as short as possible. Never use the drain wire as a ground, common or return wire. Use it only as a shield.

Summary of Common Mode Noise

As previously stated common-mode noise is the most common form of Electrical Noise. There is no way for the ginner to prevent the occurrences of these voltage and current transients. The ginner must design his electrical system to channel these disturbances away from his facility, this is mainly accomplished by good wiring practices, and the maintaining of an earth ground with less than 5 ohms resistance.

Earlier we discussed the term Normal Mode Electrical Noise. It presents itself as voltage or current distortion between line and neutral. Normal Mode Electrical Noise will be converted to Common-Mode Electrical Noise through the windings of a distribution transformer. This occurs by capacitance coupling from the primary to the secondary winding of the transformer. Therefore, most Normal Mode Electrical Noise exists in gins electrical system as Common-Mode Noise.

Other Factors that Effect Power Quality

With the advent of power electronics and the proliferation of non-linear loads in industrial power applications, power harmonics and their effects are a topic of concern. Currently in the United States, only 15 to 20 % of the utility distribution loading consist of non-linear loads. It is projected over the next ten years that non-linear loads will comprise approximately 70 to 85% of the loads on our nation's utility distribution systems.

These non-linear loads are becoming more prevalent in gins. Non-linear loads create current harmonics by drawing current in abrupt short pulses, rather than in smooth sinusoidal manner. They are solid state starters (soft-starts), A/C variable frequency drives, DC drives (most being single phase, distributor conveyor, and feed controls), personal computers, and most types of electronic controllers.

Harmonics

A harmonic is a component of a periodic wave having a frequency that is an integral multiple of the fundamental power line frequency.

Harmonic	Frequency
1st	60 Hz
2nd	120 Hz
3rd	180 Hz
4th	240 Hz
5th	300 Hz
6th	360 Hz
7th	420 Hz
8th	480 Hz

The total harmonic distortion is the contribution of all of the harmonic frequency currents or voltage to the fundamental. The 5th and 7th harmonics contribute to 90 % of the harmonic spectrum.

The terms "linear" and "non-linear" define the relationship of current to the voltage wave form (sinusoidal). A linear relationship exists between voltage and current, which is typical of an across-the-line load such as a resistive heater. A resistive load is considered to have unity power factor. A non-linear load has a discontinuous or distorted current relationship that does not correspond to the applied voltage waveform. A non-linear load has an effect on power factor but in most areas the utilities metering does not see these loads. An inductive load, although having a linear relationship between current wave and voltage wave, has a lagging current wave thus a creating poor power factor. In most areas the utilities penalize the gin plant for it's inefficient use of energy with a power factor of less than 90 %.

The effects of three-phase harmonics on circuits are similar to the effects of stress and high blood pressure on the human body. High levels of stress or harmonic distortion can lead to problems for the utilities distribution system and the gins distribution system.

Harmonics can lead to power system inefficiency. Some of the negative ways that harmonics may affect equipment are as follows:

Conductor Overheating- harmonic currents on undersized conductors or cables cause a "skin effect", which increaseswith frequency. Skin effect is characterized by the current flow crowding to the surface of the conductor.

Capacitors-can be affected if a capacitor and distributionsystem inductance is turned to one of the characteristic harmonics such as the 5th or 7th, over voltage and resonance can cause dielectric failure or rupture the capacitor.

Breakers, Fuses and Circuits-harmonics can cause false or erratic operations and trips, damaging or blowing components for no apparent reason.

Transformers-have increased iron and copper losses or eddy currents due to stray flux losses. This caused excessive overheating in the transformer windings.

Utility Meters-may record measurements incorrectly resulting in higher billings to the gin.

Drives/Power Supplies-can be affected by improper operation due to multiple zero cross firings. Harmonics can cause failure of the commutation circuits, found in D/C and A/C drives with silicon controlled rectifiers.

Computers/Telephones-may experience interference from failures.

The IEEE has set the standard for harmonic content in power distribution systems. The IEEE standard 519-1992 established recommended guidelines for harmonic voltages on the utility distribution system as well as harmonic currents to the utility distribution system. According to the standard, the industrial user is responsible for controlling the harmonics injected on the utility distribution system. This standard may be affecting gin facilities at present, most assuredly it will affect the ginning process in the future.

Reducing Harmonics

How do we prevent the damaging effects to both the gin facility and to the utility's power distribution system due to harmonics? There are many ways to reduce harmonics, ranging from adjustable frequency drive designs to the addition of auxiliary equipment.

If we have the opportunity to build a new cotton processing facility, a significant electrical system design effort should be exercised. The design should limit non-linear loads to 30% of the maximum transformer's capacity. If we are making modifications to an existing plant with power factor capacitors installed, resonating conditions can occur that could potential limit the percentage of non-linear loads to 15 % of the transformer's capacity. If problems of transformer heating, or increasing audible noise from that transformer exist, a transformer with a K4 design in place of the K1 designed transformer may solve the problem. In some situations, the neutral conductor may become excessively warm. The reason for the rise in temperature may be attributable to harmonics. A good rule of thumb to use in a 3 phase, 4 wire application, size the neutral conductor 150 % of normal rating.

When using A/C or D/C variable speed drives, solid state starter (soft starts) the use of input line reactors to add impedance is a cost-effective means reducing harmonic content. A/C drives when installed in a facility may or may not require input line reactors. The latest A/C drives are close to 98 % efficient, therefore reducing the need for power correction capacitors. If power correction capacitors are present the use of A/C drives and solid stated starters should be approached with care. Line reactors can provide the proper impedance to prevent damage and heating to the capacitor bank. This should be attempted after a power study has been completed to determine total impedance of the system.

Summary of Harmonics

Harmonic contents exist in every electrical system. It may or may not have an adverse effect on the electrical system. The best solution is not to overreact. Observing standard wiring practices is the best first step. There may not need to be a second step. If problems occur as previously discussed, then additional steps may be required. Be very careful, look for help at traditional electrical firms. These may include utilities but surely should not be limited to your largest energy provider. Many electrical manufactures have taken great steps in partnering with industry to provide power quality solutions.

Power Consumption

Electrical power consumption has become an ever-upward moving factor in the variable cost of ginning cotton. The cost of electrical energy for processing a bale of cotton in 1997 averaged 3.25 cents in 1994. Electrical energy is the second largest variable cost, next to labor, in producing a bale of cotton. Therefore, it may be reasonable to assume, that a better understanding of electrical power consumption maybe helpful to producing more profits, or controlling costs, in the gin process. It may also stand to reason that this better understanding could help a ginner when presented with a number of different billing options from his/her local provider of electricity.

The Electrical Utility Bill

The most common unit of power found in a gin is referred to as horsepower. One horsepower is equivalent to 33,000 ft-lb. of work per minute. In electricity, the unit of power most commonly used is the watt. Since the watt is relatively small unit, the kilowatt is more commonly used for the unit of power. One kilowatt is equivalent to 1,000 watts. One horsepower is equal to 746 watts. This equality is valid when considering that the equipment used to produce one horsepower operates at 100% efficiency, which is not possible.

Cost of operating a 100 horsepower load for 8 hours would be calculated as the following:

$$\text{Cost} = \frac{\text{Watts} * \text{hours used} * \text{rate per kwh}}{1000}$$

Cost for operating a load of 100 horsepower for 12 hours, at a rate of .05 cents per kwh, with 100 % efficiency is as follows:

$$\frac{74{,}600 * 12 * .05}{1000} = \$\ 14.71$$

If we look at this by the figures published in 1997 in the Cotton Ginning Journal the rate would calculate be as follows:

43.6 kwh/bale
$3.62 /bale
.08 /kWH

These are averages. Your rate may vary. This may or may not take into account a number of different billing options. There may be plans for "Off-Peak" billing, plans with " Power Factor" charges, or plans with " Demand" billing. It is not stated in the article. The truth is most utilities measure total kVA and show either the kW demand or the calculated power factor. Therefore, the only way to reduce the cost per bale cotton, electrically, is to reduce demand and or consumption.

As a rule of thumb, we use the following as a constant.

1 kVA = 1 Horsepower

The actual calculation varies with every electrical system depending upon the efficiency of the loads and power factor of system.

Power Factor

Power factor is the phase displacement of current and voltages in an AC circuit. The cosine of the phase angle of displacement is the power factor. The cosine of 90° is 0; therefore, the power factor is 0 %. If the angle of displacement were 60°, the cosine of which is 0.500 the power factor would be 50%. This is true whether the current leads or lags the voltage.

In DC circuits and AC circuits that contain only resistance, this is how power would be expressed:

P(watts)= $E \times I$

P(kilowatts)= $E \times I \div 1000$

Power would be expressed in A/C circuits that contain inductive (motors) and/of capacitive reactance.(incandescent lighting)

VA (volt-amperes) = $E \times I$
KVA (Kilovolt-amperes= $E \times I \div 1000$
P (Watts) = $E \times I \times$ power factor

In a 60-cycle AC circuit, if voltage is 120 volts, the current is 12 amperes, and the current lags the voltage by 60°, the following displays the power factor; the power in volt-amperes (VA): and power in watts.

The cosine of 60° is .500: therefore, the power factor is 50%.
120×12 = 1,440 VA, which is called the apparent power.
$120 \times 12 \times 0.5$ = 720 watts, which is called the true power.

Why is a high power factor of great importance? In our example, there is an apparent power of 1,440 VA and true power of 720 watts. There are also 12 amperes of line current and 6 amperes of in-phase or effective current. This means that all equipment from the source of supply to the power-consumption device must be capable of handling a current of 12 amperes, while the device in only utilizing a current of 6 amperes. Therefore, the utility would either calculate this as increased demand or penalize the user for poor power factor. This is an extreme example to show the effects of poor power factor conditions. Most utilities are requiring more and more gins to maintain a power factor of 90% or above.

No matter how you are billed power factor is an important part in the cost of a bale of cotton.

Motors

An A/C motor is an inductive load, always creating a current wave that lags the voltage wave. Thus inherently, wasting electrical energy. This energy is costly to the ginner in both demand and kwh. As of October 24, 1997, the U.S. Department of Energy, has started enforcement of the electrical motor standards, detailed in the Energy Policy Act of 1992.

The enforcement of this law mandates the manufactures of electrical motors to meet defined Nominal Full-Load Efficiency.

This law will be enforced on 90% of motors used in ginning. American manufactures of electrical motors must meet these standards. They will not be allowed to build motors offshore sell them in the states that do not meet EPACT standards. Minimum standards for these motors will exceed 90 % in most horsepower sizes.

What are the downsides of “EPACT”motors?

1) Could run faster
2) May draw more starting amps
3) May need to change sprockets, of sheaves
4) Probably bigger, cost more

The initial costs may be more but the energy savings should repay the user over time. There has been a large number of motors hit the market at reduced pricing. The standard is applied to manufactured date not sales date. Savings are mostly still available.

A/C Variable Frequency Drives

Over the past decade, tremendous strides in technology have been achieved in the design of Variable Frequency Drives (VFD). There are a number of different names for drives, Adjustable Frequency Drives (AFD), Inverters, Freq.drives, and speed controllers. Original design of the power circuit used SCR’s (Silicon Controlled Rectifier). These devices have poor reliability and poor electrical characteristics. SCR’s are still the prevalent power component in most soft starts due to price. In the VFDs of latest design, power components are IGBT (Insulated Gate Bi-polar Transistor). When buying drives, either for new equipment or for internal application, require that the drive have an IGBT design.

There are application criteria that need to be considered in applying VFD’s. The type of load determines the current output capacity required by the VFD. The first is a variable torque application. Variable torque application is when there is no load present at start-up. A constant torque load is when the largest torque presented to the motor is at start-up. Variable torque application in gins are fans, and pumps. Although, most ginners are very cautious of applying a VFD to press pumps.

The advantages of VFD are many. Today's, drives have an efficiency of 96 to 98 %, creating less demand. The great advantage for savings exist when the ginner has the ability to reduce speed. A 10% reduction in speed equals a 27% saving in energy. The savings come from the reduction in horsepower. Other advantages of VFD are:

1) Increases Power Factor (up to .98)
2) Eliminates line power surges (proportional to acceleration time)
3) Reduces Mechanical Stress (extends motor bearing and belt life)
4) Phase loss protection as standard
5) Electronic motor overload protection

At one point, many U.S. utilities offered rebate programs for installation of A/C drives.

There is a potentially motor damaging aspect of VFD's. Corona Inception Voltage (CIV) is created by the voltage created by the high speed switching of the power transistors in later design drives. CIV will cause some motors to fail. CIV breaks down the insulation in motor windings. Motors without phase paper should not be used with drives. This does not mean old motors. Some of these motor are very compatible with advanced drives, due to their heavy construction. Motors that have been rewound usually work very well with VFDs. All EPACT and speed engineered motors will work very well with VFDs. Producing maximum efficiency and high displacement power factor.

Conclusion

Most gins today have connected horsepower of nearly 1000 hp. With stands that require 125 to 150 hp, it is easy to see why the cost of electricity is going up per bale. With hydraulic booster pumps and trampers and pushers the plant is requiring more fluid from their power plant. We are seeing cooling towers replacing heat exchangers to keep the fluid cool. Heat is the enemy of both electrical components and hydraulic equipment. High speed ginning is requiring more energy and stability from the plant equipment. The pay back is in more production and reduced labor. The trade-off is increased electrical costs per bale.

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