

Fact Sheet: Three-phase Power on Dairy Farms in New York State

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Introduction

Many of today's dairy farms have grown over the years from once small operations into operations involving hundreds of animals and facilities that cover many acres. As they have grown and expanded so too has their electrical dependence. Larger dairy operations have spawned the use of larger electrically powered equipment to ease the workload and improve efficiency. The electric motors that power equipment have by necessity grown larger in horsepower (Hp). These large Hp motors and high capacity pieces of equipment have caused many dairy farmers to question whether or not they should make the switch from single-phase to three-phase power.

What is the difference between three-phase and single-phase power?

Single-phase power is delivered as a sine wave that goes from V+ to zero to V- and back through zero to V+ sixty times each second, or 60 Hz power. Tracing the voltage over time on an oscilloscope looks like the image in Figure 1.

In a three-phase system, three conductors carry the *same single-phase sine wave power* but reach their peak values at different times. If you took one of the conductors as a reference, you would find that one of the other conductors is 1/3 of a cycle ahead of the reference and the other is 1/3 of a cycle behind the reference. An oscilloscope trace of three-phase power would appear as shown in Figure 2. This arrangement between the phases has the effect of providing a more constant power transfer over a cycle as compared to single-phase power. This makes it possible to produce a rotating magnetic field in a three-phase motor. Every utility generates and transmits its power as three-phase. It is only at the distribution level that single-phase power is broken out for customers.

The two most common utilization voltages for three-phase power on a dairy farm are 208Y/120 volts or 480Y/277 volts. Dairy farms using the higher voltage benefit from the ability to deliver useful power longer distances on smaller gauge wires. This makes it far easier and less costly to power barns that are several hundred feet in length. In order to supply 120 or 240 volts single-phase on the higher voltage system, step-down transformers are installed.

When should a dairy farm consider switching to three-phase power?

Since each dairy farm operation is unique, there is no single answer and it varies from one operation to the next. The most visible indication would be a limitation on the size of electrical equipment that could be added to the operation. Certain types of equipment have capacity limits on single-phase power. Equipment brochures may indicate that above certain capacities, the devices only operate on three-phase power; this may be one of the first indications.

Another visible indication is operation of existing motors. Sluggish starts, blown fuses, tripped breakers and overheating can all be signs that a single-phase service is just not meeting demand. These indicators may lead you to reassess your power needs and consider conversion to three-phase power.

Figure 1. Single Phase

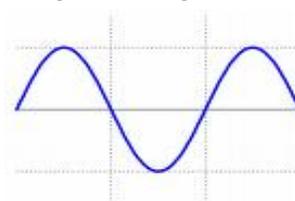
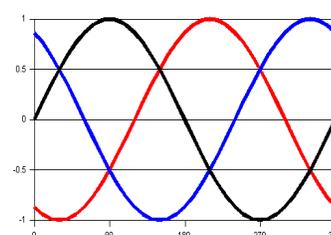


Figure 2. Three Phases



What are the advantages of three-phase power on a dairy farm?

The greatest benefit involves motors, especially large ones. Three-phase power works well with electric motors and is inherently more efficient. Additionally, single-phase electric motors larger than 10-Hp (7.5-kW) are not readily available. Stationary equipment requiring high Hp electric motors does well with three-phase power.

Key benefits of three-phase electric motors include:

- Simplicity of design - no capacitors or special starting windings are needed;
- Inherently higher torque - resulting from the rotating magnetic field as compared to the pulsating field in a single phase motor;
- Higher efficiency;
- Smaller physical size for comparable Hp;
- Lower capital costs;
- Easily reversible;
- Large HP ratings readily available;
- Less vibration - extends motor and bearing life.

Can every dairy farm have three-phase power?

The answer is a simple “yes” in many instances but in others it is a qualified “yes” because the dairy farm would have to invest a substantial sum for the utility to convert its distribution circuit to three-phase.

A good indication would be the appearance of three high voltage conductors on the utility’s feeder circuit currently supplying the dairy farm single-phase power. This indicates that three-phase power is available at the roadside. Only one or two high voltage conductors on the feeder indicate the service is on a single-phase spur. Following the feeder back to where you find the three conductors will give you an idea of how far you are from a three-phase source. The farther away you are, the greater the expense to convert the circuit. Do not hesitate to call your utility representative to discuss your interest in three-phase power.

Does three-phase power cost more?

If the dairy farm is served from a single-phase service that also supplies a residence, you are most likely being metered under a residential rate. A dairy farm on a dedicated metered that does not serve a residence is served as a commercial rate customer. Under those conditions, you may also be subject to a demand charge if your monthly use exceeds 2,000 kWh for four consecutive months. Residential rate customers will see some increase in cost while non-residential operations should not see much change in their billing rates if it is converted to three-phase.

The best source for this information is your utility representative since in New York State, each utility’s rates differ somewhat from one another. If you are seriously considering the change over, the utility can provide you with a good estimate of the costs to convert as well as what to expect in terms of ongoing costs based on your projected load.

Are you considering the installation of biogas fueled on-site generation?

Any dairy farmer who is seriously considering the installation of on-site generation (OSG) fueled by anaerobic digester gas (ADG) needs to give three-phase power conversion serious attention, since OSG systems add a new dimension to the situation. Some points to bear in mind:

- Most utilities place an upper limit on the capacity of single-phase generation that can be interconnected to the grid. 100-kW is a common upper limit. *(check with your utility)*
- Availability of single-phase generation equipment suitable for OSG use is limited.
- Three-phase generators are inherently more efficient.

Can existing single-phase equipment be utilized on a three-phase system?

Most all pre-existing equipment can be used on new three-phase service. Depending on the service voltage selected, some can be used directly and others require a step-down transformer.

In 208Y/120 systems, you will be able to connect 120-volt devices from one of any of the three phase conductors to the neutral. 240-volt devices are connected between any pair of phase conductors and will be supplied at 208 volts. Most 240-volt motors should not have a problem operating at the slightly lower voltage. Others may have a wiring connection for the lower voltage. Resistance devices such as heaters or hot water tanks using 240 volts will produce slightly lower wattage heat outputs but should not dramatically affect performance. Additionally, with the lower voltage, their life will be extended. It may be wise to replace large Hp motors with three-phase units to ensure load balance.

In 480Y/277 systems, small three-phase step-down transformers should be installed at strategic locations to power existing loads. Three-phase transformers will produce 208Y/120 volts. New equipment should be purchased to operate at the higher voltage and allow for savings in wire sizes as well as the ability to deliver the power further from the source.

In either voltage configuration one of the key points during the conversion is balancing loads on each of the three phases. Three-phase motors and equipment are inherently balanced. The electrical contractor will need to take care in distributing existing single-phase loads on the new service in such a way as to maintain a close balance of the loading of each phase to ensure efficient operation of the system.

Summary

Three-phase power provides a dairy farm with the opportunity to use large horsepower motors, ADG fueled OSG and other modern equipment that will allow them to support a large contemporary operation. The availability of three-phase power varies by location and may require a substantial contribution by the dairy farm owner to install. Most existing single-phase equipment can be used on new three-phase service.

Dairy operators considering conversion to three-phase power should:

- Assess their current large energy and high Hp equipment;
- Review plans for future growth of the operation and new equipment additions;
- Contact their utility service representative to evaluate if three-phase is an available option;
- Discuss their overall electrical needs and ideas with a knowledgeable electrical contractor;
- Evaluate the costs of conversion and the overall benefits conversion makes available to their dairy operation both in the present as well as the future;
- Determine if the conversion to three-phase power adequately offsets the costs to convert and if it adds greater value to the operation.

Economic analyses to support conversion to three-phase are difficult to develop and they will differ from one operation to the next. Conversion to three-phase is not generally a decision that can be supported by a hard and fast cost/benefit analysis.

There can be cost savings over the long term however. As noted in the discussion, three-phase motors can cost 40-50% less than comparable single-phase motors and they will be more efficient. Additionally, there may be savings when new three-phase equipment is added compared to equivalent single-phase equipment. These hard dollar benefits will be there but they would not, in all likelihood, be the deciding factor that supports a conversion to three-phase power. In most cases, the decision to proceed will be driven by the growth plans of the dairy farm.

In many cases, the conversion to three-phase power is strictly an enabling technology that allows the dairy operation to grow to the next level. This is what can be defined as “adding greater value to the operation”. In these cases, the cost of conversion becomes a part of the cost to achieve the dairy farm’s overall growth plan.