Outrush Current Mitigation Using Iron Core Reactor

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ABSTRACT

It is now a challenge for the industry to run its plant effectively and economically. The reactive power compensation is one of the essential parts of the industrial sector to run their plant at a low cost. The iron-core reactors are one of the solutions to meet reactive power demand. The industrial sector is fast-growing, and automation has been introduced to obtain effective mass production from the plant. The introduction of automation and electric drives causes the nonlinear behavior of the power system. As a result of this, the electricity bill of the plant increases. Renewable energy sources are tremendously used in the power sector to meet the electricity demand day by day, and it is difficult to maintain a healthy power system. The capacitor banks are used to compensate for reactive power demand. These banks operate automatically To overcome the reactive power issues. The switching of the bank produces a current disturbance in the system and may cause the burning of the insulation or system malfunction. This paper introduces the iron-core reactor, which reduces the magnitude of inrush current and protects the end user's power electronics devices or capacitor bank. This paper presents the design of the iron-core reactor and suppression of inrush current using MATLAB simulation.

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

1. Introduction:

Electrical drives are used in various steel industries for different applications, as they operate on different operation modes. Multiple modes of operation of electric drives or to satisfy the load demand, these types of equipment draw maximum current from the supply. This current occurs in the system for a few milliseconds and creates disturbances During its operative modes, producing the power system harmonics.

The two conducting plates are separated by a dielectric medium called a capacitor. The capacitor is a device that prevents the change in system voltage. It stores the electrical energy in the form of an electric charge. Capacitor banks fulfill the need for reactive power, but their introduction results in the generation of inrush current. The current limiting reactors can limit this inrush current. The iron-core reactor is one of the best techniques to reduce the inrush current. The iron-core reactor module using MATLAB simulation is proposed in this paper.

2. Capacitor bank in the steel industry:

Steel industries have a nonlinear load and a deficiency of reactive power provided by the capacitor bank. Capacitor banks play a vital role in the steel industries for power factor improvement. The activation and deactivation of the banks operate automatically. This function depends on the loading condition of the capacitor bank. The inrush current generation occurs during the capacitor bank's activation and injecting the reactive power into the system. And its value is 4 to 5 times the rated current. Protecting capacitor banks and sensitive devices of the power system is crucial. Inserting current limiting reactors in series with capacitor bank operation prevents this inrush current. The peak value of the inrush current and its duration decides the failure of the capacitor bank. Therefore, several factors must be considered while injecting a reactive power through the capacitor bank.[1,2]

3. Current Limiting Reactor:

A current limiting reactor is a copper coil with high inductive reactance and ohmic resistance. Its functions are as follows,

- To limit short circuit current.
- To restrict the effects of short circuits to the faulty section.
- To suppress voltage magnitude due to fault.
- To restrict the current within the permissible limit.

These reactors are placed at the coupling of the capacitor bank and system to limit the severity of outrushing current from the capacitor bank. There are two types of current limiting reactors.

(A) Air-core reactor
(B) Iron core reactor

4. Iron-Core Reactor:

Iron core reactors are made with a core material having high permeability. The winding is wound around the core. The gap between them should withstand the potential difference. The iron-core reactor is a winding formed by conductors of aluminum or copper. It has a sophisticated isolation system. The winding construction and the number of turns decide the inductance value. It has a more accessible isolation system and is designed by considering the harmonic current rating. Two types of losses occur in an iron core reactor: winding loss and core loss. The harmonic spectrum of the load current will define the loss within the core of the iron-core reactor.

With proper insulation, we can avoid eddy current loss in mechanical structure. In the air-core reactors, the losses occur only in the winding. Its value depends on the RMS value of current. Fig. 1 shows a schematic diagram of the iron-core reactor.[3]

Fig.1. Iron-core reactor

5.

6. Case Study:

The proposed system operated with a transformer of 11kV/415V, 25MVA connected to the three-phase induction machine with the active power of 20 kW and reactive power of 10kVAR In a MATLAB simulation module. 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 outrush current. This current may be responsible for damaging the system's capacitor bank or sensitive devices.

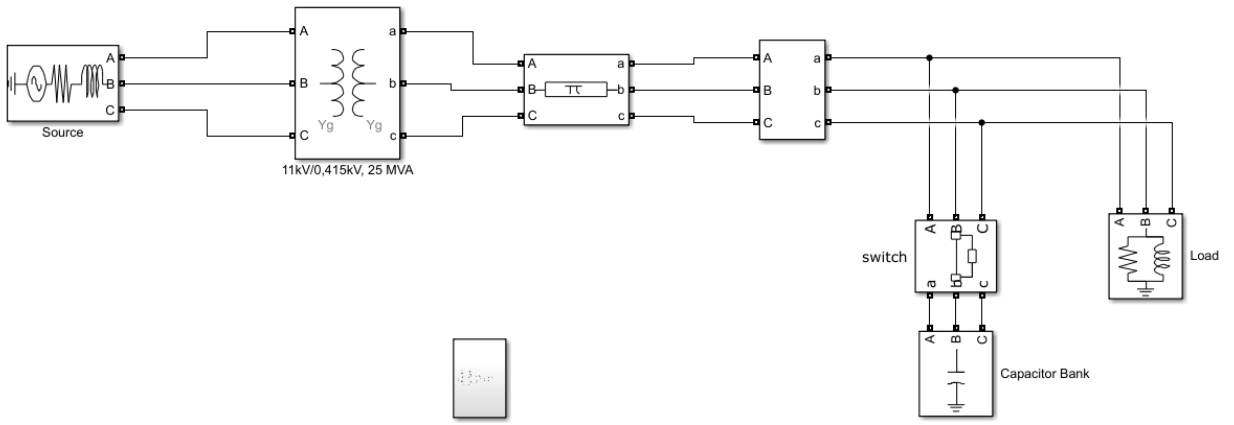

Fig.2. Simulation of the insertion of capacitor banks

Fig.2 shows the simulation of capacitor switching without an inrush current limiting reactor. To maintain the power factor, a capacitor bank is inserted. The following result was observed while switching of capacitor bank took place.

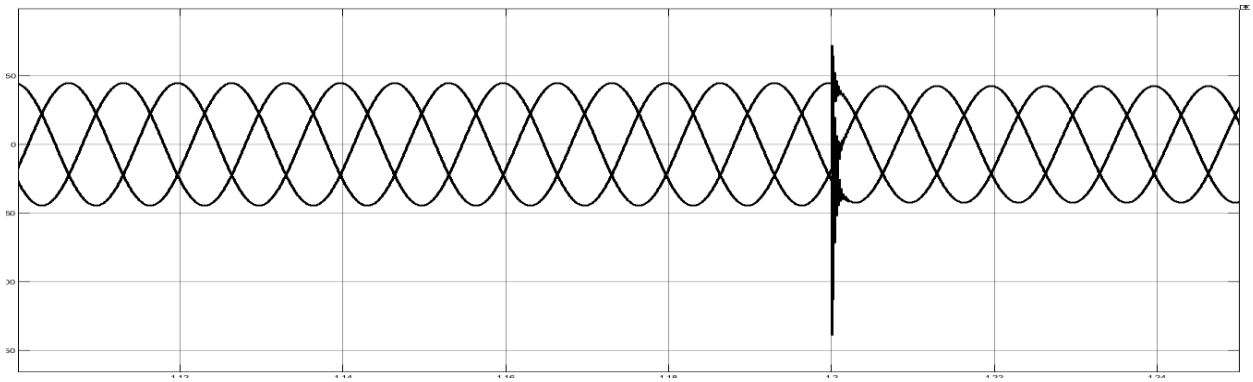

Fig.3. Simulation results of production of outrush current due to capacitor switching

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 gets improved.

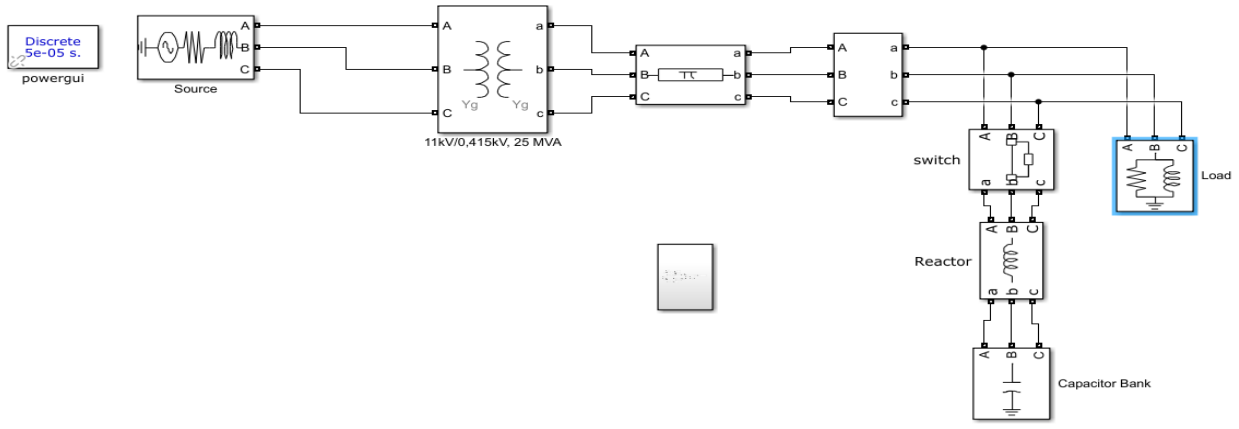

Fig.4. Simulation of the insertion of the reactor module

Fig.4 shows the Matlab simulation of the 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, outrush current is limited by iron-core reactors.

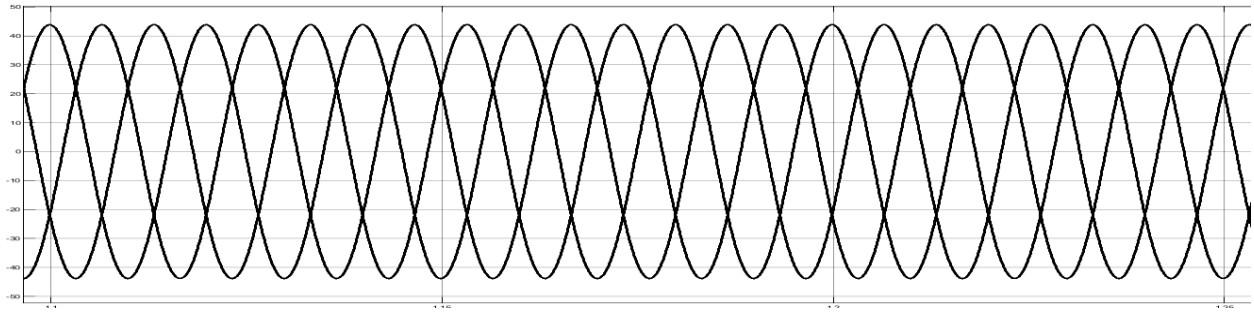

Fig.5. Simulation results of mitigation of inrush current with capacitor and iron-core reactor module

Fig.5 shows the result of the reduction of inrush current using an iron-core 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:

This paper presents an efficient way to control inrush current. The capacitor bank injects reactive power and improves power quality at the user end. During the switching operation of the capacitor bank, the generated transients are minimized by introducing an iron core reactor in series with the capacitor. The iron-core reactor is one of the best solutions to control outrush current during capacitor bank activation. Meanwhile, it improves reliability and stability.

References:

[1] L. V. Teli and H. T. Jadhav, "A Review on Protection of Capacitor in Power Quality Industry," *2018 International Conference on Current Trends towards Converging Technologies (ICCTCT)*, Coimbatore, India, 2018, pp. 1-5, doi: 10.1109/ICCTCT.2018.8550935

[2] V.V.Vashikar, Dr.S.Prakash "Protection of Capacitor Bank Against Switching Transients: An Overview," EAI DOI 10.4108/eai.7-6-2021.

[3] Dr.-Ing. Christian Kaehler, Hans von Mangoldt "Comparison Of Air-Core And Iron-Core Reactors For Medium-Voltage Power-Quality Applications" 2015

[4] M.S.Javadi, A.E. Nedzad, Pierlugi Siano and M.S.khan, "Shunt capacitor placement in radial distribution networks considering switching transient decision-making approach," Elsevier, Electrical Power and Energy Systems 92(2017)167-180.

[5] A. A. Jambukar and M. F. A. R. Satarkar, "Simulation Analysis of Switching of Shunt Capacitor Bank in 220/22 kV Substation," *2018 Second International Conference on Intelligent Computing and Control Systems (ICICCS)*, Madurai, India, 2018, pp. 1554-1559, doi: 10.1109/ICCONS.2018.8663055.

[6] A. Dzionk and R. Małkowski, "Activity coordination of capacitor banks and power transformer controllers in order to reduce power losses in the MV grid," *2016 10th International Conference on Compatibility, Power Electronics and Power Engineering (CPE-POWERING)*, Bydgoszcz, Poland, 2016, pp. 27-32, doi: 10.1109/CPE.2016.7544153.

[7] J. Wang, M. Ibrahim, Z. Gajić and M. M. Saha, "Internal failure detection and protection on capacitor banks," *13th International Conference on Development in Power System Protection 2016 (DPSP)*, Edinburgh, UK, 2016, pp. 1-6, doi: 10.1049/cp.2016.0017.

[8] M. Devi Atluri, B. R. Kumar and U. V. Reddy, "Comparative study of passive transients controlling methods during capacitor bank switching," *2016 International Conference on Signal Processing, Communication, Power and Embedded System (SCOPES)*, Paralakhemundi, 2016, pp. 131-134, doi: 10.1109/SCOPES.2016.7955676

[9] Sekhar, P. Chandra. "A Super Conductor Fault Current Limiter for Grid Connected Wind Energy System." *International Journal of Electrical and Electronics Engineering Research (IJEEER)* 3.3 (2013): 119-126.

[10] Tayade, Rohit D., and S. MOPARI SHRIKANT. "COMPARATIVE ANALYSIS OF INTERLEAVED BOOST CONVERTER AND CUK CONVERTER FOR SOLAR POWERED BLDC MOTOR." *International Journal of Electrical and Electronics Engineering (IJEEE)* 6 (2017): 1-12.

[11] Shekar, KE Ch Vidya, and R. K. Sharma. "Improvement of Power Quality in an a Induction Generator Based Wind Power Generating System Connected to Grid by Using UPFC." *International Journal of Electrical and Electronics Engineering (IJEEE)* 3.3: 1-10.

[12] Jamil, Irfan, Zhao Jinquan, and Rehan Jamil. "Analysis, Design and Implementation of Zero-Current-Switching Resonant Converter DC-DC Buck Converter." *International Journal of Electrical and Electronics Engineering (IJEEE) Vol* 2 (2014): 1-12.

[13] Ehiabhili, John, Chioma Ezeh, and Onyeka Orji. "Single Phase Microcontroller-Based Automatic Changeover Switch." *International Journal of Electronics, Communication & Instrumentation Engineering Research and Development (IJECIERD)* 8.1 (2018): 7-16.

[14] Ashwin, J. S., and N. Manoharan. "Renewable energy based micro-grid system for power quality improvement." *International Journal of Mechanical and Production Engineering Research and Development (IJMPERD)* 8.1 (2018): 883-888.