SIMULATION MODELS FOR INDUCTION MACHINE PROTECTION ANALYSIS

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Abstract: The object of research are simulation models analysis of a three-phase induction machine protection systems. The analysis is made on the parameters behavior on the machine (stator current, rotor current, rotor speed and torque) while simulating different types of faults and while there are no faults. Over current fault and protection is used in the first simulation using over current relay, while under voltage, loss of one phase and asymmetric power supply protection is used in the second simulation using over voltage and under voltage relays. The article describes how to protect your induction machine when you have this types of faults.

Key words: induction machine, over voltage relay, under voltage relay, over current relay.

1. INTRODUCTION

Induction motors are found everywhere nowadays. It is impossible to give an exhaustive list of their applications: civil engineering, port activities, material handling, conveying, air and water treatment, drying, agriculture and a whole variety of different machinery. Almost all drives incorporate induction motors. Their reliability is therefore a determining factor in continuity of operation of these machines and their durability. It is therefore essential to select the right protection systems for them. There are numerous causes of motor faults, which have varying effects but in this research we will analyze: over current fault, loss of one phase fault and asymmetric power supply. Simulation is used in this research because simulation can be defined as a process of designing a model of a real system and conducting experiments with this models for the purpose of understanding the behavior of the protection system. Simulations can be applied for small and large systems. The cost of building protection systems is more and simulation provides a replica of the exact model with the behavior of the elements which are in the systems. Direct experimentation would cost more when compared with the simulated model of the systems which is the main motive behind simulation. Simulation helps in delivering some very important decisions to be made. It is a very efficient methodology to solve complicated problems.

The purpose of the article is to analysis the parameters of an induction motor when there are faults and to project the adequate protection system for them in order to have a safe operation mode that is, not to damage the induction machine. In this reason, the basic equipment that is used in the simulation model for the research is presented in the next section and the Section 3 makes an overview of related works in the field. The main research work is in the following sections, Section 4 and Section 5.

2. FORMULATION OF THE EQUIPMENT USED IN THE SIMULATION MODELS

Induction motor. An induction motor (also known as an asynchronous motor) is a commonly used AC electric motor – Figure 1. In an induction motor, the electric current in the rotor needed to produce torque is obtained via electromagnetic induction from the rotating magnetic field of the stator winding [1-2].

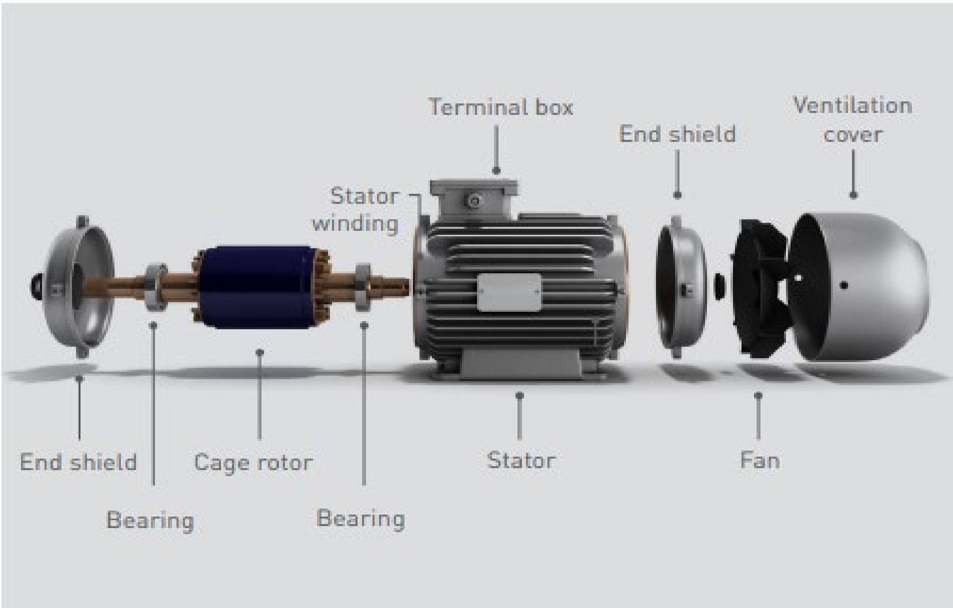

Figure 1. Example of induction motor with short-circuited rotor

The rotor of an induction motor can be a squirrel cage rotor or wound type rotor. Induction motors are referred to as ‘asynchronous motors’ because they operate at a speed less than their synchronous speed [1-2]. It is simple, from the name itself we can understand that here, the induction process is involved. When we give the supply to the stator winding, a magnetic flux gets produced in the stator due to the flow of current in the coil [1-3]. The rotor winding is so arranged that each coil becomes short-circuited. The flux from the stator cuts the short-circuited coil in the rotor [1-3]. As the rotor coils are short-circuited, according to Faraday's law of electromagnetic induction, the current will start flowing through the coil of the rotor. When the current through the rotor coils flows, another flux gets generated in the rotor. [1-3]

Now there are two fluxes, one is stator flux, and another is rotor flux. The rotor flux will be lagging with respect to the stator flux [4]. Because of that, the rotor will feel a torque which will make the rotor to rotate in the direction of the rotating magnetic field [4]. This is the working principle of both single and three-phase induction motors. In particular, an induction motor with 3-phase is used in the industry due to the reasons like it is a low cost, maintenance is easy and simple.

Protection relays. A protective relay is one which monitors the current, voltage, frequency, or any other type of electric power measurement either from a generating source or to a load for the purpose of triggering a circuit breaker to open in the event of an abnormal condition [4]. These relays are referred to in the electrical power System as protective relays [4]. The function of protective relaying is to cause the prompt removal from service of a power system when it suffer a short circuit, or when it starts to operate in any abnormal manner that might cause damage or otherwise interference with the effect operation of the rest of system.

Over current relay. Over current relay is one which monitors the current only and gives trip signal to the circuit breaker in faulty (short circuit) condition [4]. In case of short circuit faults, current in the system increases from its normal value. This short circuit current can be many times greater than the full load current [4]. The magnitude of short circuit current depends upon the fault impedance and other parameters of system.

Over voltage relay. It is a protective device used in electrical system which provides protection from over voltage condition. Power system can encounter over voltage condition which can be due to sudden drop of load, addition of power source and due to switching transients [4]. If the voltage increases from certain limit, it can damage insulation and can lead to insulation puncture. Therefore it is necessary to monitor the voltage of system continuously [4]. If high voltage is encountered in any part of power system, that faulty portion of network should be isolated. Over voltage relay continuously monitors the system voltage and if over voltage condition occurs, it sends tripping command to the breaker.

Under voltage relay. Under voltage relay is one which monitors the voltage only and gives trip signal to the circuit breaker in faulty condition. In case of faults, if voltage in the system decreases from its normal value it will open the breaker [4].

Circuit breaker. Circuit breakers are generally located so that each generator, transformer, bus, transmission line, etc. can be completely disconnected from rest of the system [5]. These circuit breakers must have sufficient capacity so that they can carry momentarily the maximum short-circuit current that can flow through them, and then interrupt this current.

3. RELATED WORK

Power system protection is needed to successfully deliver electricity from power plant to the consumers in a safe and timely manner. The main reasons for the disturbance in the power system are faults and abnormal conditions. The faults that usually happen are short circuit fault, open circuit fault, and earth fault. The abnormal conditions in power system can be under frequency overvoltage, instability or imbalance. This disturbance needs to be managed efficiently such that the delivery of electricity is not interrupted. Besides the interruption in delivery, disturbances can cause damage to equipment, present hazard to the surrounding area and in the worst case can provide total collapse to the grid [6]. Therefore, protection is very important in term of the power system in order to avoid the effects mentioned above.

In the journal of Advanced Research in Dynamical and Control Systems there is a paper (Modelling and Simulation of Definite Time Over current Relay for Radial Systems Protection) which proposed time definite over current relay is designed to perform protection for a radial power system. The relay is considered to avoid tripping under normal conditions [6]. The relays are coordinated such as protect the radial system in sequence tripping manner. In addition to this paper we made simulation models that uses the same over current relay plus under and over voltage relays using the same logic but instead of radial power system we used them on an induction motor.

Through the parameters analysis of the induction motors we observe if the protection system is working properly. There are also some researches about the algorithms and formulas with whom the electrical faults in this paper are explained in detail and what they mean in essence [7, 8]. The voltage disturbances have big effects on the induction motor and the equipment. Therefore the choice of protection equipment is very important [7, 8].

4. MODEL OF PROTECTION SYSTEM (UNDER VOLTAGE, LOSS OF ONE PHASE, ASYMMETRIC POWER SUPPLY) AND EXPERIMENTAL RESULTS DUSCUSSION

Matlab provides a simulink events library to model a protection system and also execute the various parameters as required by the research. The Library has different blocks that we require to model a protection systems for induction machine.

As shown in figure 2, this is the first model where we will simulate under voltage, loss of one phase and asymmetric power supply protection for induction machine. In this simulation we have an induction machine that its nominal power is 50 HP, nominal voltage 400 V and nominal frequency 50 Hz. The machine power supply is a programmable voltage source. Under voltage relay, over voltage relay and a three-phase circuit breaker are the components of the protection system that is implemented in this research. Through the help of the one-phase circuit breaker and the programmable voltage source we simulated our needed faults. The scopes serve us to watch the parameters of the machine and the system. Duration of the simulation is 1s, while the software uses ode45 solver. With the aid of buss A the over and under voltage relays they monitor the voltage that is coming from the source and if they detect a significant drop or increase of its value, they will send a trip signal to the three-phase circuit breaker so the machine will be removed from the system in order not to be damaged.

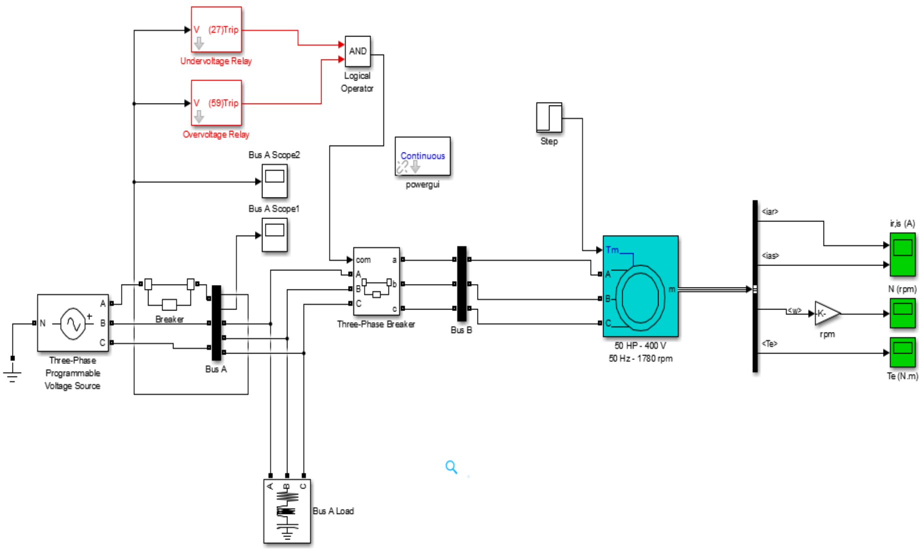

Figure 2. First model under voltage, loss of one phase and asymmetric power supply protection

In figures 3,4,5,6 are shown the results of the machine parameters (rotor current, stator current, torque, speed of rotor) while the machine is working in a normal process without faults, with a constant torque that is activated in 0.1s. As we can see the values of the parameters are constant after activating the torque in 0.1s.

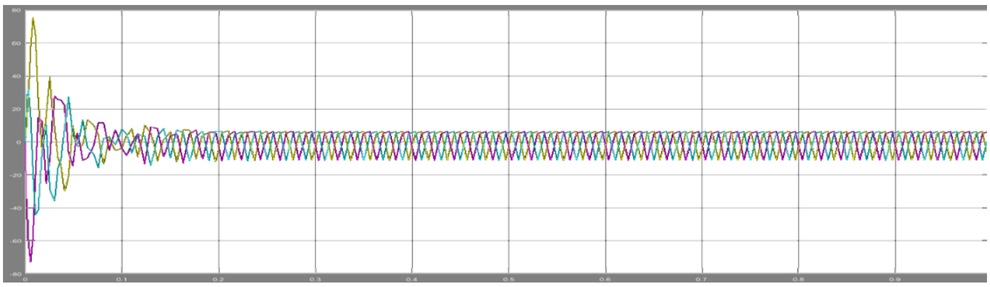

Figure 3.Sstator current

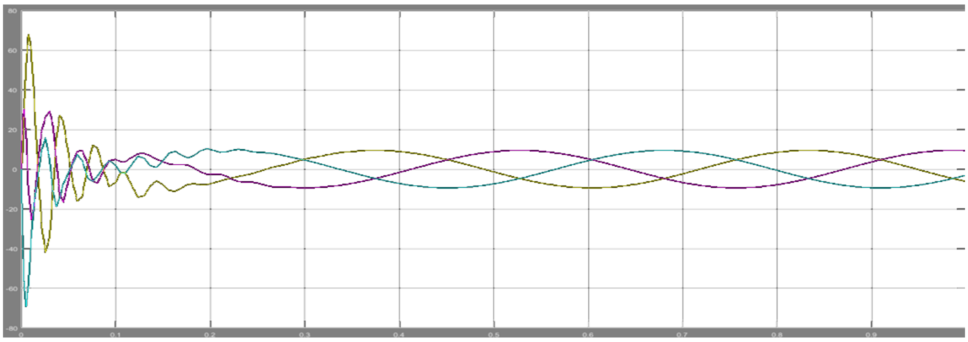

Figure 4. Rotor current

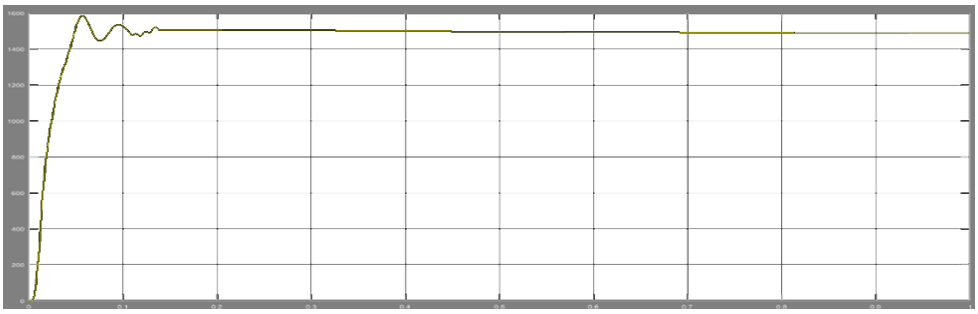

Figure 5. Speed of rotor

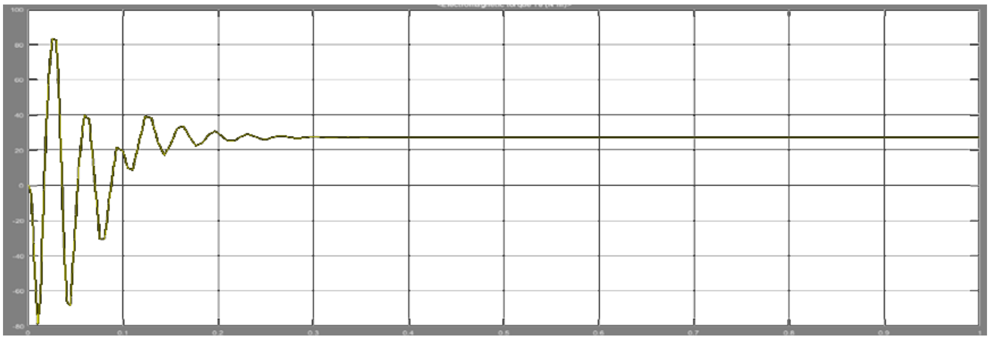

Figure 6. Torque of motor

As mentioned before through the help of the programmable voltage source and through the one-phase circuit breaker we have simulated faults. Figure 7 represents the loss of one phase fault, while figure 8 and 9 represent two scenarios of unbalanced power supply. In figure 8 the voltage in phase A has a significant increase and in figure 9 is represented the significant drop of voltage in phase A. Through our protection system (under voltage relay, over voltage relay and three-phase circuit breaker) the faults are detected and the protection is activated so the machine is turned off not to be damaged.

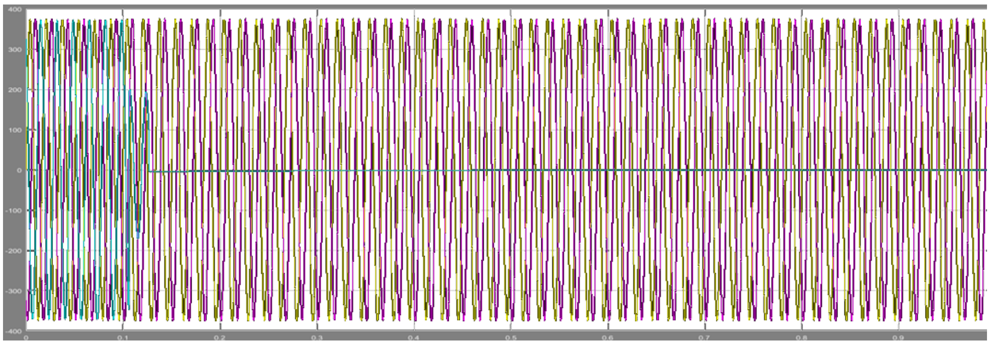

Figure 7. Loss of one phase fault

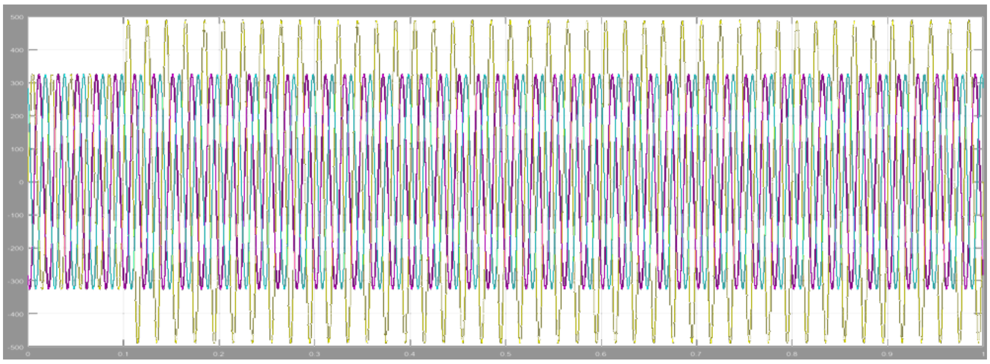

Figure 8. Significant increase in phase A

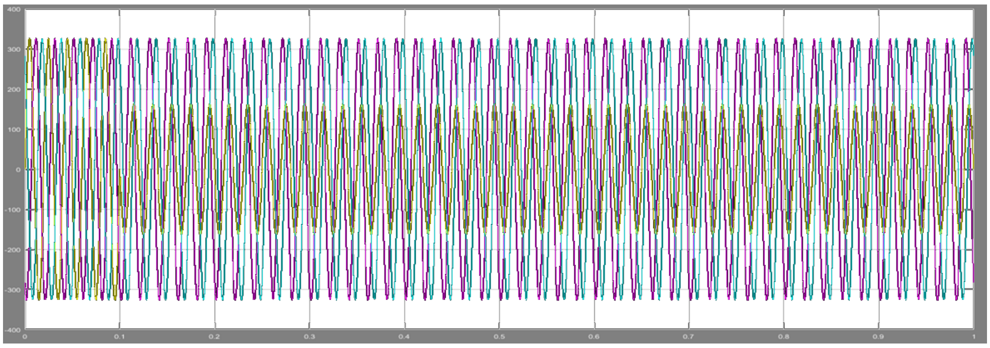

Figure 9. Significant drop of voltage in phase A

The voltage relays (under and over voltage) they monitor the amplitude of the voltage in the system and they are set up to send a trip signal to the circuit breaker if they detect a 10% variation in the voltage amplitude. The results are shown in the figures below – Figures 10, 11 and 12.

Figure 10. Stator and rotor current after activating the protection system

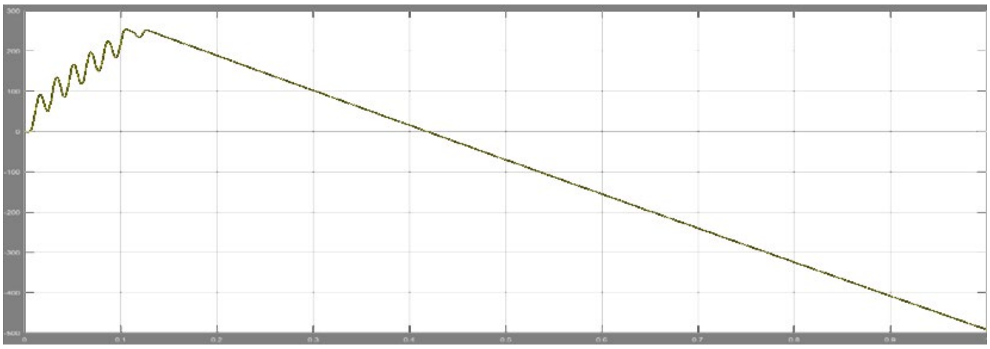

Figure 11. Rotor speed after activating the protection system

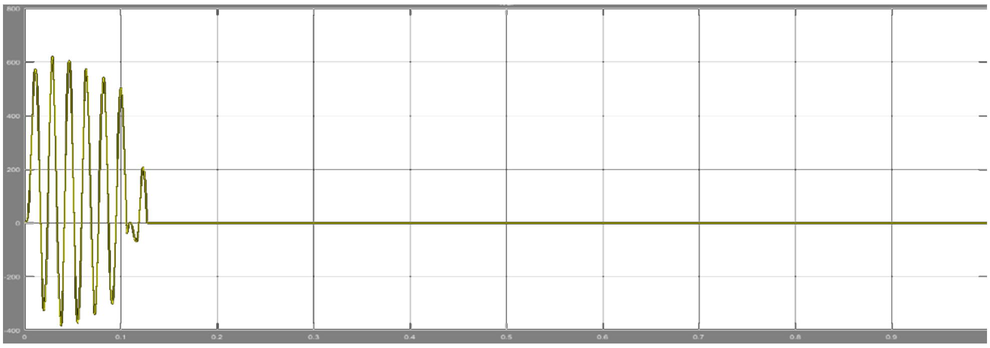

Figure 12. Torque after activating the protection system

5. MODEL OF PROTECTION SYSTEM (OVER CURRENT) AND EXPERIMENTAL RESULTS DUSCUSSION

The second simulation model is very similar to the first one, but instead of over and under voltage relays we use an over current relay because the point of this model is to simulate an over current fault and an over current protection system. The logic is the same as the first one but instead of monitoring the voltage values now we are monitoring the current values. Over current fault is simulated through the block three-phase fault which is in the library in Matlab Simulink. Figure 13 represents the second model for over current fault and protection system.

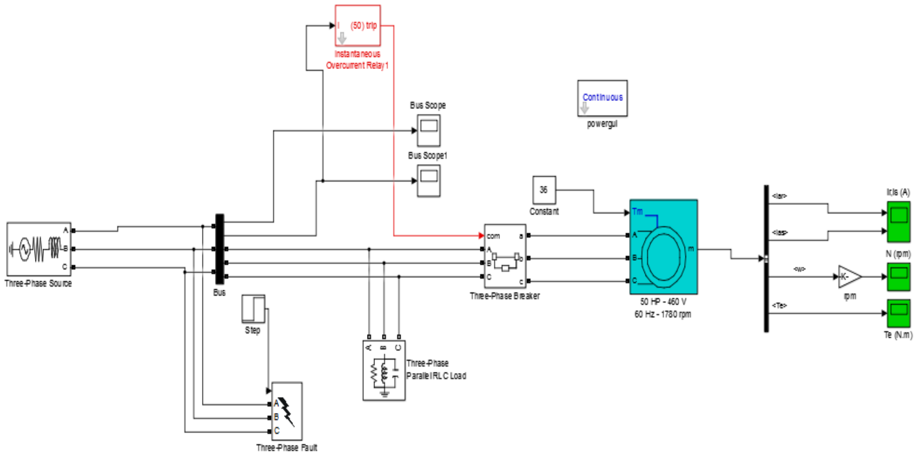

Figure 13. Second model over current fault and protection system

Figure 14 presents the over current fault which is simulated through the three-phase block. The fault is activated at 0.5s in the simulation and we can see that the value of the currents amplitudes has a drastic increase in 0.5s.

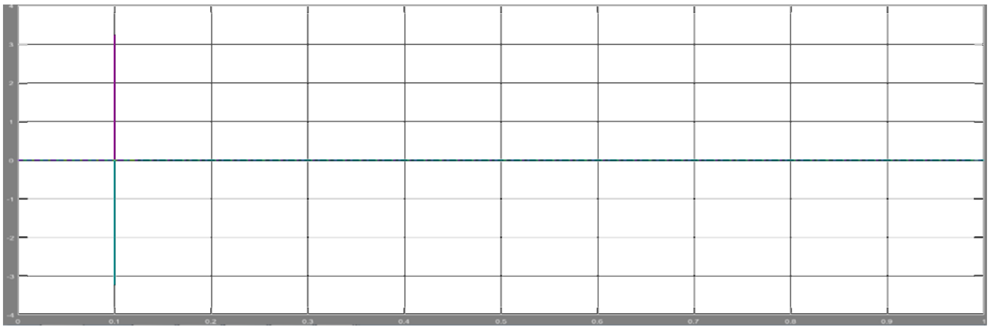

Figure 14. Three-phase over current fault simulation

After simulating the over current fault the over current relay detect a significant increase in the currents values and then sends a trip signal to the circuit breaker and once again our machine is turned off and out of harm. Same as the voltage relays, the current relay also monitors the amplitude but not on the voltage but on the current in the system. The current relay is set to send a trip signal to the circuit breaker if it detects an amplitude that is value is two times bigger than the nominal value of the system current amplitude. Results after activating the protection system are shown below in the figures 15 – 17.

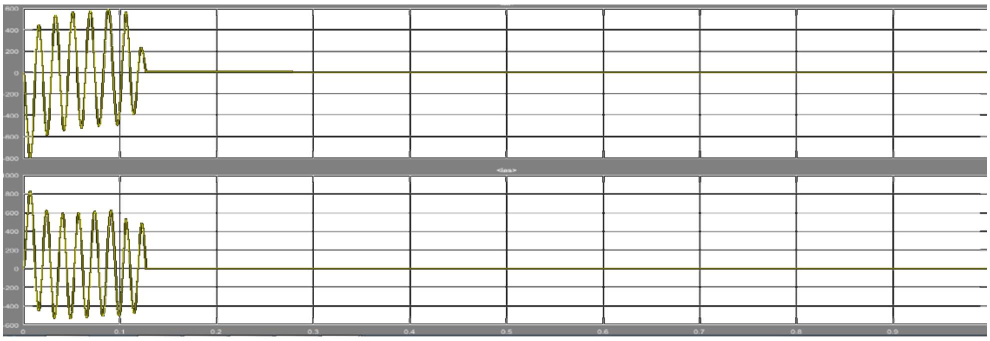

Figure 15. Stator and rotor current after activating the protection system

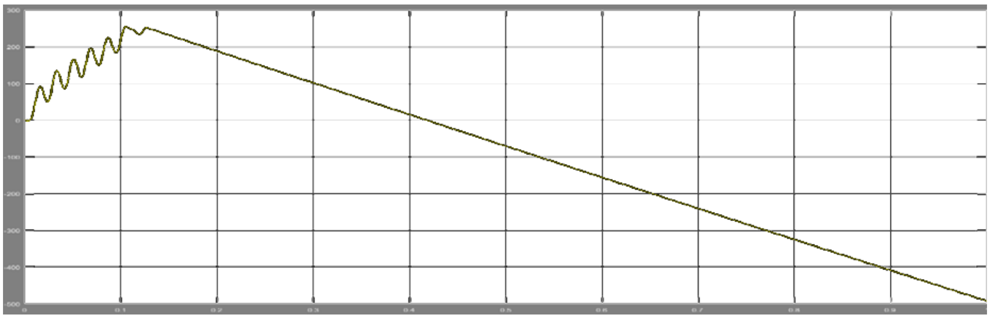

Figure 16. Rotor speed after activating the protection system

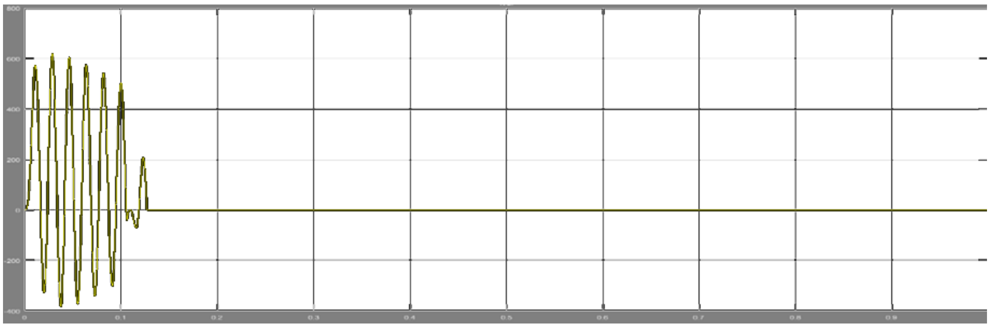

Figure 17. Torque after activating the protection system

6. CONCLUSIONS

Simulation has always been effective in study of behavior of different power energy systems. Simulation is the art to create a physical and conceptual model which can represent a system or create the illusion of reality, and through its help we can project protection systems for our machines and then we can implement them in reality. Because continuous operation of induction machines is necessary and important in many branches, therefore, protection systems are essential for its continuous and safe operation. Other benefits from simulation models like this is that we can analyze the protection system for different types of faults through monitoring the electric, voltage, power, frequency, etc. values.

Also we can analyze the timing of reactions of the protection systems, because the timing of reaction is one of the most important segments in every protection system. With this type of simulation research we can achieve selectivity, speed of reaction, sensitivity and safety in work and confidentiality in action. Selectivity is important because it's a feature of the protection to automatically isolate from operation only that element of the system in which a fault has occurred, while the rest of the system remains in normal operation.

The speed of response is especially important in the case of separation from the system of objects on which a short circuit has occurred. By disconnecting the short circuit very quickly, failure at the fault point is reduced or avoided altogether. Protective devices should be sensitive enough to react with certainty in the event of a fault in the basic and backup protection zone, even in the most adverse conditions. Failure to protect the system in the event of a fault can have catastrophic consequences for the system (e.g. its complete destruction) and major investment damage. Secondary damages (such as inability to generate energy or inability to supply larger consumer centers) can be even greater. Therefore, before protection, there is a need for confidentiality, to act correctly (whenever required).

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