Recent trends in AC motor control methods, controllers and control algorithms for multipurpose control & automation of industrial drives

Naveenkumar R Kulkarni*, Mitali S Shinde[1], Megha S Jagdale[2], Pragati P Naikawadi[3], Neha P Jadhav[4], Dnyaneshwari S Mali[5,]

* Asst. Professor, Dept. of Electrical Engineering, Sanjay Ghodawat University, Kolhapur, India
1-4, UG Students, Dept. of Electrical Engineering, Sanjay Ghodawat Institutes, Kolhapur, India
Mail: naveenrk234@gmail.com

Abstract—**Three phase induction motors are widely used in industries as it is simple in construction, self starting capacity, reliable operation and easy speed control achieved from improvements in VFD's and other power electronic control techniques. In recent days, BLDC motors are used in industrial sectors and electrical vehicles because of its construction that is suitable for handling critical applications. They have many advantages over other motors in Comparision with DC motors and induction motors. Its control comprises of classical PID controller and fuzzy logic controller used to make the system stable. Servomotors are constructed from three basic pieces which are motor, feedback device and control board. Servo encoder will measure motor rotation and position, it continuously measures through a suitable drive. So in servo drive encoder signal will work as a base signal hence motor speed will be changing continuously. On unifying the control strategies for these motors, there is a great need for a detailed review on available control strategies and controllers which can improve the performance and working of electrical motors for various applications. This paper is an attempt to understand the evolution in various control methods, controllers, control algorithms for different types of electrical motors applications like industrial purpose, electrical vehicle and electrical drive system.**

Keywords: PLC, VFD, SCADA, Induction motor, Electrical vehicle, Control Algorithm.

I. INTRODUCTION

Three phase induction motors are majorly used in industrial drives and it appears like heart of industries. Every industrial process is related with induction machines either directly or indirectly. Dileep Kumar Et al., [1], this paper proposes the protection scheme using the solid state relays coupled with PLC and magnetic contactors. Programmable logic controllers are widely used in industrial applications specifically in automation applications. The inputs of the PLC take many different types of digital or analog signals which are fed into the PLC through the various sensors. Another most essential part is HMI (Human Machine Interface), which allows operator to monitor process, measurement of parameters like voltage, current and speed etc. [1]. So for the industrial purpose, it is required to design and develop PLC based system for pneumatic pressing machine which performs the most critical operation in the engine bearing manufacturing plant. The automation system involves the speed control by changing or replacing the conventional method with a VFD (variable frequency drive) [2].

Engine bearings are primarily used in IC engines of automobiles and in other machines also. The modern trend in manufacturing industries is to automate machine operation as it can increase productivity, quality, improves the robustness of the process and increased consistency of the output [2].

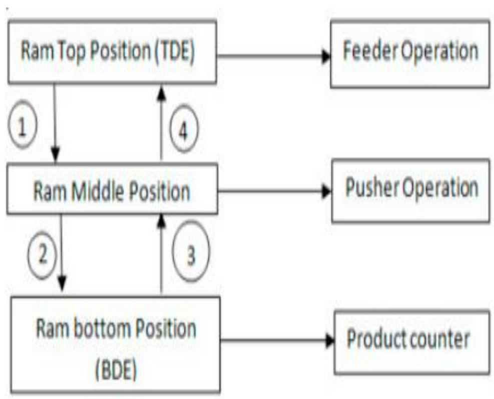


Fig. 1: PLC based operation and control of press machine

In a bearing plant all operations like stamping, blanking, Forming and coining operations in done in one stroke of pneumatic press. PLC based controlling system for pneumatic press deals with speed control feed, pusher control fault detection, safety digital inputs, outputs, PLC program flow chart etc. [2].

II. LITERATURE REVIEW

Sowmiya [3], In this paper, it is described about powder compacting press machine which is monitored and controlled by VFD (Variable frequency drive) fed 3 Phase induction motor by using PLC technology. PLC is used to co-ordinate operational parameters such as RAM down, RAM clasp, RAM loading and RAM up in pressing machine. This control method based on PLC introduces pressing machine and solenoid valves which are controlled using PLC as per the operation cycle. In this study the PLC measures the current, voltage, temperature and the addition it activates the output as per the input from the feedback according to the program [3].

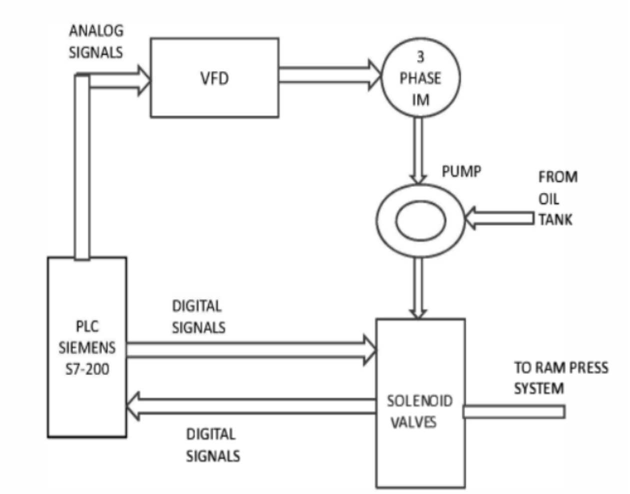


Fig. 2: Schematic diagram for the control system of powder compacting press machine using VFD. [3]

The ladder diagram will execute the operation of the HP machine as per the rung description and each step will be operated by HMI (Human machine interface). PLC program executed sequentially as per the program structure from first rung to last rung which is called as scan. So as per this procedure, cyclic operation will execute. In this paper review, the press machine RAM press system was automated using Ladder logic in PLC, so it will help to increases the efficiency and operation of pressing machine. But when the extra number of inputs and outputs are required this method may not be feasible.

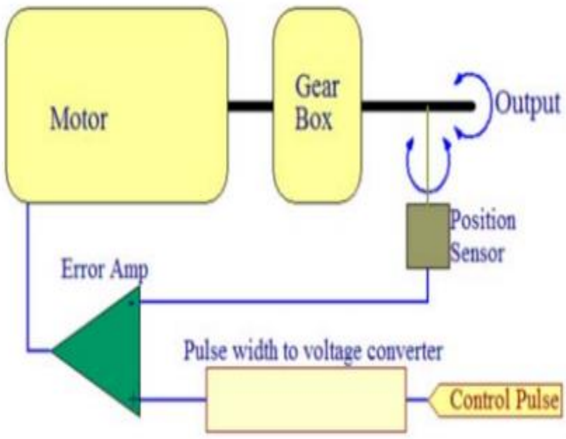
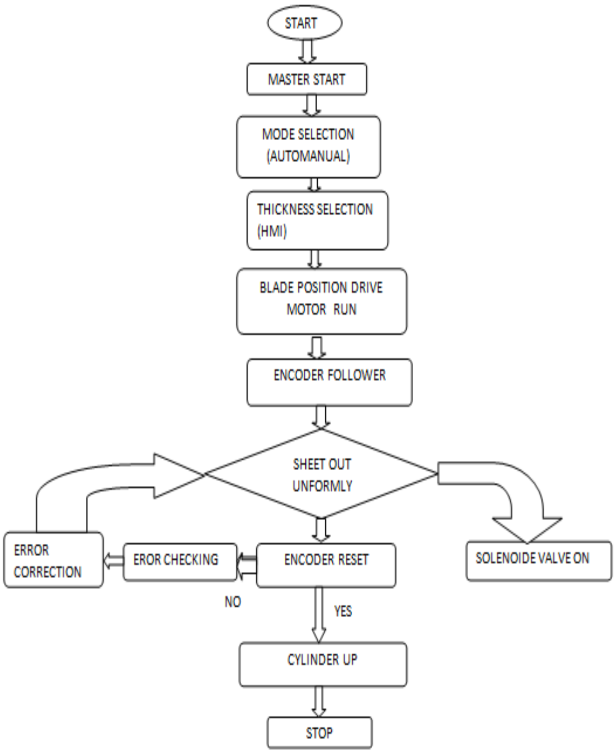


Fig. 3: Basic block diagram of servo motor

Mehul R. Patel [4], This paper deals with application of PLC for controlling Servomotor which controls turning operation and determines error if the yield position contrasts from that required part. A blunder flag is created at that point makes the engine pivot in either heading as we expected to convey the yield shaft to the suitable position [4].



Flow chart: Working of Conventional Peeling machine

Thickness of product slice is made accurate by adjusting accurate distance between main roller and raw material roller. Here the number of input output problem can be solved by using communication request to make device quite speedy and accurate [4].

III. Review on control of BLDC motors

Brushless dc motors have high power density, Low noise, simple control, etc. So this motor is widely applied in industry, home appliances, Robots and Electrical Vehicle applications. The requirement of BLDC motor increases, especially a situation of the trend of minimizing size of actuator. Application of slim type BLDC motor is being increased because phase inductance of the slip type BLDC motor is so large which causes high lagging current. There is problem that reduces motor efficiency and increases a phase current. Jin-Hong Kim Et al.,[6] suggest control scheme for efficiency improvement of Trapezoidal Type Brushless DC Motor to resolve above-mentioned problems. To synchronizing phase current and Back-emf phase of BLDC motor, it suggested Lead angle control method for use of current dynamics characteristics. P. Suganthi Et al. [7].

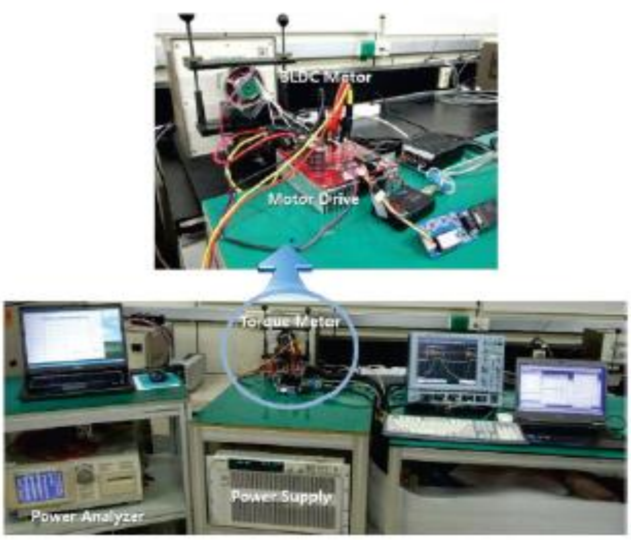


Fig. 4 Experimental setup for control of BLDC motor

Items	specifications
Output power [W]	300
Number of poles	20
Resistance [Ω]	0.1
Inductance [μ]	380
Dc- link voltage[V]	48
Motor diameter[mm]	100
Stator lamination depth[mm]	7

Table1: Specification of BLDC Motor.

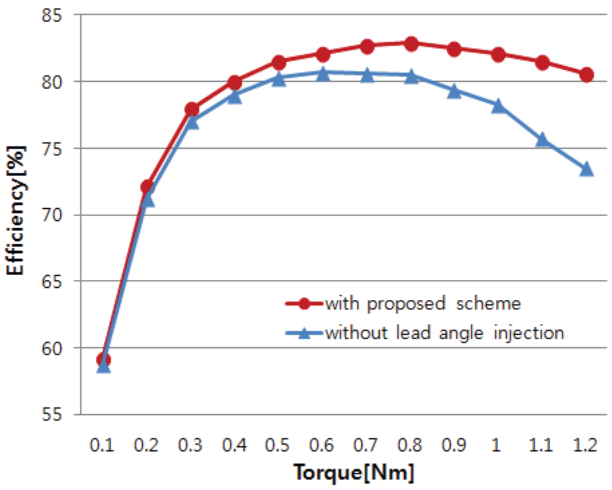


Fig. 5. Characteristic of control scheme trapezoidal type brushless DC motor (Efficiency vs. Torque)

By using software like Lab VIEW we can control operation of motor in industries. Lab VIEW means laboratory of virtual instrumentation engineering workbench. It provide simple interface to devices. The graphical programming code is used in lab VIEW software. Shared variable is laboratory function that permits sharing of data between various applications across a network of system. The most important features of Lab VIEW creates web server by automatically generating an URL that help in publishing the front panel project over internet [8].

Below fig. 6 shows front panel of the lab VIEW. The front panel of the lab VIEW provides various controls and indicators for motor start, stop, reverse/forward direction and speed control knob. The parameter of induction motor like current and speed are also displayed on front panel of lab view. When we start push button pressed, the motor starts rotating in forward direction. Forward/reverse switch is used to change the rotating direction of three phase induction motor in reverse direction. Speed control knob is used to vary analog voltage signal at inverter output of VFD. Output of VFD various the switching rate of IGBT based inverter. In this way speed of three phase induction motor is controlled [8].

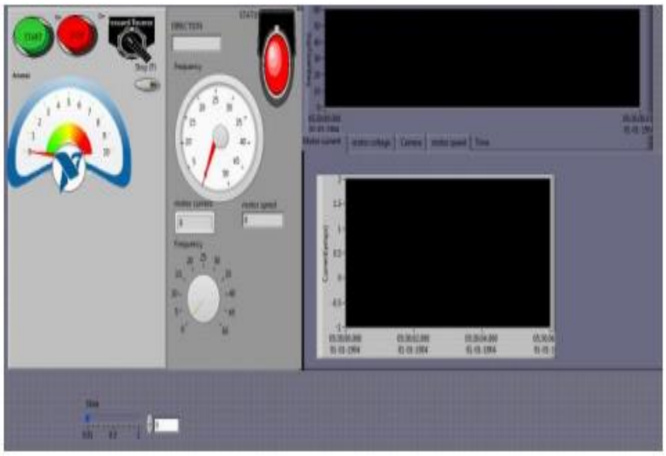


Fig. 6: Front panel of the LAB VIEW

The electrical vehicle is new technology which is used to reduce the pollution and to reduce the use of fossil fuel. The following fig.7 shows the block diagram of plug in electric vehicle. It include battery set, power converter according to motor used, AC or DC motor.The plug in electric vehicle which means pure electric car with highest efficiency [9].

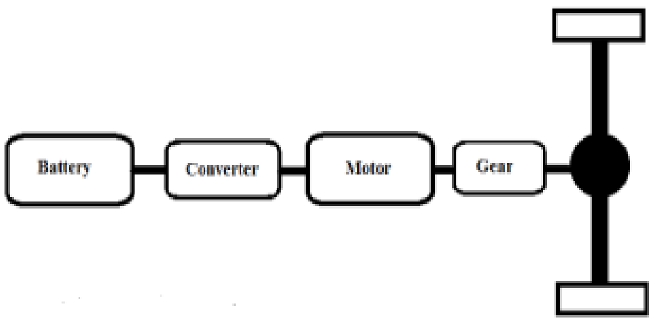


Fig. 7: Block diagram of plug in electric vehicle

To calculate the forces which are acting on vehicles some assumption are to be made. These forces are used to calculate total power requirements [9].

Assumptions considered:

1. Body mass of car =800kg
2. 4 peoples of 100 kg each=400kg
3. Battery and other accessories=300kg
4. Total weight of vehicle(W)=1500kg
5. Max. speed of car(v)=100km/hr
6. Wheel radius(R)=0.355mm
7. Angle of inclination (ø)=28°
8. Frontal area of car(A)=2.45m²

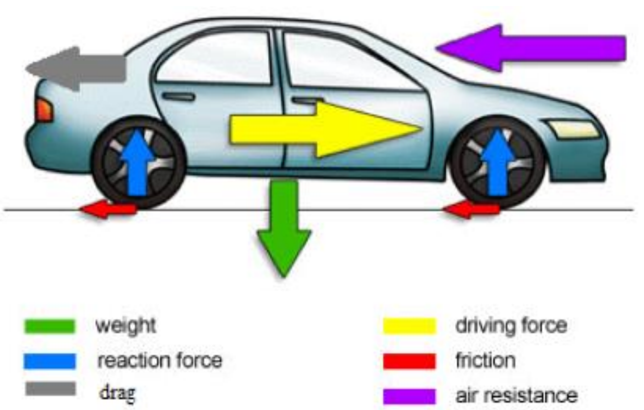


Fig. 8: Forces acting on vehicle

Total power requirement= (F × d) ÷ t

Where,
F=Mass × Acceleration and
t=Time

By using wheel torque and proper gear ratio we calculate the power requirement of vehicle.

T=F×R

Motor torque=wheel torque ÷ gear ratio [9]

IV. REVIEW ON CONTROL OF BLDC MOTORS

4.1 FIELD ORIENTED CONTROL ALGORITHM:

The field oriented control (FOC) system is designed by giving the power supply of DC 60-72V. The rectifier and inverter convert the PWM signal as a input from DSP into a sine wave output. The hardware of this controller system consists of various modules. These modules are current detection, power module an A/D detection module. These modules are used to detect current, voltage, motor and temperature of controller. The FOC controller system contain other module also, frequently the modules used are speed detection module, JTGA debugging module and SPI, CAN communication module, EEPROM storage module. The framework of hardware to control the FOC is as shown in fig.9 [10].

Compared with the V/F speed control method the FOC control has a better speed range and dynamic performance because of this reasons the motor runs smoothly with low noise. The FOC consists two constant as a input references. These two components are aligned in two coordinate (d and q coordinate) time invariant system [10].

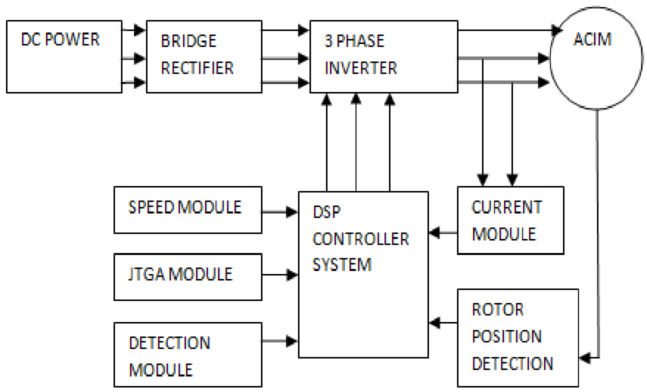


Fig. 9 System architecture diagram of FOC algorithm

The first component is torque component which aligned on q coordinate and other component is aligned on the d coordinate. The different parameters processed in a control system are real-time data. The FOC algorithm gives the precise control on various parameters of a motor. The FOC control architecture is shown in fig. 10 [10].

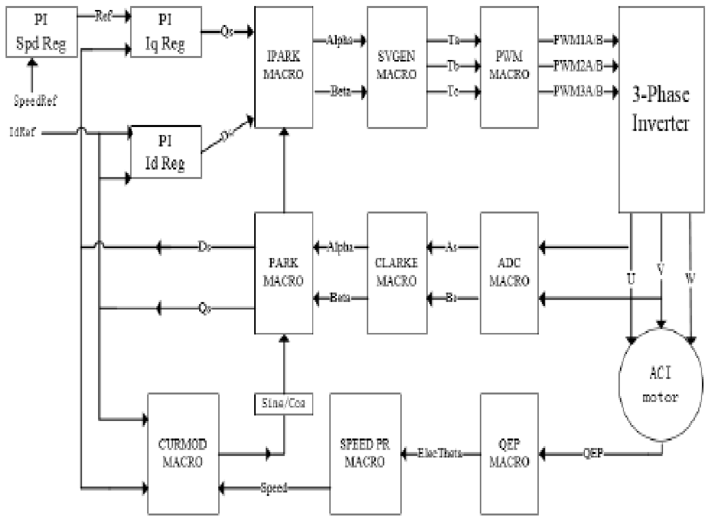


Fig.10: FOC control architecture diagram

4.2 PULSE WIDTH AMPLITUDE MODULATION TECHNIQUE BASED CONTROL ALGORITHM:

The various drives are mostly controlled with the help of V/F control technique. The reason behind using this technique is low cost and having simplicity. The Pulse Width Amplitude Modulation (PWAM) technique is applied for V/F control of quasi impedance source inverter (qZSI). The PWAM technique having excellent advantage that it reduces the switching losses and improving the system efficiency. The rams output voltage of qZSI at starting will be higher and not in the favor of the V/F algorithm.

The three phase induction motor powered by three phase supply with seven level qSZI and controlled by V/F technique. The framework consist of two main parts one of the part is power circuit and second is control circuit .The power circuit requires the three-phase qZSI system connected to the three phase induction motor. Each phase consist of three module of qZSI system which is connected in cascaded to obtain seven level in output phase voltage. To achieve the multilevel output voltage. In this circuit the pulse width amplitude modulation technique is employed. The control circuit consists of V/F controlled and DC bus voltage controller. The V/F control loop implemented by single PI control loop embedded with saturation block. The three modulating signals are the output of this controller. The DC bus voltage controller consists of two cascaded PI controllers and the output of this loop is shooting through duty ratio. The control signal from these two loops is given to pulse width amplitude modulation control block [11].

In production line the electro-pneumatic system plays an important role. But it will go through some loss in energy and the efficiency gets decreased. To overcome this drawback we can use suitable PLC controller with high response and reliability. By using PLC controller the compressor also reduce the power consumption. For reduced power consumption we can add VFD which improves motor performance by increasing torque and speed[12]. Block diagram for the experimental setup of electro-pneumatic system using VFD is shown in below Fig .11.

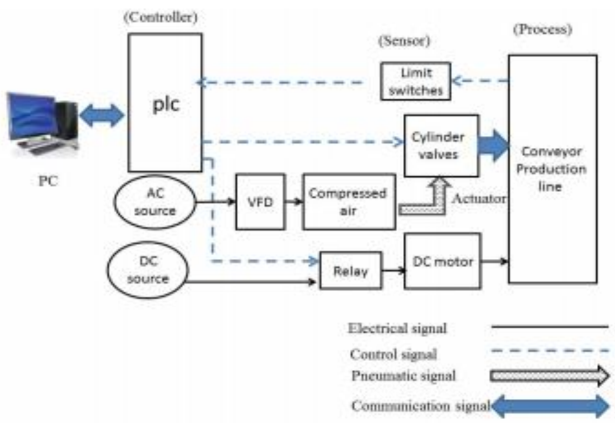


Fig. 11: Block diagram representation of implemented setup for Electro-pneumatic system

Here PLC will control pneumatic valves and DC motor. They will pass signal to conveyor production line. And by using feedback through the sensor again feedback send to PLC and by controlling through the user's PC user can control the pneumatic valves and DC motor of conveyor. VFD will control the consumption element in the supply i.e. compressor this will done with extra added equipment such as ammeter, voltmeter in between VFD (variable frequency drive) and compressor [12].

FOLLOWING TABLE SHOWS THE EXPERIMENTAL RESULT OF ELECTRO PNEUMATIC SYSTEM

System Frequency (Hz)	**Motor Performance**			
	Time to fill tank(S)	**Current (A)**	**Volt (v)**	**Power (Kw)**
Without VFD (50 Hz)	3.20	3.2	230	.625
Without VFD(50 Hz)	3.10	1.5	220	.2805
Without VFD(45 Hz)	3.25	1.8	200	.306
Without VFD(40Hz)	4.14	1.7	180	.260
Without VFD(35Hz)	4.46	1.6	160	.2176

Table 2: Experiment results of Electro-pneumatic system

Here we can observe that without using the VFD the compressor will consume the large amount of power. When user use VFD it will reduce the consumption at same frequency or by changing the frequency the consuming parameters can be controlled. So by using VFD we can decrease power consumption, improvement of torque and speed thus the productivity automatically get increased at same frequency.

In this paper [13] they are using a centrifugal machine for liquid separation process in sugar manufacturing processes. As the conventional controllers have not been successful for real time applications as the reference will change so the predictive controllers are used. For the PID-predictive controller the control algorithm will be created in PLC. So in industry we are using PID-predictive controller for high accuracy. Here by performing tests using ramp function for three phase induction motor without controller with conventional PID controller and PID -predictive controller the different results are obtained. For the comparison the system is implemented with PID and PID-predictive controller are also done. By comparing two results the output error will be measured by using RMSE (Root mean square error) qualitatively [13].

States	RMSE
Without Controller	20.59
PID	15.32
PID-Predictive	7.86

Table 4: RMSE results of PID predictive controller

PID and PID-predictive controller both can follow the reference .The PID- predictive control follow smoothly but PID-predictive controller follow the reference with lots of tooth signal in the response [13].

So we can use PIC based PID- Predictive controller design for three phase induction motor on centrifugal machine for sugar manufacturing processes. So PID-predictive concept in applicable in PLC. Thus we can make the system output to track the desired input. With the help of PLC it can be used in the sugar industry to maintain the sugar quality [13].

V. Conclusion

This paper is a sincere attempt to study, understand and evaluate current technological updates in the areas of AC motor control for various applications using different types of controllers, control logics, control algorithms and its applications to different fields like industrial processes and motor control in electrical vehicles.

This review and study paper could be beneficial to great number of researchers working in the areas of designing control systems and control algorithms with its application to industrial processes and electrical vehicles. Authors of this review paper are currently working in designing a unique control logic with various controllers and to design control algorithms for the same which are intelligent with smart decision making capabilities for industrial automation processes which can reduce human efforts in a great way. Updates of our work will be updated in our upcoming papers after successful experimentation and validation of results. .

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