DSP implementation of Fuzzy based Power Quality enhancement strategy for IPOS converter fed drive

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Abstract

The paper attempts to develop a Fuzzy based Pulse Width Modulation (PWM) scheme through the use of a Digital Signal Processor (DSP) with a view to improve the input power factor of a drive system. It corners to exploit the merits of an inherent decision making mechanism to construct a control algorithm and there from articulate a methodology to reshape the input current wave to a sinusoidal form. The procedure forges to facilitate an increase in the fundamental component of the current through the entire operating range. The scheme, investigated using a prototype model envisages to enhance the power quality indices of the AC-DC converter fed drive system, in addition to regulating its speed

Keywords: *IPOS, Pulse Width Modulation (PWM), Fuzzy control, Power Quality*.

1. Introduction

An electric drive is defined as a form of equipment designed to convert electric energy into mechanical energy and provide electrical control of the process. The fundamental elements of an electric drive are the electric motor, the associated transmission auxiliaries and the related control elements. It is constituted with a purpose to extract the characteristics for the motor in order to suit specific requirements of the load driven by the drive system.

The Power Electronic Converters, owing allegiance to the developments in the device technology offer several advantages as exquisite interfaces over traditional systems. They turn out to be more efficient because of lower losses, compact nature, reduced cost, besides enabling greater flexibility in the sense the voltage and current can be shaped through astute switching mechanisms and availability at higher power ratings.

The advantages of multiple connected converter systems evolve a new dimension for the drive apparatus in terms of a higher reliability in light of the increased level of redundancy. It paves the way for a reduction in the manufacturing time and cost and allows a high-current power-supply realized using low-current converters that are easier to design and manufacture. The filter requirement can be reduced leading to a higher power density and possibly higher efficiency of the overall system [1-2].

A single-phase switch-mode boost rectifier constructed through two dissimilar DC-DC converters with their inputs tied in parallel and their outputs connected in series has been presented [3-7]. The input current has been sinusoidally wave shaped with a near-unity power factor and the arrangement tested using a microcomputer as a controller to experimentally investigate the operation. A new high-power step-up converter based on the phase-shifted parallel-input/series-output (PISO) modular converter with two dual inductor-fed push-pull converters has been proposed [11]. It has been operated at a constant duty cycle and the output voltage controlled with a phase-shift between the modules. A control strategy for sharing of the output voltage of an Input Parallel Output Series (IPOS) has been developed [10]. The simulation and experimental results have been presented to verify the effectiveness of the proposed method.

Power Quality in recent times appears to invite greater attention in view of the extensive use of motor loads interfaced through the switched mode Power Converters. The lagging nature of the rippled source current along with the distorted terminal voltage necessitates control measures to improve the power quality indices and the performance of the drive.

2. Problem Formulation

The primary focus is to design a fuzzy strategy that envisions to enhance the power quality indices of an IPOS connected AC-DC converter fed drive. It orients to program a Digital Signal Processor (DSP) to enable it to function both as a Fuzzy Logic Controller (FLC) and a PWM pulse generator. The methodology pioneers to create an inference mechanism in order to arrive at appropriate pulse width for the firing pulses. The performance is evaluated through an experimental arrangement to portray its viability over the entire operating range of loads.

3. Proposed Strategy

The approach echoes to design a Fuzzy based PWM mechanism suitable for a multiple connected converter fed separately excited DC Motor drive. It attempts to shape the input current in an effort to garner an improved quality of power for the AC-DC conversion system. The topology of the power module explained in Fig. 1 is constituted of two high frequency switched units fed from the available single phase source to energize a separately excited DC motor drive. The basic theory emphasizes to ensure that the supply current and the output voltage are equally shared among the two converters.

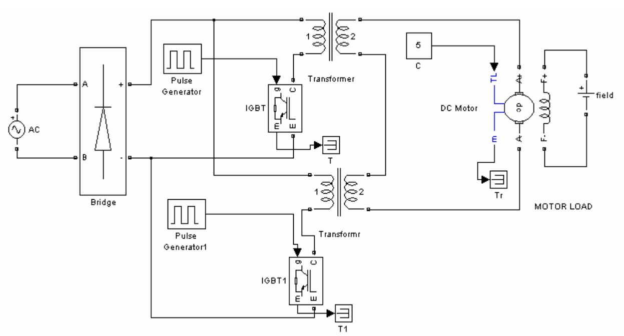

Fig.1 Power Circuit

4. Control Algorithm

The scheme revolves around the fact that incorporates the advantages of feedback strategy. The regulation error E_{reg}, is generated by calculating the error between actual output voltage and the reference which is the average of the two converter output voltages, as implied in Fig.2. An error defined as the adjustment error as indicated in the same figure is computed as a difference between the output voltage of either converters and the corresponding reference, in order to ensure equal sharing of output voltage between the two series connected converters.

The controller generates a gain G, which is multiplied by the input voltage to acquire the reference current $I_{ref.}$ The current reference is compared with the input current in a comparator from where the control pulses are derived for the IGBT switch in the converter. The input current is therefore tailored to be more or less in phase with the input voltage thus enabling the best possible input power factor for each operating point under consideration.

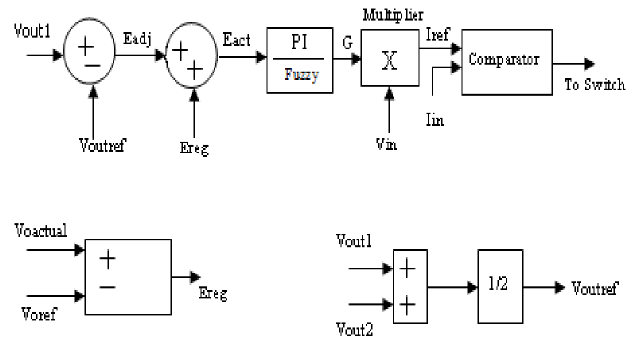

Fig.2 Controller

5. Fuzzy model

It embodies a mechanism to accrue intermediate decisions in search of a directive based on Fuzzy rules, which attempt to tune the parameters and pave the way to change them according to each operating point. A rule based controller is easy to understand and equally easy to implement. The sensor measurements are used as scheduling variables that govern the change of the controller parameters as a function of the operating point in a pre-programmed fashion. The Fuzzy strategy is isolated in a rule base natural language opposed to an equation based description.

The algorithm involves a combination of trapezoidal and triangular membership functions shown in Fig.3 to establish a relationship between the input variables error (e), change in error (ce) and the output (u). It resorts to IF-THEN format to acquire the closed loop intermediate corrective action, seen in the shaded part of the Table 1.

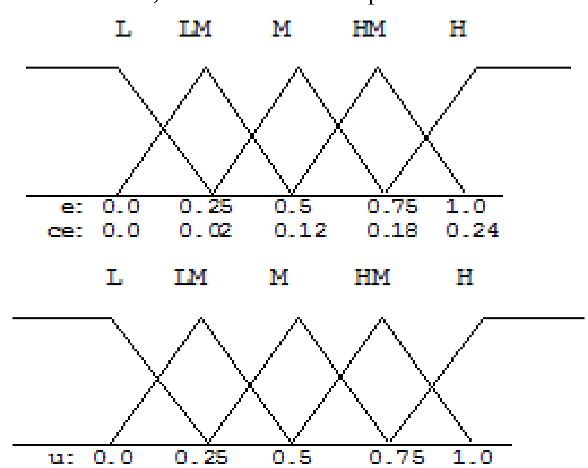

Fig.3 Chosen membership functions for input and output variables

Table 1 Fuzzy Rule Base

AND		CE				
		L	LM	M	HM	H
E	L	LM	LM	L	L	L
	LM	M	LM	LM	L	L
	M	M	M	LM	LM	L
	H	HM	M	M	LM	LM
	H	H	HM	M	M	LM

6. Performance Evaluation

The methodology is implemented using a suitable proto type that seeks the role of a DSP to function as a FLC, which enables to generate the PWM pulses to fire the power switches in the second stage of both the converters. The performance of the drive motor powered from the IPOS AC-DC module are tested over a range of operating loads to exhibit its applicability for practical applications.
The DSP is configured to meet the needs of control-based applications and optimized for motion control applications. The devices within a generation of a TMS320 platform imbibe the same CPU structure but different on-chip memory and peripheral configurations. The system costs are reduced and circuit board space saved by integrating memory and peripherals onto a single chip. The TMS320F2407 DSP posses a very flexible instruction set inherent operational flexibility, high-speed performance and innovative parallel architecture. The photograph of the hardware model built to power the same DC motor drive is displayed in Fig.4.

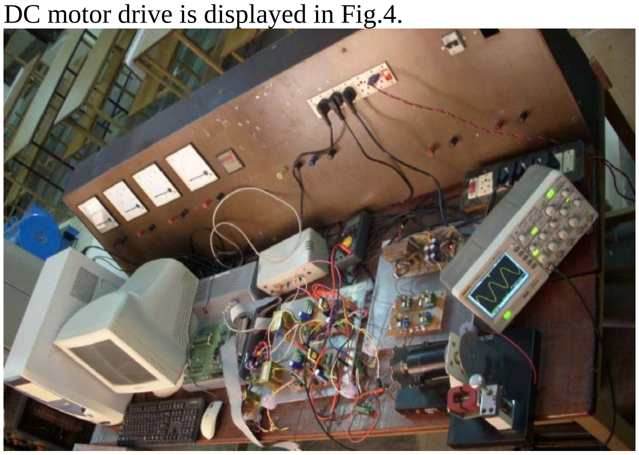

Fig.4 Experimental setup

The approach owes to the adjustment in the duty cycle to regulate the speed of the drive motor. The flow diagram explaining the generation of firing pulses is shown in Fig.5. The photographs seen in Figs. 6 and 7 pertain to the pulse generated using DSP for the IGBTs and the input current wave overlapped with the voltage wave captured through the DSO at the operating point corresponding to a load of 3 kW.

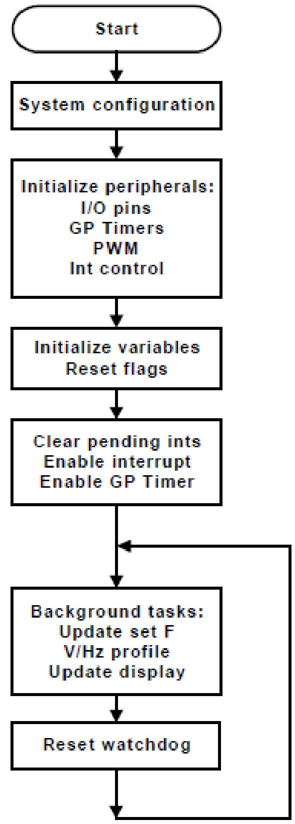

Fig.5 Flow diagram

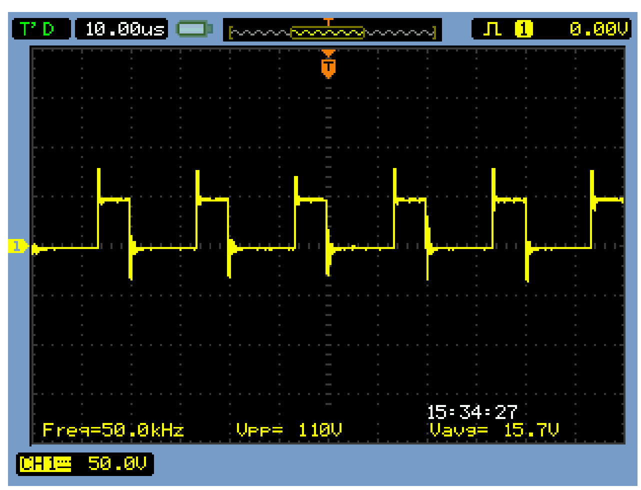

Fig.6 Pulses from DSP

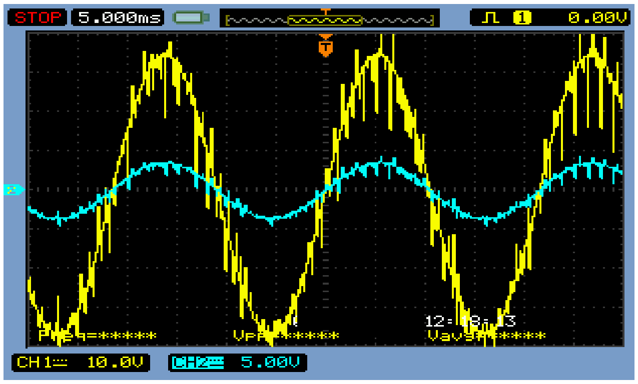

Fig.7 Input Voltage and Current waveform

The entries in Table 2 relate to the performance of the scheme in terms of a considerable improvement in input power factor and elicit its speed regulating capability, through its entire operating range. The fact that the proposed scheme culminates in enhancing the input power factor over the entire range and reducing the harmonic content of the input current visualized through the THD spectra obtained both through simulation and hardware (Tektronix) for the same operating point of 3kW load is presented in Figs. 8 and 9 respectively. It further exhibits the accuracy of the simulated results [12] through adequate validation with that obtained using the prototype. It is seen that the lower order harmonics follow a falling exponential envelope and go to minimize the ripple in the torque. The speed regulating characteristics seen in Fig.10 unambiguously highlights the merits of the proposed PWM technique and illustrates its suitability for practical applications.

Table 2 Comparison of Simulation and Hardware results

Load kW	Load voltage (Volts)		Load current (A)		Converter 1 o/p voltage (V)		Converter 2 o/p voltage (V)		Speed (rpm)		Input Power Factor		%THD	
	Simulation	Hardware	Simulation	Hardware	Simulation	Hardware	Simulation	Hardware	Simulation	Hardware	Simulation	Hardware	Simulation	Hardware
1.0	230	229.5	4.6	4.9	115	115	115	114	1500	1500	0.91	0.90	10.1	14.3
1.5	230	229.3	6.8	7.0	115	114	115	115	1500	1500	0.91	0.91	9.51	12.6
2.0	230	229.4	9.1	9.6	115	114	115	115	1500	1500	0.92	0.92	7.6	11.7
2.5	230	229.0	10.5	10.91	115	115	115	114	1500	1500	0.95	0.94	5.3	11.4
3.0	230	229.0	13.09	13.1	115	114	115	115	1500	1500	0.98	0.95	4.5	10.8
3.75	230	228.8	16.0	16.4	115	114	115	114	1500	1500	0.99	0.98	4.0	10.1

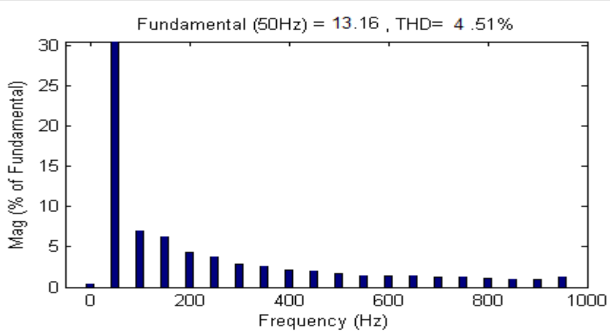

Fig.8 Simulation THD spectra

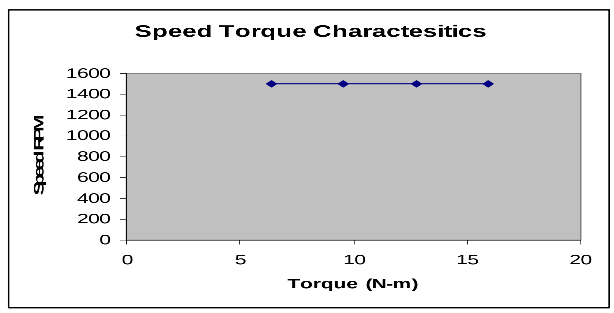

Fig. 10 Torque speed characteristics

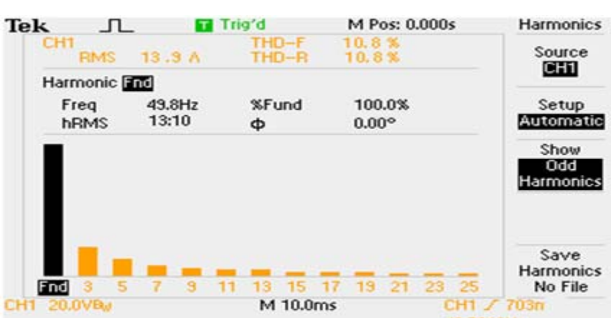

Fig.9 Hardware THD spectra

7. Conclusion

The suitability of connecting converters in parallel at the input and series at the output has been displayed to meet the needs of present day automated world. The advancements in the semiconductor industry have been found to be useful in order to explore the role of a digital processor to coordinate an appropriate control algorithm. A three cornered control strategy has been developed to circumvent the circuit parasitic and elicit a speed regulating capability for the drive motor. The methodology has been able to project equal sharing of input current and output voltage between the two converters through the preferred operating range. The results have been found to portray an improved power quality in terms of almost an unity power factor and much lower THD to garner a claim for the emergence of sophisticated drive utilities.

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