Quick Design of Switched Reluctance Motor and Effect of Switching Angle ANSYS MAXWELL

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***Abstract*—This working paper presents a design of the switched reluctance motor (SRM) for the electric scooter using the coefficient method. Experienced designers usually design an electric motor by analytical or magnetic field analysis. Difficulties arise for those who lacked experience in designing reluctance motor. So this working paper aims to produce guidelines to construct a switched reluctance motor. In this working paper, switched reluctance motor is modelled using coefficient method developed as a quick reference in determining the geometry of SRM based on past research. Next, the designed model would be analyzed using ANSYS Maxwell finite elements software. Simulation of the said model is in the Maxwell two dimensions with standard external circuit excitation with different switching angles. The expected outcome can be observed from the effects of switching angle on torque and current winding profile. As a result, the effect of switching is identified.**

***Index Terms*—Switched Reluctant Motor; Switching Angle; ANSYS Maxwell.**

I. INTRODUCTION

Large scale industrial activities and an increasing volume of petroleum based on the road had contributed towards pollution and hence the quality of the environment is affected. The emission of noxious gases from internal combustion engine (ICE) is now becoming a major environmental issue and the lack of efficient fuel in the combustion process had worsened the problem.

Switched Reluctance Motor (SRM) has simple and rugged construction, wide speed range, and high torque density, high level of fault tolerance capabilities, magnet free rotor, low inertia, and potentially low cost production exist as an attractive candidate for EV application [4]. This paper consists of four parts where section two explains on the coefficient method used in designing SRM, the next section is on control methods on the SRM and its effect on switching mode and the last section is about the result analysis and conclusion. The proposed switched reluctance motor is designed using coefficient methods and the complete dimension will be constructed using ANSYS Maxwell finite elements software.

II. METHODOLOGY

A. *Coefficient Method*

A proper designed procedure must be performed to ensure the efficient performance of the motor. In this paper, the dimension of SRM will be determined using coefficient method. Here, coefficient method is defined by gathering SRM motor dimensions from numerous technical publications [5][7] in producing a feasible boundary of designed ratio from various geometric dimensions as in Table 1. The basic geometric parameter for SRM is shown in Figure 1 and Figure 2. In determining the designed ratio, every motor dimension from previous publications will be defined by measuring ratio for every parameter. For example, if the outer diameter of stator is 96.56 mm and the inner diameter is 48.86 mm, the ratio is around 0.51.

Table 1
Design Parameter Using Coefficient Method

Parameter	Symbol	Coefficient
Diameter inner stator to diameter outer of stator	Dsi:Do	0.26-0.88
Inner diameter of stator to bore diameter of stator	Dsi:Di	0.13-0.54
Outer diameter rotor to outer diameter of stator	Dro:Do	0.56-0.87
Rotor inner diameter to outer diameter rotor	Dri:Dro	0.51-0.87
Bore of rotor to shaft	Dro:Dsh	0.32-0.57
Stack length to rotor bore	Length:Dro	0.32-3.8

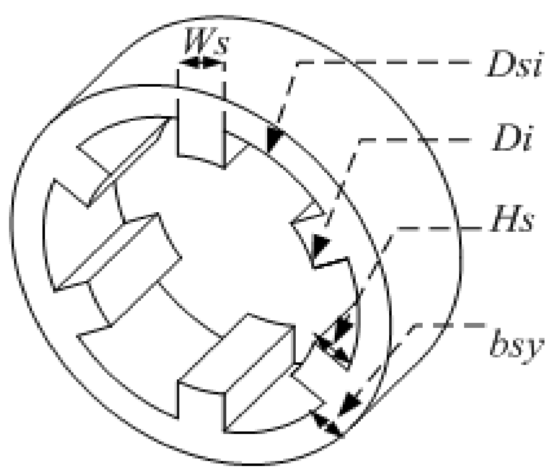

Figure 1: Basic geometry of SRM stator

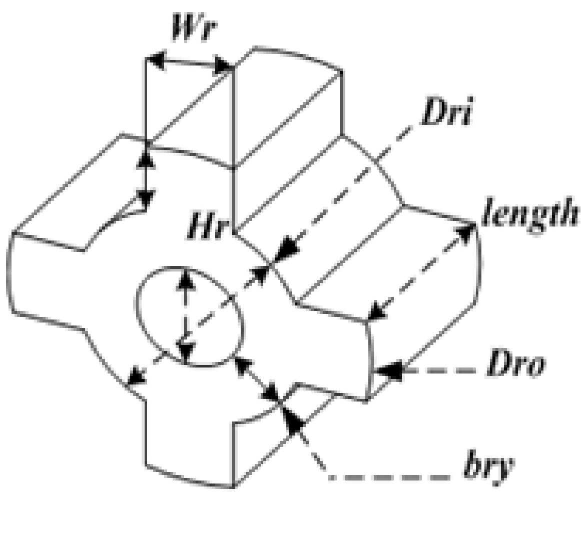

Figure 2: Basic geometry of SRM rotor

B. Production of Torque and Effect of Switching Mode

Switched reluctance motor is widely used in line with the growth of research in power electronics. Due to its simple basic structure, ruggedness and low cost of manufacture, this motor is highly interesting. However, it also has a few drawbacks especially on control methods in producing a required torque. This motor has difficulties due to rotor position that needs to be aware of at all times. It needs a proper timing to excite phase winding and the position of rotor is compulsory in producing a positive torque. The current is applied as the inductance starts to rise and this happens when the stator and rotor starts to align. Basic switching sequences in controlling the SRM is applied based on the previous principle. So this paper provides the simulation results on how the switching timing influences the torque production with the help of ANSYS Maxwell finite elements software. The simulation runs under three modes which are before ascending, during ascending and during descending.

The preliminary design is analyzed without consideration of saturation effects and several optimizations is performed to have a predictable design. Previously, in literature, to determine performance of SRM motor, there are two common techniques used which are magnetization analysis through analytical method and finite element technique. Here, the finite element method ANSYS Maxwell chose to analyze the performance of SRM. The motor is designed in 2D section and simulated using half fractions of model to reduce simulation computational time.

The phase winding will be excited using external circuit editor which provides a control method using voltage control pulse width modulation technique. The result will display the effects on torque and current winding in three modes which is before inductance starts ascending, while ascending and after inductance descends. Methods on excitation is shown on one phase only which is phase A, but effects on torque and winding current will cover for overall phases. Mode 1 in Figure 3 shows the phase winding excite with setting time delay -20 ms before the inductance starts ascending for every phase. Initial starting of this SRM is 30 degrees to ensure the motor have a self-starting. Mode 2 in Figure 4 shows the phase winding excite with setting no time delay before the inductance ascends. Mode 3 in Figure 5 shows the phase winding excite after inductance descends with time setting 20 ms for every phases.

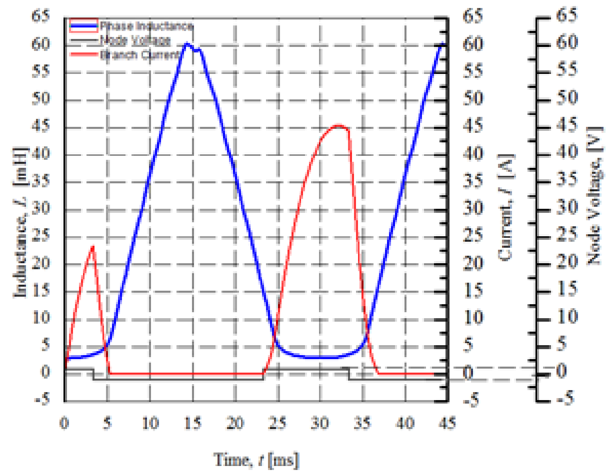

Figure 3: Phase A excite before inductance ascends

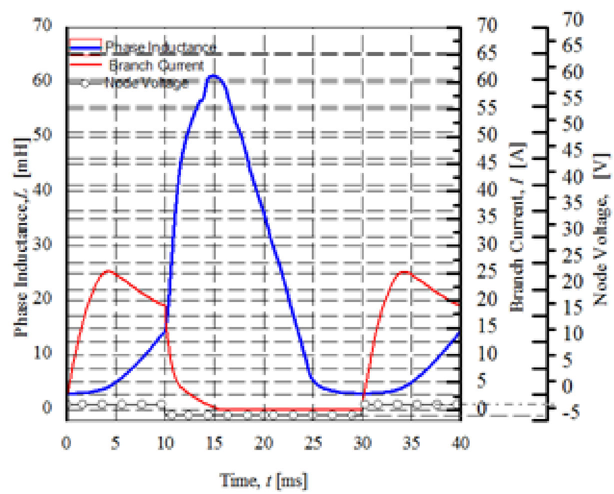

Figure 4: Phase A excited while inductance ascends

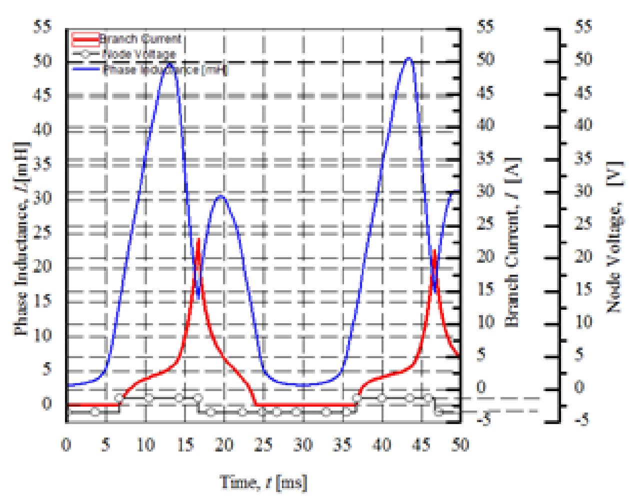

Figure 5: Phase A excited while inductance descends

III. RESULTS AND DISCUSSION

A. Simulation Results

This section explains the effects of switching on SRM in three differences mode. The result will show the torque and current winding while switching mode applies in three modes which are before inductance ascends, while inductance ascends and when the inductance starts to descend. Figure 6 and Figure 7 shows the effects before the inductance starts to ascend. Torque generated is proportionate to the current and rotor position. At this time, the rotor position is starting to approach close to the stator position. Meanwhile, the inductance remains constant and starts to reach the increase point. Since the voltage pulse was injected earlier, the current produced is high and slowly re-move the earlier and appeared as negative torque.

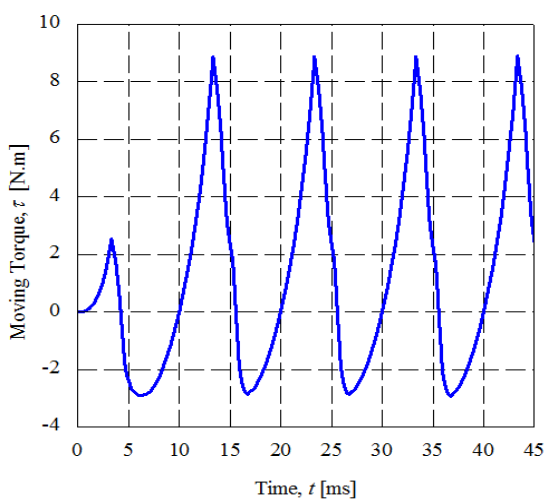

Figure 6: Torque production before inductance ascends

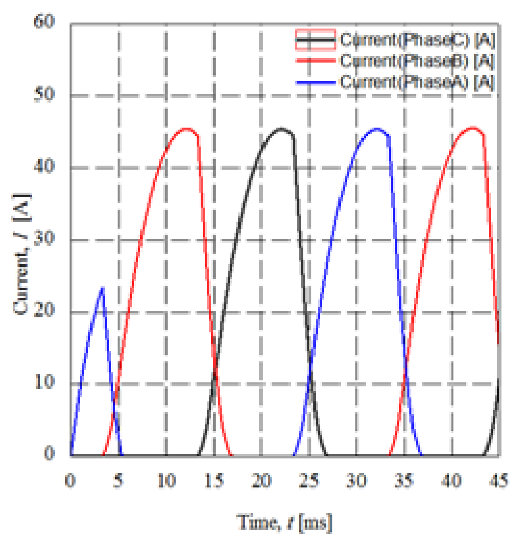

Figure 7: Winding current before inductance ascends

Figure 8 and Figure 9 show the effects when inductance starts ascending, this time the rotor position is slightly overlapped with stator position. The inductance starts to increase linearly. At this time the torque generated is at the positive side and voltage is removed earlier so that the current is decayed which makes the torque positive.

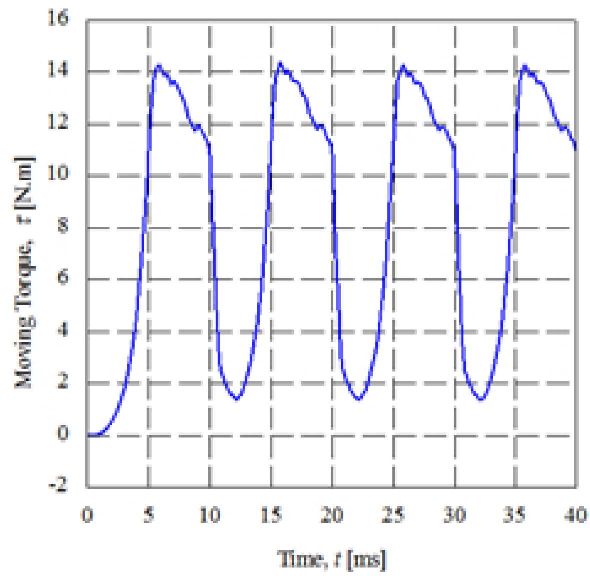

Figure 8: Torque production while inductance ascends

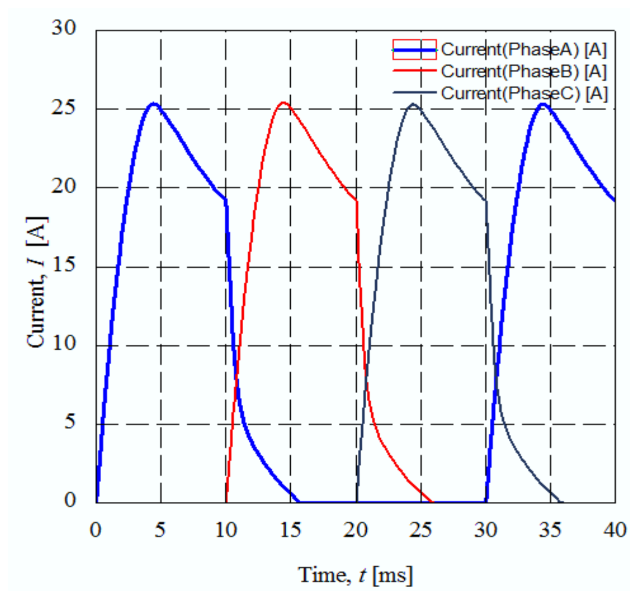

Figure 9: Winding current while indctance ascends

Figure 10 and Figure 11 shows effect while inductance goes down, this time rotor position is slightly unaligned from stator position. The inductance starts to decrease linearly. While this time the torque generates at negative side and voltage is removes later so the current will decay slowly and makes the torque negative.

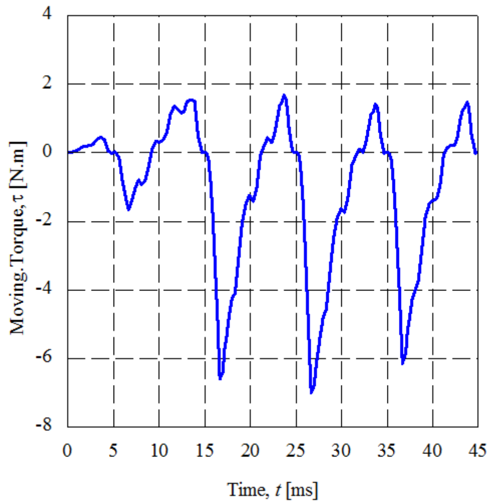

Figure 10: Torque production after inductance descends

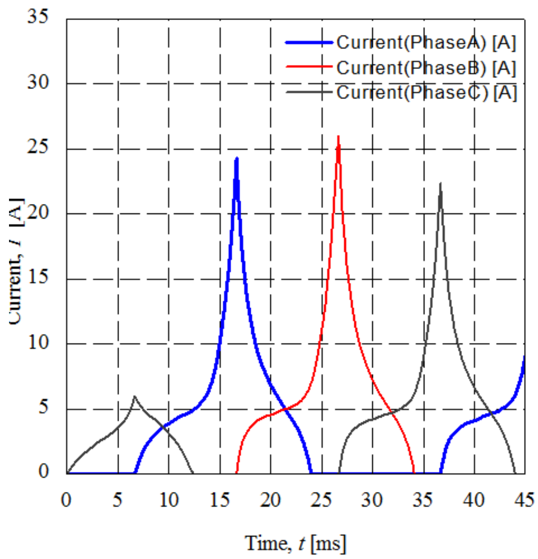

Figure 11: Winding current while inductance descends

IV. CONCLUSION

The coefficient method successfully applied as preliminary guidelines on SRM construction. Later, it had to be strengthened with another designed tool to enhance the output performance. The optimization stage is performed in order to achieve the desired performance on the topic, however, the lack of accuracy and aspects on effects of saturation is not included. Regarding the effects on switching mode, it can be concluded that, to generate positive output torque, voltage pulses must be injected accurately while rotor position and stator position starts to align. Otherwise, the negative torque is produced.

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