

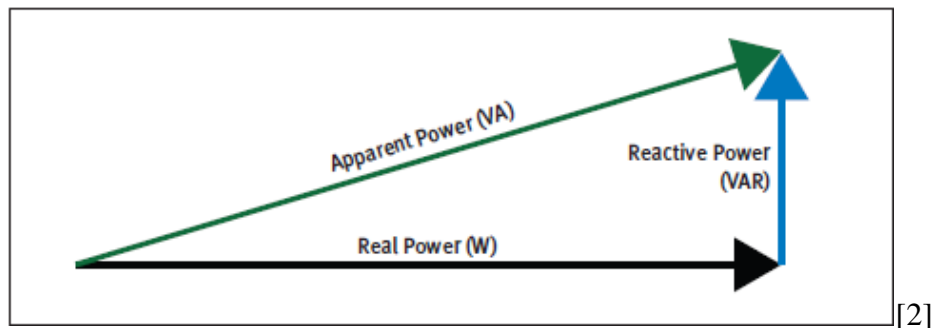


Americans for a Clean Energy Grid

Integrated Volt-VAR Regulation/Optimization

Before diving into integrated volt-VAR optimization, it is important to understand the concept of VAR. VAR stands for Volt-Amps Reactive and is the measuring unit for reactive power, which is created by energizing transformers and powering motors, pumps, air conditioners, and other similar devices [2]. These electric appliances have large coils and magnets inside them and require both real and reactive currents to operate. Real current does the actual work done by the motor, whereas reactive current enables the production of magnetic fields in inductors [2]. Both real and reactive currents flow through transformers and feeders (a circuit that carries a large block of power from the service equipment to some point where the block power is broken into smaller circuits). By contrast, electric loads such as incandescent bulbs are purely resistive and only require real current to operate.

The real work done by real current is measured in Watts (W) while the reactive power from reactive current is measured in Volt-Amps Reactive (VAR). Real and reactive power combined is known as apparent power, which is measured in Volt-Amps (VA), shown in the figure below:



Although utility companies must supply both real and reactive power, they only charge consumers for real power. To cover the cost of unbillable reactive power, power factor penalties

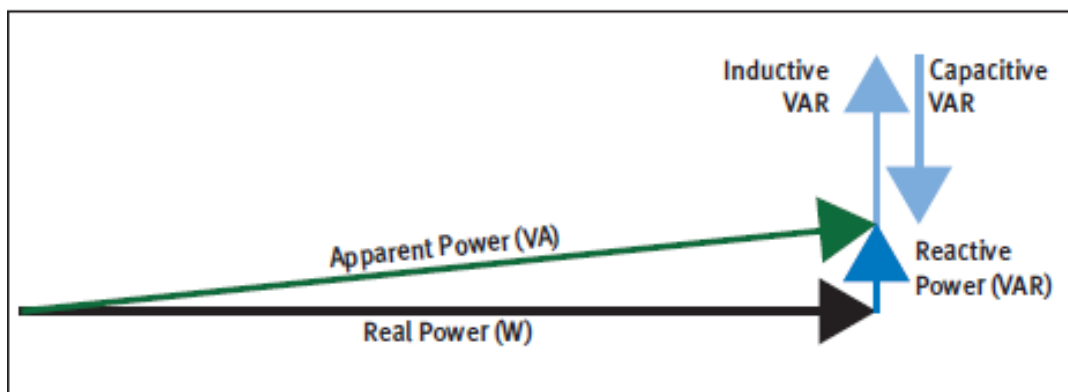
are charged by generation companies to utility companies, and by utility companies to certain consumers [2]. Power factor penalties are proportional to the amount of reactive power supplied by generation companies. Power factor refers to the ratio of real power divided by apparent power. For example, a power factor of 0.95 tells us that 95% of supplied power is real power and the rest is reactive. Reactive current does not do any real work, but it uses the current carrying capacity of transmission lines and contributes to power losses [6]. Therefore, utility companies try to minimize the amount of reactive current flowing through transmission lines.

Voltage Regulation: Voltage control is essential for utility companies to ensure that voltage being supplied to consumers is within an acceptable range. On a 120 volt (V) base, the desirable service range is from 114 V to 126 V, and the acceptable range is from 110 V to 126 V [3]. Any deviations from this acceptable range can damage the appliances and electric equipment of consumers. Utility companies use Load Tap Changer (LTC) transformers and LTC voltage regulators to control the amplitude of voltage being supplied to consumers [1]. LTC transformers and voltage regulators can increase and decrease the amplitude of voltage to ensure that consumers receive voltage within the acceptable range.

VAR Regulation: To avoid power factor penalties, utility companies use VAR regulation methods to ensure that the power factor ratio remains close to 1, meaning nearly all real power. Motors and other similar inductive loads increase the reactive power flowing through the grid, which pushes the power factor down from 1. Utility companies use capacitor banks to counter inductive loads (inductive motors, pumps, air conditioners etc.) and reduce the amount of reactive power flowing through transmission lines, as can be seen in the figure below [2]:

Integrated Volt-VAR Regulation/Optimization (VVO): Reactive power flow through transmission lines can have a positive or negative impact on voltage amplitude [3]. Experience has proven that overall costs and performance of power system operation can be best managed if voltage control and VAR control are well-integrated [3]. The availability and deployment of microprocessor-based controls, advanced communications technology, sophisticated computer algorithms, sensors, and advanced metering infrastructure (AMI) have made it easier to integrate voltage control alongside VAR control.

Traditionally, each voltage and VAR control device installed on a feeder is controlled independently; this technique does not account for the impact of controlling a single



voltage/VAR device on neighboring devices in the system and only works well at a local level [6]. Localized and independent control of voltage and VAR can have suboptimal effects on a broader level – for example, adjusting VAR at one point can negatively impact the voltage level at a different point [6]. Integrated volt-VAR regulation uses a two-way communications network to coordinate the voltage/VAR control actions amongst various control devices, and regulates

VAR without affecting the voltage [6]. Integrated volt-VAR regulation offers a number of benefits including higher visibility into system operating parameters, reduced emissions of greenhouse gases and increased transmission efficiency:

- **Higher visibility into system operating parameters:** Volt-VAR optimization (VVO) systems allow grid operators to closely monitor and control the voltage and power factor of the grid. With increasing integration of renewable and distributed energy into the existing grid, voltage and power factor values tend to change more frequently and rapidly. It is imperative that the grid operators are aware of the trends in voltage and power factor values in order to take precautionary measures to avoid not only power factor penalties, but also grid failures. [3]
- **Reduced emissions of greenhouse gases:** VVO systems allow utility companies to enforce Conservation Voltage Reduction (CVR) programs. CVR programs reduce peak demand, which reduces the amount of electricity required by peaker plants—generally gas turbines or newer combined-cycle gas turbines. Reduction in generation from these fossil-fuel power plants also reduces their greenhouse gas emissions.
- **Increased transmission efficiency:** In the case of a vertically integrated utility, VVO systems allow the utility to control the power factor and reduce transmission losses. Therefore, VVO systems increase the transmission efficiency of the existing grid by allowing grid operators to reduce transmission losses through VAR optimization. More efficient grid operations provide grid operators with greater flexibility to address grid resilience. Again, if transmission losses are reduced, less electricity needs to be generated from fossil-fuel power plants, and fewer greenhouse gases are emitted. [3]

The Smart Grid Investment Grant (SGIC) program under the American Recovery and Reinvestment Act of 2009 (ARRA) funded the installation of 26 volt-VAR optimization systems [5]. Initial results from these projects were that 31 feeders experienced line loss reductions in the range of 0-5%, and five feeders experienced line loss reductions greater than 5% [5]. Additionally, CVR programs enabled by VVO systems reduced peak power demand by 1-2.5% [5]. Duke Energy Progress of North Carolina has also installed VVO systems at 315 substations, while Duke Energy Florida has installed VVO systems at 262 of its substations [4].

Integrated volt-VAR optimization systems provide a cost-effective way of reducing line losses and avoiding power factor penalties. Most utility companies can install VVO systems with minor changes or upgrades and can integrate the VVO systems in existing Supervisory Control and Data Acquisition (SCADA) systems [2]. Often, these programs can pay for themselves in a relatively short period of time [2]. As utility companies push towards grid resilience and greater integration of renewable and distributed energy, VVO systems offer the opportunity to better monitor system operating parameters and improve transmission efficiency.

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