IMPLEMENTATION OF PLC FOR SIMULTANEOUS CONTROL OF BRUSHLESS DC MOTOR & LINEAR INDUCTION MOTOR SPEED

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***Abstract*:** *Present paper describes the simultaneous speed control of Brushless DC Motor and Linear induction motor drive employing PWM technique using Programmable Logic Controller. PLC is used to write the program to control speed as well as direction of BLDC and Linear induction motor. Based on hall sensor output signal of BLDC motor, PLC triggers the IGBT driver circuit to generate the Pulse width modulation signal, which is given to the stator of the motor. The drive performance is studied for motor starting, speed control and direction control. The hall sensor signal, speed command and phase currents are the input to the controller. Controller incessantly monitors the input and activates the output according to the program. With programming single PLC, simultaneous control of more than one motor through extra input and output is possible. PLC performs well for speed up to the 1500 rpm. The BLDC motor doesn't run faster due to the switching delay of the PLC.*

Keywords: BLDC Motor, Linear Induction Motor, PLC, Intelligent power module (IPM), Electronic Circuits

I. INTRODUCTION

A. Brushless DC Motor

Brushless Direct Current (BLDC) Motors are one of the motor types gaining popularity mainly because of their better linear characteristics and performance, the current to torque and frequency to speed relationship are linear of BLDC motor. It is used in industries such as Appliances, Automotive, Aerospace, Medical, Industrial Automation Equipment and Instrumentation. BLDC motor is a electric motor powered by direct current DC, it has a electronic commutation rather than mechanical commutation and Brushes. It has more poles on rotor rather than stator or reluctance motor.BLDC motor has many advantages over brushed DC motors and induction motors [3], it has better speed verses torque characteristics, high dynamic response, High efficiency, Long operating life, Noiseless operation, High speed ranges. BLDC motors are the type of synchronous motor [4]. The Hall sensors are embedded on the stationary part of the motor, Whenever the rotor magnetic poles pass near the Hall sensors it gives high or low signal indicating the N or S pole is passing near the sensors, thus by refer figure 1.

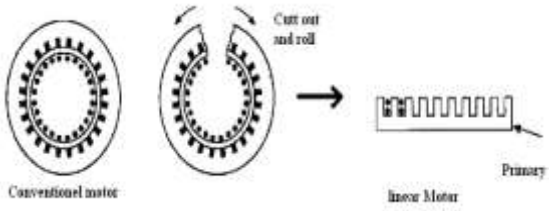

Figure1: Circular and linear motion type rotor

B. Linear Induction Motor

The Linear Induction Motor (LIM) is linear in motion instead of circular. It constructed so that primary stator move and secondary rotor remains stationary rail constant. The secondary rail is wider enough to handle induced current with little resistive losses along the transfer edge.

Such losses are known as transverse edge effects which can reduce between stator and armature in SLIM electric motors is perpendicular to the direction of travel. The electric motor's stator and armature are either attracted or repelled by this force. Linear induction Motor (LIM) finds new application in industry, as linear drives. In industry automation systems usually employs small power and relatively small speed linear induction motors, and based on this the electric drives are designed. The LIM is used due to its simplicity in construction, robustness and reliability of operation. However large air gaps and low efficiencies prevented linear motors from being widely used. Linear induction motors are increasingly chosen for material handling applications because they are more reliable, and less expensive than rotary electric motors

C. Simultaneous Control of Motors

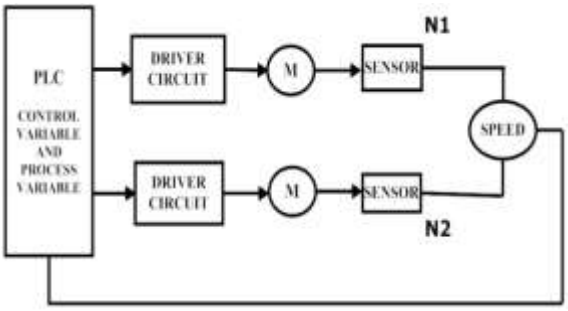

Figure 2: Bolck Diagram for Simualtaneously Control of motors

II. SOFTWARE DESCRIPTION

The PLC program uses a cyclic scan in the main program loop, such that periodic checks are made to the input variables. The program loop starts by scanning the inputs to the system and storing their states in fixed memory locations. Input address is indicated by I, and output is by O. The ladder program is then executed rung-by-rung, scanning the program and solving the logic of the various ladder rungs determine the output states. The updated output states are stored in fixed memory locations. The output values held in memory are then used to set and reset the physical outputs of the PLC.The time taken to complete one cycle or the scan time is 0, 18 ms/K (for 1000 steps) and with a maximum program capacity of 1000 steps. The development system comprises a host computer (PC) connected via an RS232 port to the target PLC[1]. The host computer provides the software environment to perform file editing, storage, printing, and program operation monitoring. The process for develop the program to run on the PLC consists of using an editor to draw the source ladder program, converting the source program to binary object code which is run on the PLC's microprocessor and downloading the object code from the PC to the PLC system, via the serial communication port. The PLC system is online when it is inactive control of the machine and monitors any data to check for correct operation.

PLC or programmable controller is a computer-type device used to control equipment in an industrial facility. In a traditional industrial control system, all control devices are wired directly to each other according to how the system is supposed to operate. In a PLC system, however the PLC replaces the wiring between the devices. Thus, instead of being wired directly to each other, all equipment is wired to the PLC. Then the control program inside the PLC provides the "wiring" connection between the devices. The PLC may be used to control a simple and repetitive task, or a few of them may be interconnected together with other host controllers or host computers through a sort of communication network, in order to integrate the control of a complex process.

PLC controls through analog and digital inputs and outputs, the PLC continuously monitors the inputs and activates the corresponding outputs according to the control program.

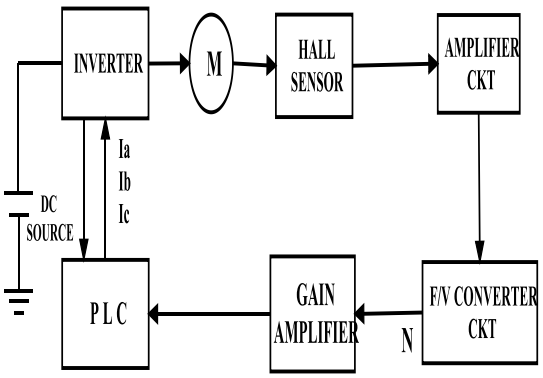

Figure 3: Block Diagram for Motor Speed Control System

TABLE I. BLDC MOTOR TECHNICAL SPECIFICATION

Type	**Trapezoidal Motor (Preferred Motor type)**
Motor Rating	**1.1 HP**
Voltage	**310VDC**
No of Poles	**4.00**
Max Speed	**4600rpm**
Electrical time constant	**7.01ms**
Moment of inertia H/L	**1.8/1.4kg**
Torque constant Kt	**0.49Nm/A**
Armature resister Ra	**2.18ohm**
La	**15.3mH**

III. HARDWARE DESCRIPTION

The objective is to control the speed of two different motors i.e. BLDC Motor and Linear Induction Motor simultaneously. The speed of the motor is sensed by Hall sensor which is embedded on the motor stator, the sensor output is in the form of High and Low, based on the sensor output the corresponding IGBT are triggered to rotate the motor. PLC accepts 24Volts signal, the sensor output is in the form of 5 Volts, so the amplifier circuit is designed to drive PLC input. The IGBT driver circuit requires 5V supply. Voltage divider circuit is design to drive the IGBT circuit.

TABLE III: HALL SENSOR O/P AND DRIVER IGBT SWICHING

SENSOR OUTPUT			FORWORD PWM SIGNAL						REVERES PWM SIGNAL					
H1	H2	H3	T1	T2	T3	T4	T5	T6	T1	T2	T3	T4	T5	T6
0	1	0	1	0	0	0	0	1	0	1	0	0	1	0
1	1	0	0	0	1	0	0	1	0	0	0	1	1	0
1	0	0	0	1	1	0	0	0	1	0	0	1	0	0
1	0	1	0	1	0	0	1	0	1	0	0	0	0	1
0	0	1	0	0	0	1	1	0	0	0	1	0	0	1
0	1	1	1	0	0	1	0	0	0	1	1	0	0	0

The PLC is programmed for motor start, stop, forward reverse direction, and to control the duty cycle of the inverter circuit to control the motor speed. The flat ribbon cable (FRC) is used for communication between PLC and IPM voltage source inverter. The 741 op-amp is used to amplify the sensor output as shown in figure 3, the speed of the motor is directly proportional to the inverter output voltage and the inverter output voltage is directly proportional to the Pulse Width Modulation (PWM) duty cycle. The pulse width modulation technique is used to generate the pulses signals. The PLC based control system for motor can be controlled both by

close loop control system and open loop control system . The close loop control system is to maintain constant speed operation, configured with speed feedback and load current feedback, the BLDC motor drive the variable load which is fed to the inverter.

The LIM motor stator has three legs laminated by iron and identical coils are wound on them. The three coils are powered by 3-phase supply, then the current I flow in the winding of A B and C three coils, due to which the flux is produced from legs and salient pole, the fluxes are created by the current that flow though the respective winging, consequently the fluxes are 120 degree out of phase. This phase shift means that the fluxes attain their maximum value at deferent times, separated by intervals of 1/(3*f) where f is the frequency of the source. For example if frequency is 50HZ, and phase sequence of the is A-B-C , flux ϕ_b become attain its maximum value 1/50 s after ϕ_a. Similarly, ϕ_c reach its maximum value 1/50s after ϕ_b . Thus the flux continuously shifts from left to right across the face of salient poles. If two of the supply lines are independent, the phase sequence reversed, and the flux become shift from right to left across the poles. Knowing the distance between the poles can measure the speed at which the flux moves, this is called synchronous speed Vs because it is directly related to the frequency of the power supply. The synchronous speed is given as.

$$Vs = 3*d*f \quad (2)$$

Where

Vs = synchronous speed [m/s]

d = distance between poles [m]

f = frequency [HZ]

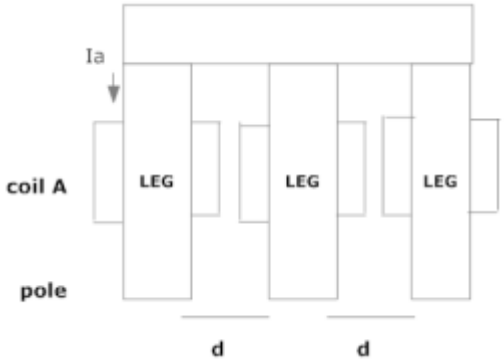

Figure 4: Rotary part of LIM motor

The PLC control the duty cycle switching or triggering IGBT to control inverter V/F output to maintain the constant speed of the BLDC motor, where the open loop control system is for variable speed operation, the BLDC motor drive the variable load and is fed by an inverter in constant V/F control mode.

IV. PLC PID CONTROLLER

The PID controller instruction in PLC consist of process variable and control variable and also uses scale parameter instruction.

A . PID INSTRUCTION IN PLC

The control variable is the speed set point value of the motor speed and process variable is the actual motor speed, thus by reffering to Fig. 5. Fig. 6 shows screen of the tuning parametes and speed setpoint which is assigned. The motor speed signal is given to the frequency to voltage converter circuit , the F/V circuit output is speed in terms of voltage in low level signal form, which is amplified by operational amplifier to drive analoge module of the PLC controller, propotional ,Integral and Derivative value for PID instruction of PLC is calculated by Matlab

simulink ,it is used to find the transfere function of the motor.

$$G_{PID}(s) = K_P\left[1 + \frac{1}{T_i} + T_D\right] \quad \text{.....(1)}$$

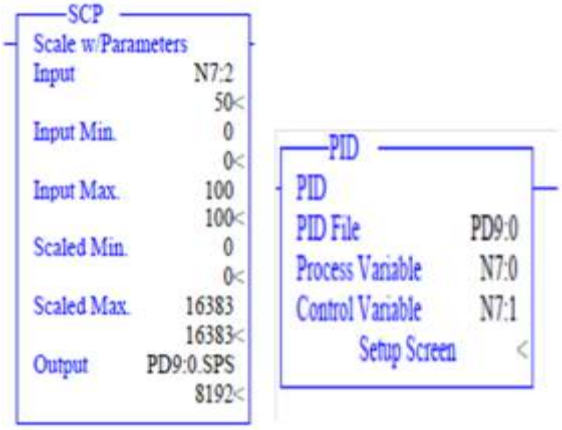

Figure 5: PID and Scale parameter Instruction Block of PLC

B. PID SETUP SCREEN

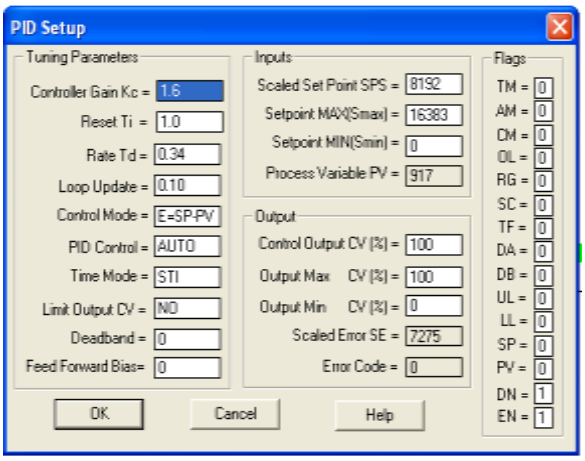

Figure 6: PID Parameter Bolck in PLC

V. RESULT

PLC Program for simultaneous speed control of BLDC motor and LIM motor are successfully executed and implemented. PLC monitored the motor operation and correlates the parameter according to the program. Allen Bradley with 16 digital Input/output and 8 analog input/output PLC is used; RSLogix500 software is used for ladder diagram. Intelligent power module IPM (PEC16DSM01) consists of gate driver circuit, operates at 15Vdc supply, used as the voltage source inverter.

VI. CONCLUSION

PLC based simultaneous motor speed control used in multiple process control industrial application. The efficiency of PLC control is about 95% of the synchronous speed; PLCs prove themselves as effective tool to control the electric drives application. PLC program has been developed to start/stop and to control direction of motor i.e. forward and reverse.

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