DIGITALLY CONTROLLED DRIVER FOR SUPPLYING ELECTRIC RELUCTANT MOTORS

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Abstract. *The paper deals with the aspects regarding the simulation, implementation and testing of a PWM inverter for reluctant motors, using an IR2101 driver made by International Rectifier. Two types of reluctant motors are used, a variable reluctance motor (VRSM) and a switched reluctance motor (SRM). The simulation of the inverter in PSpice environment and the acquired waveforms with LabVIEW environment in case of inverter testing are presented.*
Keywords: *reluctance motors, IR2101 driver, PWM inverter, PSpice simulation, testing platform.*

Introduction

The advance of incremental motion control systems, where one usually uses stepping motors, has been enforced by the multiplicity of their utilization in digital controlled machine-tools drives, peripheral computer equipments, telecommunications through laser and satellites, nuclear techniques, industrial robots, aeronautical and military equipments etc. In this context, the VRSMs promise the low-cost production and motivate the comprehensive research and design although they are not included in the classical treatment of the DC or AC electrical drives.

Among reluctant motors, variable reluctance stepping motors (VRSM) and switched reluctance motors (SRM) are the most popular. VRSM, witch is very representative as reluctant motors, serves especially in digitally controlled open-loop positioning servo-systems and is very suitable for board instrumentations. SRM has imposed itself in the last years, especially in variable speed applications, due to the simple technology involved. It is used especially in speed servo-systems and operates with self-commutation of their phases.

Despite of their excellent robustness as actuators in special applications, both types of motors are confronted with a major problem of their supplying and driving systems, witch focused much interest among specialists in the last decade.

Motor description

Two types of reluctant motors are involved: a switched reluctance motor (SRM), and a variable reluctance stepping motor (VRSM). The SRM used is of 8/6 4 phase type and his electromagnetic structure is depicted in figure 1 [1].

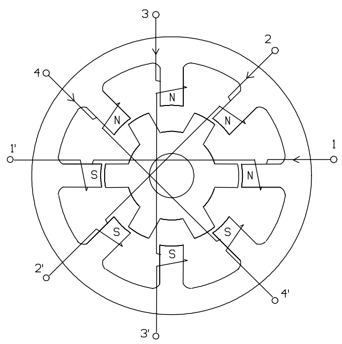

Figure1. Structure of the SRM.

The used SRM has the following characteristics:

Electromagnetic peak torque =4 Nm;
Phase current = 9 A;
Phase voltage = 200V;
Step angle = 15^0.
The VRSM taken for study is a common 8 pole, 4 phase motor [2], with the following main characteristics:

Electromagnetic peak torque = 2 Nm;
Phase current = 4 A;
Phase voltage = 60V;
Step angle = 2.65^0 (136 steps/rot).

Figure 2 shows the electromagnetic structure of its stator.

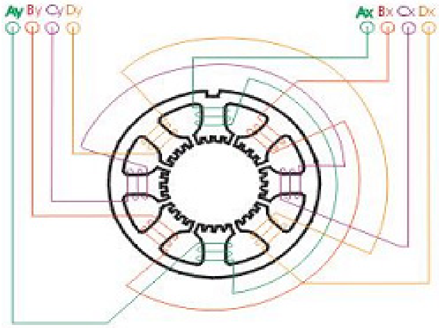

Figure 2. Structure of the VRSM stator.

Each phase is built from two diametrically opposite poles windings, in such a manner that each phase has two ends, available for various connecting techniques in PWM inverters.
The VRSM was design and dimensioned starting from the following data:
Figure 3 shows the picture of the whole motor, as it has been manufactured in authors' laboratory.

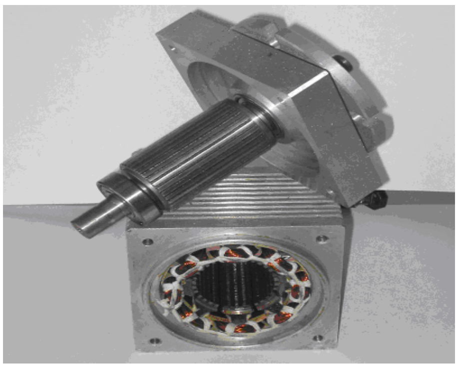

Figure 3. VRSM picture.

Figure 4 presents the measured inductivities with volt-ampere method:

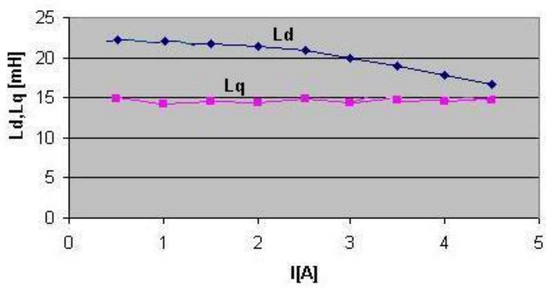

Figure 4. Measured inductivities.

PWM inverter

A unique PWM inverter has been designed to supply both VRSM and SRM. Usually reluctant motors are supplied by voltage sources (series resistance switches or dual voltage schemes) or by current sources (PWM schemes). PWM schemes are the most popular inverters in case of reluctant motors [3] due to their adaptability to various techniques based on voltage and current processing. In this case, OrCAD environment has been used in order to design and simulate the PWM inverter. Figure 5 shows the block diagram of the inverter as base for design in OrCAD Capture, and figure 6 illustrate the current and voltage waveforms in case of PSpice simulation of the inverter. In figure 7 we can see the picture of the real inverter.
As phase currents are unipolar in case of both types of motors, MOS half-bridges inverter scheme is chosen. Each bridge is controlled by four high/low side drivers for MOS transistors. As MOS drivers IR2101 from International Rectifier has been used. The IR2101 is a high voltage, high speed power MOSFET and IGBT driver with independent high and low side referenced output channels. The logic input is compatible with standard CMOS or LSTTL outputs. The output drivers feature a high pulse current buffer stage designed for minimum driver cross-conduction. The floating channel can be used to drive an N-channel power MOSFET or IGBT in the high side configuration witch operates up to 600 volts [4].
The PWM operation is performed by current feedback from shunt resistors R_{sh13}, respectively R_{sh24} and voltage comparators. Due to the two-phase-on control of motor phases, the coupling of phases 1 and 3, respectively 2 and 4 is possible, therefore only two current feedbacks are needed. Output signals L_{o1}-L_{o4} are sent directly from pulse sequencer by signals L_1-L_4 to drive low MOS switches, while output signals H_{o1}-H_{o4} are processed by the two current feedback signals H_{13}, H_{24} to drive high MOS switches.
The PWM inverter as described provides excellent voltage and current waveforms in case of reluctant motors. It is associated to VCC

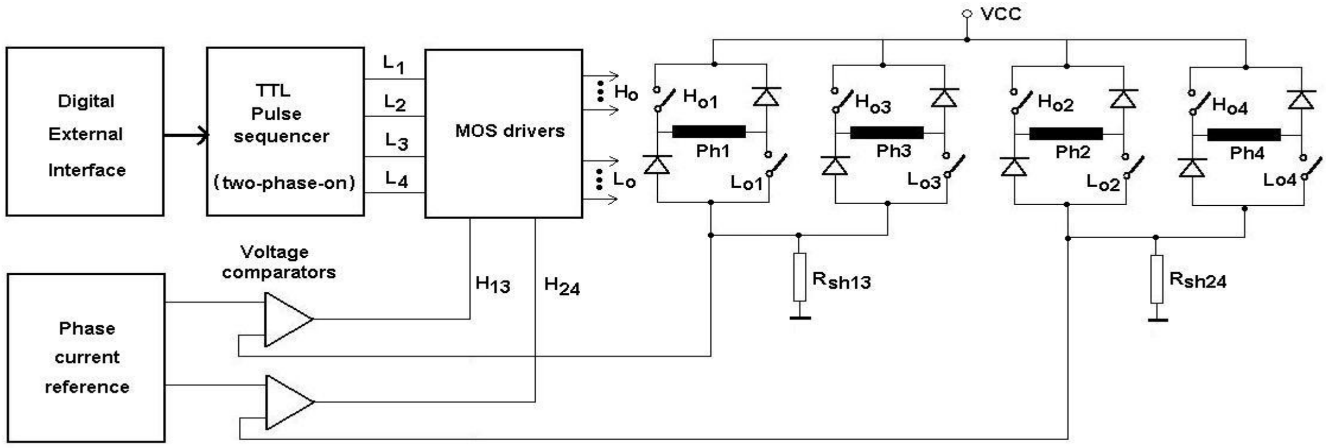

Figure 5. Block diagram of the inverter.

sources and additional electric devices into a Motor Driver.

Inverter testing

The testing platform consists in VRSM and SRM, PWM inverter, a PC workstation containing a plug-in card LabPC 1200, for acquisition and measurement with LabVIEW environment, DC sources etc.

LabVIEW environment of National Instruments Co. [5] for virtual instrumentation of the inverter as part of the testing platform has been used to get experimental results. It allows creating virtual instruments for viewing and saving current and voltage waveforms. Graphic language "G" is used in order to design the above block diagram, which allows defining the data flux and the components (buttons, switches, cursors, recipients, objects for graphic representations etc). All components are connected through wires.

Lab-PC1200 board is used, witch is a completely switch-less and jumper-less data acquisition board. This allows DMA, interrupts, and base I/O addresses to be assigned into the system to avoid resource conflicts with other boards in the system. This board was designed for high-performance data acquisition and control for applications in laboratory testing, production testing, and industrial process monitoring and control. Lab-PC 1200 board has eight analogue input channels ACH0-ACH7 that can be configure as eight single-ended or four differential inputs, a 12-bit successive-approximation ADC, 24 lines of TTL-compatible digital I/O, and three 16-bit counter/timers for timing I/O [6].

We are using for each of the four phases of the motors, current transducer (LEM LA 55-P) and voltage transducer (LEM LV 25-P) in order to have a galvanic separation between the power module and measure module (the LabPC board). Also, in order to protect the digital part against the disturbance that could appear, we decided to galvanic separate the digital part.

Using the LabVIEW environment, we have acquired the PWM signal provided by the board. Figure 8 reveals clearly the 3 time intervals within an ON period of one branch of the inverter: forcing interval – when the voltage is kept constant until the current reaches the nominal value (also seen in figure 9), PWM interval – when voltage and current are hard chopped and suppression interval – when the phase current decays under a constant negative voltage. Figure 9 shows the acquired waveform for phase voltage and current in case of VRSM.

Conclusions

The inverter was first simulated in OrCAD - PSpice environment, but because the IR2101 driver is not included in the PSpice library and a PSpice model was made, the simulated results

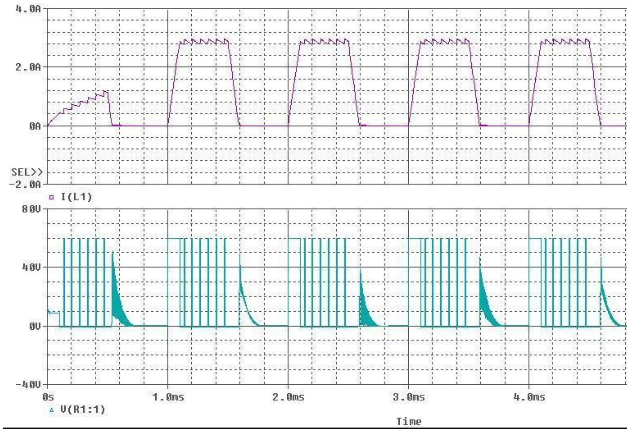

Figure 6. Waveforms of PWM current and voltage, simulated in PSpice.

Figure 7. Picture of the PWM inverter.

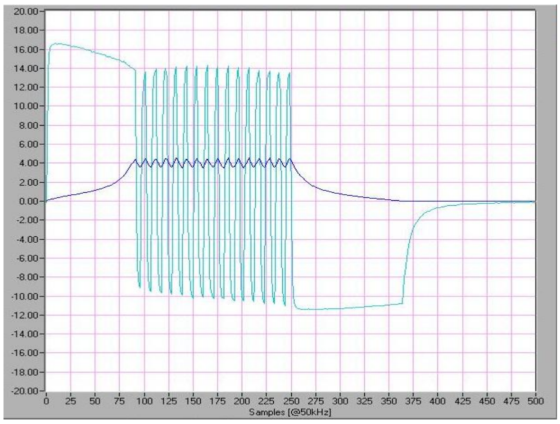

Figure 8. Acquired waveforms of PWM current and voltage.

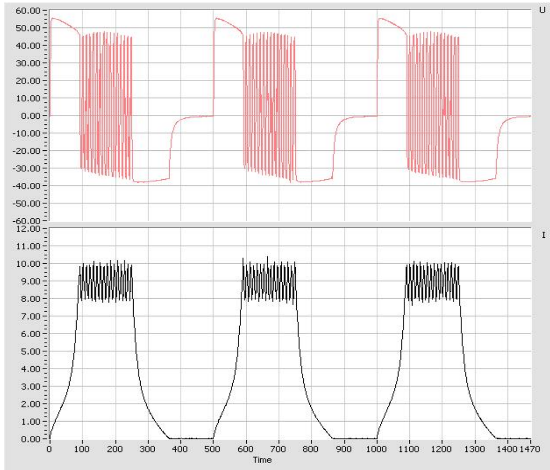

Figure 9. Acquired voltage and current at motor standstill.

containing only the waveform for current and voltage in case of soft chopping.

Regarding the acquired waveform for current and voltage with LabVIEW environment in case of inverter testing, we can see that the results are very close to the ideal form so we can conclude that the inverter works properly, and could be used as a premise to develop new research for upgrading motor performance up to general purpose electrical drives requirements.

References

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[4]*** *IR2101 Data Sheet*; International Rectifier.

[5]*** *LabVIEW User's Guide*; National Instruments, 1998.

[6]*** *Lab PC122 User Manual*; National Instruments, 1998.