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SOFTWARE CONTROL USED FOR AC MOTORS

BY

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Abstract. With a view to obtaining higher performances regarding the harmonic content of voltage and load current, we use a modern modulation strategy that is also intended to modify the ration between the fundamental magnitude voltage from the inverter output and the power supply value. There are various modulation techniques that use exact mathematic equations for turning on the transistors within the power converter. In this paper, we present the results obtained by using the DPWM-S5 modulation technique for circuit control, through simulation and through practical implementation.

Keywords: microcontroller, PWM technique, inverter, power supply, software.

1. Introduction

The Discontinuous Pulse Width Modulation S5 (DPWM-S5) [1] modulation technique uses mathematic equations to control the turning on of the transistors within the three-phase inverter, as shown in equations (1). The performances achieved are comparable with those obtained by Sinusoidal Pulse Width Modulation (SPWM) [2], Space Vector Modulation (SVM) [3]. However, DPWM-S5 has an important advantage: it reduces the number of commutations in an output voltage period. Out of 4 conduction intervals, in two the transistors within the inverter are in continuous conduction and in the other two there are switching moments; this also results from equations (1). The reduced number of commutations in an output voltage period means diminished power losses on the power transistors, which leads to less heating and therefore, the use of smaller heat-sinks for these transistors.

2. Theoretical considerations

The basic equations for modulating signal S5 are presented below and Fig. 1 shows its waveform.

$$s_5 = \begin{cases} \sqrt{3}m_a \cos\omega_m t + m_a \sin\omega_m t - 1; & 0 \le \omega_m t \le 2\pi/3 \\ -1; & 2\pi/3 \le \omega_m t \le \pi \\ -1; & \pi \le \omega_m t \le 4\pi/3 \\ \sqrt{3}m_a \cos\omega_m t + m_a \sin\omega_m t - 1; & 4\pi/3 \le \omega_m t \le 2\pi \end{cases} \quad (1)$$

Fig. 2 illustrates the waveforms of the modulator signals (s5a, s5b and s5c) obtained for the DPWM-S5 technique and the control signals for the transistors within the three-phase inverter.

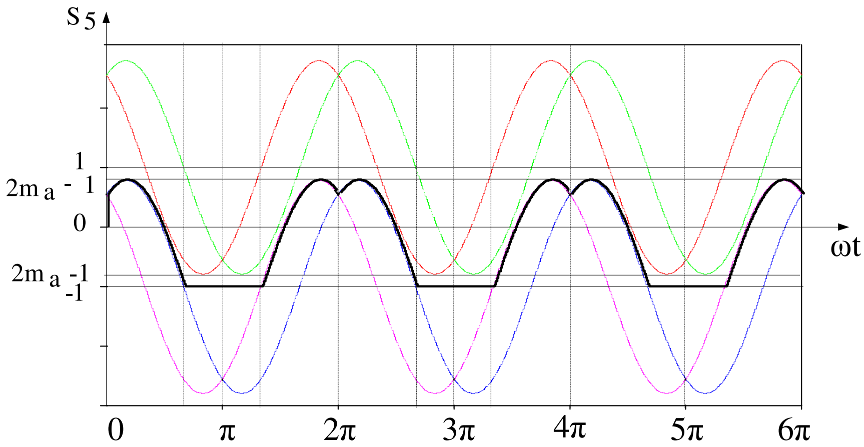

Fig. 1. The modulator signal DPWM-S5

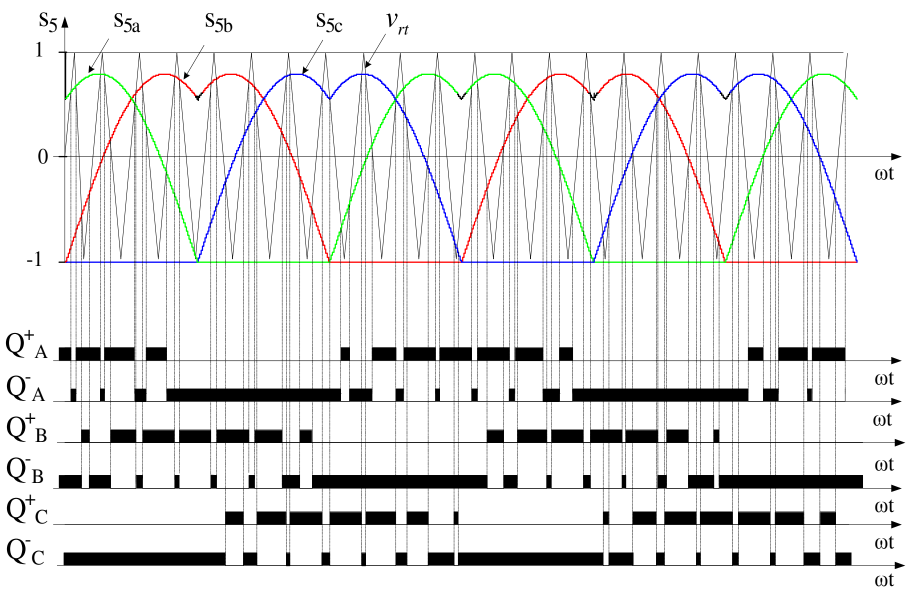

Fig. 2. Waveforms of the modulator and control signals for all six transistors.

Fig. 3 shows the power inverter that will be controlled by DPWM-S5 signal.

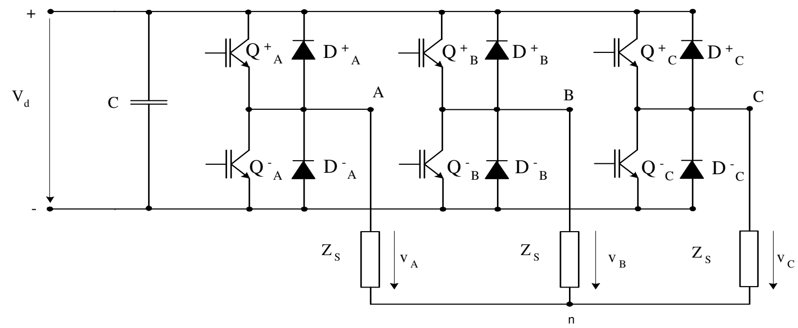

Fig. 3. Power inverter architecture

3. Control algorithm

For applying the control technique DPWM-S5, we used the C8051F120 microcontroller and we implemented the flowcharts presented in figures 4(a) and 4(b). Fig. 4(a) shows the main flowchart and Fig. 4(b) presents the flowchart of the interruption routine required by timer T3.

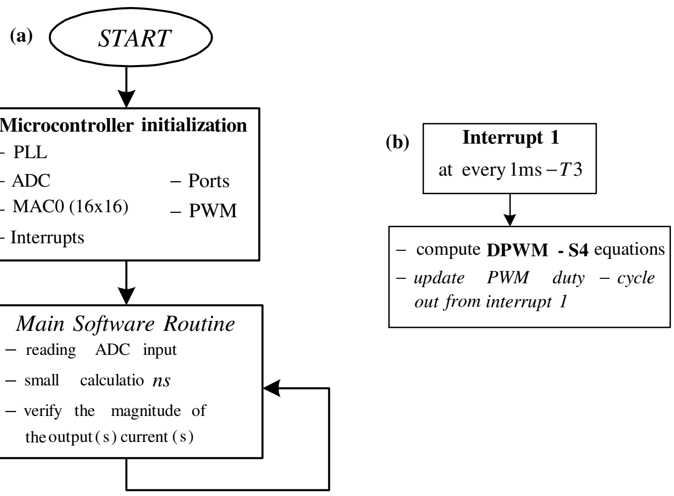

Fig. 4(a). Software control flowchart
Fig. 4(b). Flowchart of Interrupt 1

After the microcontroller initialization (Timers, ADC, Output Ports, PWM block, PLL block etc.), the main program is run. The switching moments for the 6 transistors within the three-phase inverter are calculated in interruption routine 1 of timer T3 every millisecond. More precisely, switching moments are calculated for transistors Q_A^+ Q_B^+ and Q_C^+, and control signals for transistors Q_A^-

Q_B^- and Q_C^- will be obtained by complementing the signals corresponding to transistors Q_A^+ Q_B^+ and Q_C^+; this is carried out by the practical circuit. We must point out that the 6 transistors ($Q_A^+, Q_A^-, Q_B^+, Q_B^-, Q_C^+$ and Q_C^-) are grouped, so that the "+" transistors are placed in the upper part of the three-phase transistor and the "-" transistors in the lower part.

3. Control software

The control software is written in C language, using the development environment provided by Silicon Laboratories. The most important code fragment for obtaining modulating signals s5a, s5b and s5c is given below. This partial code is run every millisecond (time is measured by timer T3 based on interruptions). Although this microcontroller works on 8 bits, due to its work speed (100 MIPS) and to the MAC 16x16 block, all equations are calculated in less than 300µs.

```
void Timer3_ISR(void) interrupt 14
{
        unsigned char SFRPAGE_SAVE = SFRPAGE;
        s5();
        SFRPAGE = TMR3_PAGE;
        TF3  = 0;
        SFRPAGE = SFRPAGE_SAVE;
}
void s5(void)
{
        signed char s;          // signed sine
        unsigned char o;        // output value
        unsigned int p;         // 16 bit //product
        unsigned char SFRPAGE_SAVE = SFRPAGE;
        float f0, f1, f2, tr0, tr1, tr2;
        Sum += (freq << 6);
        q0 = (Sum >> 8);
        tr0 = (q0/40.6);
        if(!reverse)
                {
                        tr1 = tr0 + xx1;
                        tr2 = tr0 + xx2;
                }
        else

                {
                        tr2 = tr0 + xx1;
                        tr1 = tr0 + xx2;
                }
        SFRPAGE   = PCA0_PAGE;
        f0 = s5abc(tr0);
        s = f0*0x7F;
        p = amplitude * (signed int)s;
//multiply by v
        o = p>>8; // throw away low byte
        o += 0x80;   // center sinewave at 50%
        PCA0CPH0 = o;
        f1 = s5abc(tr1);
```

```
        s = f1*0x7F;
        p = amplitude * (signed int)s;
//multiply by v
        o = p>>8;       // throw away low byte
        o += 0x80; // center sinewave at 50%
        PCA0CPH1 = o;
        f2 = s5abc(tr2);
        s = f2*0x7F;
        p = amplitude * (signed int)s;
//multiply by v
        o = p>>8;       // throw away low byte
        o += 0x80;      // center sinewave at 50%
        PCA0CPH2 = o;
        SFRPAGE = SFRPAGE_SAVE;
}
//-------------------------------------
float s5abc(float tr)
        {
                float dpwm5;
                if(tr<=2.093 && tr>0)
                        {
                                dpwm5=1-(sqr3*ma*cos(tr)+ma*sin(tr));
                        }
                if(tr<=3.14 && tr>2.093)
                        {
                                dpwm5 =  1;
                        }
                if(tr<=4.18 && tr>3.14)
                        {
                                dpwm5 =  1;
                        }
                if(tr<=6.28 && tr>4.18)
                        {
                                dpwm5=1-(sqr3*ma*cos(tr)-ma*sin(tr));
                        }
                return dpwm5;
        }
```

4. Simulation and experimental results

After implementing the above software on the microcontroller, the signals s5a and s5b are obtained and shown in Fig. 5.

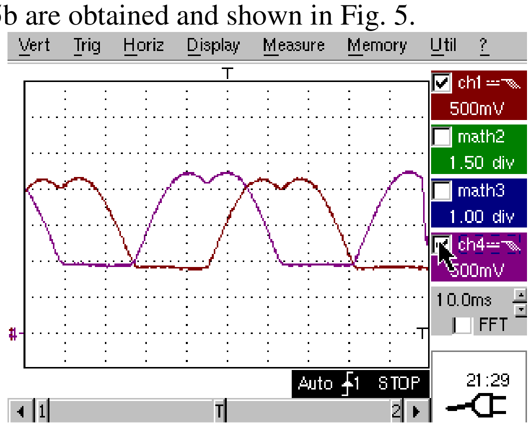

Fig. 5. Modulation signals s5a and s5b obtained by measurement

Fig. 6 shows the waveforms of the command signals for transistors within the three-phase inverter. The carrier frequency used in the program to modulate signals s5a, s5b and s5c is of 17.25 KHz.

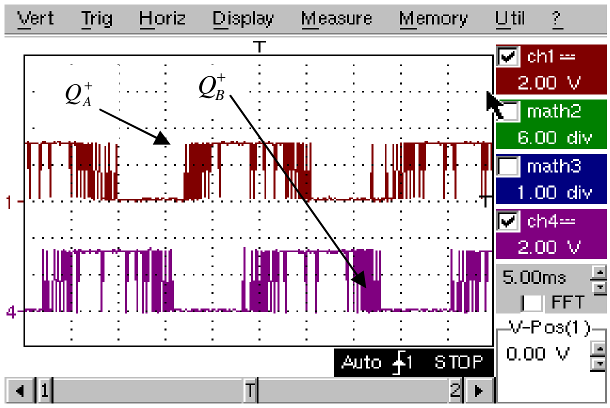

Fig. 6. Waveforms from the oscilloscope of the command signals for QA + and QB + transistors.

Fig. 7 shows waveforms between phases A and B of the line voltage; on the left side these waveforms are read on the oscilloscope, and on the right side, they are obtained by simulations. The harmonic content is presented underneath.

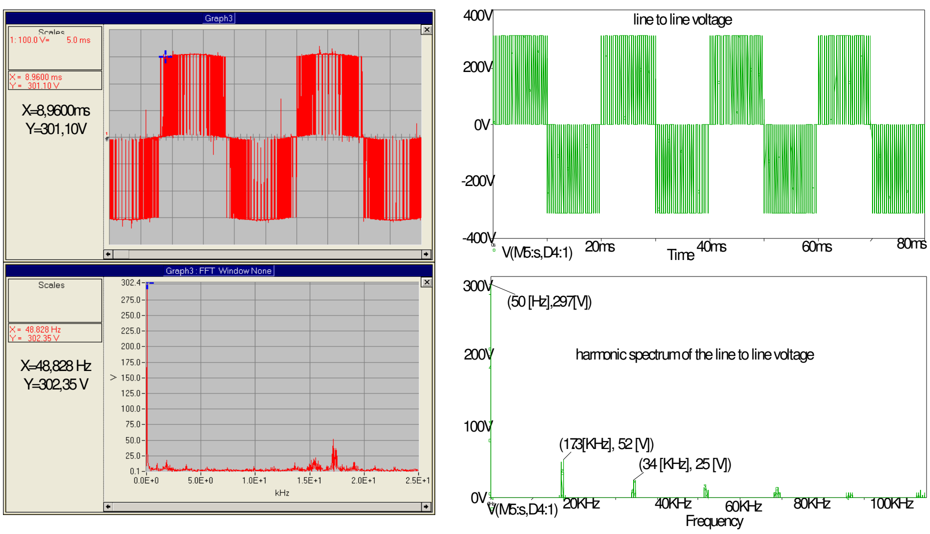

Fig. 7. – left side: waveforms and harmonic spectrum of the line to line voltage, obtained from oscilloscope.
– right side: waveforms and harmonic spectrum of the line to line voltage, obtained by simulations

The supply power of the three-phase inverter is 310 V. As load current, we used a 0.37 kW three-phase motor.

As shown in Fig. 7, the amplitude of the line voltage fundamental for the practical circuit is 302V, and the simulation value is 297V.

Fig. 8 shows the waveform of the voltage between phase A and the virtual neutral point. On the left side the waveform is read on the oscilloscope, and on the right side, it is obtained by simulation. The harmonic content is presented underneath.

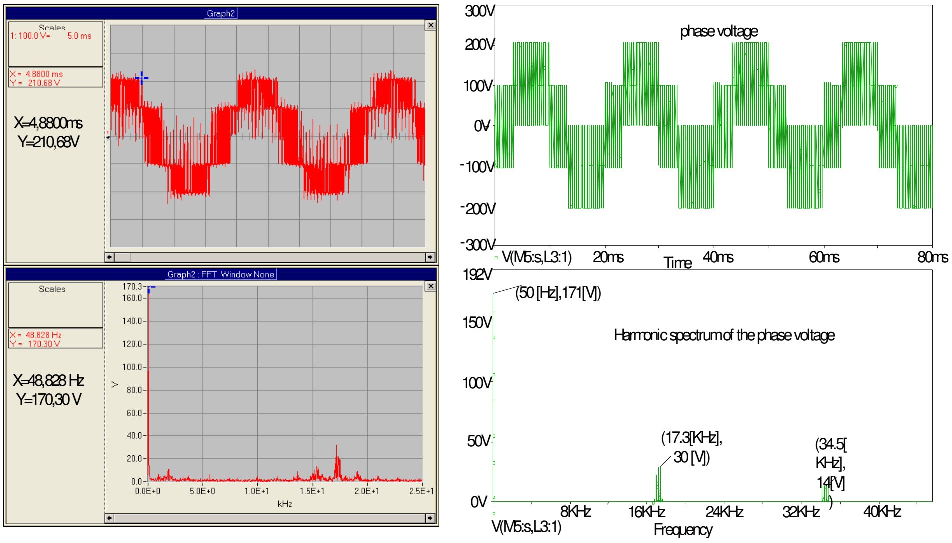

Fig. 8 – left side: waveforms and harmonic spectrum of the phase voltage A, obtained from oscilloscope.
– right side: waveforms and harmonic spectrum of the phase voltage A, obtained by simulations.

As shown in Fig. 8, the amplitude of the phase voltage fundamental for the practical circuit is 170,3V, and the simulation value is 171V.

6. Conclusion

This paper presents the implementation of DPWM-S5 equations on a microcontroller and compares theoretical simulation results with results obtained from practical measurements. As compared to the Space Vector Modulation control technique, the performances of this technique are slightly lower, but power losses on the transistors within the inverter are significantly smaller. This control technique is adequate for cases where a low harmonic content is not necessarily a requirement, but where the inverter needs to work with increased efficiency.

Acknowledgments

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CONTROL SOFTWARE FOLOSIT PENTRU COMANDA MOTOARELOR DE CURENT ALTERNATIV

(Rezumat)

În această lucrare se prezintă modul de implementare al semnalului DPWM-S5 pe un microcontroler, după care se analizează rezultatele şi se compară cu cele obţinute în urma simulărilor folosind programul SPICE. Microcontrolerul folosit este C8051F120 produs de compania Silicon Laboratories, ce controlează un invertor trifazat bazat pe puntea IRAMX16UP60A. Ca sarcină pentru invertorul trifazat s-a folosit un motor asincron trifazat cu trei perechi de poli de 0,37KW iar frecvenţa de comutaţie a semnalului PWM este de 17,25KHz.