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Corroboration of Normalized Least Mean Square Based Adaptive Selective Current Harmonic Elimination in Voltage Source Inverter using DSP Processor

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ABSTRACT

A direct Selective current harmonic elimination pulse width modulation technique is proposed for induction motor drive fed from voltage source inverter. The developed adaptive filtering algorithm for the selective current harmonic elimination in a three phase Voltage Source Inverter is a direct method to improve the line current quality of the Voltage Source Inverter base drive at any load condition. The self-adaptive algorithm employed has the capability of managing the time varying nature of load (current). The proposed Normalized Least Mean Squares algorithm based scheme eliminates the selected dominant harmonics in load current using only the knowledge of the frequencies to be eliminated. The algorithm is simulated using Matlab/Simulink tool for a three-phase Voltage Source Inverter to eliminate the fifth and seventh harmonics. The system performance is analyzed based on the simulation results considering total harmonic distortion, magnitude of eliminated harmonics and harmonic spectrum. The corroboration is done in the designed Voltage Source Inverter feeding induction motor using digital signal processor-TMS320L2812.The developed algorithm is transferred to digital signal processor using VisSim^{TM} software.

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1. INTRODUCTION

Induction motor for many years has been regarded as the workhorse in industrial applications. In the last few decades, the induction motor has evolved from being a constant speed motor to a variable speed, variable torque machine. Its evolution was challenged by the easiness of controlling a DC motor at low power applications. When applications required large amounts of power and torque, the induction motor became more efficient to use. Recent advancements in power electronics has paved the way to provide the variable voltage, variable frequency drives (VVVF), the use of an induction motor has increased [1]-[4]. Three phase dc/ac voltage source inverter (VSI) is used extensively in induction motor drives and the controllable frequency and ac voltage magnitudes are obtained employing various pulse width modulation (PWM) strategies [5]-[9]. The PWM theory was advanced in the 1960s. The popular modulation technique used in communication field was brought into the application of power converters. The Sinusoidal PWM (SPWM) technique has been applied in inversion since 1970s, making the performance of inverter greatly improved and being widely spread. The principle of PWM control is to control the on-off states of power electronic switches in order to obtain a series of pulse waves with same amplitude but different width. When an induction motor is fed by such a PWM controlled VSI, the line current becomes a distorted waveform

[10]. Therefore time-harmonics influence the magneto-motive force and increase the harmonics with mismatching of air-gap permeance [11]. Owing to radial magnetic forces caused by the harmonics, the core and rotor system experience large vibrations. The basic PWM strategy helps in filtering the harmonics easily. While an ingenious PWM strategy can prevent objectionable harmonics from appearing in line current. The unprecedented growth of power electronics is mainly due to development in control and digital platform [12]. That is performance improvement in power converters are mainly in coining an improved PWM theory and successfully implementing in a digital platform. The implementation is supported by a host of simulation and interface software tools and processors. Matlab backed SIMULINK tops the power electronics simulation in educational institutions [13], [14]. VisSim is also in this influential group. There have been quite a number of successful work on simulating electrical machines, power systems and power electronic networks by using the software mentioned above, surprisingly the VisSim had little attention [15].

The potentiality of faster converging of the normalized least mean square (NLMS) algorithm over the LMS algorithm has been indicated [16]-[17]. Also a very simple model for the input signal vectors that greatly simplifies analysis of the convergence behaviour of the LMS and NLMS algorithms has been proposed. A generalized normalized gradient descent (GNGD) algorithm for linear finite-impulse response (FIR) adaptive filters has been introduced. The GNGD represents an extension of the NLMS algorithm by means of an additional gradient adaptive term in the denominator of the learning rate of NLMS [18]. An algorithm has been shown for highly non-stationary interference signals, where previous gradient-adaptive learning rate algorithms fail. The proposed interference-normalized least mean square (INLMS) algorithm extends the gradient-adaptive learning rate approach to the case where the signals are non-stationary [19]. Performance of noise canceller with DSP processor, TI TMS320C6713 using the LMS, NLMS and VSS-NLMS algorithms has been investigated [20]. A modified NLMS algorithm has been proposed which has the ability of handling insensitive to the time variations of the input dynamics [21]. The MATLAB has been a successful numerical tool to solve non-linear differential equations and power electronic simulations can be carried out by developing system differential equations. Simulation of pulse width modulation (PWM) inverters using MATLAB has been done based on differential equations using function “ode23” [22]. The maximum power point tracking (MPPT) for the mathematically modeled squirrel-cage induction generator (SCIG) wind power generation system has been implemented in VisSim with the double loop of control system [23].

The contribution of earlier research in selective harmonic elimination is mainly on voltage harmonic elimination while the performance enhancement of drive depends largely/directly on current harmonics. A adaptive selective current harmonic elimination pulse width modulation is developed and tested for induction motor drive fed from voltage source inverter (VSI). The developed adaptive filtering algorithm requires only the values of frequencies to be eliminated. The corroboration of the proposed scheme is done in the prototype VSI feeding induction motor using digital signal processor (DSP) TMS320L2812 [24]. The effort in writing DSP code is largely reduced through VisSimTM software.

2. VISSIM

VISSIM means visual simulation. It is interfacing software between DSP controller and personal computer. It was found in 1989 and developed in collaboration with United Technologies. VisSim is a mathematical modeling environment for developing non-linear dynamic system simulations. VisSim provides a means by which systems can be created with block diagrams, connected by wires, in a way that would be done on a piece of paper, but then processes the mathematical operations represented within the block diagram iteratively over a time range. VisSim allows the developer to structure models hierarchically which readily lends itself to creating "top down" models, using function blocks to represent components and subsystems. These can then be brought together to produce larger, more complex models. VisSim provides block "primitives" for building systems.

VisSim is a simulation environment which handles mixed continuous- and discrete-time elements with a graphical user interface. With the aid of MS Visual Basic program, a menu is prepared to classify the power electronic networks. This menu is displayed on the screen; thus users can easily select the type of the power electronic system. VisSim is an easy-to-use, yet powerful solution for accurately modeling and simulating motion and motor control systems. VisSim/Motion consists of a comprehensive motion control block library, which includes motors, amplifiers, filters, controllers, loads, sensors, sources, and transforms. The design of a system involves in simply selecting and then connecting system components. Later, with the push of a button, the simulation can be run and the system behavior may be noticed. There is another advantage of having dynamic simulation software that the real time control can be achieved through the interface hardware without any low-level language. In Figure 1 the VisSim model of the three phase induction motor drive is presented.

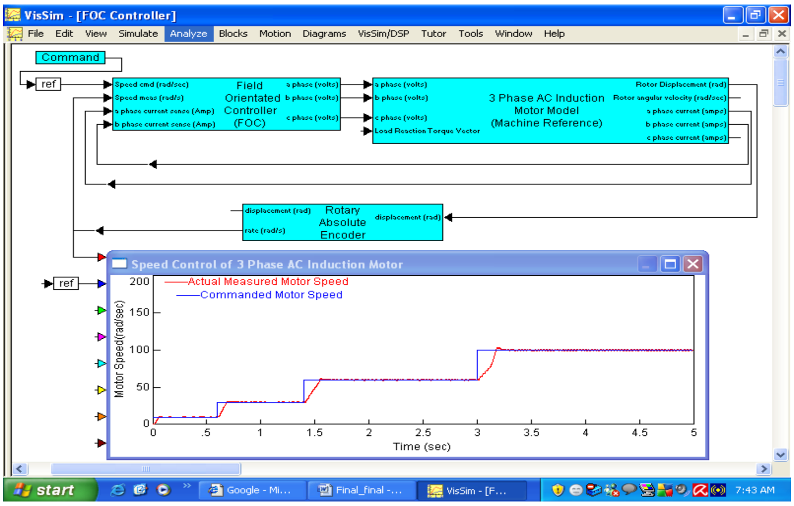


Figure 1. Speed Control of Induction Motor

3. PROPOSED NLMS BASED ADAPTIVE SHE

As shown in the above Figure 2 the inverter had PI controller U_reg for dc bus voltage control and two PI regulators Iq1 and Id1 implemented in synchronous reference frame for current control. Reference angle for generation of sine and cosine functions with frequency of fundamental component and frequencies of fifth and seventh harmonics is created by a phase look loop (PLL) block. Sine and cosine components with fundamental frequency are phase locked with utility voltage and are used for stationary to synchronous (and vice versa) reference frames transformations. Sine and cosine components with five and seven times higher frequencies are used for selective harmonic elimination. Sample currents Ia,Ib,Ic from the stationary (a,b,c) reference were transformed into two phase q,d stationary reference frame (block 3/2) and then into synchronous frame Iq,Id (block s/e) [25]-[26].

The conventional part of control works as follows: voltage regulator U_reg depending on dc bus voltage error creates an active current reference Iq*. For unity power factor reactive current reference Id* is kept zero. PI current regulators maintain an average value of feedback currents Iqe and Ide equal to the average values of corresponding references. Outputs of current regulators are transformed first from synchronous to stationary reference frame (block e/s) and then from two-phase (q,d) to three phase (a,b,c) system and written into PWM control the inverter. The components contributed to PWM from ASHE blocks will create voltage at the output of the inverter with amplitudes and phase angles as needed to cancel harmonic components from the load currents.

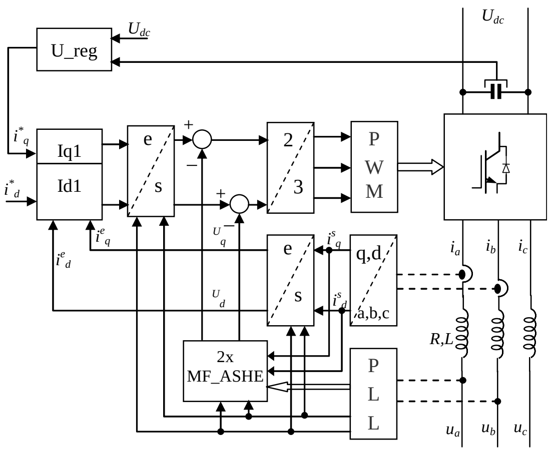


Figure 2. Propoased NLMS basedASHE scheme for VSI

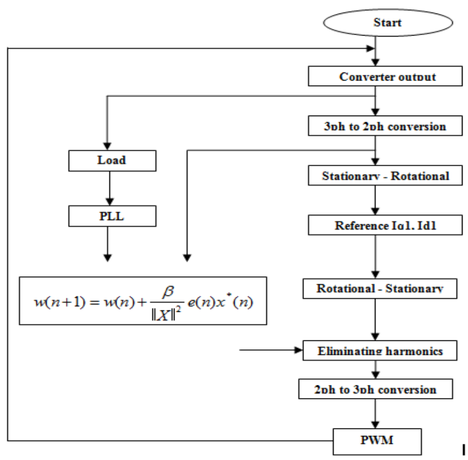


Figure 3. The steps involved in the propoased SHE-PWM

3.1. Hardware Implementation

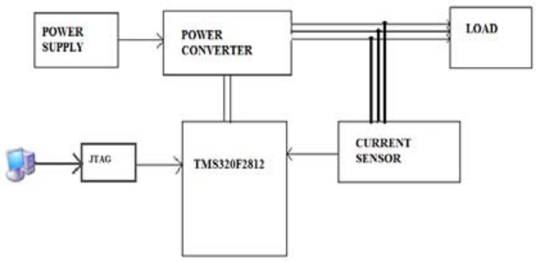


Figure 4. Layout for hardware implementation

Figure 5. Photograph of experimental setup

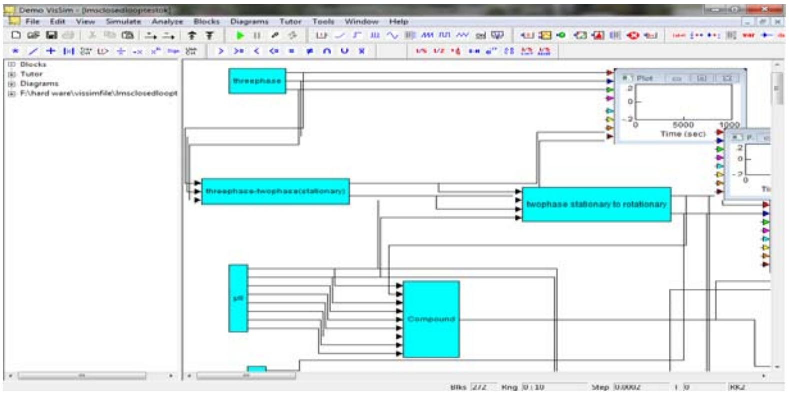
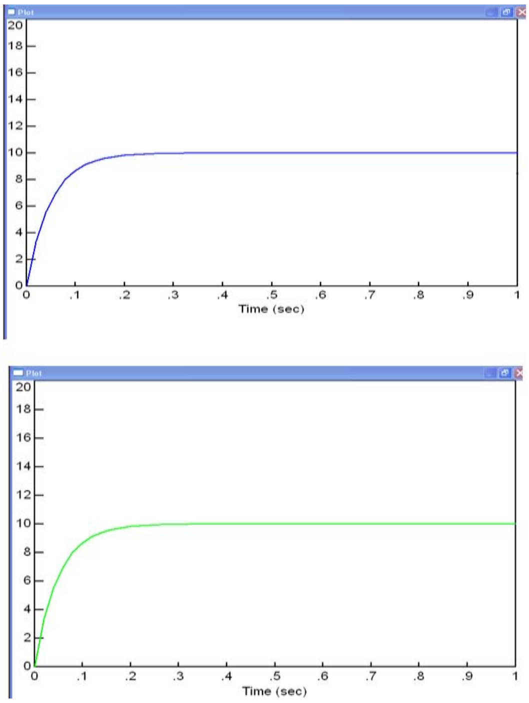


Figure 6. NLMS algorithm in VISSIM window



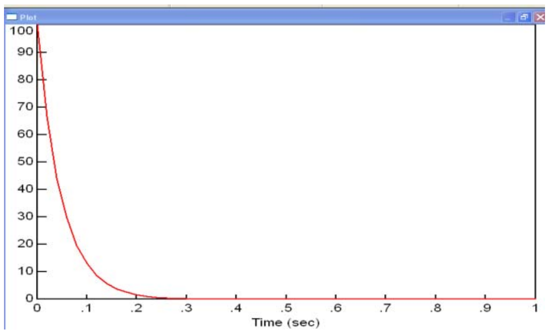


Figure 7. Weight update in NLMS algorithm

Figure 8. Error from NLMS algorithm

The layout of the proposed system is shown in Figure 4. The experimental setup for the Hardware implementation of SHEPWM strategy is shown in Figure 5. It mainly consists of an uncontrolled rectifier, DC link filter, Application Specific Intelligent Power Module (ASIPM) and Texas TMS320LF2812 DSP Processor. Gating pulses for the inverter switches are generated by DSC controller and 0.25kW, 415V, 50Hz three phase Induction motor is used as load. The NLMS based adaptive algorithm is schematized in VISSIM and then downloaded to personal computer. The developed schematic is diagrammed in Figure 6. The representative weight update is presented in Figure 7 while the error is indicated in Figure 8.

3.2. Waveforms and Comparison

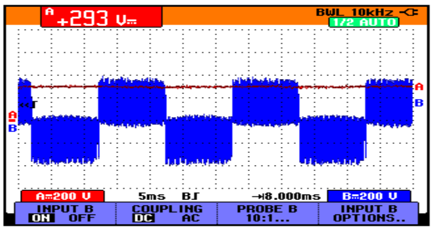


Figure 9. DC link voltage and line voltage (V_{ab})

Figure 9 shows the dc link voltage and output line-line voltage along with the dc link voltage. Figure 10 details about the R-Phase line current while NLMS algorithm is in process. Figure 11 shows R-Phase line current when NLMS algorithm reached optimum point and corresponding harmonic spectrum is illustrated in Figure 12. Table 1 shortens the results of both simulation and hardware for comparison.

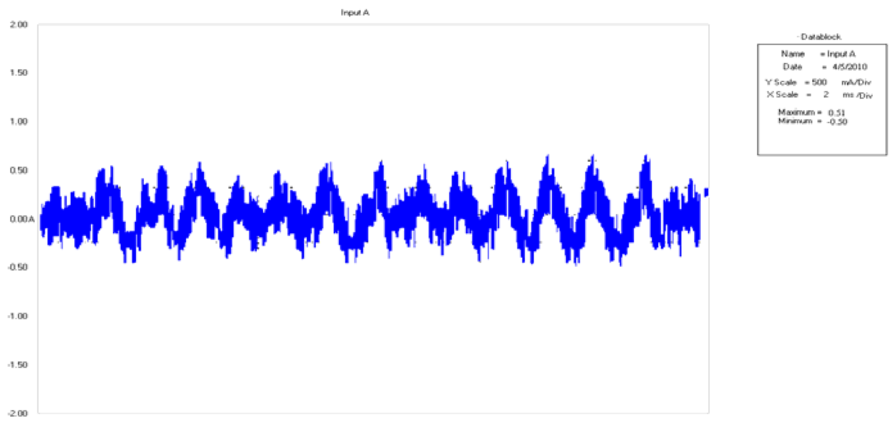


Figure 10. Output current while LMS algorithm is in process

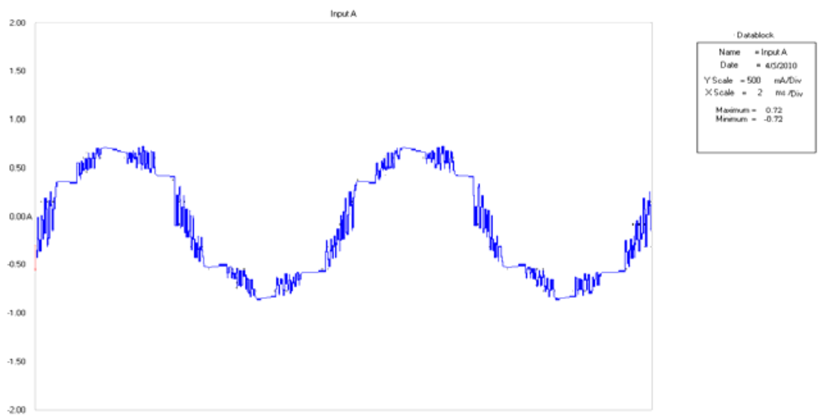


Figure 11. R-phase line current when LMS algorithm reaches optimum point

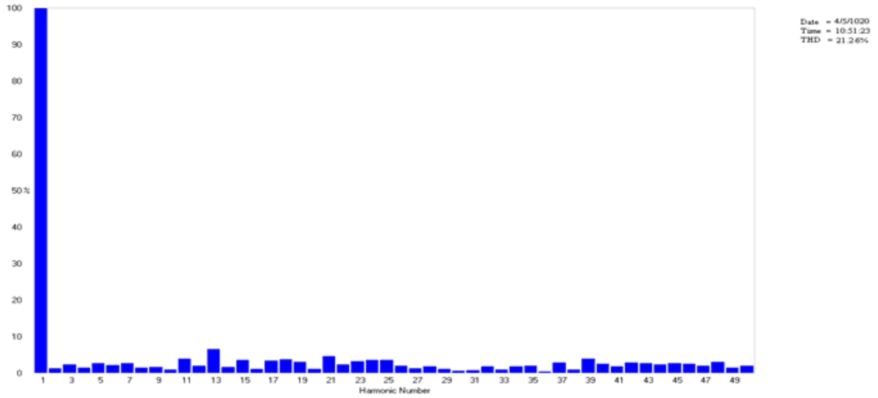


Figure 12. R-phase line current when NLMS algorithm reaches optimum point

Table 1. Comparison of simulation and hardware results

	Simulation			Hardware		
	I_5 % of I_1	I_7	THD %	I_5 % of I_1	I_7	THD %
Without ASHE	19.82	14.41	109.06	22.12	14.81	113.26
With ASHE	1.29	1.50	75.86	2.09	1.77	77.44

4. CONCLUSION

The concept of pulse width modulation has been borrowed from communication engineering and involved in power converters, particularly in voltage source inverters. A host of PWM techniques have been developed and investigated. These techniques have their specific objective and principle towards satisfying their application. Current harmonic elimination techniques are class of PWM techniques which are direct way to enhance the performance of drives. NLMS algorithm based adaptive online current harmonic elimination techniques is proposed and simulated in MATLAB software. It is evidenced that selected harmonics current harmonics (fifth and seventh) are suppressed below 2% of fundamental. The system is implemented in hardware using VISSIM software and DSP TI TMS320L2812.

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