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A Novel Approach For Sensorless Speed Control Of Brushless DC Motor Drive Using Modifiedant Colony Optimized FOPID Controller

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Abstract

This paper deals with the time response performance analysis of the brushless DC (BLDC) motor i.e. electronically commutated motors based on Modified Ant colony optimization Techniques. The BLDC motor is becoming increasingly popular because of the wear-prone brushes used in traditional motors has been replaced with an electronic controller which improves the reliability of the unit and finds applications in the fields of motion control systems, positioning and actuation systems, industrial engineering etc. The BLDC motor's controller requires the rotor's orientation / position relative to the stator coils for directing the rotor rotation. In conventional BLDC motor, hall effect sensors or rotary encoders might be used for measuring the rotor's position directly. In sensorless BLDC motor, back EMF has to be measured in the undriven coils to infer the rotor position. The proposed method explores the characteristics of Modified Ant colony optimization algorithm based on torque, speed and flux control by reducing the steady state error for optimizing the PID controller of the BLDC motor. Simulations based on MATLAB and its results illustrate the improved performance of BLDC motor by the proposed method.

Keywords —BLDC Motor Drive, Sensorless Control, Modified Ant colony optimization Technique

1. INTRODUCTION

In conventional brushed DC motors, the field and armature windings are placed on the stator and the rotor respectively. The motor costs a lot of money and need a process of keeping it in good condition by regularly because of the brushes, the accumulation of the brush has been destroyed and dirt, and commutator outside wear. Moreover, in certain dangerous locations, the application of DC brushed motors is limited because of the arcing. This can be solved by interchanging the mechanical switching components (commutator and brushes) into the electronic semiconductor switches [1].

BLDC motor has a permanent magnet (PM) rotor and a copper coil wound field stator. its connected to power semiconductor switching devices. The BLDC Motor have no brushes and commutators. Here used Three Hall sensor for detect the rotor position. Based on rotor position signal the semiconductor device will operate corresponding coil energized.The Sensorless BLDC motor does drive the highpotential, less maintenance and last longing life, less noise, easy to access, less weight, and compact construction. Basically Sensorless BLDC motor able to find rotor position without Hall sensors by means of Estimation techniques. Sensorless BLDC motorcontrol drive systems are based on the feedback of rotor position has obtained on fixed points usually every 60 electrical degrees for six-step commutation of the phase currents.depends on the shape and size of their back Electro Motive Force (Back EMF), The brushless motors have the ability of classified as trapezoidal or sinusoidal [2].

Modified Ant colony optimization (MACO) studies artificial systems that take stimulation from the performance of real ant colonies. It is used to solve separate optimization troubles.MACO have been applied to many hybrid optimization troubles. Modified Ant colony optimization algorithms have been used to produce near best solutions to the travelling salesman trouble.

2. METHODS AND MATERIALS

2.1 Sensorless BLDC motor Drives

A BLDC motor drive, in general, requires one or more positioning sensors to maintain synchronisation. Due to sensor wiring and motor implementation, such a design results in a greater driving cost. Furthermore, sensors cannot be employed in applications where the rotor is enclosed in a closed housing and the number of electrical entry is limited, such as in a compressor, or in applications where the motor is submerged in a liquid, such as some pumps. Until date, the commutation has been based on the Hall sensor's rotor position. Back EMF signals are used to commutate the BLDC motor instead of Hall sensors.When the BLDC motor does rotate, each winding does generate a voltage called as Back Electromotive Force(Back-EMF), which opposes the main voltage had suppliedto the windings according totheLenz’s Law [3].

In each commutationsequence has one of the windings energized with positive, the second negative and the third left open. As shown in Fig. 1. basic blocks of sensorless BLDC motor drives, when the voltage polarity of back EMF crosses from a positive to negative or vice versa the Hall sensor signal changes the state. In ideal cases, this happens on zero-crossing of back EMF, but practically, there will be a delay due to the winding characteristics.

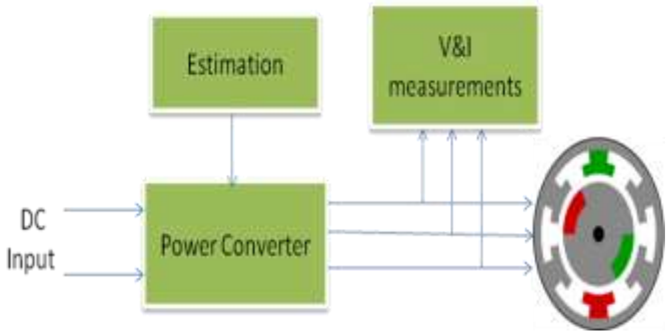

Fig.1Basic blocks of Sensorless BLDC motor Drive

The control should be changed to the back EMF sensing, When sufficient back EMF is built to detect the zero-cross point. The minimum speed at which back EMF can be sensed is calculated from the back EMF constant of the motor.The Hall sensors can be eliminated due to this method of communication.

2.2. Modified Ant colony optimization

Modified Ant colony optimization (MACO) is a metaheuristic algorithm in development that is based on the combined activities arising from the hybrids of several search threads and has shown to be effective in tackling hybrids optimization problems. The PID controller's gains (G) are changed using a trial-and-error method based on the prior experiment and system performance. The gains are optimised using the Modified Ant colony optimization technique, and the values are fed into the system's controller. This algorithm's goal is to optimise the PID controller's gains for the supplied systems. The controller employs error proportional gain to respond. To decrease the number of steady state error [4].

MACO is a metaheuristic algorithm design approach for combinatorial optimization issues. The MACO was inspired by natural ant colony activities on how to locate food sources and return to their nest by constructing a one-of-a-kind path. The conventional fixed gain PID controller is frequently utilised in industrial control processes. Proportional gain (Kp), integral time constant (Ti), and derivative time constant (Dti) are the parameters utilised to construct the controller (Td). To optimise the gains and values, the suggested MACO-PID controller is applied to the PID controller of the systems [5]. As shown in Fig. 2. Decision making process of ants choosing their accordingto pheromone.

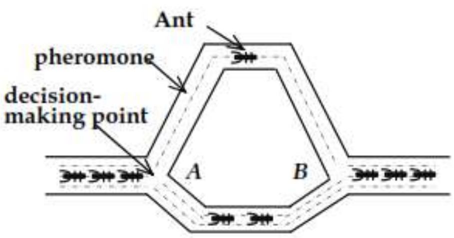

Fig. 2. Decision making process of ants choosing their trip according to pheromone

3. PROPOSED METHOD

Three phase AC voltage is delivered to the controlled rectifier which converts AC voltage into DC voltage. This DC voltage is delivered for VSI which in turn turns it into again Ac voltage for giving square wave to BLDC motor.The block diagram of proposed BLDC with Ant Colony Technique is shown in fig.3.

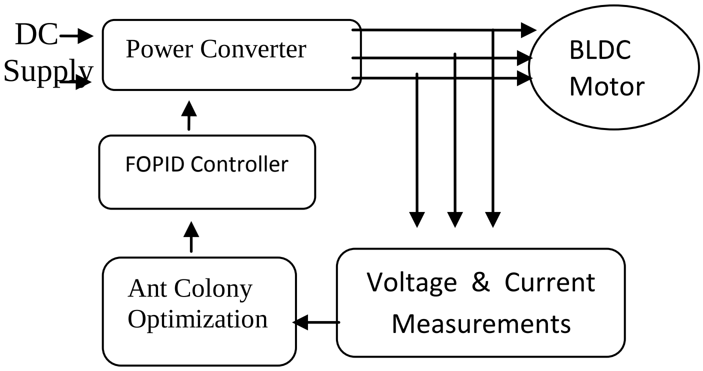

Fig. 3SensorlessBLDC motor drive with Modified Ant colony optimization

The BLDC motor rotates with parameters such as speed and torque after receiving square wave. It is necessary to estimate the parameters of a BLDC motor in order to control its speed, which may be done by converting three phase to two phase utilising park transformation. The predicted speed and torque values, as well as reference speed and torque values designated as "Nref" and "Tref," are sent to the controller block.Then, using the inverse park transformation, convert two phase to three phase, which is then fed into a space vector pulse width modulation (SVPWM) generator. This SVPWM generator generates VSI gate signals from input error signals. The BLDC motor's speed is controlled by these gate signals.

3.1 Modified Ant Colony Technique

MACOs are frequently utilised to find solutions to various optimization problems. A colony of artificial ants assists in the discovery of standard solutions, which emerge as a result of the ants' cooperative cooperation. Ant algorithms are molecularly similar to ant colonies in nature, so they can be used to solve different versions of the same problem as well as other optimization problems.Artificial ants share many characteristics with their wild counterparts. Artificial ants are distinguished by the fact that they live in colonies to aid persons and communicate by depositing pheromone. To find the shortest path from a starting position to a destination location, only local moves and local information are used. In order to handle a specific optimization difficulty, artificial ants have been modified with several additional qualities not observed in real ants. [6]

An ant seeks for a good solution to a given optimization issue collectively[8]. Individual ants can develop solutions, but it takes a group of ants to discover the best solution.

It is a powerful effect of such cooperation because the best degree of solution can only be found by working with other ants in a colony. While seeking for a solution, the ants communicate indirectly by releasing pheromones into the environment. An ant moves from one starting state to the next in a series of neighbouring states in order to discover the shortest path to solve a problem.

MACO is depending upon the pheromone matrix $\tau = \{\tau_{ij}\}$ for the construction of good solutions. The initial values of τ are

Set$T_{ij} = \tau_o \forall (i,j)$, where $\tau_o > 0$(1)

The probability ${P_{ij}}^A(t)$ of choosing a node j at node I is defined in the equation (2). At each generation of the algorithm, the ant constructs a complete solution using this equation, starting at source node.

$$ {P_{ij}}^A(t) = \frac{[\tau_{ij}(t)]^\alpha [\eta_{ij}]^\beta}{\sum_{ij \in T^A} [\tau_{ij}(t)]^\alpha [\eta_{ij}]^\beta} \quad ; i,j \in T^A \ (2) $$

Where $\eta_{ij} = \frac{1}{K_j}$, $j = [p, i, d]$ represents the heuristic function.

T^A= the path effectuated by the ant A at a given time.

The quantity of pheromone $\Delta\tau_{ij}$ on each path may be defined as

$$ \Delta{\tau_{ij}}^A = \begin{cases} \frac{L^{min}}{L^a} \text{if } i,j \in T^A \text{else} \ (3) \\ 0 \end{cases} $$

3.2 Modified Ant Colony Algorithm

Steps in Ant Colony Algorithm

Step I Using a uniform distribution, generate random potential solutions for the parameters Kp, Ki, and Kd. Set the heuristic value and the pheromone trail to zero.

Step II On the node, the Ath ant should be positioned. Calculate the objective's heuristic value (minimize the error).

Step III To avoid an infinite rise in pheromone trails and to allow for the forgetfulness of bad choices, use equation 4's pheromone evaporation.

Step IV In light of the objectives, evaluate the produced solutions.

Step V The optimal values of the optimization parameters will be displayed.

Step VI Using the optimum solutions obtained in step V, update the pheromone. Iterate from step II until you've achieved the maximum number of iterations.

Flowchart of Modified Ant colony optimization shown in fig. 4.

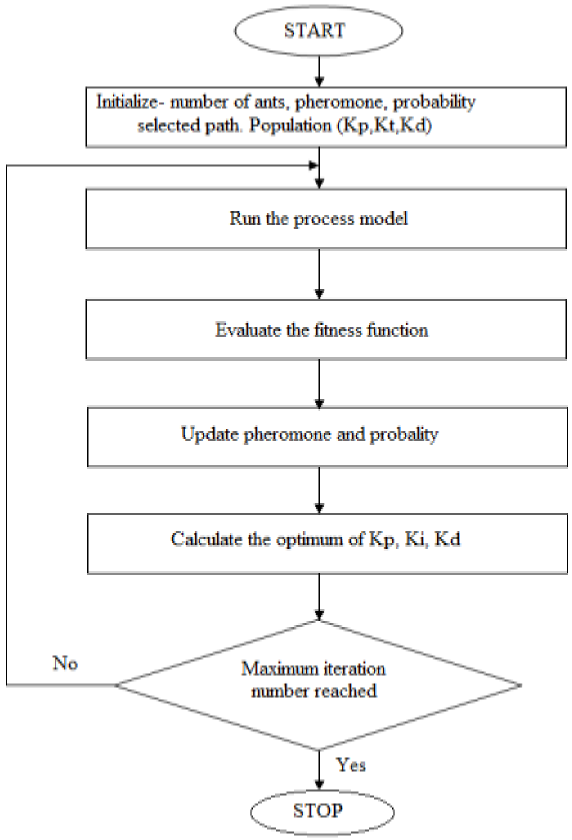

Fig.4.Flowchart of Modified Ant colony optimization

Each ant adjusts its velocity and position with the following equations:

$$v' = v + c1.r1.(pBest - x) + c2.r2.(gBest - x)x' = x + v' \quad (5)$$

v refers to the current velocity, v' refers to the new velocity, x the current position, x' the new position, P Best and

4. RESULTS AND DISCUSSION

In this section the proposed results have been discussed. The sensorless control of BLDC motor using Modified Ant colony optimizationhas been verified through the Matlab simulation output. The sensorless BLDC motor drive to achieve desired speed, torque and flux control with Modified Ant colony optimization. The reference speed is set by500 rpm.

The reference speed is compared with the calculated speed. Similarly, the reference torque is compared with the measured torque. Fig.5 to 9 shows the Matlabsimulation output wave form for sensorless BLDC motor drives with Modified Ant colony optimization.

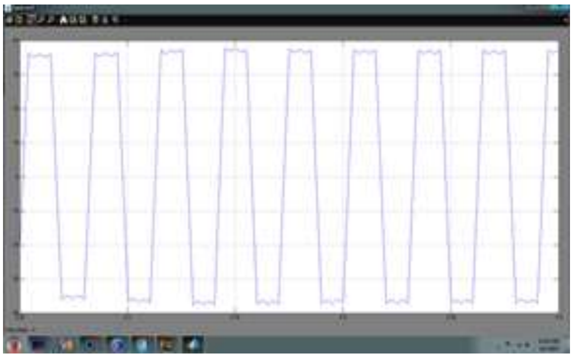

Fig.6.Trapezoidal back EMF of BLDC motor.

The supply voltage is set by 250v. By controlling the current speed can be controlled. The theta value is estimated by integrating the speed. The flux value can be obtained through the stator voltage and current.

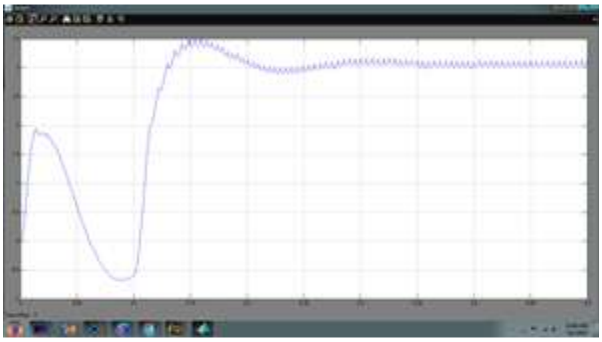

Fig. 7. Stator current of BLDC motor

The three phase brushless DC motor stator current which can be controlled by MACO techniques. stator current and stator flux are directly proportional therfore if stator current controlled at same time stator flux also controllable. The five standarded techniques for time respones analysis purpose. first of all fuzzy logic PID controller setting time very higher than other techniques. second Ziegler-Nichols something better than fuzzy logic PID controller. now Modified Ant colony optimization techniques setting time 1.09ms. it is better settling time respones for sensorless BLDC motor drivessystmes. As shonw in table 1. Time respones comparison of MACO and various techniques.BLDC motor speed can be controlled with help of ant colony optimazation techniques using PID controller.

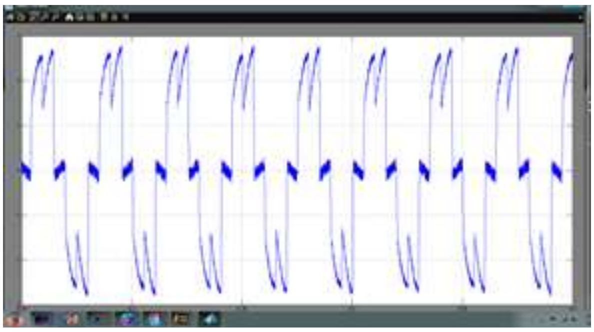

Fig 8 Torque of the BLDC motor

The time response characteristics obtained from the various control techniques for PID controller. The rise time, settling time and peak response from the MACOcontroller are tabulated in table 1. The results show that the MACO based PID controller has got better performance and characteristics when compared to other control techniques. The results illustrate the robust stability and system disturbance rejection. The sensorless BLDC motor drives systems focusing steady state respones of given systems.

Time Respones / **Techniques**	**Setting time (ms)**	**Rise time (ms)**	**Peak time (ms)**	**Peakover shoot time (ms)**	**Delay time (ms)**
Fuzzy logic	9	3	4	1.17	2.6
Ziegler-Nichols	3.76	0.79	3.2	13.13	2.2
Modified Ant colony optimization	**1.09**	**0.52**	**3.00**	**1.11**	**1.56**
Artifical Intiligent	1.79	1.89	7.8	1.16	1.76
Partical Swam Optimisation	1.26	0.71	0.80	1.59	1.35

Table 1 Time respones Comparisonof MACO and various techniques.

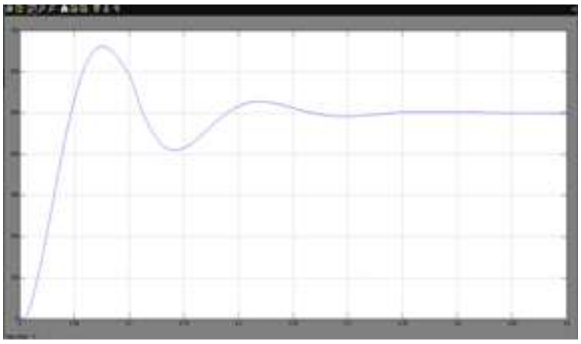

Fig. 9Rotor Speed of BLDC motor

This graph depicts the variation in time responses as a function of time. The sum square error is one in the beginning, then gradually decreases, then climbs again after around 3 seconds due to undershoot. Finally, as the duration hits 12 seconds, the overshoot drops to 1.11ms, the error drops to practically zero, and the system reaches its steady state response. 8.55 is the integral absolute error, while 22.36 is the integral absolute time multiplied error. Sensorless BLDC motor drives systems have steady state time response characteristics.

5. CONCLUSION

This work discusses sensorless BLDC motor control using modified Ant colony optimization. Using Matlab software, the MACO approach is used to estimate the Trapezoidal back-EMF waveform. The total harmonic distortion has been reduced, which has boosted efficiency (THD). The current can be regulated to control the speed. The value of theta must be estimated by integrating the speed. The reference speed is compared to the estimated speed. The calculated torque is compared to the reference torque in the same way. The stator voltage and current can be used to calculate the flux value. To reduce overall system error and predict the backlog, modified Ant colony optimization is used. It is clear that MACO based PID controllers are more effectivethan fuzzy based PID controller Ziegler-Nicholsbased PIDcontroller and PSO based PID controllers for steady state time response.

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