International Journal of Science and Technology (IJST)
ISSN: 3049-1118, Volume- 2, Issue- 4 (Oct – Dec 2025)

Strategy of Eliminating Contact Bounce Using TRIAC for AC Contactor

Chun Il Kim[1*], Chang Won Kim[2]

[1, 2] Faculty of Electrical Engineering, Kim Chaek University of Technology, Pyongyang, Democratic People's Republic of Korea

Abstract

In the operation of the contactor, contact bounce at closing period is an important factor affecting the performance and electrical life of the contactor. To improve the service life of the contactor by reducing the core impact and contact bounce when the AC contactor is closing, dynamic characteristics of the contactor have been analyzed and various excitation control methods have been invented to reduce the contact bounce. In this paper, a novel DC excitation circuit using TRIAC and a current control strategy based on the phase control to reduce the contact bounce for AC contactor are proposed. The dynamic characteristics of the proposed electromagnetic system are analyzed. Simulation of the proposed circuit and control scheme is implemented by MATLAB/SIMULINK and ADAMS for a 63A AC contactor. The simulation results show that the proposed DC excitation circuit and coil current control scheme can control the current through the contactor coil and the speed of the moving part of the contactor and can reduce the contact bounce during collision of the contactor by phase control to the TRIAC.

Keywords: AC Contactor, Contact bounce, TRIAC, DC Excitation, Phase Control.

1. Introduction

The contact bounce during the closing process of contactor generates an arc phenomenon and it causes the corrosion of contact so that the service life of the contactor is contracted. The current controllers are used to reduce core collisions and contact bounce when the AC contactor is closed, and to improve the service life of the contactor. Also, various control methods have been proposed to reduce the contact bounce throughout analyzing the dynamics of the contactor. The closing process of the AC contactor is a nonlinear and complex dynamic process because of the electromagnetic characteristics.

If the input energy is greater than the energy consumed by the coil and the other, then the excess energy is consumed by the oscillation of the contact and core (Lin Shuyi & Xu Zhihong, 2014). Therefore, many researches have been done on the contact bounce during the closing process.

*Corresponding Author Email: kci781113@star-co.net.kp
Published: 04/10/2025
DOI: https://doi.org/10.70558/IJST.2025.v2.i4.241092

With the continuous development of intelligent control technology, the vibration of the core and the contact can be reduced or eliminated by controlling the dynamic process of the AC contactor by modern control technology based on rational structural design.

The dynamic performance of the closing process can be affected by the control strategy and the phase angle selection used in the controller (Chi Chieh-Tsung, 2009, Hung Chih-Yu, 2011). Moreover, attention is paid to optimizing the dynamic closure of the intelligent AC contactor. There are two issues related to the dynamic performance of the contactor, phase angle selection and dynamic control strategy. These affect the closing characteristics.

To improve the control performance, closed-loop methods have been studied to eliminate contact vibrations of contactors (A. G. Espinosa et al., 2010). Since the closing process of AC contactors is affected by phase angle selection, optimal phase angle determination method and control method to compensate the effect of the closing process at various phase angles have been investigated (Liang Shu et al., 2015), and methods to reduce the contact vibrations by PWM control by feeding the voltage and current of the contact excitation coil have been also investigated (Ming Zong,Lei et al., 2016, Yingyi Liu et al., 2007).

A closed-loop control method to reduce the contact bounce of AC contactors using feedback of the displacement velocity of the core, coil voltage and coil current has also been studied (Lei Qi etal., 2020, J. R. Rida et al., 2009, X. B. Wang et al., 2010).

The motion characteristics of the contact are more direct than the power feedback by targeting the control, and the PI parameters had been controlled in real time based on fuzzy control to reduce the contact bounce.

In this paper, a novel DC excitation circuit using TRIAC and a current control strategy based on the phase control to reduce the contact bounce for AC contactor are proposed. Eliminating or reducing contact vibrations is significant to improve the electrical life and overall performance of the contactor.

2. DC excitation circuit using TRIAC

Contactor operating principle that high DC voltage is applied to make up the contactor and small DC voltage is applied to hold the contactor is usually implemented in the DC excitation of AC contactor.

The circuit is determined according to which semiconductor device performs this operating principle of contactor. In the case using the transistors, the transistor must be placed in the DC link, and a high duty cycle PWM signal is provided at the beginning of the closing to provide a high DC voltage or large DC current, while a low duty cycle is used to provide a low DC voltage or current during the holding period. That is, the semiconductor device must be active during the whole operating time of contactor.

In the case using thyristors, it can be placed in the DC link or in the AC link. When thyristor is placed in DC link, the control angle is small to provide large closing current. While holding contactor, small DC current is needed by increasing the control angle to thyristor. When thyristor is placed in AC link, at closing period, small control angle is used to provide large closing current as when thyristor is placed in DC link. The holding of Contactor can be implemented in two ways. One is to provide a small hold current by increasing the control angle, such as when the thyristor is placed in the DC link, and the other is to provide a small DC current by the capacitor without providing a control signal by connecting the capacitor in parallel to the thyristor.

The thyristor is a unidirectional device. The circuit using thyristor in AC link is complicated by the reason that the two devices must be reversely parallel connected.

TRIAC can be considered as reverse-parallel of two thyristors. The gate control circuit of TRIAC has the advantages of simple and stable performance, which makes them applicable to voltage control of the contactless AC switching, temperature controller and speed control of AC motors, etc.

The DC excitation circuit using TRIAC for AC contactor is showed in Figure 1.

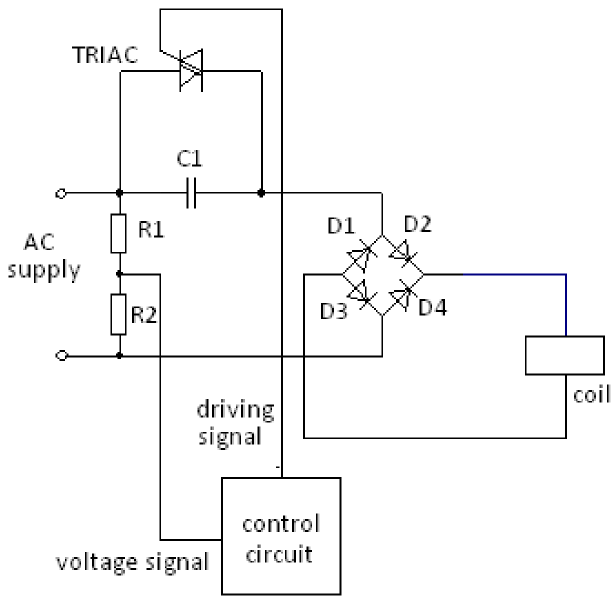

Figure 1. DC excitation circuit of AC contactor using TRIAC

The operating principle of the circuit is as follows.

When an AC power is applied to the power input terminal, the control unit generates a drive signal to ensure the contact bounce is minimized and provides the closing current of contactor. That is, the control circuit detects the voltage zero and generates a triangular wave synchronizing with the supply voltage. At the same time, the excitation current characteristic signal is generated to drive the TRIAC by changing the control angle gradually and significantly in each half cycle to fit the current curve to minimize the contact bounce.

After the closing period, the control circuit does not output the drive signal. The contactor is completely closed and then the current flowing through the capacitor keeps the holding state of contactor.

3. Analysis of the Motion Characteristics of Contactor

To prevent the oscillation of the contact, the contact spring force at the contacting instant should be increased and the contact speed should be decreased.

The traction of the AC electromagnet does not change significantly throughout the closing period, but the traction of the DC electromagnet varies inversely with the square of the size of the operating air gap.

In DC operation of the AC contactor, the contact spring force is constant, so the motion speed of the contactor is much higher than that of the AC one without the current limiting device. Therefore, in DC operation of an AC contactor, it is necessary to control the coil current so that the traction force of the electromagnet is somewhat greater than the resistant spring forces.

When closing the AC contactor at the AC operation and the DC operation, the current maximum in the first half period is the same. Then, since the inductance of the contactor increases from half cycle, the AC current in AC operation becomes smaller and smaller, and the DC current in DC operation does not change much. As a result, when the electromagnet is nearly closed, the DC traction is much larger than the AC traction. Thus, the final speed of the contact during DC operation is higher than that of AC operation, so that the contact bounce is more severe. Therefore, it is necessary to control the closing-current to reduce the contact bounce in DC operation of AC contactor.

The vibration of the contact is estimated by the amplitude $X_{\max}$ at which the moving contact firstly bounces from the fixed contact and the magnitude of the time $t_{\max}$ bouncing this distance.

$$X_{\max} = \frac{m_{C\Sigma} v_C^2 (1 - K_{ins})}{2Q_{CP}}$$

$$t_{\max} = \frac{2m_{C\Sigma} v_C \sqrt{1 - K_{ins}}}{Q_{CP}}$$

Where Q_{CP}- the initial compression of the contact spring, N

$m_{C\Sigma}$ - resultant mass of moving part, kg

v_C - contact velocity at the instant of contact, m/s

K_{ins} - shock absorption coefficient of contacting elements (Table 1)

The contact should not to be opened and also corrosion of contact should not be significant by contact bounce. To ensure that the contactor is working safely, the total vibration time t_Σ must be as follows:

$$t_{\Sigma} \leq 0.008 \sim 0.01$$

$$\text{Where } t_{\Sigma} = (1.5 \sim 1.8) 2 t_{max}$$

To prevent the contact bounce, the speed of the contact at the closing moment should be reduced and the force that drives the moving part should be reduced.

Contact bounce can also be caused by the impact of actuator elements at the closing period, so its impact must be small. That is, the motion speed of the moving core at the moment of collision of the moving core and the fixed core should be small. Ideally, if the speed of the moving core is allowed to zero, collision will disappear.

The energy exerted by the traction of the electromagnet on the moving part of the contactor is dissipated to overcome the force and friction force of the restoring spring and contact spring. The energy that the traction of the electromagnet transfers to the moving part can be expressed as follow.

$$W_T = \int F_T d\delta$$

This energy is accumulated in the springs or consumed by friction, which can be expressed as follow.

$$W_{AT} = \int (F_{AT} + F_{FR}) d\delta$$

To avoid collisions during the closing period, $W_T = W_{AT}$ should be used.

$$\int F_T d\delta = \int (F_{AT} + F_{FR}) d\delta$$

In the given contactor, right-hand side of the above equation is constant. Thus, the traction of the electromagnet and its operating time can be controlled to eliminate the impact of core at the closing period.

In view of the magnitude of the current flowing in a semiconductor device, it is safer and more economical to allow a smaller current to flow in the semiconductor device.

In this paper, the constant magnitude traction is applied throughout the air gap to reduce the core impact. Thus, the average traction force acting on the armature is equal to Eq. 1.

$$F_{TD} = \frac{W_{AN}}{\delta_0} \quad (1)$$

The traction force in a DC electromagnet is also as follow

$$F_{TD}=\frac{1}{2}(Iw)^2\frac{\mu_0 S}{\delta^2}=\frac{1}{2}(\frac{I}{\delta})^2 w^2\mu_0 S \quad (2)$$

To maintain a constant traction force in a DC electromagnet, it is necessary that I/δ and C_F have a constant value from the above equation.

From Eq. 1 and Eq. 2, we have

$$I=C_F\cdot\delta \quad (3)$$

$$C_F=\sqrt{\frac{2W_{AT}}{w^2\mu_0 S}}=\frac{1}{w}\sqrt{\frac{2W_{AT}}{\mu_0 S}} \quad (4)$$

When the traction force of W_{AN}/δ_0 is applied to the movable part of the contactor, the acceleration a is given by Eq. 5 until the contact is closed.

$$a=\frac{F_{TD}-F_R}{m_{C\Sigma}}=\frac{W_{AN}}{m_{C\Sigma}\cdot\delta_0}-\frac{F_R}{m_{C\Sigma}}=\frac{W_C}{m_{C\Sigma}\cdot\delta_0} \quad (5)$$

The δ is the instantaneous size of gap.

$$\delta=\delta_0-at^2/2$$

where, the δ_0 is the size of initial gap of core, the a is the acceleration of the moving part, and t is the time from the time when the power is switched on.

$$I\propto \delta_0-at^2/2 \quad (6)$$

In the DC excitation circuit constructed in Fig. 1, the average current in the contactor coil according to the control angle is

$$I_d=U_d/R=0.9U(1+\cos\alpha)/(2R) \quad (7)$$

Where

U_d, I_d, R– voltage across coil, current through coil, and resistance of coil

U – supplying voltage

α - control angle

Since Eq. 4 and Eq. 7 must be equal, the following relation holds.

$$0.9U(1+\cos\alpha)/(2R)=C_F\,\delta \quad (8)$$

$$1+\cos\alpha=\frac{2R\cdot C_F\cdot\delta}{0.9U} \quad (9)$$

$$\cos\alpha = \frac{2R \cdot C_F \cdot \delta}{0.9U} - 1 \tag{10}$$

$$\cos\alpha = \frac{2R \cdot C_F \cdot \delta_0}{0.9U}(1 - \frac{at^2}{2\delta_0}) - 1 \tag{11}$$

Substituting Eq. 5 into Eq. 11, we have

$$\cos\alpha = \frac{2R \cdot C_F \cdot \delta_0}{0.9U}(1 - \frac{W_C}{2 \cdot m_{C\Sigma} \cdot \delta_0^2} t^2) - 1 \tag{12}$$

With the control angle α, which is in accordance with Eq. 12, the TRIAC of Fig. 1 is driven to reduce core and contact bounce during the closing period of the contactor and also reduce the power consumed.

Acceleration of contact is as follows.

$$a_{con} = \frac{F_{ANC} - F_{TD}}{m_C} = \frac{F_{ANC}}{m_C} - \frac{W_{AN}}{m_C \cdot \delta_0} \tag{13}$$

m_C - mass of moving part except moving contact and contact spring, *kg*

The time that the armature moves until the contact is closed from the initial position is as follows.

$$t_1 = \sqrt{\frac{2(\delta_0 - \delta_C)}{a}} \tag{14}$$

δ_C : Size of core air gap when contact is fully closed

The time from closing of contact to closing of core is as follows.

$$t_2 = \sqrt{\frac{2\delta_C}{a_C}} \tag{15}$$

The whole operating time is

$$t = t_1 + t_2 = \sqrt{\frac{2(\delta_0 - \delta_C)}{a}} + \sqrt{\frac{2\delta_C}{a_C}} \tag{16}$$

Basing on the above equations, the Matlab Simulink model for analyzing the movement characteristics to reduce the contact bounce is established.

4. Simulation and Results Analysis

The electromechanical model of the contactor is shown in Figure 2.

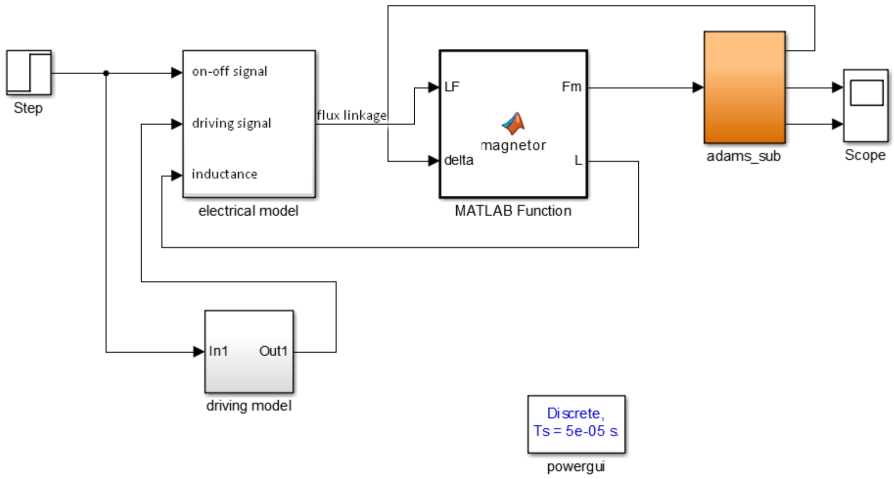

Figure 2. Electromechanical model of the contactor

The electromechanical model of the contactor is composed of four main types ; the electrical circuit model consisting of the TRIAC and the electromagnetic coil of the contactor, the drive circuit model for the TRIAC, the motion analysis model for the simulation of the mechanical motion characteristics of the contactor (ADAMS model), and the MATLAB function for calculating the electromagnetic traction force of the contactor and inductance of the coil using the values of the flux-linkage output and the gap size output of the motion analysis model.

The electric circuit model and the drive circuit model are shown in Figure 3 and Figure 4.

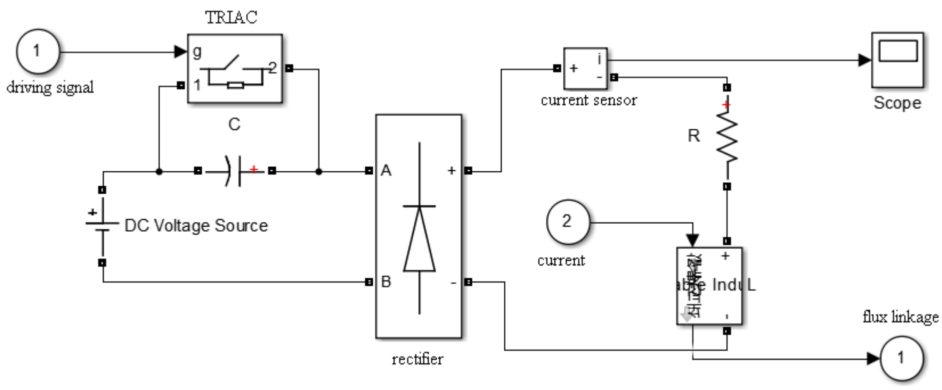

Figure 3 The electric circuit model

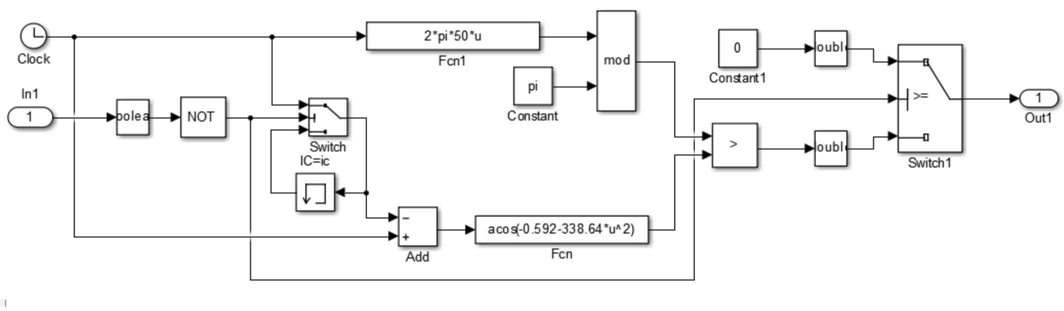

Figure 4. Driving circuit model

The simulation of the contactor was carried out on a 63A AC contactor.

Table 1 The elastic property of model

	modulus of elasticity, N/mm	initial compressive force, N	stroke distance, mm
return spring	0.228	6	8
contact spring	2	8.8	2
auxiliary contact spring	0.176	0.68	6

Table 2 shock absorption coefficient (K_{ins})

material	K_{ins}
copper	0.9
brass copper	0.85~0.9
Iron	0.75~0.95

According to Eq.12 and Eq.16, When power is applied, control angle shall be 126° in the first half cycle, 129°, 136°, and 154° in the next half cycles respectively.

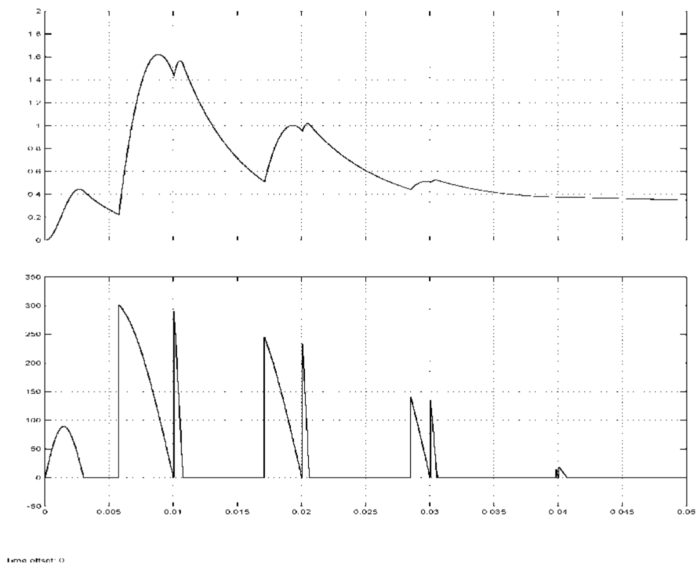

Figure 5. Current and voltage waveforms of the contactor coils on phase control

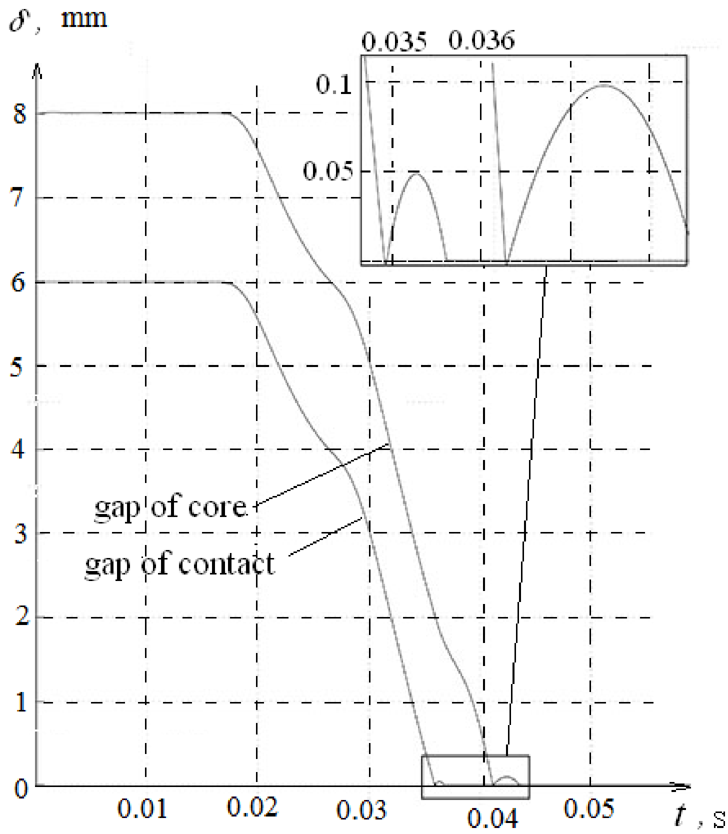

Figure 6. Core and Contact Displacement Using Control Circuits

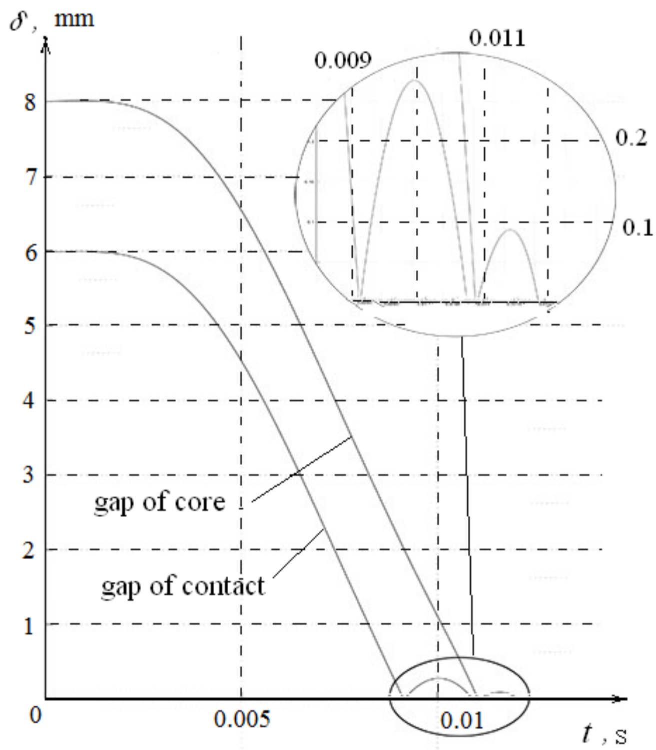

Figure 7. Core and contact displacement when uncontrolled

The results of the MATLAB simulation using the proposed control method are shown in Figure

5 and Figure 6. Figure 7 shows the displacement of the core and the contactor when the AC voltage is turned on without control.

As you can be seen, the amplitude of the contact bounce is 0.27 mm when the AC voltage is applied as it is, the vibration time is 1.8 ms, the amplitude of the contact vibration is 0.05 mm when the control circuit of Fig. 1 is used, and the vibration time is 0.8 ms, which is reduced by 1/5 and the vibration time is reduced by less than that when the AC voltage is applied.

5. Conclusion

AC contactors are widely used in automation systems as well as for motors. When the contactor is closed, no contact bounce is allowed because it causes an arc to shorten the life of the contact. Contact bounce is caused by the inevitable impact of contact and mover when the contactor is closing. The higher the impact velocity, the more the bounce is.

So, various methods have been investigated to reduce the bounce. The anti-bounce technique with PWM is the most widely used technique, which greatly reduces contact bounce. However, it is relatively expensive. The anti-bounce technique with phase control has the advantage of lower cost than the aforementioned method.

In this paper, a circuit and an open-loop control method to reduce contact bounces by controlling the DC excitation circuit of a AC contactor using TRIAC are proposed. The simulation of the proposed circuit and control method is implemented with MATLAB/SIMULINK and ADAMS for a 63A AC contactor.

The simulation results show that the proposed DC excitation circuit and current control method can control the speed of the moving part of the contactor by controlling the current flowing in the contactor coil by phase control to TRIAC and reduce the contact bounce and core collision during the closing period of contactor.

References

1. Lin Shuyi, Xu Zhihong (2014). Control Program of AC Contactor Based on Energy Control. *Proceeding of IEEE, International Conference of Mechatronics and Automation*, 978-1-4799-6068-2-14, 8.7
2. Xu Zhihong, Lin shuyi, (2014). Energy Analysis of the Closing Process of an AC Contactor, *Proceeding of IEEE, International Conference of Mechatronics and Automation*, 978-1-4799-6068-2-14, 8.8
3. Chi Chieh-Tsung. (2009). An Approach to The Reduction of Contact Bounce for AC Contactor. *International Journal of Innovative Computing Information and Control*, vol. 5, no.10, 3031-3044
4. Hung Chih-Yu (2011). Contact-bounce control and remote monitoring interface implementation of a PM contactor. *WSEAS Transactions on Systems and Control*, vol.6, no.5, 157-171

5. A. G. Espinosa, J. R. Riba, J. Cusidó, et al. (2010). Closed-Loop controller for eliminating the contact bounce in DC core contactors. *IEEE Transactions on Components and Packaging Technologies*, vol.33, no.3, 535-543
6. Liang Shu, Chengwen Xu, Guichu Wu (2015). Impact Detection of Intelligent AC Contactors and Optimization of the Dynamic Characteristics. *Proceedings of IEEE 2015*, 1065-1069
7. Ming Zong,Lei Qi,Xuejie Wang,Ying Zhang,Shenghui Wang (2016). A Review of Intelligent Contactor Design and Its Control Technology. *International Journal of Control and Automation*. vol.9, no.6, 389-402, http//dx.doi.org/10.14257/ijca.2016.9.6.37
8. Yingyi Liu, Degui Chen, Liang Ji, Yingsan Geng, (2007). Dynamic Characteristic and Contact Bounce Analysis for an AC Contactor with PWM Controlled Coil. IEEE 2007, 289-293
9. Lei Qi, Ming Zong, Xuejie Wang (2020). Eliminating Contact Bounce of AC Contactor Based on Speed Feedback. *International Journal of Circuit Theory and Application,* vol.49 no.18 , 731-745
10. A. G. Espinosa, J. R. Rida and J. Cusido (2009). Contact Bounce Elimination by Means of a Sensorless Closed-Loop Current Controller in DC Core Contactors. *IEEE Transaction on Industrial Electronics*, vol.45, no.117
11. J. P. Chen, J. T. Hu and Q. Li, (2010). Study of AC Contactor Bounce Control in Dynamic Process. *Low-voltage apparatus*, vol.19, no.4
12. Tang Longfei, Xu Zhihong, (2012). Design of a New Intelligent Anti-voltage Sag Control Module for AC Contactors. *Proceedings of the Chinese Society for Electrical Engineering*, vol.32, no.27, 95-103
13. H. B. Xu, X. G. Zhu and G. C. Wu, (2013). Research of Closing Time for Hybrid AC Contactors. *Low-voltage apparatus*, vol.19, no.10
14. Heyun Lin, Xianbing Wang, Shuhua Fang, Ping Jin, and S. L. Ho, (2013). Design Optimization, and Intelligent Control of Permanent-Magnet Contactor. *IEEE Transaction on Industrial Electronics*, vol.60, no.11, 5148-5159
15. T. C. Chien, (2009). Applying closing phase-angle control technique in bounce reduction of AC permanent magnet contactor. *Active Passive Electron. Compon.*, vol.9, 609 298-1 – 609 298-12
16. X. B. Wang, H. Y. Lin, S. L. Ho, et al. (2010). Analysis of dynamic characteristics of permanent magnet contactor with sensorless displacement profile control. *IEEE Transactions on Magnetics*, vol.46, no.6, 1633-1636