PLC Based Power Conservation of Industrial Electric Motors Using PWM Tecnique

Muhammad Gharib Nawaz, Muhammad iftikhar Khan, Anis Ur Rehman

Abstract— This study aims to reduce electric power consumption of an industrial motors with Programmable Logic Controller (PLC) while using Pulse Width Modulation (PWM) technique. The few percent of power consumption of huge industrial motors saves many of kWh daily hence increase in revenue especially when motor is in no-load condition. A complete hardware system is designed in this paper and motor selected for this study was tested under two different modes of open and closed loop while considering conditions of no-load, small and high loaded motor. The proposed model use concept of chopped sine waves with Thyristor SCR based on PWM signals feed from PLC. The output voltage of motor is regulated by Automatic Voltage regulator (AVR) to reduce current drawn by motor. A reduction of 40% was observed during No-load condition and about 20% reduction in consumption when motor is running under normal rated loaded condition.

Index Terms— Industrial Motors, PLC, PWM, Chopping, Power consumption, AVR, Open and Closed loop mode.

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1 Introduction

THIS modern world of industrial revolutions is facing the crisis of power generation and its efficient utilization. The shortage in power generation and distribution of power are the significane problems for residential, commercial and industrial sectors in underdeveloped countries. Highest power demand equipments, devices and utilities has to be searched out while considering the less-than-required generation of electric power in fast growing industrial world to meet the power demand.

In industries electric motors consumes more than 60% of overall power utilized. With good planning and strategies the consumption of power may be reduced to a level of just 18%. Strategies included variable frequency drives (VFD) and VSD were proposed reducing more than 80% power consumption in industry when motor is running under no load for the large range motors greater than 200 hp [1]. High energy efficacy is the most interested area in power engineering research form the past decades. It need broad varieties and flexibilities in control and regulation of consumption of motors. Motors constitute about 90% of total of 70% usage of world's electric power generation [2].

In literature [3] it is estimated that motors run at highest efficiency under full load condition. Due to power loss at low input voltages the efficiency reduces [4]. Among various techniques energy loss can be reduced by utilizing good copper conductior for winding. It results in 11-19% reduction in power loss of motors [5].

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Efficiency of electric motors in industry may be improved by: 1). Power semiconductor technology, 2). Power supply conversion technique, 3). Low power processing techniques and 4). Low loss passive components technique

In last decades an economical method of AC phase control was proposed to regulate and control the input power to motors [6]. Phase aangle control technique was proposed in literatures "[7, 8]" using thyristers (SCR) but the large harmonic distortion problems were observed. Pulse width modulation (PWM) technique is used for the efficient control of power and speed of industrial motors where AC or DC wave is chopped according to the input PWM signal duty cycle. It is advantages over other methods discussed [9].

In this research work technique of power consumption reduction is proposed when motor is running in no-load and full load condition. Minimum hardware setup is required with major of user friendly software in this technique to implement the technique efficiently in industries. The proposed model is based on PLC and PWM techniques. PLC is logic controller programmed to control, regulate, monitor and measure the industrial motor's parameters like speed, current, voltage and power etc. PLC are also especiaaly used to make automization in industrial sectors. PLC is taken under study due to its low cost and basic need of modern industries as compared to related equipments and machines. In this work PLC is used to design a PI controller loop for an intelligent functioning of AC motors controllers.

1.1 Testing Methods Adopted

(1). First of all the selected motor is run in an open loop mode without connecting load while using Ammeter/Digital Multi meter (DMM) to measure current drawn

(2). Next motor is run in loose connected built or light load mode and a conveyor and current is measured again. Test is performed three times and average value is take.

(3). The belt is tighted or we say motor is fully loaded and current is measured

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(4). The above three tests are repeated but in closed loop mode. Here all the circuits and encoder are attached and the tests are conducted.

(5). Then graphs are generated both in the PLC interface and manually in excel

1.2 AC Voltage Chopping with PWM Technique

Methods for the control of the speed of an Induction motor include frequency variation and voltage variation to the motor. Another method for power control of the motor is by using SCR. PWM method is also popular among researchers for the efficient control of motor. The average value of the power i.e. voltage and current that is fed to the motor in a controlled manner is done by switching the input ON and OFF by using a controller. The frequency of the switching must be high enough so that the change is not apparent. The ratio of the ON time of the switch to the TOTAL time of the signal is called as the duty cycle. The longer the switch is ON, the more power is delivered to the load.

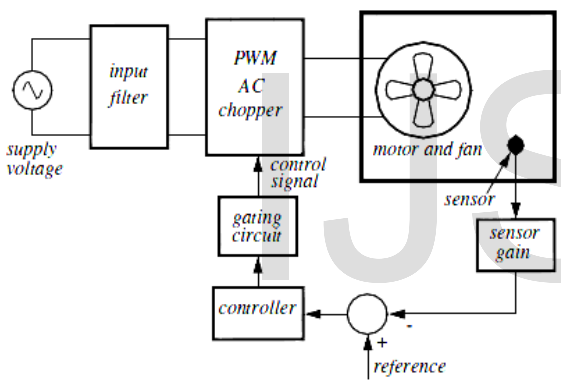

Fig. 1. Block diagram of the AC chopper

But this method has some drawbacks too. This controlling method can result in harmonics that are of lower order and can degrade the power factor of the motor. Thus a quality factor improvement circuit would be needed.

2 HARDWARE DESCRIPTION

The mechanical design and the circuits are arranged and set up in an arrangement for testing purposes as shown below in the illustration: The motor is placed on one end of the conveyor system to balance the weight of the aluminum frame. The encoder is attached to the shaft of the motor and is a 500 pulse per revolution optical encoder. The AVR, SCR Circuit and the PLC and their electrical connections in logic can be seen in the illustration. The pulley has 2 belts, one according to the setup and of proper circumference, and another of a slightly smaller circumference. The different belts serve to simulate loading effect on the motor by making the rotation of the conveyor system tighter and resistive for the motor. Thus, the motor draws more current and puts more effort on the system. Also, to aid this mechanism, additional blocks of concrete are wrapped in paper and placed on the belt to load the motor.
The power section of the project is divided into three parts.

1. Power Source (AC)
2. Power Source (DC)
3. Signal Level Converter

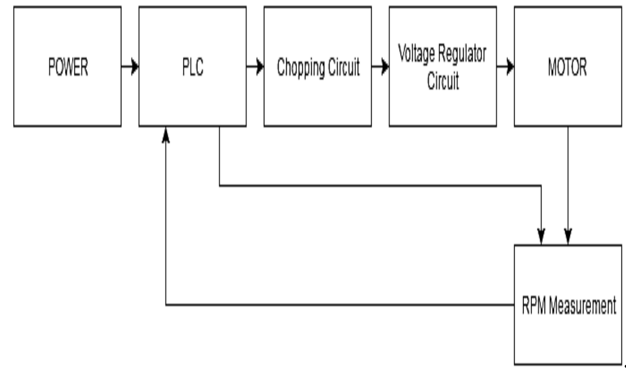

Fig. 2. Block Diagram representing the arrangement of components

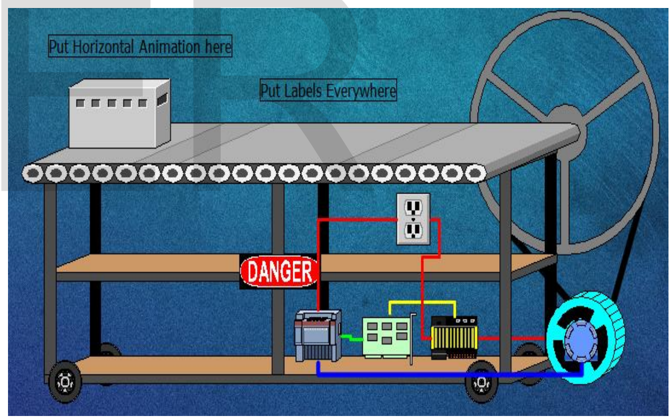

Fig. 3. Assembally of the test bid

The RPM of the motor shows a linear behavior w.r.t Torque and comes to stall with 127kgcm applied torque. This also confirms the theoretical model from the datasheet of the motorwhich also shows a linear behavior w.r.t increasing torque. The efficiency graph shows a peak efficient performance at loads near rated value. A 27kgcm torque applied to the motor results in 85% efficiency for the system.

3 RESULTS AND DISCUSSIONS

3.1 Open Loop No Load Test of Motor

The open loop test was conducted by powering the motor through direct power and measuring its current with a clamp meter and power through calculations from found values. The motor's speed behaves somehow like a sigmoid function and reached 4200 RPM in around 2.5 seconds. The power of the

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motor is calculated theoretically from the values of current. The graph was expected and found to be same as that of current as shown in Fig. 4. Next the motor is constrained through a conveyor system and the procedure is repeated for graphs. A 27 kg load was put on the conveyor and the responses were recorded for the motor. The various graphs for this test are shown as follows. In the current consumption, I have seen that the values tend to become linear with load, rather than a sigmoid S curve. The current starts with a large value and decreases gradually until the current at which the load can be carried is achieved and the motor reaches a certain speed of around 3000 RPM. The decrease in RPM is due to the increased load. The same procedure as previously done is applied but the load is increased to 65Kg. The different curves for this test are recorded and shown below: See here that the power consumption has increased due to increased load.

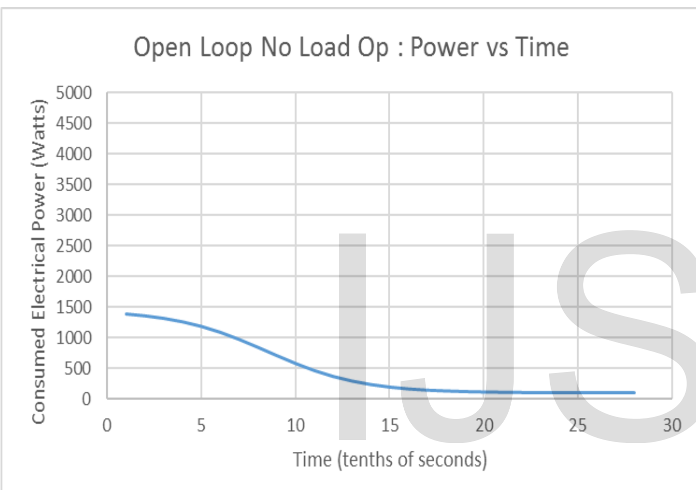


Fig. 4. Power consumption per time in open loop: No load mode

The power consumption has been tested in various scenarios as is evident from the graphs and data in the appendices. The motor is a small 0.5hp motor. In the open loop the total power consumption including startup, operation and loading etc. has been calculated in the following tables 1 and 2. The current consumption and power consumption during startup and operation of the motor in No load condition is shown as follows:

3.2 Closed Loop Tests and Discussions

The closed loop tests were carried out when the motor was fitted in the assembly shown in topic 1. The motor is supplied a proportionate increase or decrease in voltage according to the PWM signal generating from the PLC. The PLC acts like a signal corrector when the Encoder sends the RPM signals to the PLC, the PLC checks whether the current value is greater or less than desired speed input by user in HMI and then increases or decreases the duty cycle to make sure the motor is operating in the desired speed regardless of the load.

We should expect a decreased consumption in power as a whole. This is discussed in the end of the chapter. In each of the test, the motor is left to reach full speed in 5 seconds, after that the feedback loop starts and decreases the RPM to a desired value set by the user. Now the various findings for our closed loop behavior are shown belowClosed loop No load

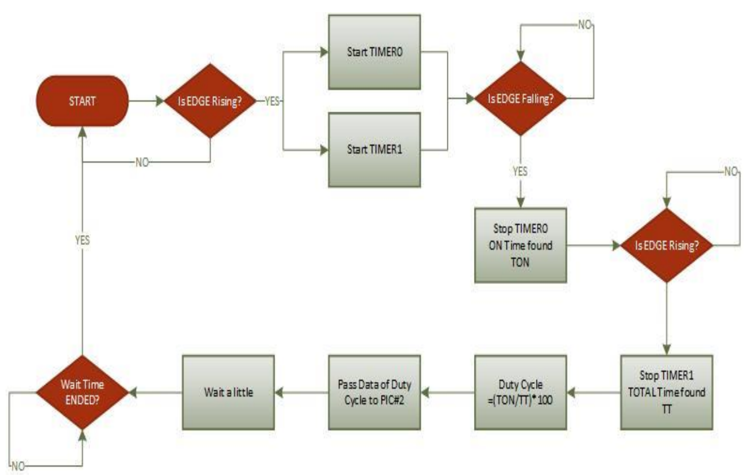
Here the motor reaches its full speed of 4200RPM in around 5 seconds after which the feedback starts to decrease its speed. The desired values set in this test is 2100. The motor is slowed down to 2100 RPM and is maintained at that speed for the rest of the operation.

Table. 1. Power Conusmption of motor in Open loop

Power Consumption of 0.5 hp motor in Open Loop Operation (kWh)			
	Hourly	**Daily (12hrs)**	**Monthly**
No Load	0.498497	5.981964	143.5671
Small Load	0.959697	11.51636	276.3926
Large Load	3.321209	39.8545	956.5081

Table. 2. Power Conusmption of motor in closed loop

Power consumption of a 0.5hp motor in Closed Loop (kWh)			
	Hourly	**Daily (12hrs)**	**Monthly**
No Load	0.1037	1.244402	29.86566
Small Load	0.446531	5.358376	128.601
Large Load	Stall	Stalls	Stalls



PLC Flow Chart

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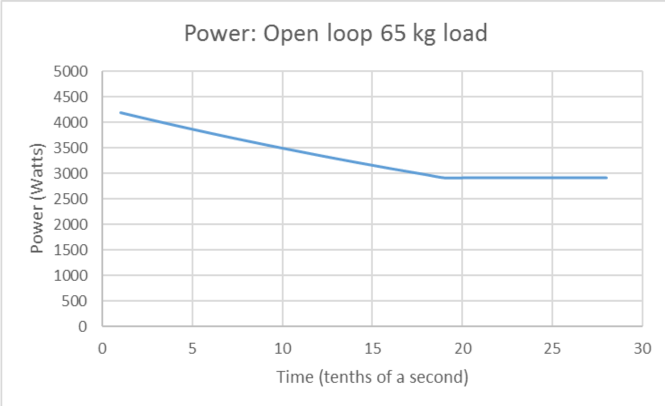

Fig. 5. Power Conusmption of motor at 65kG load in closed loop

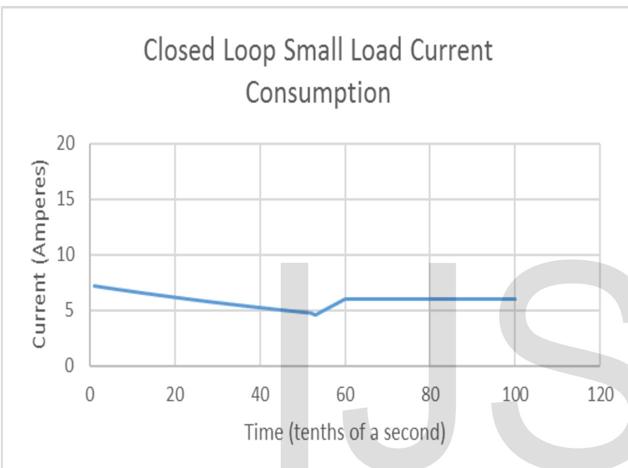

Fig.6. Corresponding Current consumption curve for the motor

3.2.1 Closed Loop Small load

For a small load within the capacity of the motor, the speed of operation decreases linearly. In this test, a 15 Kg load was placed on the conveyor and the full speed of the motor decreased to around 3700 RPM. This decrease in RPM was due to the restriction in current from the circuit. The motor slowly gained its full speed and current consumptions at startup, feedback and stabilizing states are shown in the following figures.

3.2.2 No Load Power Conservation

In the no load state, both in open loop and closed loop, the tests showed an 40% decrease in the power usage. This is because the motor is gradually deprived of current when no load is sensed. In open loop mode, power usage was 498 Watts as an average. In closed loop it was 292 Watts as an average for the same time duration and same settings which is ~40% lower than in the open loop mode.

3.2.3 Load less than or equal to the rated load value

In conditions where load is put on the conveyor and hence on the motor inside the rated range of load, the motor in open loop mode withdrew a lot of current than was necessary for working initially and then slowly stabilized the current withdrawal after a while. In the closed loop mode however, the current withdrawal was constrained and the current supply to the motor could only be possible if the PLC unit decided to.
In this test, a load of around 27kgcm was put on the motor and the response of the open loop in power usage was 959 Watts. In closed loop mode, the overall power usage was 669 Watts. It is 30.2% less than that in the open loop. This conservation is due to the fact that the motor is slowly provided power rather than left to withdraw as much as it wants. This ensures that enough power to complete the required work within a given time is available to the motor.
This conservation does not stay the same. For different loads different percent of power is saved. This behavior is due to the varying efficiency with varying loads. Best power savings are resulted for values near the rated load of the motor due to peak efficiency of 85%.

3.2.4 Load greater than the rated load

For values of load greater than the rated load, the motor withdraws current larger than that the motor could withstand and becomes hot in a matter of a few seconds. This behavior is only in open loop operation. However, in closed loop, the current demand becomes larger but the PLC can only signal 100% duty cycle at most, so the current greater than rated current cannot flow through the circuits to the motor. This results in slowing down of the motor and hence becomes difficult to compare it with Open loop operation due to heterogeneity in testing nature. Although motors are most of the time operated within the rated load range, the open loop withdraws current almost 5 times larger than rated value and is unsafe for operation.

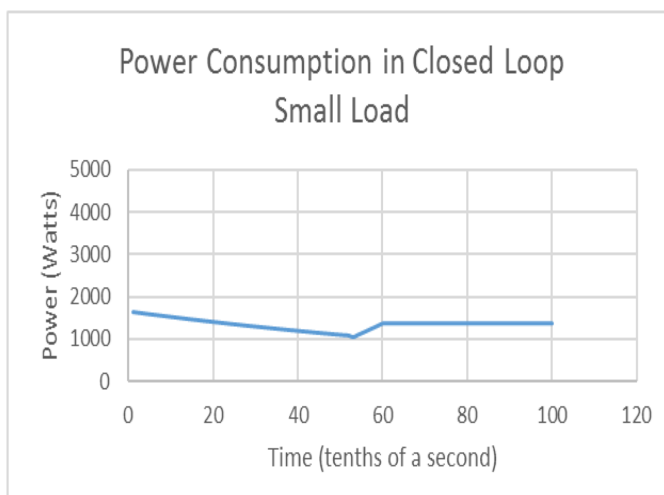

Fig.7. Power consumption curve for the motor in closed loop

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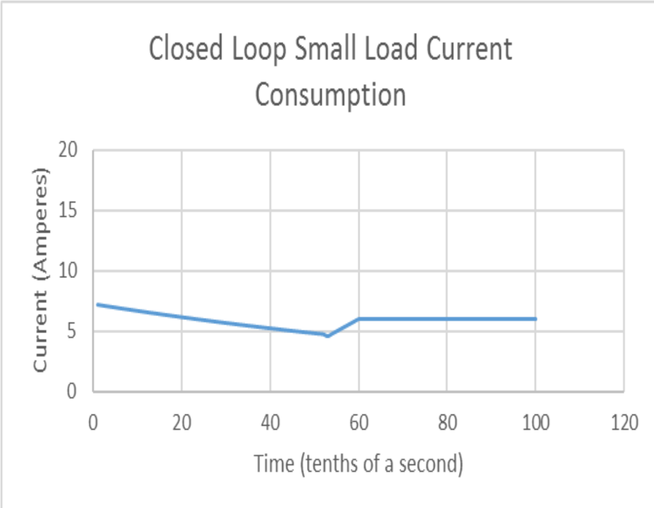

Fig. 8. Current consumption curve under small load in closed loop

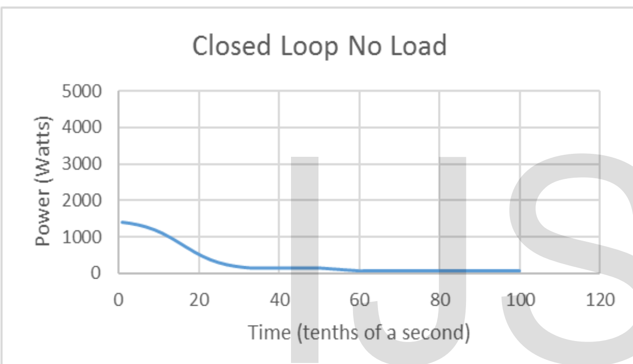

Fig. 9. Power Conusmption of motor in no load condition and closed loop

4 Conclusion

It can be concluded that the experiment for a hybrid technique of power conservation has been successful and that more than 20% power usage is reduced by the application of the controlled power flow using PWM Chopped AC applied to Motor through Voltage Level regulator. The tests were conducted and found satisfying and according to expectations.

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