TCU Department of Engineering

COLLEGE OF SCIENCE ENGINEERING

The Importance of Power Quality

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SciCom Let's Talk Science

The use of capacitors to improve power factor in an electrical system was investigated. Power factor is a measure of the efficiency with which electrical power is used, and is influenced by the reactive power of inductive loads. By introducing a capacitor in parallel with the load, the team can counterbalance the reactive power and improve power factor. A capacitor-based power factor correction circuit was designed and tested, and its effectiveness in reducing reactive power was measured and power factor was improved. The results demonstrate the potential for capacitive power factor correction to increase energy efficiency in electrical systems.

Introduction

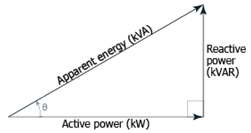
Power quality is the compatibility between the voltage that comes out of an electrical outlet and the power load that is being plugged into it. A power load (also known as electrical load) is any electrical device that needs to be plugged into a larger power grid to run, such as televisions and microwaves. This project's focus is how power factor correction improves overall power quality.

Power Factor and Power Triangle

Power Factor is one of the most important parameter influencing power quality. It is the ratio of real power to apparent power.

A high-power factor indicates that energy is being used efficiently, whereas a low power factor shows that more energy is being wasted.

When improving power factor, the goal is to increase the value to as close to 1 as possible.



$$\text{Power factor} = \cos\theta = \frac{\text{Active power (kW)}}{\text{Apparent energy (kVA)}}$$

The Power Triangle

Power Quality

Power quality refers to the characteristics of electrical power that affect the operation of electrical equipment. There are various methods of improving power quality, such as installing power filters or surge suppressors and Voltage regulation devices. Power factor correction equipment through capacitors can improve the efficiency of electrical systems by reducing reactive power and improving the power factor. In addition, proper grounding and shielding can improve the overall quality of the electrical power supply.

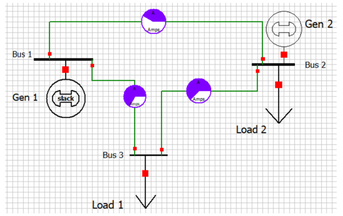
Benefits from improving Power Factor

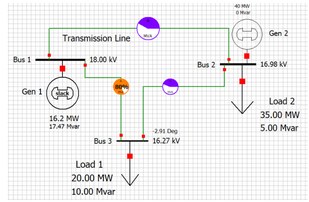
- Increased energy efficiency
- Lower energy costs
- Assist stabilize the voltage and eliminate voltage fluctuations
- Extending the lifespan of electrical equipment life and preventing damage
- Limit the amount of reactive power in the system
- Lowering energy consumption and electricity expenditures
- Allows for increased capacity on transmission and distribution lines because less apparent power (S) needs to flow for the same real power (P)

Power System Improvement

PowerWorld Simulation

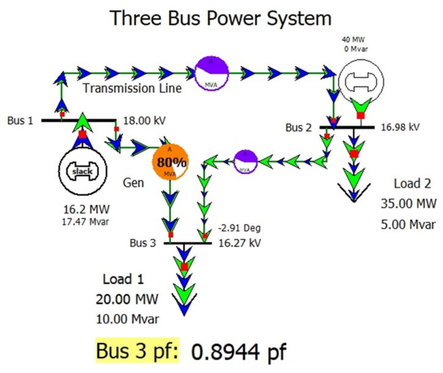
PowerWorld simulation is a power flow analysis software for high voltage power systems that allows the user to visualize electrical power flow. The software is capable of modelling an entire network of components including generators, buses, loads, shunt branches, transformers, and transmission lines. The model uses a one-line circuit diagram to represent three phase power and is solved using the Newton-Raphson iteration method. Some of the other functions PowerWorld is capable of include load scheduling/forecasting, generator cost curves, and remote bus voltage control.

1. 

2. 

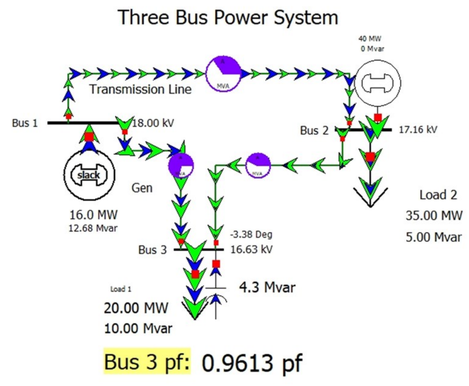
1. This is edit mode, where the user adds network components and draws transmission lines between them.
2. After adding values to the components, the user can add labels to display the system results.

System without capacitor



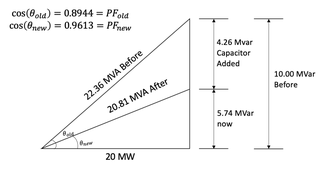
This is the system before a shunt capacitor is added. The power factor is 0.89, one of the transmission lines is close to being overloaded, and the slack generator must produce 16.2 MW and 17.47 Mvar.

System with capacitor



This is the system after the shunt capacitor is placed in parallel with load. The power factor increased to 0.96, the lines are carrying a safe amount of current, and the slack generator is producing 16.0 MW and 12.68 Mvar.

The Power Triangle of The System



The equation to calculate the capacitance necessary to achieve a specific power factor

$$Q_{cap}\ [kVar] = P_{load}\left[\tan\left(cos^{-1}PF_{old}\right) - \tan\left(cos^{-1}PF_{new}\right)\right]$$

$$Q_{cap} = \frac{1}{2\pi f_C}$$

Core Technology

Electrical loads such as air conditioning, refrigeration, and LED lighting have inherent reactive qualities, also known as inductance. Inductance causes current to lag voltage in the load. Laggings means there are times when the current and voltage have different signs so negative power generated, in other words, power is fed back into the power supply.

Shunt Capacitors:

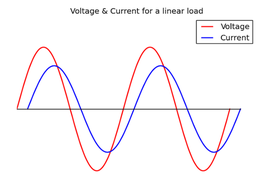
- Increase power factor

-Capacitors in parallel with the load act as reactive current generators which reduces total amount of current the load draws from the utilities companies

- Provide leading current to compensate lagging current of inductive load

- Improve bus voltage

A graph of current lagging voltage in time domain



Results

- The overload power delivered to Bus 2 was decreased from 80%MVA to around 65% MVA, which helped the system being more stable
- The power factor at Bus 3 was increased from 0.8944pf to 0.9613pf.
- The voltage at both Load 1 and Load 2 were increased from 16.27kV and 16.98kV to 16.63kV and 17.16kV respectively.

Conclusion

In conclusion, adding the capacitor helps improve the system and provide benefits. Shunt capacitors support voltage and reduce reactive current in the overall system. By supplying reactive power next to the load, it allows transmission lines to supply power elsewhere. In other words, there will be less stress on the lines for the same amount of usable power supplied (P) to the load.

Acknowledgement and References

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