Dynamic reactive power compensation of container cranes

Information from Impact Energy

Overall requirements for the reactive power compensation of a container crane vary based on overall crane size and container weights. These dynamically changing requirements affect not only the efficiency of the crane, but also put a significant strain on the local electrical distribution system.

Harbour cranes exhibit the characteristics of an asynchronous motor. During normal lifting and trolleying modes, power is consumed by the motors. When the motors are lowering containers, they utilise dynamic braking and produce active power which is exported to the local electrical distribution system. However, harbour cranes consume reactive energy (kvar) during all load conditions. The large reactive energy demand causes voltage stability issues (flicker), decreased electrical service utilisation and reduced crane efficiency.

The only complete answer to the dynamic reactive energy consumption of harbour cranes is real-time compensation. This solution requires four-quadrant measurement capability as well as the ability to respond to all reactive energy requirements in less than one network cycle (20 ms at 50 Hz).

Typical crane power factor system

As a standard design, container cranes are fitted with no-load capacitor systems, typically rated at less than 25% of the reactive energy requirements of the crane at peak load. Fig. 1 illustrates an operating measurement of a 80-ton container crane with 300 kVAR fixed capacitors installed.

The peak reactive power requirements are still ~1500 kvar (500/phase), and the voltage drop caused by the large reactive energy demand is > 10%. Further, peak currents were well above 2000 A.

Typical container crane power profile

A typical container crane will both consume and produce active power (kW). Consumption takes place during lifting a container and trolleying. Due to dynamic braking present, when containers are lowered, the crane produces kW and exports power to the electrical distribution system. However, the motors consume reactive power (kvar) during all load conditions. Fig. 2 graphically depicts the power profile of a typical container crane.

During the cross-over between lifting and lowering, the kW load of the motor(s) crosses the zero-axis. At this time, there is a purely inductive (kvar) load, then transitions to – kW and + kvar. This phenomenon causes significant problems for most power factor correction systems, as negative kW readings cause operating errors. The solution is in the form of a four-quadrant controller, which can detect (+/-) kW and (+/-) kvar. Only with such a controller can accurate compensation be attained.

Voltage drop

Voltage drop can cause significant operating problems for motors and drives. Many times the voltage drop impacts motor efficiency and performance,
however it can also cause the motor or drive to shut down. The result of supply voltage drop is increased cycle time to reset motors and drives. Fig. 3 shows an example of a harbour crane with 2 x 300 kW DC hoist motors and a 150 kW DC trolley motor without dynamic compensation. Voltage drops of over 10% are quite common in container crane applications.

Current: Spikes, harmonics and their impact

Due to the very large and dynamic reactive energy requirements of a container crane, large current spikes are an inherent characteristic in these machines. Many times, the peak currents are either at the limits of the protective devices (breakers/fuses) or exceed their ratings. The result of such high currents is premature fuse failure or nuisance tripping of the main circuit breaker(s), causing downtime and lost revenues.

A further problem associated with current is harmonics. Most container crane motors employ some type of drive, whose function(s) can range from changing AC to DC to vary the speed of a motor depending on its load. High harmonic levels can cause many different power quality issues that impact the overall maintenance and life of drives, motors and electrical infrastructure.

Real-time dynamic compensation – the results

The impact of real-time, dynamic reactive compensation on container crane performance and electrical system efficiency is significant. In Fig. 4, a dynamic compensation system was installed to minimise voltage drop and reduce peak currents to avoid nuisance circuit breaker trips and improve the efficiency of the crane motors. As evidenced in the graph, nominal voltage levels were raised to normal supply values, voltage drop was reduced by nearly 60% and peak currents were reduced by over 50%.

Fig. 5 depicts the dramatic impact on the reactive energy requirements of the crane motors in this same application. They are all but eliminated, minimised to 50% of the smallest step size of the compensation system – a resultant drop of almost 90%.

Conclusion

Container ports throughout the world are realising the benefits of real-time reactive power compensation. By installing Elspec’s equaliser system, container ports around the world have improved voltage stability, lowered maintenance costs, increased service utilisation of the port’s electrical system, achieved harmonic current reductions and decreased power system losses. Further, many container crane operators have benefited from increased hoist acceleration and final trolleying speed without the nuisance trips resulting from over-current and under-voltage.

Contact Wayne Bromfield, Impact Energy, Tel 031 201-7191, wayne@impactenergy.co.za

Fig. 5: Reduction of reactive energy demand.