Journal of Engineering and Applied Sciences 13 (21): 8935-8938, 2018
ISSN: 1816-949X

Loss Detection in Converter Power Electronics of a Switched Reluctance Machine

Nikolay Grebennikov and Alexander Lebedev
Closed Joint-Stock Company Scientific-Technical Center (PRIVOD-N), Krivoshlykova Street 4a,
346428 Novocherkassk, Russia

Abstract: The given study presents the development of a computer modelling in MATLAB/Simulink Software for detection of losses in a power converter while supplying the switched reluctance motor.The initial data for modelling is the data given in datasheet for IGBT and wheeling diode of IGBT power module. The proposed method ensures the practical approach for the precise loss detection and makes possible a quick selection of power electronics for the converter as well as an analysis of its performance in different modes.

Key words: Losses, IGBT modules, power electronic, converter, modes, loss detection, modes

INTRODUCTION

Now a days there is an intensive development of frequency-controlled traction commutatorless electric drives for vehicles. To Supply switched Reluctance Machines (SRM) it is mostly used a half-bridge inverter equipped with two controlled keys for each phase (Miller, 1993; Grebennikov and Kireev, 2015). The distinguishing characteristic of this scheme is that it is always switched inductance (phase winding) between controlled keys. This fact essentially eliminates through fault in the invertor which is typical for traditional schemes of inverters powering frequency-controlled asynchronous motors and motors with permanent magnets.

For design and development of a power converter for a switch reluctance motor it is needed to select its basic components such as IGBT, wheeling diodes and capacitors. The selection is performed based on data for current load, losses evolved from devices and voltage value. To determine these parameters it is necessary to simulate the electric drive operation in different modes (start-up, nominal, load acceleration process).

MATLAB/Simulink Software complex has great opportunities for development and simulation of electric drives (Grebennikov *et al*., 2015). The detailed development of a SRM Model is described in (Grebennikov and Lebedev, 2016). The present study considers the process of the model development for detection of losses in power elements of the converter for SRM supplying.

MATERIALS AND METHODS

Power converter: The power converter of the motor is designed for timely connection and disconnection of motor phase windings to DC link. The power converter includes power semiconductor devices-IGBT modules consisting of IGBT transistor and diode for short energy storage the capacitor is used. IGBT modules are placed at the cooling radiator provided with either air or liquid cooling.

The most common scheme is the classical scheme of the power converter designed as a half-bridge invertor with two power transistors and two diodes connected diagonally (Fig. 1). In such scheme when opening of both transistors full voltage is applied to the winding. When opening only one of the transistors, the winding is short-circuited by the key or diode allowing us to keep the value of winding magnetic flux as almost constant. The alteration of winding switching modes with relatively small switching frequency of power keys makes it possible to keep the given value of phase current. When

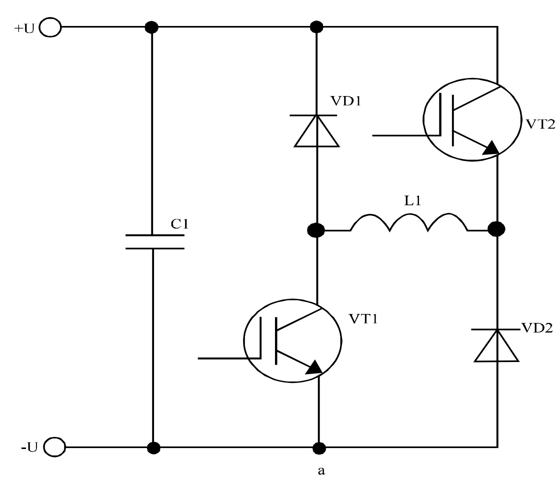

Fig. 1: Half-bridge converter

Corresponding Author: Nikolay Grebennikov, Closed Joint-Stock Company Scientific-Technical Center (PRIVOD-N), Krivoshlykova Street 4a, 346428 Novocherkassk, Russia

switching off transistors to phase winding with wheeling diodes it is applied negative voltage leading to quick magnetic field killing due to extraction of energy from electromagnetic contour to the capacitor.

For electric drive management the following sensors are installed in the power converter sensors of motor phase current, a DC link voltage sensor and temperature sensors of IGBT modules. All signals from sensors go to the microprocessor control system of the drive for processing and following controlling action for IGBT transistors.

Losses in IGBT transistor operating in key mode are calculated based on two components, conductivity losses and switching losses (Oberdorf, 2006). The initial data for loss detection is datasheet at IGBT module providing current-voltage characteristics of transistors and module diodes, dependence of energy for transistors switching on and off and diode reverse recovery characteristics. Conductivity losses of transistors are calculated by the following equation:

$$L_{C\_VT} = \frac{1}{T}\sum_{n=1}^{N} I_n \times Uce_n \times \Delta t$$

Where:

Δt = Stride parameter of time sampling
T = Duration of phase current period
N = Number of measurements in a period
I_n = Collector current
Uce_n = Transistor junction voltage drop under current I_n

Switching losses in transistors are calculated by the following equation:

$$L_{S\_VT} = \frac{1}{T}\sum_{n=1}^{N} Eon_n \times OnT_n + Eoff_n \cdot Off\,T_n$$

Where:

Eon_n = Energy losses for transistor switching on under current I_n
OnT_n = Characteristic value of transistor switching on
$Eoff_n$ = Energy losses for transistor switching off under current I_n
$OffT_n$ = Characteristic value of transistor switching off

Diodes conductivity losses are calculated by the following equation:

$$L_{C\_VD} = \frac{1}{T}\sum_{n=1}^{N} I_n \cdot Uf_n \cdot \Delta t$$

Where:

Uf_n = Diode voltage drop under current I_n
D_n = Characteristic value of diode conductivity

Losses of diode recovery are defined by the following equation:

$$L_{R\_VD} = \frac{1}{T}\sum_{n=1}^{N} Erec_n \cdot OffD_n$$

Where:

$Erec_n$ = Energy loss for diode reverse recovery characteristics under current I_n
$OffD_n$ = Characteristic value of diode switching off

Total losses in power elements are defined as a sum of conductivity and switching losses of the transistor:

$$L_{VT} = \frac{1}{T}\sum_{n=1}^{N}\left(I_n \cdot Uce_n \cdot \Delta t + Eon_n \cdot OnT_n + Eoff_n \cdot OffT_n\right)$$

And diode module:

$$L_{VT} = \frac{1}{T}\sum_{n=1}^{N}\left(I_n \cdot Uf_n \cdot \Delta t + Erec_n \cdot OffD_n\right)$$

Computer modelling: Library sim power systems of MATLAB/Simulink Software includes models of various components using in power converters. Having the standard models of IGBT elements such as transistors, diodes and capacitors it is possible to assemble the model of electrical scheme of a traditional half-bridge converter. IGBT and diode settings enable to indicate the needed parameters of elements. In addition the given elements have an inbuilt measuring port which allows us to get the value of current flowing through the element and voltage value.

For loss determinationin the given elements it has been developed the supplementary unit Loss-power converter where losses are calculated bothin IGBT moduleand in wheeling diode (Fig. 2).

Input signals are the following: pos-scan of angular position depending on time, current VT-current of IGBT transistor, contol VT-control signal of IGBT transistor, currentVD-current of wheeling diode.

Scan of angular position is necessary for calculation of a period and for triggers action in blocks integrator, accumulation and triggered subsystem. Block table VA-VT is set the characteristic soft ransistor junction voltage drop depending on collector current, block table Eon-VT is set energy characteristics for transistor activation, block table Eon_VT is set energy characteristics for transistor deactivation. To sumup transistor conductivitylosses (I_n.Uce_n.Δt) block integrator1 is applied providing the possibility to reset till initial condition. The analogue block integrator 2 is applied for calculation of diode conductivity losses.

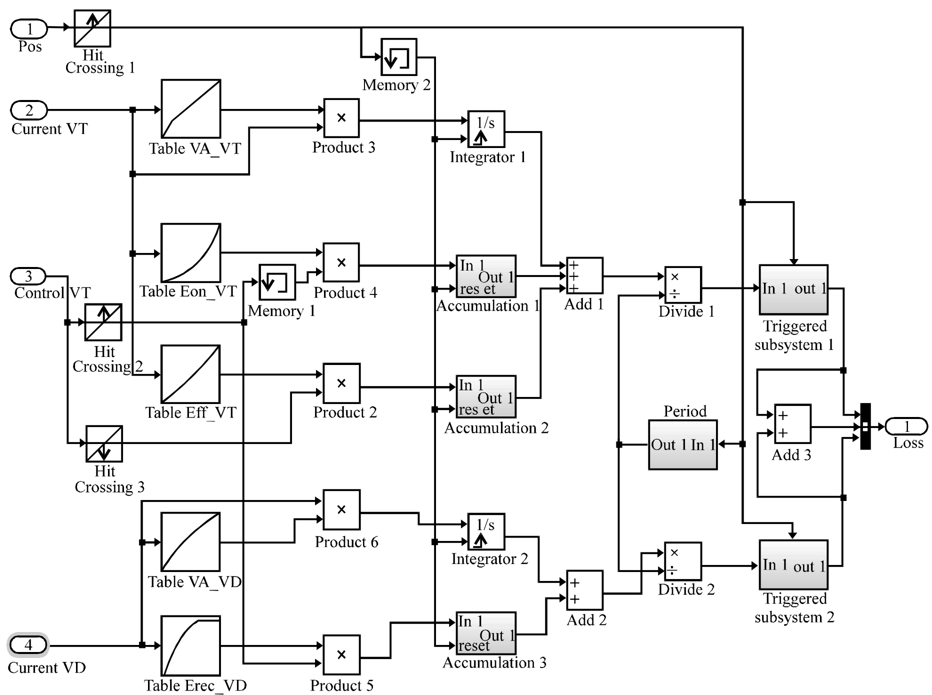

Fig. 2: Structure of loss_power converter unit

To accumulate energy for transistor switching block accumulation 1 is used which allows us to sum up the quantity of output energy at each transistor switching. When starting a new period the condition is reset till zero. The block structureis given at Fig. 3.

The quantity of energy for transistor switching off and diode resetis calculated in asimilar way using blocks accumulation 2 and 3. Block add 1 sums up losses for IGBT and block add 2 does for diode. Block divide 1 refers IGBT loss value to the period. Block divide 2 refers diode loss value to the period.

Since, the period of phase current of SRM changes depending on rotation frequency ofa motor shaft, it should be calculated. The structure of period block is given at Fig. 4.

The block is based on triggered subsystems which capture simulation time (block clock) when actuation hit crossing 1 (Fig. 2) triggered subsystem 2 actuates with delayinone simulation time-step by means of memory block. Further add block compares stored time when hit crossing 1 actuation and stored time when the period starting. Triggered subsystem 3 remembers time period and store sit up to the next one.

Add 3 block (Fig. 2) sums up losses in IGBT and diode. Losses in IGBT in diode and total losses of the module are generated into busbar and transmitted to output loss.

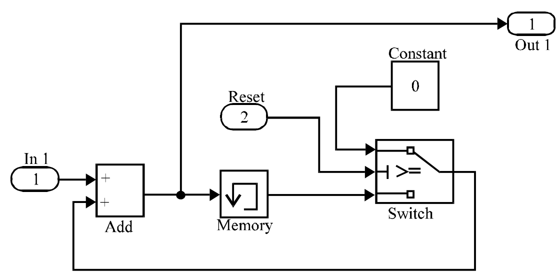

Fig. 3: Accumulation block structure

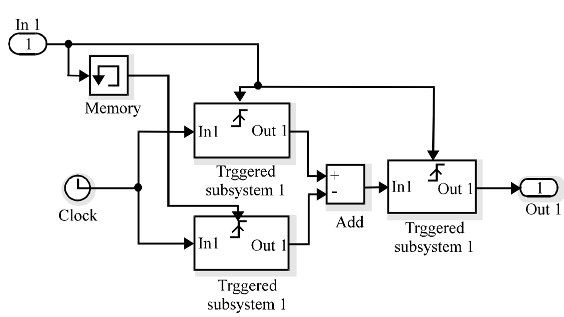

Fig. 4: Period block structure

The results of IGBT loss simulation are given at Fig. 5 and 6 presents diode loss simulation.

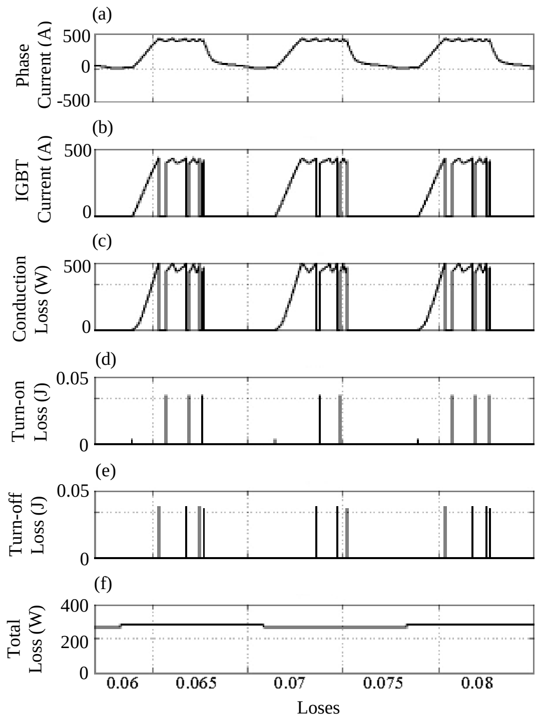

Fig. 5: IGBT loss

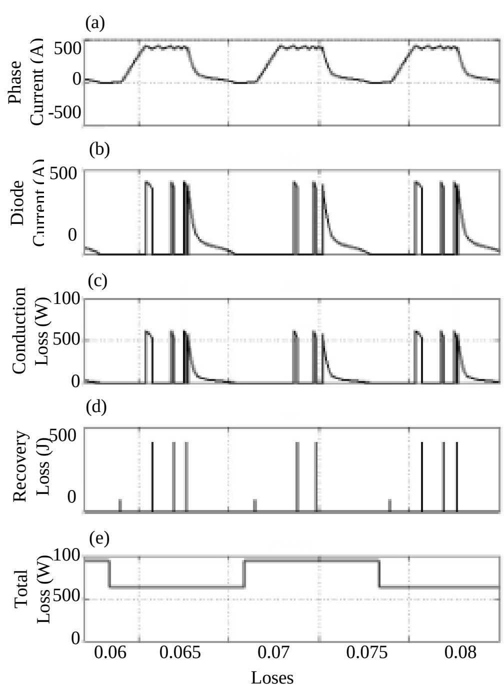

Fig. 6: Wheeling diode loss

In order to balance the loads at transistors the management of VT1 and VT2 (Fig. 1) in the mode of current corridor is performed one by one.

Therefore, IGBT current and diode current differ from phase current. Additionally, total loss differs from one period to another. Simulation has been performed for the electric drive operating under frequency 1000 rpm at nominal power 125 kW, modules DF 600 R 12 IP4D produced by infineon technologies (Anonymous, 2013) were usedas keys (switching devices). Average losses in IGBT for two periods are 273 W for diode-79 W, total losses in module is 352 W. Total loses in power electronics of the converter is 2112 W.

CONCLUSION

The study presents the development of a computer modelling in MATLAB/Simulink Software to detect losses in a power converter while SRM supplying. The distinguishing characteristic of the model is that losses in converter IGBT and diode are detected based on data given in datasheet. This approach ensures the practical method of the precise loss detection and provides a quick selection of electronics for the converter. Moreover, the specific feature of the given method is the possibility for loss simulation in any dynamic modes of electric drive operation.

ACKNOWLEDGEMENT

The presented research has been developed with support of Russian Ministry of Education, grant RFMEFI57916X0132.

REFERENCES

Anonymous, 2013. Your exclusive insight on the new 600 V IGBT3 TRENCHSTOP™ advanced isolation TO-247. Infineon Technologies, Neubiberg, Germany. https://infineoncommunity.com/2018May_GLOB_IPC_WP_Advanced_Isolation_ID970?elq_mid=3399&elq_cid=579095&intc=0320185

Grebennikov, N. and A. Lebedev, 2016. Development of switched reluctance machines model in MATLAB/Simulink. J. Eng. Appl. Sci., 11: 1434-1438.

Grebennikov, N.V. and A.V. Kiereev, 2015. Analytic model of electromagnetic processes in switched reluctance machines 18/15 configuration. J. Eng. Appl. Sci., 10: 28-32.

Miller, T.G.E., 1993. Switched Reluctance Motors and Their Control. Magna Physics Publishing, Oxford, ISBN: 9780198593874, Pages: 200.

Oberdorf, M.C., 2006. Power losses and thermal modeling of a voltage source inverter. Master Thesis, Naval Postgraduate School, Monterey, California, USA.