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Research paper

Study on Rotor Position Sensing Method using Inductance Displacement Sensor

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Abstract

Background/Objectives: There are disadvantages of position sensing method using the encoder. In this paper, we use inductance displacement sensor to reduce the disadvantages of existing position sensing method.
Methods/Statistical analysis: The inductance displacement sensor outputs the inductance value that changes according to the eddy current of the conductor surface. At this time, if the conductor pattern is provided, the inductance value changes as the motor rotates. It can be used as a sensor for measuring the rotor position at which the inductance at this time is divided by 360 degrees between the lowest value and the high value.
Findings: The position sensing method using the encoder used in the existing electric motor system is difficult to downsize due to the size of the encoder itself and the additional structure, and the dynamic characteristic also decreases due to the mechanical connection part. However, when using an inductance displacement sensor, no additional structure is required, and position can be sensed simply by inserting the conductor pattern. Through the experiment, the encoder and the conductor giving the pattern were connected, the inductance displacement sensor was attached, and then the position of the rotor was measured using the LabVIEW program. As a result, it was confirmed that the position of the rotor measured by the position of the rotor inductance displacement sensor measured by the encoder matched. The measured position sensing waveform was input to a simulation PMSM (Permanent Magnet Synchronous Motor), and the result was derived to confirm that the motor was operating normally.
Improvements/Applications: In this paper, we have proven that the inductance displacement sensor can replace for the encoder through the experiment, so we can solve the shortcomings of the existing encoder

Keywords: *Encoder, Inductance Displacement Sensor, Position Control, PMSM, LabVIEW*

1. Introduction

In the case of a PMSM motor rotating at high speed, it is necessary precisely and rapidly sensing the rotation information when controlling the electric motor, and it is necessary to grasp the precise position of the rotor for accurate control. When an accurate position is not sensed, a harmonic component is generated. Therefore, there arises a case where a desired output can not be obtained. Recently, industrial equipment is required to have higher performance precision, and researches and developments of industrial sensors are actively advanced based on such a trend[1].
In the existing case, the position of the rotor was sensed using an encoder or resolver sensor. In this case, there is a disadvantage that the price is expensive, installation is difficult due to space restriction, and the durability against external impact is deteriorated. When estimating the position of the rotor by using the Hall sensor signal, it is difficult to accurately estimate the position of the rotor in the extremely low speed range or the section where the speed suddenly changes.
When the position is sensed by using the inductance displacement sensor, the mechanical connection disappears, which improves the dynamic characteristics of the motor and enables miniaturization. And Since the position is sensed by a pattern, it is possible to sense the position even with a sudden speed change. Therefore, in this paper, we introduce a position sensing method using an inductance displacement sensor.

2. Materials and Methods

2.1. Theory of Operation of Inductance Displacement Sensor

There are two kinds of encoders with position sensing method using existing encoder. The incremental encoder outputs a wave form corresponding to the change in the position of the rotor. Therefore, it is impossible to know the change of the position of the rotor when turning on the power again. Therefore even when the power is turned on again, mainly use absolute rotary encoders that can accurately know the current direction. In the case of the absolute rotary encoder, the absolute position value can always be found in order to obtain the position value by scanning the position code where the light emitted from the encoder light emitting diode is binary encoded on the internal rotating disk[2,3]. However, in the case of an absolute rotary encoder, there are disadvantages such as spatial restrictions and price. But, using an inductance displacement sensor, it is possible to measure position of the rotor similar to that of an absolute rotary encoder. It also compensates for the disadvantages of Absolute rotary encoders.

In The inductance displacement sensor forms a magnetic field when current flows through the coil, which is the sensing part of the sensor. At this time, when the conductor comes close to the sensing part, an eddy current is induced in the conductor. The magnitude of the eddy current is proportional to the distance and the size of the sensing conductor and the target conductor. This eddy current produces a magnetic field opposite to the magnetic field generated by the coil, which changes the inductance value of the coil. This inductance displacement sensor can be said to have a mechanism similar to that of a transformer in which a coil is a primary winding and an eddy current is a secondary winding, as shown in Figure 1.

2.2. Position sensing theory of Inductance Displacement Sensor

In order to sense the position of the rotor using an inductance displacement sensor, it is first necessary to confirm that the inductance displacement sensor can measure the same angle of rotation as the encoder. As shown in Figure 2, the conductor which has a pattern as shown in Figure 3 is fixed at a position where the inductance displacement sensor can sense and then rotated. Then, convert the sensed value into 360, convert it to degree value, and check the output waveform using LabVIEW program[4].

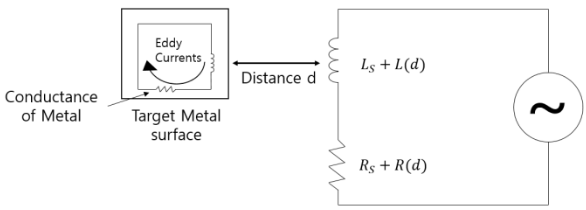

Figure 1: Metal Target Modeled as L and R

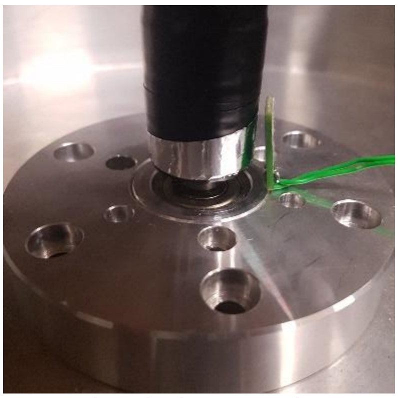

Figure 2: Encoder and Inductance Displacement Sensor

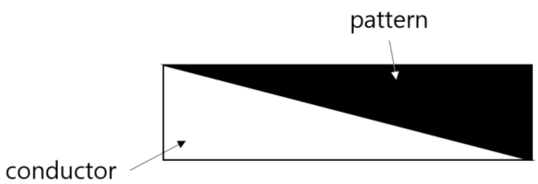

Figure 3: Pattern applied to conductor

2.3. Simulation of PMSM Using Position Sensing Value of Inductance Displacement Sensor

Although PMSM has the disadvantage of difficult control, it has high efficiency and wide operating range. It is also a motor that has excellent performance in position control. Figure 4 shows that the position of the sensor is used as the feedback signal of the controller to control the position or speed of the motor[5,6].

The FOC algorithm steps for PMSM control are summarized as follows. First, the three-phase stator currents i_a and i_b are measured. $i_a + i_b + i_c = 0$ to calculate the current in the two current sensors. Next, three-phase current is converted to two-axis method. The i_α and i_β variables can be obtained from the i_a, i_b, and i_c values measured through this transformation. i_α and i_β are orthogonal current values that vary with time from the standpoint of the stator. Then rotate the biaxial coordinate system using the conversion angle calculated from the last iteration of the control loop and align it with the rotor flux. Then i_d and i_q variables can be obtained from i_α and i_β. Now convert the quadrature currents i_d and i_q to the rotational coordinate system. i_d and i_q remain constant during stable static conditions. And i_d and i_q, each reference value is used to form an error signal. Thei_d reference controls the rotor magnetization full speed. The iq reference controls the torque output of the motor. The error signal is input to the PI controller. Next, the voltage vectors $V_d$and V_q, which are sent to the motor through the PI controller output, can be obtained. Therefore, V_α, V_β, i_α, and i_β are input. The new angle will dictate the FOC algorithm and decide where to place the next voltage vector. Rotate the V_d and V_q output from the PI controller back to the static reference frame using the new angle. Through these calculations, new orthogonal voltage values V_α and V_β can be obtained. Finally, $V_\alpha$and V_β are converted to V_a, V_b, and V_c. The three-phase voltage value is used to calculate a new PWM duty cycle value that produces the desired voltage vector

In since the PMSM used in the simulation has a distribution form, it is assumed that the magnetoresistance is uniform. That is, as shown in Figure 5, the BackEMF and the current wave form have a sine wave form. The position value sensed by the inductance displacement sensor was input as input value through PMSM simulation in LabVIEW program. And check the output of the PMSM simulation[7].

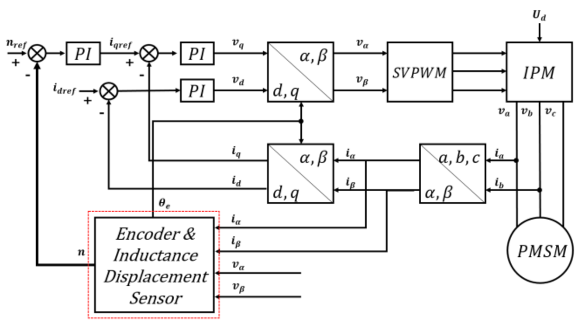

Figure 4: SVPWM Simulation block diagram

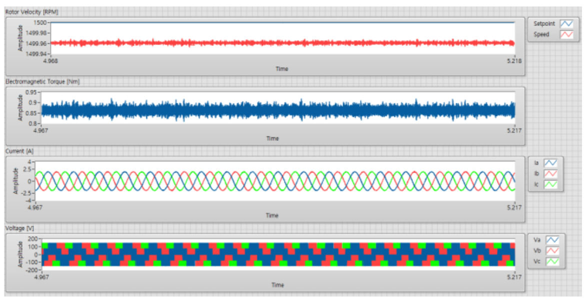

Figure 5: PMSM Simulation waveform in Ideal state

3. Results and Discussion

The degree waveform of the inductance displacement sensor and the encoder waveform are compared as shown in the Figure 6. This is a waveform obtained by rotating the encoder and inductance displacement sensor at a constant speed with the sensor set as shown in Figure 2. As a result of the test, it is confirmed that the inductance displacement sensor has almost the same waveform as the encoder showing the correct value.

One of the disadvantages of Hall sensors in existing position sensors is that they are fatal to sudden speed changes. This disadvantage does not occur when using an encoder. This is because the encoder always knows the absolute position value. We have approached this problem by using an inductance displacement sensor. Using the inductance displacement sensor, the conductor rotating at a constant speed suddenly rotated at a high speed. Figure 7 shows the result. As a result of the test, it shows that accurate position sensing is possible even in a section where speed changes.

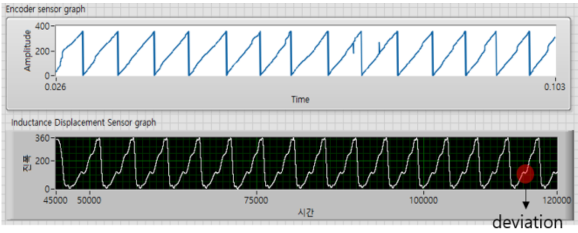

Figure 6: Waveform of Encoder and Inductance Displacement Sensor

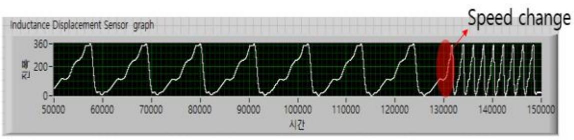

Figure 7: Measure sudden speed change using Inductance Displacement Sensor

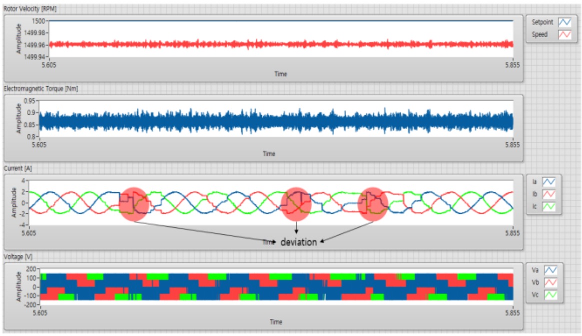

Figure 8: PMSM Simulation waveform using Inductance Displacement Sensor

In Figure 8 shows the PMSM simulation result using the waveform sensed by the inductance displacement sensor. Simulation results show that the current and the back electromotive force waveform are distorted rather than in the ideal state. This part appears to be due to an error when compared to the encoder waveform as shown in Figure 6. Therefore, if you adjust the offset for this part, it is expected that the waveform will be similar to the ideal state.

4. Conclusion

The existing position sensing method using an encoder, resolver or hall sensor is disadvantageous in that it can not be reduced in weight and size, is deteriorated in dynamic characteristics, and are fatal to sudden speed changes. In this paper, it is shown that the existing position sensor can be replaced by the position sensing method using the inductance displacement sensor. It also shows that the existing disadvantages can be solved by using the inductance displacement sensor. However, the non-linear part of the position of the rotor waveform of the inductance displacement sensor is generated. Because it is difficult to rotate the conductor at a perfectly constant speed in the experiment. And the area of the sensing portion of the inductance displacement sensor is narrow. Therefore, additional research is needed to compensate for this part of the program.

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References

[1] Yong Liu, Z Q. Zhu, David Howe. (2007). Commutation-torque-ripple minimization in direct-torque-controlled PM brushless DC drives. IEEE Trans. Ind, 43(4), 1012–1021.

[2] J.J. Blakey. (2000). Two-dimensional position sensing using absolute-type encoder scheme employing pseudorandom binary arrays. Electronics Letters, 36(15), 1277-1278, doi:10.1049/el:20000911

[3] S. Wekhande, V.Agarwal.(1992). High-Resolution Absolute Position Vernier Shaft Encoder Suitable for High-Performance PMSM Servo Drives. IEEE Transactions on Instrumentation and Measurement, 55(1), 357-364, doi:10.1109/TIM.2005.862020

[4] Qingyong Zhang, XuepingMeng, Yujie Liu, Kexiong Chen. (2015). Design of Autonomous Mobile Metal Detector Based on LDC1000. Industrial Informatics – Computing Technology, Intelligent Technology, Industrial Information Integration (ICIICII), 2015 International Conference on, 124-127, doi:10.1109/ICIICII.2015.114

[5] Hyunchal oh, Ki Young song, Kwan Yuhl Cho, Hag Wone Kim, Byung Moon Han.(2013). Initial rotor position detecting algorithm of PM synchronous motor using incremental encoder. ECCE Asia Downunder (Ecce Asia), 2013 IEEE, 681-686, doi:10.1109/ECCE-Asia.2013.6579174

[6] DrissYoufi, Mustapha El Adnani.(2007). Indirect position and speed sensing for PMSM sendorless control. Power Electronics, 2007.ICPE '07. 7thInternatonal Conference on, 817-822, doi:10.1109/ICPE.2007.4692500

[7] Matheus Alexandre Bevilaqua, AdmirNied, José de Oliveira. (2014). Labview FPGA FOC implementation for synchronous Permanent Magnet Motor Speed Control. Industry Applications (INDUSCON), 2014 11th IEEE/IAS International Conference on, 1-8, doi:10.1109/INDUSCON.2014.7059427