Australian Journal of Basic and Applied Sciences, 5(5): 296-299, 2011
ISSN 1991-8178

A Novel Approach in Soft Starting of Large Induction Motors

Siamak Masoudi, Majid Amirfakhrian, Mehdi Firouzi Abhari

Abhar Branch, Islamic Azad University, Abhar, Iran.

Abstract: Soft starters have been widely used in fans and pumps drives. It is difficult to start high-power heavy-duty induction motor for traditional soft starter. In this paper a new circuit is proposed in order to mitigate the adverse effects of starting torque transients and high inrush currents of induction motors. The proposed circuit consists of three similar diode-bridges and a single coil that each connects in series with each-phase of induction motor. This circuit has almost no effect in normal operation of induction motors. The simplicity of proposed circuit, easy to build and absence of control circuits are the main attractive points of circuit. The analytical analysis and designing characteristics for DC reactor in proposed circuit are presented. The overall circuit operation in transient and steady state cases are studied in detail. Simulation results are obtained to verify the valuable operation of proposed circuit in soft starting.

Key word: Soft Starter, DC Reactor, Induction Motor

INTRODUCTION

The electric power consumption of AC motor is a great part of the total domestic consumption. So, high efficiency and stability of AC motor can realize energy-saving and cost reducing effectively. Not only AC motor need to be soft-started to lessen current surge and electric fence voltage-drop, but also its speed need to be able to adjusted to improve efficiency. Three-phase asynchronous motors have characteristic of simple structure, lower costs, good mechanical properties, easy operation and maintenance. They are widely used in industrial control and electrical drive system. As a result people raise higher and higher requirements to the start performance. If the induction motor is started directly, its starting current will be up to 5-8 times the rated value, which causes a sharp decline in voltage of the connecting power network, affecting normal operation of other equipments and causing a great impact on the motor, especially on cage-type rotor whose bars and rings would be destroyed enormously. As the development of the power electronics technology, computer control technology and automatic control technology, electronic soft-start controller has appeared (Liang, X. *et al*, 2011). While in generally, the starters on the market only have basic modes such as current-limited and voltage step ramping soft-start. Although it can meet the demands of most kinds of loads, the start state is not optimal (Gui-xi, Jia *et al*, 2010) (Nied, A. *et al*, 2010). Direct online induction machine starts have many disadvantages. Torque pulsations are often large and vary from positive to negative values. These torque transients in a motor shaft are transmitted to the load, resulting in mechanical wear in the motor bearings and load couplings. Therefore, properly controlling the starting currents and torques of induction machines is of great importance in many instances. Additionally, the resulting starting currents are high, especially during the first few cycles of a starting transient. These high currents are endured by the motor and power system, causing the heating of the machine windings (Mark G. *et al*, 2006). Like induction motor (IM) variable speed drives, soft starters are also essential components in every modern IM drives and automation systems (Adel Gastli *et al*, 2005). Numerous attempts have been made on the performance analysis and control techniques of a three-phase IM fed from a thyristorized voltage controller (G. Nath *et al*, 1981) (S. A. Hamed *et al*, 1990). In (W. Deleroi *et al*, 1989), a dynamic function was used for the thyristor triggering angle in the voltage controller proving to be a simple and effective way to improve transient performance. The rate at which the main flux builds up is decreased, and the transient torque is smoothed by employing a proper triggering function. In (G. Zenginobus *et al*, 2001), some control strategies are proposed to eliminate electromagnetic-torque pulsations, both at starting and reclosing, and to keep the line current nearly constant at a preset value over the entire starting period. The proposed current control strategy is composed of successive cosines and constant function segments of thyristor triggering angle. In (G. Zenginobuz *et al*, 2004), the performance of the IM during voltage-controlled soft starting has been optimized by eliminating the supply frequency torque pulsations using a pulsating-torque elimination strategy applied in (W. S. Wood *et al*, 1965) and (I. Cadirci *et al* 1999), by extending it to cover all of the operating conditions of a soft starter, and by

Corresponding Author: Majid Amirfakhrian, Abhar Branch, Islamic Azad University, Abhar, Iran.

keeping the line current constant at the preset value over the entire soft starting period. Thus, in (G. Zenginobus *et al*, 2001) and (G. Zenginobus *et al*, 2001), the technique used to start the IM with soft starter is based on the close-loop control with current limitation.

This paper proposes a new series compensator based circuit for soft starting of IM. This circuit consists of a diode-bridge type DC reactor that connects in series with each phase of transformer. It does not need any control, measurement and gate driving circuits. The power circuit simplicity, reliable operation and almost no effect on normal operation of IM are other advantages of proposed circuit. The theoretical analysis and the effect on voltage quality are presented. The simulation results are obtained to verify the performance of proposed method in transient and steady states.

Power Circuit Topology and Proposed Limiter:

Fig. 1 shows the power circuit arrangement of proposed system.

The proposed circuit is shown with a series connected diode bridge and a DC reactor. By choosing appropriate value for inductor L_d, it is possible to achieve a nearly DC current in DC reactor at steady state operation of motor. Therefore the DC reactor has not significant rule on normal operation of system. When the motor starts the inrush current passes through DC reactor and the voltage drop increases through it that it results in decreasing of inrush current magnitude.

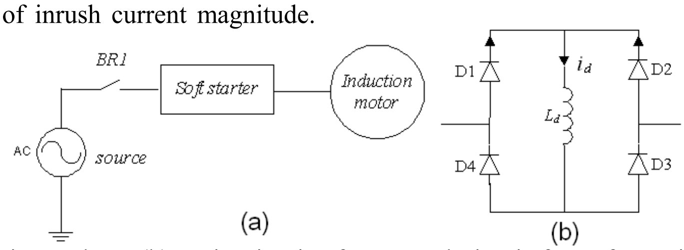

Fig. 1: (a) Power circuit topology (b) main circuit of proposed circuit for soft starting

Circuit Analysis and Simulation Result:

The power circuit topology of Fig. 1 is used for getting the simulation results by PSCAD/EMTDC software. The parameters of simulated power circuit are as follows:

Source data:
Z_s = 0.01+jω 0.001 (Ω)
$v_s(t)$ =10 Sin(314t) (kV)

DC reactor data:
r_d =0.01 (Ω)
L_d = 0.2 (H)
V_{DF} = 3 (V)

Induction motor general data:
Rated voltage=10 (kV)
Rated power=1.2 (MW)
Stator/rotor turns ratio=2.6376
Angular frequency=377 (rad/s)
Mechanical damping=0.01 (pu)

At *t=1 (sec)* induction motor is switched on.

Figs. 2 and 3 show the current of induction motor without and using limiter, respectively. Obviously the secondary side current starts after switching on of induction motor. These figures show the effect of proposed circuit in limiting of start-up current of induction motor.

Fig. 4 shows the mechanical start-up speed of induction motor with and without using limiter. This figure shows that using limiter results in a little increasing of settling time of motor speed that is not considerable in many practical applications. Fig.s 5 and 6 show the electrical torque of induction motor without and using starter, respectively. Comparison of these figures shows a considerable decreasing of oscillating torques of induction motor using the limiter.

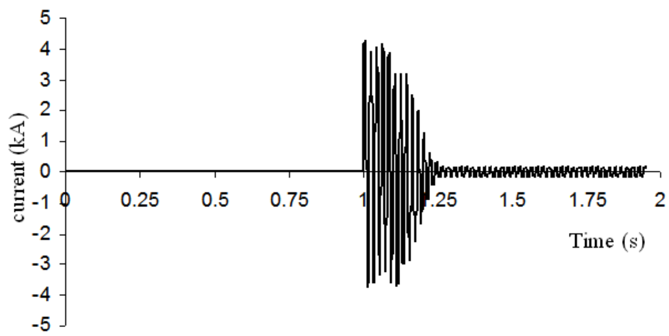

Fig. 2: Current of IM without using starter

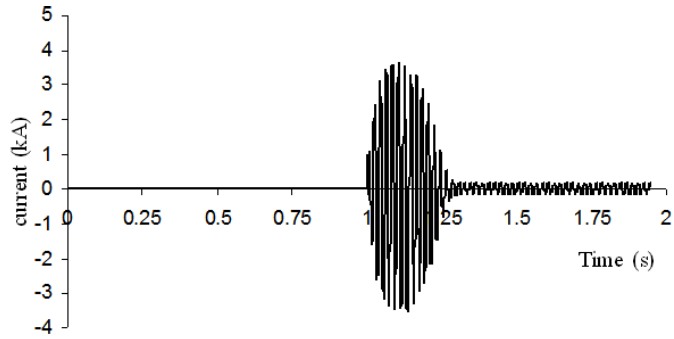

Fig. 3: Current of IM using starter

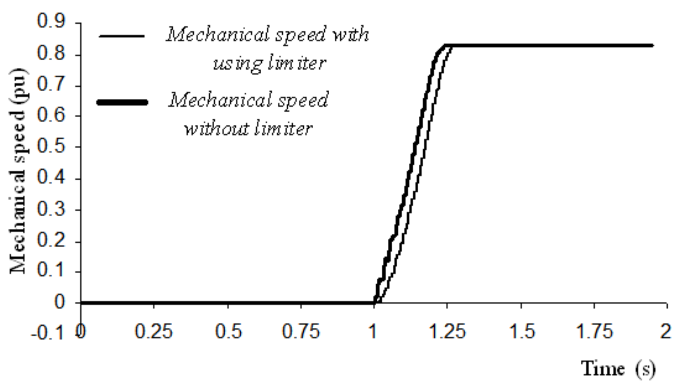

Fig. 4: Mechanical speed of induction motor at starting mode with and without using limiter

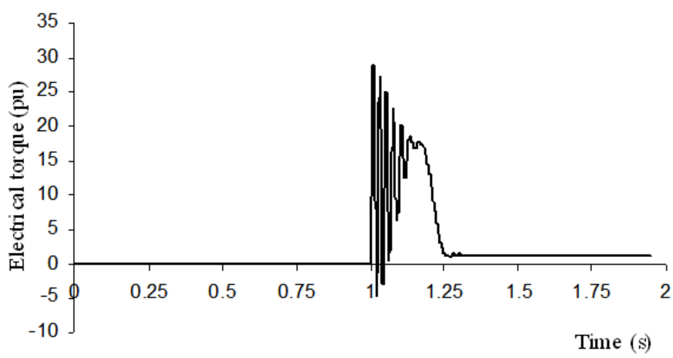

Fig. 5: Electrical torque of induction motor without limiter

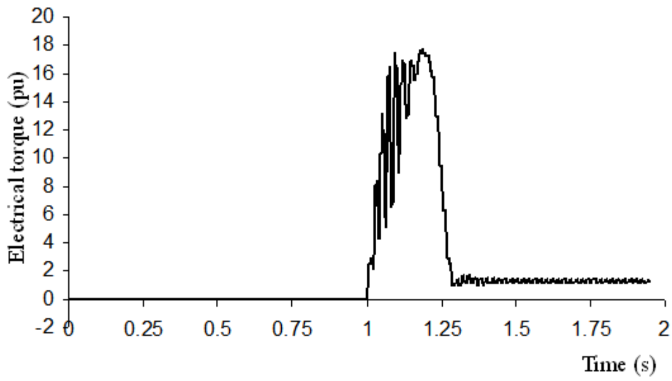

Fig. 6: Electrical torque of induction motor with using limiter.

Conclusion:

In this paper, a novel method for controlling soft-starter induction-motor-drive systems is introduced. Proposed circuit is based on series connected diode-bridge DC reactor. The simulation results show valuable operation of mentioned circuit in softening the start-up current of induction motor.

It seems that the low initial cost and simple technology of proposed circuit would make this kind of limiters as a good alternative for its industrial applications in near future. Furthermore, the study of operation of soft starter element for fault current limiting in short-circuit conditions could be interesting for future researches.

REFERENCES

Adel Gastli, and Mohamed Magdy Ahmed, 2005. ANN-Based Soft Starting of Voltage-Controlled-Fed IM Drive System, IEEE Transaction on Energy Conversion, 20: 497-503.

Nath, G. and G.J. Berg, 1981. Transient analysis of three-phase SCR controlled induction motors," IEEE Trans. Ind. Appl., IA-17: 133-142,

Zenginobus, G., I. Cadirci, M. Ermis and C. Barlak, 2001. Soft-starting of large induction motors at constant current with minimized starting torque pulsations, IEEE Trans. Ind. Appl., 37: 1334-1347.

Zenginobuz, G., I. Cadirci, M. Ermis and C. Barlak, 2004. Performance optimization of induction motors during voltage-controlled soft starting, IEEE Trans. Energy Convers., 19: 278-288.

Gui-xi, Jia, Yuan, Su, 2010. Research on soft starter of asynchronous electromotor based on magnetically controllable reactor, 2nd IEEE International Symposium on Power Electronics for Distributed Generation Systems (PEDG), 549-552.

Cadirci, I., M. Ermis, E. Nalçaci, B. Ertan, and M. Rahman, 1999. A solid state direct-on line starter formedium voltage inductionmotors with minimized current and torque pulsations," IEEE Trans. Energy Convers., 14: 402-412.

Liang, X., O. Ilochonwu, 2011. Induction motor starting in practical industrial applications, IEEE Transaction on Industry Application, 47: 271-280.

Mark, G., Solveson, Behrooz Mirafzal, and Nabeel A.O. Demerdash, 2006. Soft-Started Induction Motor Modeling and Heating Issues for Different Starting Profiles Using a Flux Linkage ABC Frame of Reference, IEEE Transaction on Industry Application, 42: 973-982.

Nied, A., de J. Oliveira, de R. Farias Campos, R.P. Dias, de L.C. Souza Marques, 2010. Soft Starting of Induction Motor With Torque Control, Industry Applications, IEEE Transactions on, 46: 1002-1010.

Hamed, S.A. and B.J. Chalmers, 1990. Analysis of variable-voltage thyristor controlled induction motors, Proc. Inst. Elect. Eng., 137: 184-193.

Deleroi, W., J.B. Woudstra and A.A. Fahirn, 1989. Analysis and application of three-phase induction motor voltage controller with improved transient performance," IEEE Trans. Ind. Appl., 25: 280-286.

Wood, W.S., F. Flynn and A. Shanmugasundaram, 1965. Transient torques in induction motors due to switching of the supply, Proc. Inst. Elect. Eng., 112: 1348-1354.