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Controlling power of short circuited induction motor via modern sensors without speed change

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Abstract. Short-circuited rotor induction motors are the most common and largest power consumers in industry. Therefore, it is necessary to find ways to ensure optimal performance of this type of motors and reduce their energy consumption. By this work, we will have the opportunity to automatically control the power of motors used in processes that do not have a stable operating mode. To perform this experiment, we use modern sensors and make special changes to the stator coil. Through our work, we create a special induction motor that is efficient, energy-saving and has a long service life. However it should be kept in mind that our developed motor is distinguished by its slightly complicated construction.

1 Introduction

According to Ampere's law, a force F acts on a conductor with a current I in a magnetic field. If a conductor with a current of I is bent into a frame and placed in a magnetic field, two sides of the frame located at right angles to the magnetic field will generate oppositely directed forces F. The forces acting on the frame create a turning moment or moment of force, which is a physical principle common to all electric motors. Figure 1 shows the above-mentioned classifications [1].

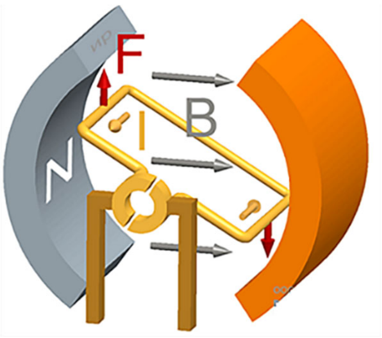

Fig. 1. Classification of the magnetic field affecting the rotor.

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Motor motion control and speed adjustment are required in many processes, be it domestic application or industry. Systems that work for these purposes are called drivers. Such a system, if it uses electric motors for control, is called an electronic control (driver). Electronic drives use various sensors and control algorithms to control the motor speed using appropriate speed control methods. Traditionally, there were different ways of adjusting the power of electric motor, and they have some advantages and disadvantages are used even nowadays. One of the main and common methods is power adjustment via a frequency converter, which is used in many cases where speed change is required (Figure 2). This is a major drawback [2].

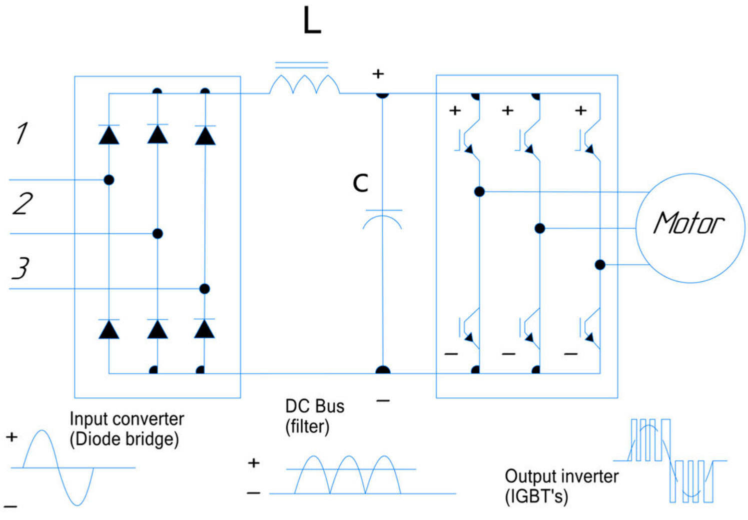

Fig. 2. Typical schematic of a PWM variable frequency drive.

2 Results and discussion

If we look at the following graphs, we will see how the electric motor changes the main parameters related to it at the initial speed. The first basic indicator is the speed, that changes over time in most cases, depends on the power of the motor. During the initial start-up period, the rotor speed reaches the nominal value (Figure 3).

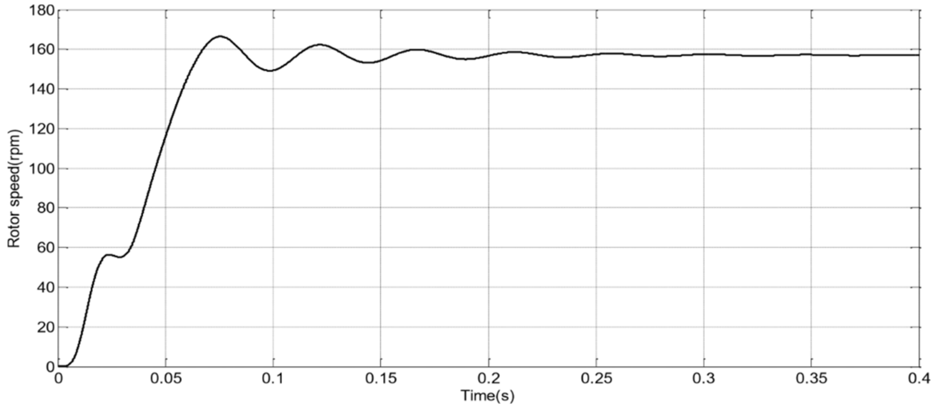

Fig. 3. The value of time and speed during the initial excitation period of the asynchronous motor.

It should be noted that the value of the current flowing in the stator during the initial operation of our electric motor is high (5-7 times less than the rated current) [3]. Because a large amount of current is needed to move the rotor and raise it to its nominal speed (Figure 4). If the value of the load on the rotor is high, the value of the excitation current is also high. The graph below shows the characteristics of the stator phase current and speed relationship under different voltages [4].

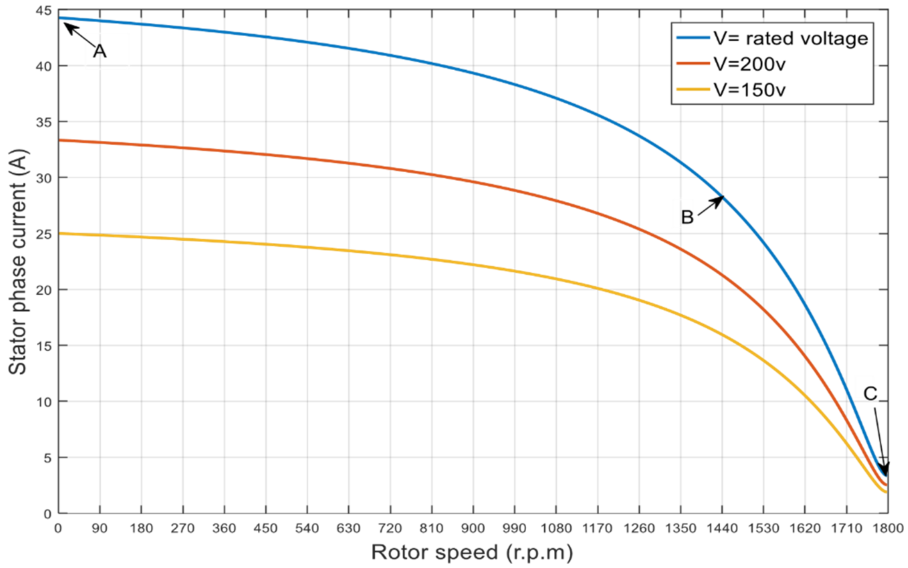

Fig. 4. Characteristics of stator phase current and rotor speed relationship under different voltages.

But in the following project, we will adjust the power of designed motor without changing the speed. This process is carried out by changing the electromagnetic field in the asynchronous motor stator and the analysis response of the signals received by the sensors and transmitted by the controller. The basic block diagram of the automatic control is shown below in Figure 5.

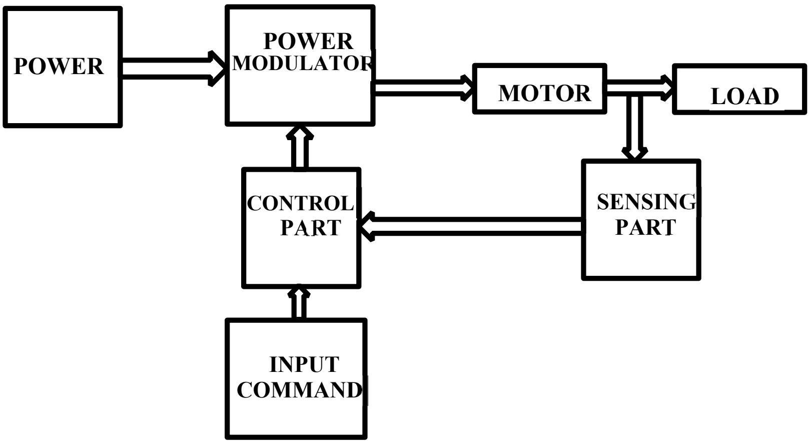

Fig. 5. Diagram view of the project.

Using the above scheme, the control based on the electromagnetic current vector restores the main advantages of the direct drive. It is based on a comparative evaluation of the stator field vector determined in the designed motor to the response of the angular position and speed of the rotor. This process estimates and controls the spatial angular position of the rotor flux [5]. A microprocessor is used to enhance fast data processing and analytical modeling of the motor's electrical characteristics. By adding a pulse encoder, higher speed and torque accuracy can be achieved. This addition of a pulse encoder is the main advantage of the process. The torque (load detector) is controlled indirectly rather than directly. This also proves to be a major advantage, as it increases the speed of signal analysis passed through the process, and leads to further refinement of the program to be entered [6].

Direct torque control and electromagnetic field control create some complications and require the use of modern sensors. In addition to the use of the above-mentioned encoder and load sensors, a $\cos f$ sensor that controls the power coefficient and produces an analog signal is also needed. Because $\cos f$ transmits the change of the power coefficient to the controller, and through the transmitted signal, we can keep the power coefficient of the divergent at the same level. Through this, it is possible to limit the consumption of reactive power by regulating the consumption of active power, which is used for useful work. It should be mentioned that the reactive power demand can be exceeded due to the significant increase or decrease of the power on the shaft of our electric motor compared to the nominal power (Figure 6). This means the device that we are designing shows that only the load is unstable, i.e., the power applied to the shaft of the motor is used for the continuous turning process, which ensures high efficiency [7].

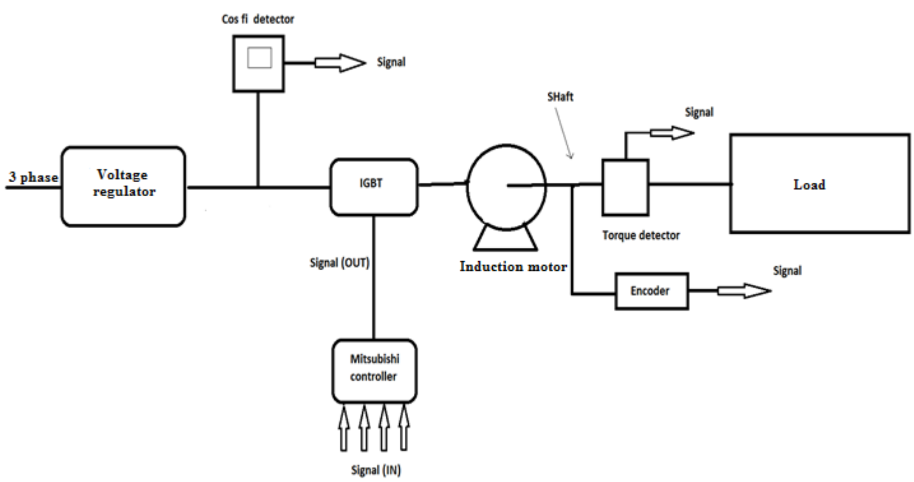

Fig. 6. Connection graph of the designed motor with detectors.

The diagram above shows the order of connecting the motor via the sensors in a simplified form. The complexity of our work is that the motor power without speed change can only be realized by changing the electromagnetic field and voltage range in the stator to a limited amount. At this point, it is natural to ask the question, in what order is the current of the electric magnetic field in the stator controlled? The answer to this question can be understood through the transformer, the principle of operation of which is the same as this motor. It is known that medium power transformers have a voltage regulator consisting of five steps. Using the transformer voltage regulator in the stator allows changing the resulting magnetic current within a certain range. However, it should be said that the change in the number of windings causes a change in the resistance of the windings, and a sudden change in the load on the diverter shaft requires an increase in the speed of the commutation process of the regulator. In this process, it is necessary not to forget the maximum current value of the motor. Because if the value of the current flowing in the coils I_{mot} exceeds the specified value, the burn of the varnish on the upper layers will lead to the breakdown of the insulation between the coils [8].

$$I_{mot}=K\cdot I_N\cdot\sqrt{\frac{T_{max}-T_s}{T_{max}-25C^o}\cdot\frac{R_{th1}+R_{th2}}{R_{th1}}} \quad (1)$$

where; I_{mot} −current flowing in the coils, K- overload factor, I_N- nominal current, T_{max}- max. permissible winding temperature, T_s- stator temperature, R_{th}- resistance winding-temperature.

The process of commutation in the regulator, i.e. changing the number of stator windings, is carried out by means of IGBT (insulated gate bipolar transistor - base protected bipolar transistor) creates a number of advantages.

The most visible positive aspect of IGBT is the protection of the base, which prevents the violation of the operational current source, i.e. the controller OUT (output) signal. Because the high value current flowing through the collector and emitter is not likely to pass its sphere of influence to the base. Our transistor below is an exception. Another positive aspect that is needed for our project is that by changing the value of the small operating current supplied to the base of the IGB transistors, we can proportionally change the amount of high value current flowing in the collector and emitter. The advantage of this is that the change in the number of windings causes a change in the resistance and at the same time the current flowing in the stator windings. As a result, we will be able to regulate the value of the current supplied to the stator by means of IGB transistors and prevent damage to the stator windings due to high current. In this kind of non-stationary mode of operation, the observation of heating conditions ΔT_w occurring in the stator coil is naturally explained by the following expression [9].

$$\Delta T_w=\frac{(R_{th1}+R_{th2})\cdot R_{TA}\cdot I_{RMS}^2}{1-\alpha_{Cu}(R_{th1}+R_{th2})\cdot R_{TA}\cdot I_{RMS}^2} \quad (2)$$

where; R_{TA}- winding resistance, I_{RMS}^2- RMS current, α_{Cu}-resistance coefficient.

In addition, it is possible to implement a fast, reliable and safe commutation process through IGB transistors. In our ongoing project, there are five outputs from each phase of the motor, each of these outputs is equipped with a pair of IGBTs directed opposite to each other, and it is ensured that the sinusoidal current is delivered to the stator without changes. It should not be forgotten that if the sinusoidal current flows without changes, it is important to understand the input and output characteristics of transistors. It is necessary to choose a transition transistor that is suitable for the process. At the same time, the total number of transistors required for our project is thirty, five pairs of transistors are required for each phase [10].

The encoder sensor is a device that is attached to the motor shaft controlling the speed change. The output signal is analog and the power source is 24V. Through this loop, we constantly monitor the number of rotations in the motor stator (Figure 7). As a result, if the number of stator windings changes or the speed drops below the specified value, the encoder will quickly transmit the status information to the controller and prevent the possibility of braking.

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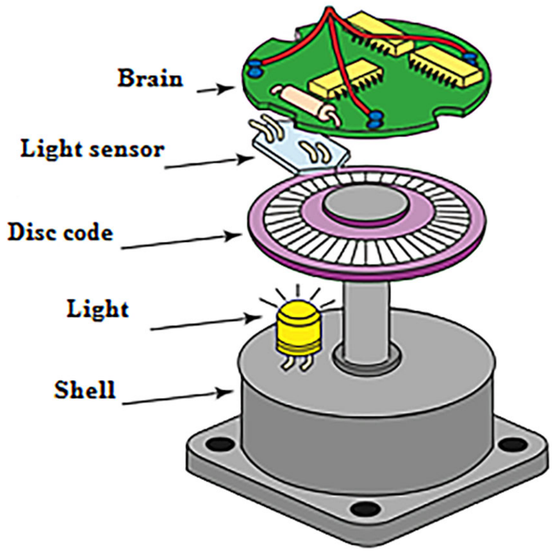

Fig. 7. The internal structure of the encoder detector, which should be installed on the shaft.

In addition, a torque or load tester that analyzes the load change through an analog output signal is also used in our project as one of the main required units (Figure 8). The task of the following sensor is to quickly transmit information about the change in force acting on the shaft to the controller (Figure 9). It is not a secret that in many areas of use of the motor, there is a sharp change in the load on the shaft and it shows its sharp negative aspects to the working characteristics of our motor.

$$M_{in,a} = \left(J_{in} + J_1 + \frac{J_L + J_2}{i_G^2 \cdot \eta}\right) \cdot \frac{\pi}{30} \cdot \frac{\Delta n_{in}}{\Delta t_a} = \left(J_{in} + J_G + \frac{J_L}{i_G^2 \cdot \eta}\right) \cdot \frac{\pi}{30} \cdot \frac{\Delta n_{in}}{\Delta t_a} \quad (3)$$

Where; $M_{in,a}$-torque on the shaft, J_{in}-moment of inertia-input, J_L-moment of inertia-load, i_G^2-reduction ratio, η- efficiency, Δn_{in}- speed change, Δt_a- acceleration time.

Using the above formula, it is possible to consider the change of torque on the shaft $M_{in,a}$ when the motor speed changes, and we can enter it into the PLC and analyze the connection between the load and the speed in the form of software. With the presence of a torque sensor, we ensure that the number of stator windings of our divegate is changed accordingly, depending on the load change.

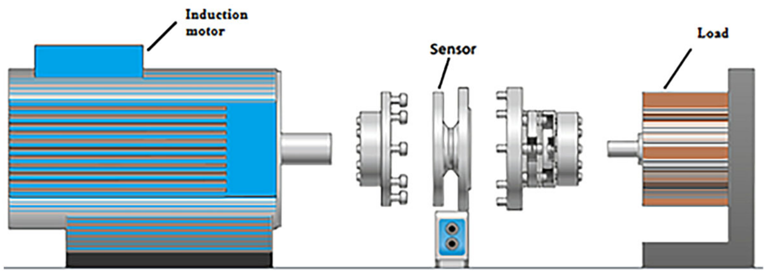

Fig. 8. Torque (load sensor), series 4200.

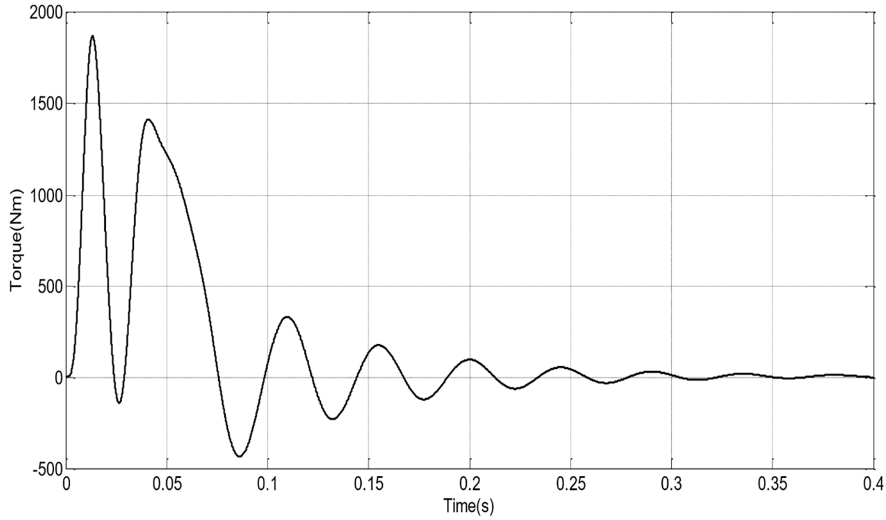

Fig. 9. Changing torque of motors during time.

Ensuring the reliability and speed of our scientific work is largely dependent on the type of controller. The Mitsubishi controller is considered to be a device with high economic efficiency that meets this requirement. The Mitsubishi controller is a type of controller that performs the analysis of input and output signals -5V (output from the IN-cells and the signal to the OUT-IGB transistor base). There is also a module between IN and OUT (a device that reduces the -24V signal from the cell to -5V or the reverse process). The Mitsubishi controller requires only NPN type switches, and therefore all the selected switches must be NPN type switches that produce a negative (-) signal. Because the negative (-) signal, unlike the positive (+) signal, performs a safe operation and does not cause any serious damage even if there is a possibility of creating a circuit with the ground during the control or repair process. For this reason, this series is considered preferable to the Siemens programmable controller. The Mitsubishi controller is a multifunctional microcontroller device that performs simultaneous analysis of several signals and has a simple programming language [11]. However, it should not be forgotten that the software that needs to be created for the following project has a high potential.

3 Conclusion

In conclusion, it should be said that today various types of motors are used in many production areas and economic zones, but short-circuited rotor asynchronous motors are one of the most widely used motors among them. It can be seen that short-circuited rotor asynchronous motors are used in different conditions and in different regions and it is important to solve various problems caused by them. During the following dissertation work, various problems that arise in asynchronous divegatels and various issues related to them have been solved. That is, our work is aimed at preventing asynchronous motors from idle operation, working under load, power factor drop, reactive power consumption increase, and stator current overshoot, that is many of our motors have a power factor drop. As a result, reactive power consumption increases during digital operation. The signals that need to be transmitted using various sensors are received by the controller, the signal received from the controller is analyzed and the signal is put into practice through the included alternative program. The advantage of our dissertation work is that the response speed of the process is very high and its performance is of high quality, and we can achieve high energy efficiency through this method. Among them, it is necessary to highlight some problems, that is, due to the slightly complicated scheme of the work we want to do below and the breadth of the operational control method, the program to be introduced will be a little complicated and characterized by its low reliability. But by finding a solution to this type of problem, i.e., by improving the performance of the sensors and perfecting the software to be inserted, we can achieve high efficiency, including high energy efficiency, and we will achieve great economic benefits.

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