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# The use of input capture method to increase torque on switched reluctance motor

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**Abstract.** Electric drives are used in many industrial applications, one of these is Switched Reluctance Motor (SRM). Such a motor is used because it has a simple construction, efficient, and low cost. Three-phase switched reluctance motor commonly has some stators and rotors, which is implemented on the asymmetric converter. To operate the Switched Reluctance Motor, an optical encoder or hall-effect sensor will affect motor performance. To improve motor performance, the input capture method is used. Such a method can give accurate commutation angel so the excitation can be given in proper angel and increases torque on SRM. To verify the proposed method, analysis, and experimental tests were done.

## 1. Introduction

Switched reluctance motor is one type of electric drive that people used and researched in industry applications. SRM is widely used because of their efficiency and low cost. SRM offers the interesting features such as simple stator and rotor construction, simple stator windings, no rotor winding, no brush, no permanent magnet, simple cooling system, high reliability and good performance in a wide speed range [1]. SRM rotor rotates from low-inductance to high-inductance region. The attraction between rotor and stator is constantly linear that produced magnet by an electric current. This phenomenon usually called electromagnetics [2][3].

The switched reluctance motor can not operate directly by input AC or DC source. To operate SRM, the converter is needed to control the polarity and phase currents that produce a continuous motor movement. The control circuit processes the phase current and rotor position control to produce switching signals for power converter. A converter circuit is used to increase and reduce the supply of currents to windings [2].

The additional sensor is needed to operate SRM. The sensor is used for determining switch that will be activated. Position sensors are installed in motor drive systems to provide reliable rotor positions. The rotor position determines the signal which is injected into the converter switches [4]. However, these sensors have several disadvantages that can reduce the performance of SRM. The disadvantage of using a sensor is that an inaccurate installation at 120 degrees can cause a reduction in performance and only have six possible commutation conditions. Then the input capture method is recommended because it can provide the appropriate commutation at the proper angle.

In this paper, a method is discussed to reduce weakness caused by sensors. This method uses the Input Capture facility on dsPIC30F4012 to determine the position of the rotor so that it can determine the proper commutation for SRM. Laboratory tests have been conducted to confirm that the proposed method can improve SRM performance.

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## 2. Construction of Switch Reluctance Motor

### *2.1. The motor and Converter*

Switched Reluctance Motor on this paper uses 12 salient poles on the stator and 8 salient poles on the rotor. The SRM stator is divided into three-phase. Every phase has four salient poles connected. Two opposite salient poles are connected to a phase winding [5]. Two windings which intersecting in a 90-degree angle can be connected into a single-phase on stator. There is no brush, no magnet, no winding inside the rotor [6]. The intersection of salient poles on stator can be seen in figure 1.

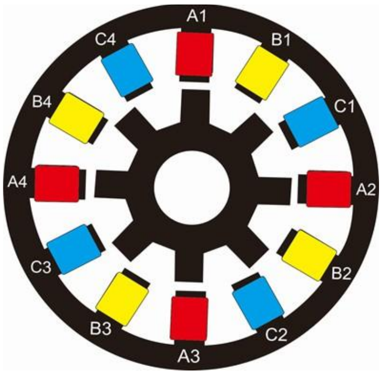


**Figure 1.** The intersection of salient poles on stator and rotor.

The fundamental operation of Switched Reluctance Motor is based on differences in magnetic reluctance. The motor receives a voltage source and produces a magnetic field at the stator. Then it pulls the closest rotor poles and produces reluctance torque [7]. The values of voltage and torque are presented in equation 1 and equation 2.

$$v = \iota.R + \frac{dL(\phi)}{d\phi} \tag{1}$$

$$\mathrm{T}(\phi,\iota) = \frac{1}{2}\iota^2 \frac{dL(\phi)}{d\phi} \tag{2}$$

Equation 1 and equation 2 show where $V$ is voltage, $T$ is SRM torque, $I$ is current, and $dL(\phi)/d\phi$ is different flux.

Switching strategy in converter is used to operate SRM. The asymmetric converter is implemented in this SRM operation. It has two switches and diodes in every phase. The switches are turned on and turned off, determined by the rotor position. When switching is not at a proper condition, SRM cannot be rotated [8][9]. An asymmetric converter and the sequence of SRM operation block diagram can be seen in figure 2 and figure 3.

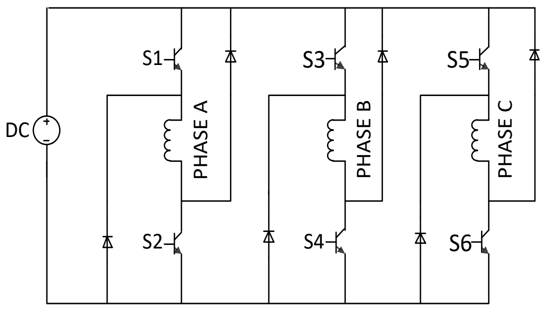


**Figure 2.** Equivalent circuit asymmetric converter.

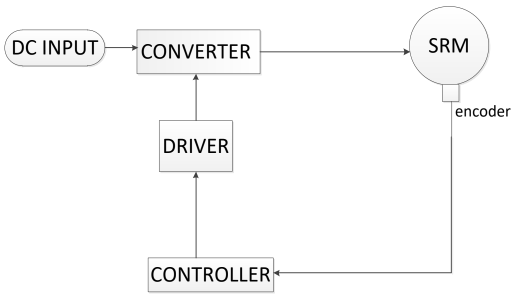


**Figure 3.** Block diagram of switched reluctance motor

### *2.2. Optical Encoder (hall effect) and Input Capture*

The optical encoder is installed at a distance of 120 degrees. These sensors produce a digital signal of output which is processed by the microcontroller dsPIC30F4012. Then commutation signals will be sent to the converter for determining switching operation. The switching operation is used to energize stator for rotating the rotor [10]. The ideal output produced by the optical encoder and proper converter switching are shown in figure 4 and the switches are activated at the exact time described in table I.

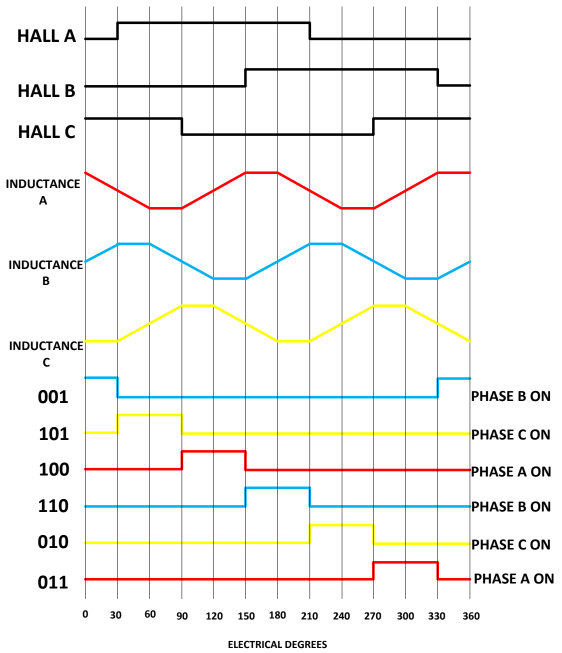


**Figure 4.** The ideal output of optical encoder and converter switching

**Table 1**. A slightly more complex table with a narrow caption.

| Stage | Optical encoder | *Switche on* | Energized stator |
|---|---|---|---|
| **I** | 011 | S1&S2 | Phase A |
| **II** | 100 | | |
| **III** | 001 | S3&S4 | Phase B |
| **IV** | 110 | | |
| **V** | 010 | S5&S6 | Phase C |
| **VI** | 101 | | |

Improper commutation signals make rotor rotation not optimal. This is caused by manual installation of the optical encoder.

The input capture method can resolve the disadvantage on the optical encoder. Input capture is an existing facility in dsPIC30F4012 which functions to convert digital signals into integer value. The integer value can be calculated and processed using certain equations. Digital signals are obtained from SM534 (speed sensor) then managed by the microcontroller dsPIC30F4012 at the facility input capture which produces integer value to determine the proper angle position for commutation signals. The flow chart that shows the proposed system operation is shown in figure 5.

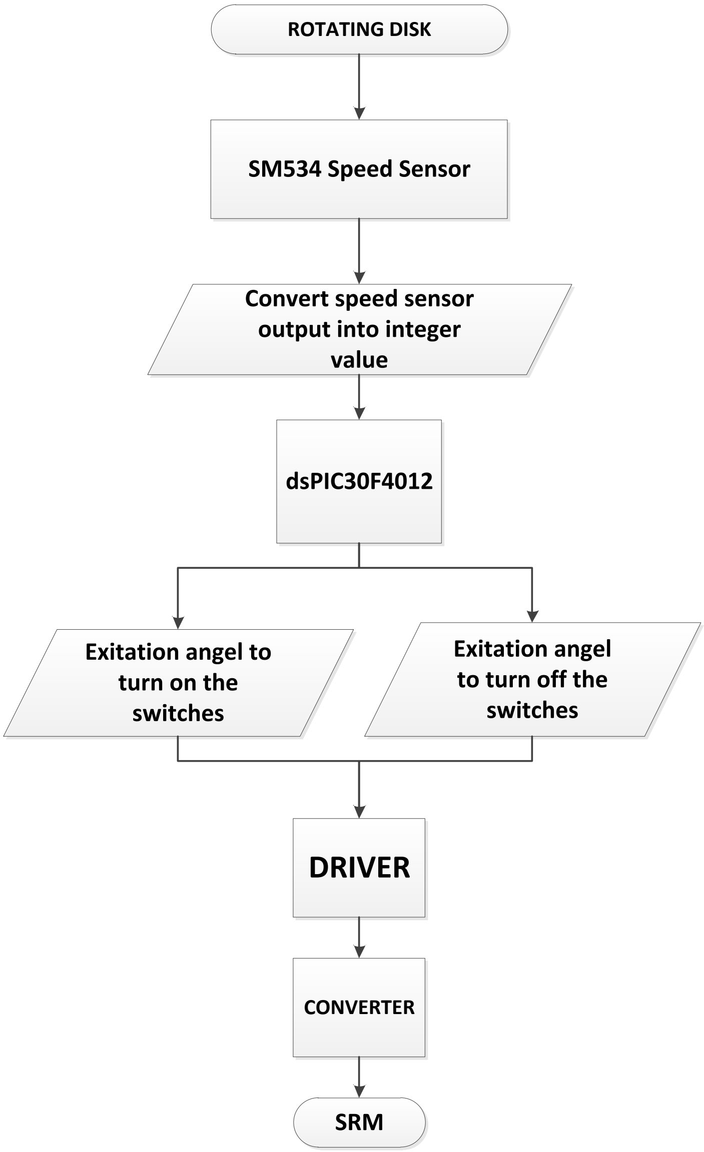


**Figure 5.** Flowchart of input capture method

Rotating of Switched reluctance motor with input capture method requires an angle value to energize the stator. Angle values can be presented equation 3 and equation 4.

$$Don = \frac{ton}{360} \times EDIC \tag{3}$$

$$Doff = \frac{toff}{360} \times EDIC \tag{4}$$

Variable *Don* and *Doff* is degrees on and off, *ton* and *toff* show the angle position switch turn on and angle position switch turn off, *EDIC* is the electrical degrees on input capture.

The determination of angles is used to energize stator according to the rotor position. The determination of angles when turned on and off can be seen in figure 6.

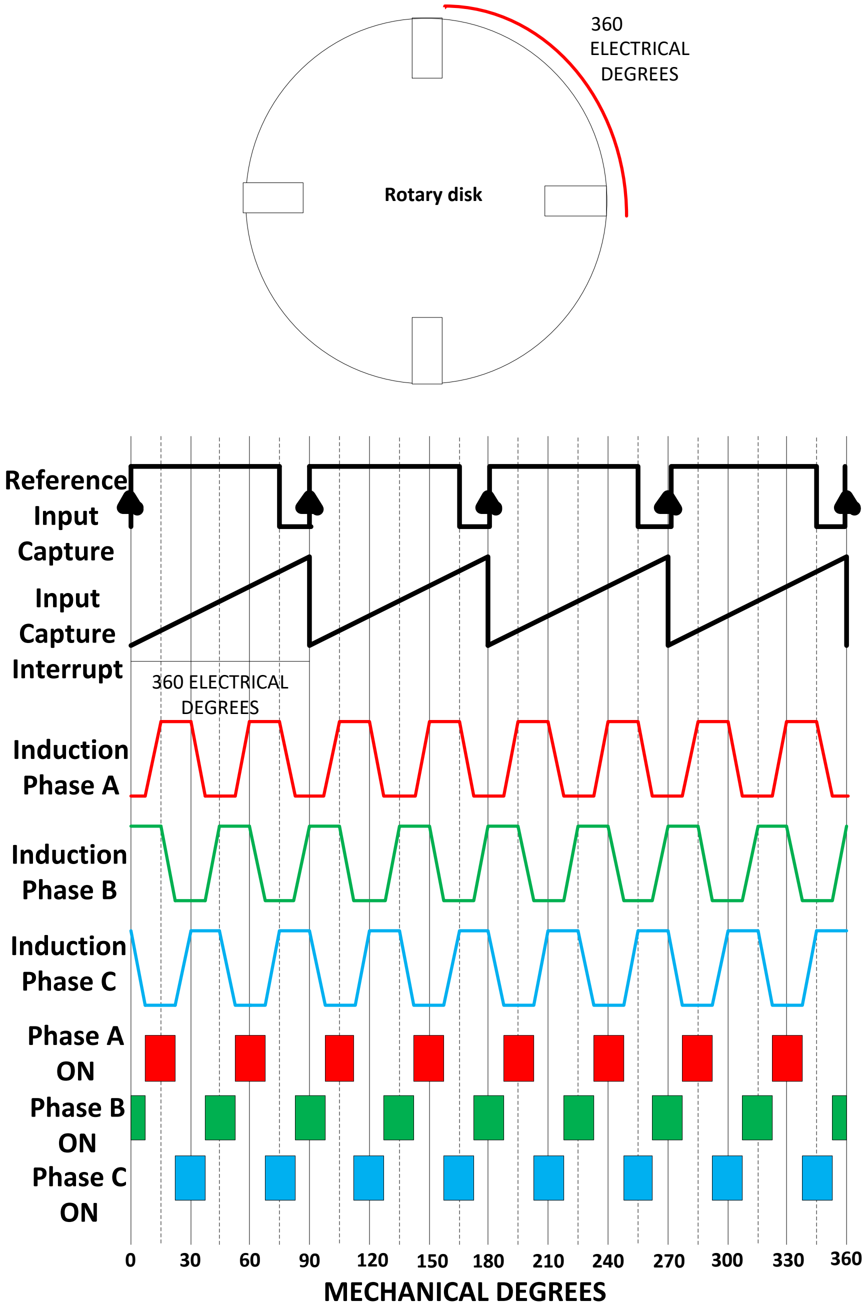


**Figure 6.** Determining the position of angles when turned on and off

## 3. Result and Discussion

To prove the analysis, some experiments were done with the prototype of Switched Reluctance Motor in the laboratory. Switched Reluctance Motor using twelve salient poles stator and eight salient poles rotors. The prototype of Switched Reluctance Motor can be seen in figure 7.

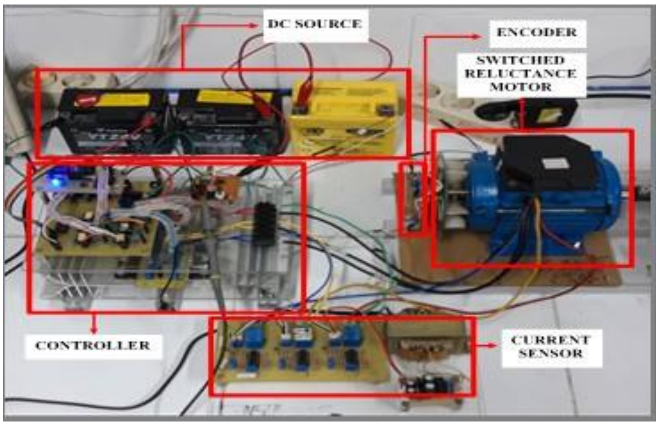


**Figure 7.** Prototype of experimental works.

Switched reluctance motor was supplied with 30 Volt a power supply shown in figure 7. Switched Reluctance has two encoders as detection of rotor positions, optical encoder and input capture encoder (SM534). The microcontroller dsPIC30F4012 is used to control switch patterns in Switched Reluctance motors. The output of the optical encoder and input capture are the references. It can be seen in figure 8.

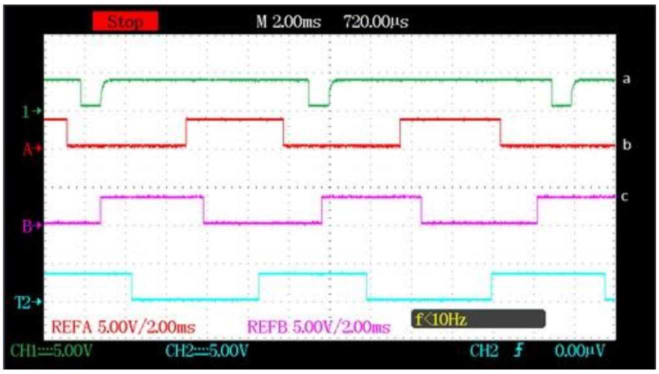


**Figure 8.** Experimental result of reference signals (a) input capture, (b) sensor 1, (c) sensor 2 , dan (d) sensor 3.

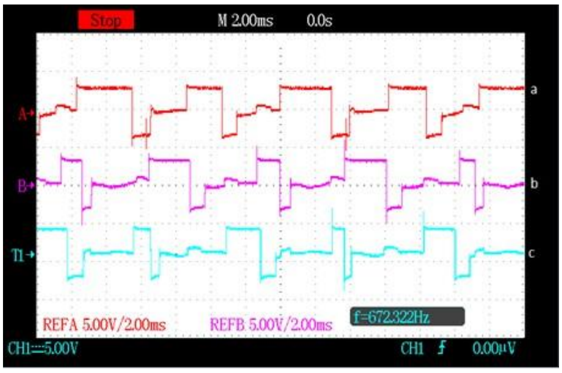


**Figure 9.** Experimental result of phase voltages with 30V input using an optical encoder sensor (a) phase A, (b) phase B, (c) phase C

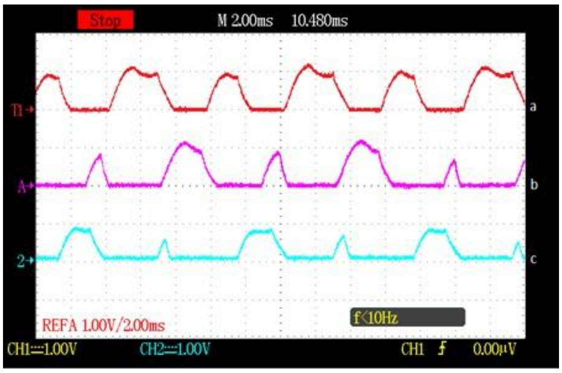


**Figure 10.** Experimental result of phase currents with 30V input using an optical encoder sensor (a) phase A, (b) phase B, (c) phase C

Results of the experiment used an optical encoder sensor, shown in figure 9, figure 10. The voltage signal and current signal are not proportional. It causes the torque and rotational speed on Switched

Reluctance Motor are decreasing. Then, the input capture method facility used in microcontroller dsPIC30F4012.

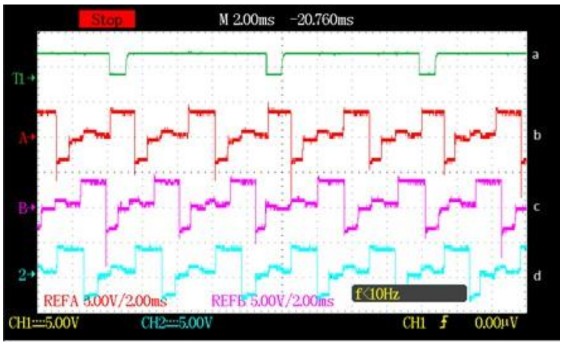

**Figure 11.** Experimental result of phase voltages with 30V input using method of input capture (a) input capture signal, (b) phase voltage A, (c) phase voltage B, (d) phase voltage C.

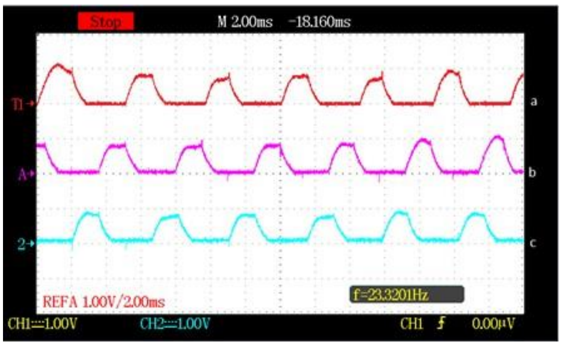

**Figure 12.** Experimental result of phase currents with 30V input using method of input capture (a) phase current A, (b) phase current B, (c) phase current C.

Result of the voltage and current signals using the input capture sensor (SM534) with 90-degrees of intersection is more proportional, so it can improve speed and torque at the motor. The signals are shown in Figure 11, Figure 12.

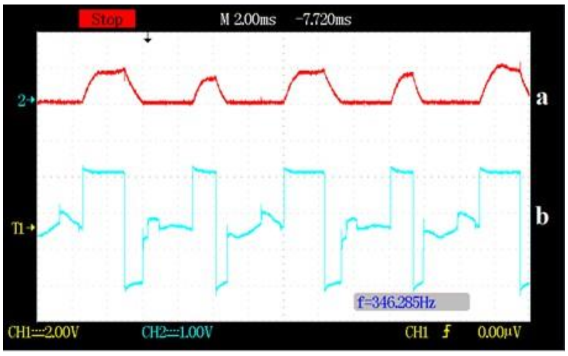

**Figure 13.** Experimental result of current and voltage with 30V input used an optical encoder sensor (a) phase current A, (b) phase voltage A

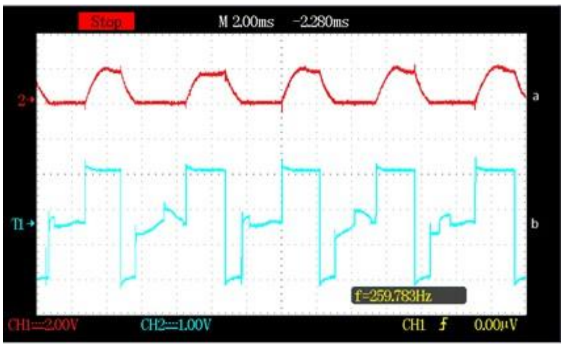

**Figure 14.** Experimental result of current and voltage with 30V input using method of input capture (a) phase current A, (b) phase voltage A

Comparison using optical encoder and input capture can be seen in figure 13 and figure 14. The disadvantage of using an optical encoder is that the installation can not be precise at 120-degrees will affect the provision of excitation to the stator that is not in accordance with the rotor conditions. It causes the rotation on the SRM is not optimal. In figure 13, it can be seen that the current and voltage signals are inaccurate due to the lack of matching excitation angles. Using input capture can increase torque and speed and improve the giving of excitation to the stator. The currents and voltages in figure 14 are more precise because they provide an excitation angle that matches the rotor position.

The speed of motor which used an optical encoder or hall-effect is 1,340 rpm. While the motor uses input capture, it speeds up to 1,562 rpm.

$$\frac{\mathrm{P}}{\mathrm{T}} \approx n \tag{5}$$

According to the equation above, the increase in speed is proportional to the increase in torque on the same voltage. It means the purpose method can increase speed and torque.

## 4. Conclusion

The proposed method is able to operate Switched Reluctance Motor to increase motor torque. Using an optical encoder can rotate the motor, but the installation can be less precise at 120-degrees, causes a lack of precision in distributing energy from stator to rotor, it reduces torque and speed on the motor. The input capture method helps to improve the distributed energy to rotor be more precise. Proper distribute of energy can increase torque and speed of switched reluctance motor.

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