Journal of Positive School Psychology
2022, Vol. 6, No. 4, 1088-1091 http://journalppw.com

Analysis of Capacitor Switching Inrush Current

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Abstract

The industrial sector is trying to make the system faster. For system efficiency and regulation, new technologies play an essential role. The average industry possesses 80% of inductive load and has a lagging power factor. The use of power electronic devices in the system causes power quality disturbances. Nowadays, the electricity demand is increasing, and it is necessary to supply/serve power with good quality. The inductive load is responsible for reducing the power factor. Power factor improvement capacitors are used in the system. But during the switching of capacitors, current transients are produced in the design and lead to damage to capacitor bank and power electronic devices.

This paper proposed a design and case study of the inrush current transients and phenomena using MATLAB simulation.

Keywords: Capacitor switching, transient/inrush current, current limiting reactor, Power Quality

1. Introduction:

The demand for electricity increases day by day, and it is challenging to serve generated power more effectively and efficiently with low losses. In other words, it is essential to improve power quality at the consumer end. The capacitor plays a vital role in power quality improvement. For smooth operation of the power system, it is necessary to connect or disconnect the capacitor bank by power quality issues; this is possible with automation only.

We cannot avoid the role of power electronics devices responsible for the fast operation of the system. When this operation occurs or when the capacitor bank comes in the process, it creates switching transients and may lead to failure/damage of highly sensible devices at the consumer end. So to limit these transients and avoid damage to power electronics/realistic devices, reactor technology is proposed in this paper by MATLAB simulation. [1][2]

2. Capacitor Bank Switching Transients:

At switching on a capacitor bank, the voltage that appears at the terminals is zero. The capacitor voltage is not changed immediately. Activation of a capacitor bank affects the system voltage, and instantaneously voltage is dropped toward zero to attempt fast voltage recovery. Finally, a fluctuating voltage overlap/affects the system frequency. The observed voltage is two times larger than the regular peak voltage during the immediate activation or under abnormal conditions. It means that the voltage peak value is associated with instantaneous system voltage. A current is four to six times greater than the average current.[3][4]

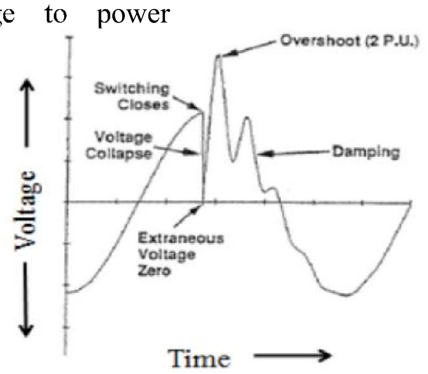

Fig.1. Switching Transients

The current drawn by the electric equipment during energization is called the Inrush current. This current passes into the circuit; this current attempts the peak value and is greater than the average operating current value. Then the current value decreases gradually and sets up to its average value. If the equipment is operated with an inrush current, it may be overheated, and breakdown occurs. This failure depends on the peak value of inrush current and duration.[5]

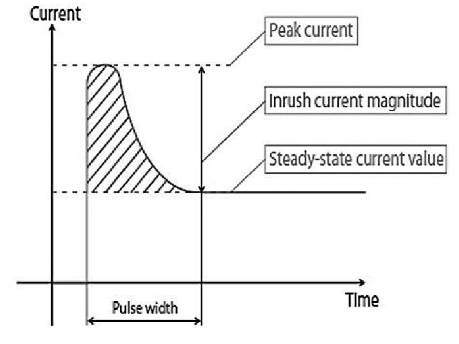

Fig.2. Inrush current production

3. Reactor:

In AC systems, The opposition to the current flow is called the reactance. The reactor is a coil placed between two points to insert a rated impedance in the connected line to reduce inrush current. The I^2R losses take place in the reactor. There are two types of reactor.

1. **Dry/Air-Core reactor:** The windings of these reactors are wound with foils of copper or aluminum and supported by the mechanical structure. This structure provides isolation from ground potential. In these reactors, the winding is designed for RMS current and has a large number of turns.
2. **Iron-Core reactor:** The windings of these reactors usually consist of the copper winding wound on the iron core. The winding is designed for harmonic current in these reactors and has fewer turns than a dry-type reactor.

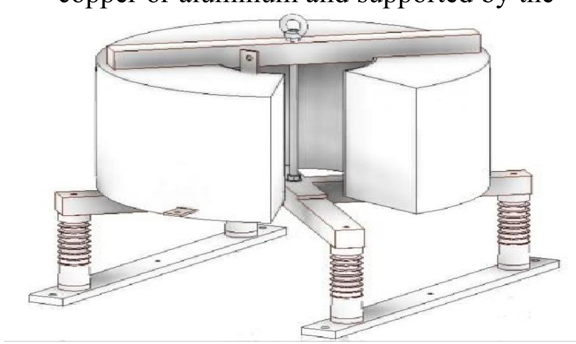

Fig.3. Dry/Air-Core reactor

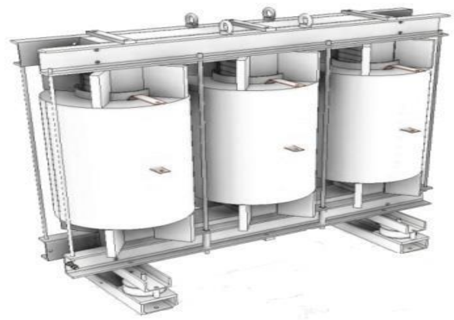

Fig.4. Iron-Core reactor

4. Case Study:

The proposed system operated with a transformer of 11kV/420V, 25MVA connected to the three phases static load having active power 20 kW and reactive power 10 kVAR. In a MATLAB simulation module, a 0.89 power factor was observed with this consideration.

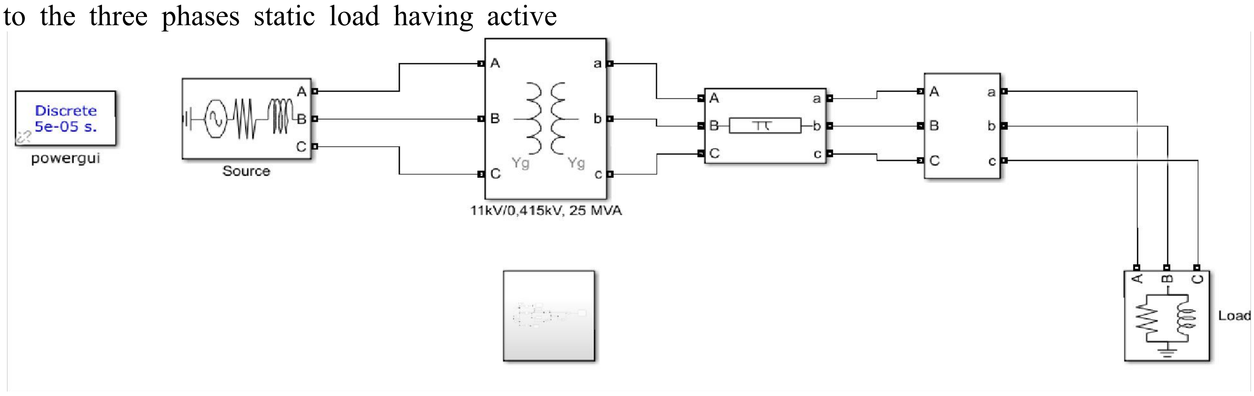

Fig.5. Simulation of the proposed system

To increase the power factor up to 0.95 capacitor bank was installed. With the installation of the capacitor bank, switching transients are produced, such as inrush current. This current may damage the capacitor bank or sensitive devices in the system.

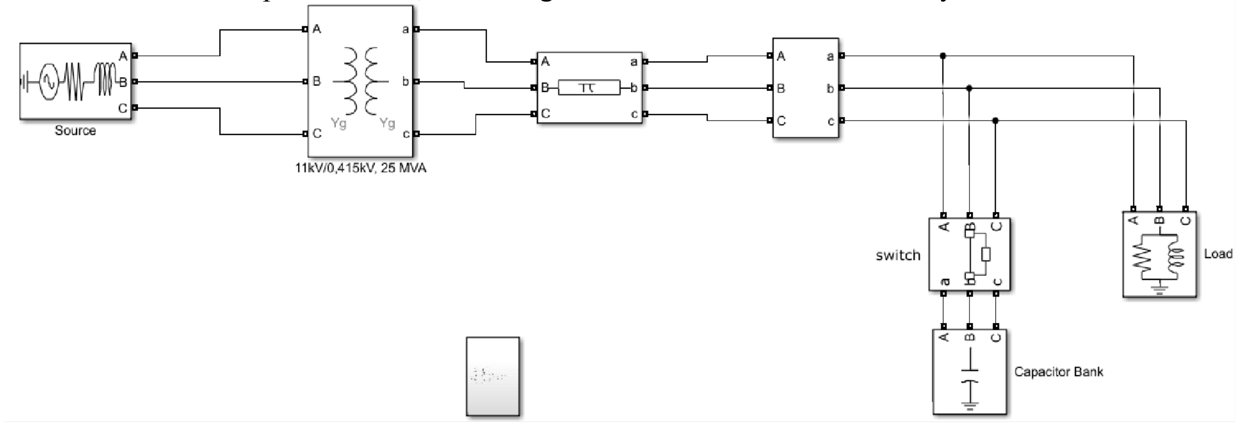

Fig.6. Simulation of the insertion of capacitor banks

Fig.6 shows the simulation of capacitor switching without an inrush current limiting reactor. To maintain the power factor at 0.95 capacitor bank is inserted. The following result was observed while switching of capacitor bank take place.

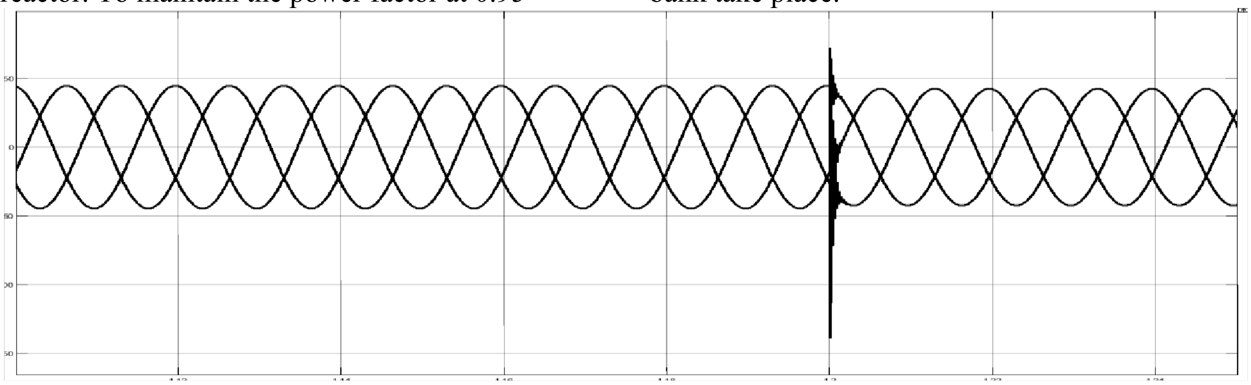

Fig.7. Simulation results of production of inrush current due to capacitor switching

The major disadvantage is it produces the inrush current, which is harmful to the capacitor bank and other nearby connected equipment. Many industrial loads are nonlinear, which aims to low power factor. The industry should pay the penalty to the electricity authority utility for low power factor. With the installation of the capacitor bank, the power factor is improved.

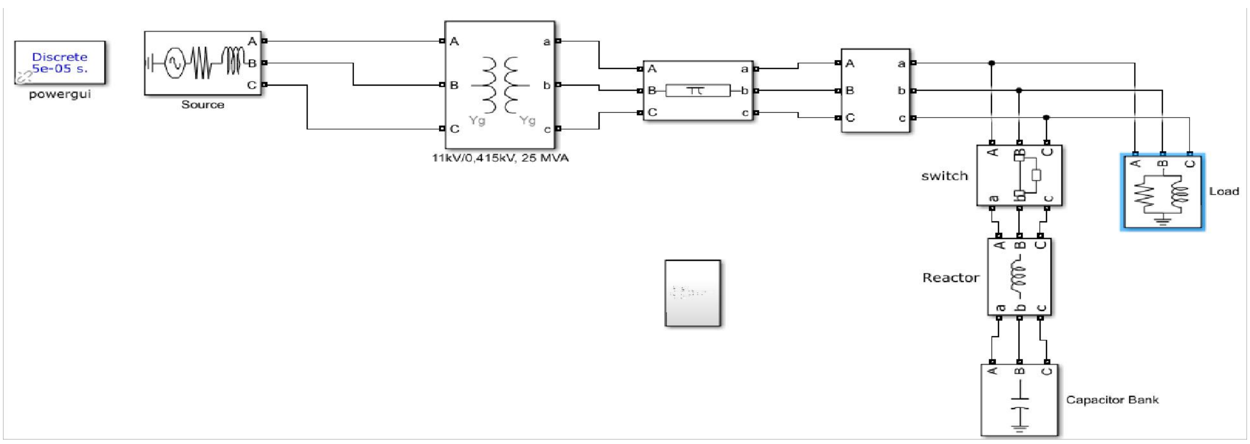

Fig.8. Simulation of the insertion of the reactor module

Fig.8 shows the Matlab simulation of capacitor switching phenomenon with an inrush current limiting reactor. The inrush current limiting reactor reduces the switching transients of the capacitor bank and protects the capacitor bank. It also improves the reliability and efficiency

of the system. The reactor has a coil with many turns, and the ohmic resistance value is much greater. The short circuit's current causes damage to the equipment of the power system. Therefore, Inrush current is limited by reactors.

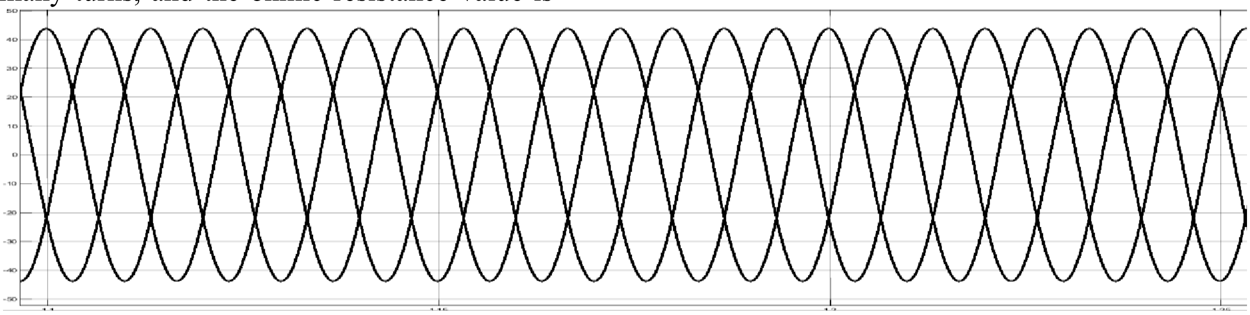

Fig.9. Simulation results of mitigation of inrush current with capacitor and reactor module

Fig.9 shows the result of the reduction of inrush current using the reactor. The inrush current magnitude and frequency were reduced. Also, it reduced the extent of the inrush current and gave the sinusoidal wave. It also improves the system efficiency.

Conclusion:

At the consumer end, the capacitor bank was inserted to minimize power loss and improve power quality. During the switching operation of the capacitor bank, the generated transients are suppressed by introducing a reactor or resistor into the system. The current limiting reactor is one of the best solutions to control switching transients during capacitor bank operation. Meanwhile, it maintains the system's stability. In this paper, the economic growth and the efficient way of capacitor bank utilization are considered.

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