Electrical systems using alternating current are subject to situations where voltage and current get out of step with each other… they get “out of phase.” When voltage and current are out of phase, the power produced – the product of voltage times current – is affected. *Apparent power*, what is metered and what we typically pay for, is composed of *real power*, that provides useful work, and *reactive power*, that only exists to balance out the misalignment between voltage and current. That misalignment is referred to as power factor (PF). Among other things, low PF results in consumers paying for more power, the apparent power, than actually does useful work, the real power.

**THE POWER TRIANGLE**

The relationship between real power, reactive power, and apparent power is described by the power triangle – a right triangle whose perpendicular legs represent the real and reactive components and whose hypotenuse represents the apparent power. Apparent power is traditionally described in units of VA (volt-amp). Reactive power is traditionally described in units of VAR (volt-amp-reactive). Real power is traditionally described in units of W (watt).

The angle between real and apparent power, \( \theta \), is the angular displacement by which the voltage and current are out of step. PF is the cosine of that angle.

When \( \theta \) is 0 degrees, there is no reactive power, apparent power equals real power, and PF = 1. When \( \theta \) is 45 degrees, there are equal amounts of reactive and real power, and PF = 0.7.

**REACTIVE POWER AND THE NORTHERN POWER TURBINES**

By virtue of its full power converter, the NPS 60 and NPS 100 wind turbines can be configured to provide reactive power compensation regardless of how much, if any, real power it produces. Each turbine can provide anything between +/-45 kVAR. This ability is referred to as “reactive power compensation.” By providing or consuming (providing positive or negative) reactive power, the NPS wind turbines can help to support the power quality of the electrical system it is connected to.

This reactive power compensation capability can be useful in a number of situations. We will discuss two: a site with low PF and a site where turbines are connected at the far end of a long distribution run on a weak diesel grid.
LOW-PR SITE

At a site with low PF, the up-to-45 kVAR reactive power available in a Northern Power wind turbine can be used to reduce the height of the reactive power leg of the power triangle. This reduces the angle between the real and apparent power legs, effectively reducing the apparent power and reducing the amount of energy billed from the utility. For example, imagine a site with PF of 0.6 using 180,000 kWh/year of real power. Averaging the energy usage over the year gives an average demand for real power of 21kW.

![Power Triangle Diagram](image)

The 0.6 PF corresponds to an angle of 53°. The power triangle shows us that the site has an average apparent power demand of 34 kVA, corresponding to about 300,000 kVAh/year, and an average reactive power demand of 27 kVAR. So the end user at this site pays for 300,000 kWh, but can only make use of 180,000 kWh. Providing 27 kVAR of reactive power compensation from an NPS 100 or NPS 60 wind turbine can reduce the reactive power leg of the triangle, effectively raising the PF to 1, reducing the apparent power demand to 21 kVA, and resulting in apparent energy consumption of just 180,000 kWh, saving 120,000 kWh/year in billing from the utility. Wind-generated energy from the turbine is an additional benefit.

LONG DISTANCE RUN

A remote island has a power plant containing a small number of diesel-powered generator sets. Power is distributed from the power plant at one end of the island, about 10 miles to the other end, with branches being drawn from the main line along the way. The voltage drops off along the distribution line, with adjustments made at transformers for branch lines.

Adding generating capacity at the far end of the distribution line would affect the voltage drop along the line, requiring changes to be made to the transformer adjustments on the branch lines. If the power being generated at the far end varies to any extent, then the transformer adjustments for the branch lines would need to be changed as the amount of power from the additional generating capacity changed.

An NPS wind turbine could be configured to consume reactive power to offset the voltage-drop impact of the real power it fed to the distribution line. By increasing the reactive power draw along the line to support the turbine’s reactive power consumption, the apparent power being transmitted would stay high, maintaining a voltage-drop profile similar to the situation without new generating capacity.

HOW NORTHERN POWER SUPPORTS EACH PROJECT

Northern Power’s NPS 100 and NPS 60 are the premier wind turbines for use in applications where power quality is an issue. Our knowledgeable and experienced staff can help you with the following activities.

- During project development, we can help you estimate the effect of reactive power compensation from the NPS 100 or NPS 60 on your environment.
- During engineering, we can support your electrical design engineering team in their overall system design.
- During construction, we can provide logistics support to your construction crews to ensure that our equipment gets packaged appropriately to the needs of the site. We provide training for installers and on-site installation support to ensure quality installation. We also provide commissioning services to ensure safe startup and operation and to guarantee that the reactive power compensation behavior of the turbine is as expected.
- To support continuing operations, we can provide 24/7 turbine monitoring. We provide training services for maintenance technicians both for annual service calls and for front-line troubleshooting.