Multi-objective solution with PSO algorithm for minimization of torque ripple and speed settling time by using solar-fed 11,9 and 3-level multi-level inverter with vector control of induction motor

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ABSTRACT

The 11,9 & 3-level cascaded multi-level inverter is fed with vector control of induction motor. The speed performance of the machine is dependent on the PI controller used for speed control. Regulation of speed can go till 5% is allowable. If the PI controller parameters are not optimal the speed error gets increase. The torque ripple can be reduced by using the multilevel inverter. More than that the PI controller output is related with torque. So, the problem is formulated with reduction of settling time of speed and torque ripple. The Multi-objective Particle Swarm Optimization (MPSO) algorithm is used to solve the problem. And the performances are compared with PI controller and PSO-PI control of vector control drive. MATLAB is used to solve the entire system.

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1. INTRODUCTION

In recent days the speed control of the induction machine needed to be faster and accurate for many sensitive applications. The vector control of induction machine provides better control over speed. The problem in vector control is settling time. To improve the settling time many researches are carried out. In [1] the 5-level cascaded multilevel inverter is used for pumping load. The PI controller is replaced with fuzzy based PSO algorithm in [2] for improving stability. Only type-2 fuzzy is used in [3,4]. PSO tuned PI controller is used in [5] for PMSM machine and in [6] GA-PSO is used for the speed and current control for vector control of induction motor. PSO based online vector control is also carried out in [7]. The vector control of three stage multilevel inverter is discussed in [8]. To reduce the harmonics multilevel inverter is used in vector control technique in [9]. Many new types of inverters are used to control the motor and which are discussed in [10-25].

In this paper Photo-Voltaic (PV) fed cascaded multilevel inverter with 11,9 &3 level and the speed control of induction motor with vector control using MPSO optimized PI to minimize the settling time and reduce the torque ripple is proposed.

2. PROBLEM IDENTIFICATION

The vector control has a speed control loop with PI controller to produce proportional torque value for electromagnetic torque reference to control the torque of the motor. It can be derived as follows

$$N_{error} = N^{*} - N \quad (1)$$

When applied to PI controller it can be defined as

$$T_e = (K_p + \int_{T_{e,min}}^{T_{e,max}} K_i) * N_{error} \quad (2)$$

So, the torque results are totally depending on the Kp and Ki values of PI controller. By changing the values of PI controller, the torque ripples can be changed. So, it is formed as a discrete optimization equation with settling time as another objective. So, the problem is formulated as minimization of torque and settling time of speed of the Direct torque Control (DTC) is done by considering an arbitrary limit for Kp and Ki values.

3. OBJECTIVE FUNCTION

Objective function used here is done for torque minimization with reduction of settling time of speed. Both the objectives are made as multi-objectives as given in (1)

$$F = \min\left\{\sum_{t=0}^{n}\left(\frac{T_e(t)}{n}\right)\alpha_1 + T_s\alpha_2\right\} \quad (3)$$

$T_e(t) - electromechanicaltorqueatsamplet$
$n - totalnumberofsample$
$T_s - speedsettlingtimeinsec$
$\alpha_1, \alpha_2 - weightvaluesformultiobjectivefunction$

Constraints

$$K_{p,min} < K_p < K_{p,max} \quad (4)$$

$$K_{i,min} < K_i < K_{i,max} \quad (5)$$

4. MULTI-OBJECTIVE PARTICLE SWARM OPTIMIZATION

MPSO is based on the behavior of the food search in a group of fish or bees or birds. The procedure of the algorithm is given as follows.
Step 1. Assume the size of the swarm or particle (m). usually size of 20 to 30 particles are used.
Step 2. Generate the initial population of X in the range X(l) and X(u) randomly as X1,X2,…XN.
Step 3. Evaluate the objective function value using (3).
Step 4. Find the velocities of particles. All velocities are initially assumed as zero. All particles move towards the optimal point.
Step 5. Find the historical best value of the particles, which is known as local best, or particle best (Pbest) and find the best particles of all the previous iterations called as global best or Gbest. Find the velocities of the particles j in ith iteration as follows,

$$Vj(i) = Vj(i-1) + c1r1[Pbest – Xj(i-1)]+c2r2[Gbest-Xj(i-1)] \quad (6)$$

Where,

j = 1,2,…N.
c1, c2= learning factor assumed as 2
r1, r2 = Uniformly distributed random numbers range 0
and 1. Now find the position or coordination of the jth particle in the ith iteration

$$Xj(i) = Xj(i-1) +Vj(i) \quad (7)$$

Now evaluate the objective values of the above Xj.
Step 6. Check the convergence of the current solution, if the positions of all particles converge to the same set of values the method is assumed to have converged else increment the iteration number and evaluate step 5.

5. RESULTS AND DISCUSSION

Figure 1. shows the Eleven level cascaded multi-level inverter fed induction machine with solar MPPT. Figure 2. shows the Convergence of PSO technique. Figure 3 shows the Speed curve of PSO-PI controlled with 11-level,9-level and 3-level vector control. PSO-PI controller pulls the settling time faster compared to PI controller. the PI controller settles in 0.334 sec where as PSO-PI controller settles the speed in 0.325 secs for 11-level. And Figure 4. shows the torque curve of PSO based PI controller vector control. Figure 5. shows the speed curve of PI controller-based vector control Figure 6. shows the torque curve of PI controller-based vector control. It can be seen that the PSO-PI performs faster and with less ripple in torque compared to PI controller. The Speed response of PI and PSO-PI controlled vector-controlled drive, Motor specification, PSO Algorithm parameters are shown in Table 1-3 respectively.

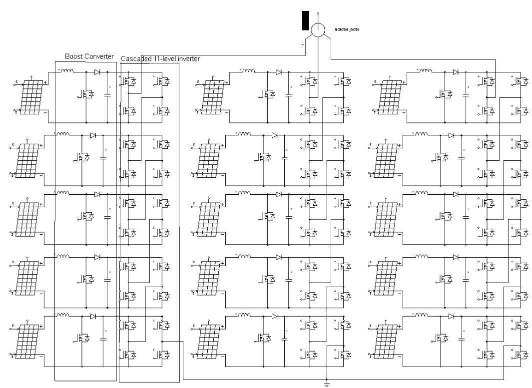

Figure 1. Eleven level cascaded multi-level inverter fed induction machine with solar Maximum PowerPoint Tracking (MPPT)

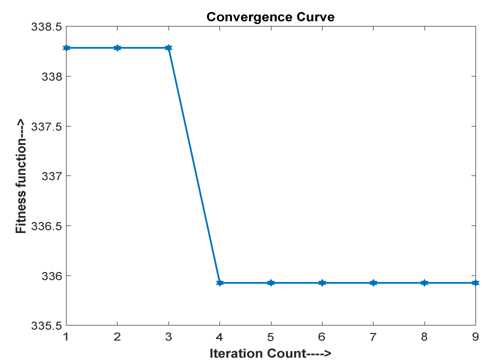

Figure 2. Convergence of PSO technique

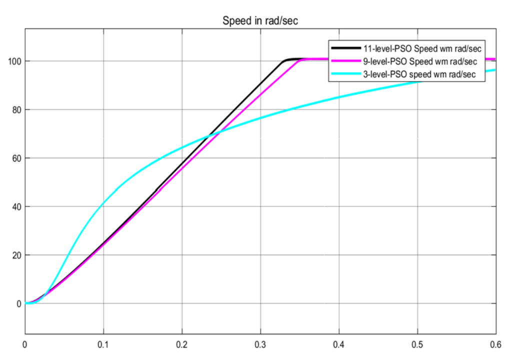

Figure 3. Speed curve of PSO based PI controller vector control

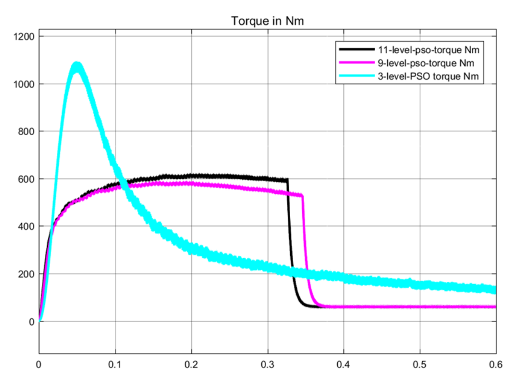

Figure 4. torque curves of PSO based PI controller vector control

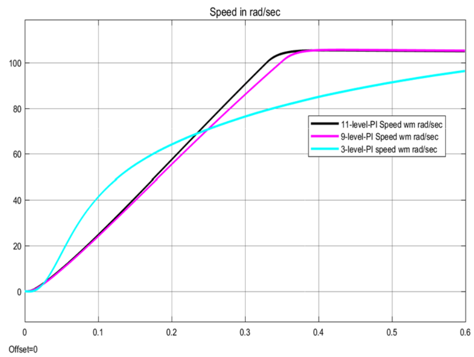

Figure 5. Speed curve of PI controller-based vector control

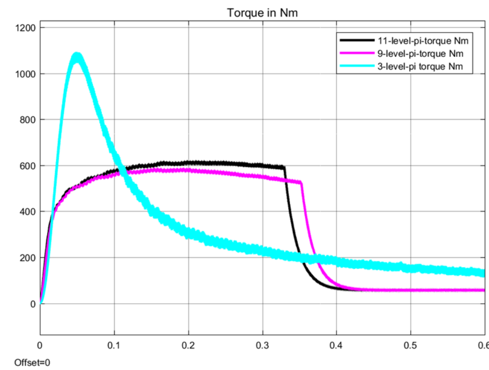

Figure 6. torque curve of PI controller vector control

Table 1. Speed response of PI and PSO-PI controlled vector-controlled drive

	PI	PSO-PI
Rise Time (sec)	0.25609	0.24928
Settling Time (sec)	0.33421	0.32502
Settling Min (rad/sec)	93.106	90.564
Settling Max (rad/sec)	105.38	100.65
Overshoot in %	186.93	2.114
Undershoot in %	5.0487	5.1904
Peak (rad/sec)	105.38	100.65
Peak Time in sec	0.41064	1.5337

Table 2. Motor specification

Motor parameters	
specifications	Values
Nominal power (VA)	37300
voltage (line-line) (Vrms)	460
frequency (Hz)	50
Stator resistance (ohm)	0.087
Stator inductance (H)	8.00E-04
Rotor resistance (ohm)	0.228
Rotor inductance (H)	8.00E-04
Mutual inductance Lm (H)	3.47E-02
Inertia (kg.m^2)	1.662
friction factor (N.m.s)	0.1
pole pairs	2

Table 3. PSO Algorithm parameters

PSO algorithm	
specifications	Values
range min	0
range max	550
swarm size	2
Number of variables	2
iteration	10
inertia weight	0.1
acceleration factors	2

6. CONCLUSION

The 11-level cascaded multi-level inverter fed vector control of induction motor with minimization of torque ripple and minimization of settling time in speed with MPSO tuned PI controller is done with MATLAB simulation. The system settling time improved by .01 secs and surprisingly the rise time is improved with, overshoot of 2.11%, reduced from 187% compared to PI and PSO-PI. And the 5 rad/secs speed error in PI controller is over come in PSO-PI control. The PSO-PI control with 11-level multilevel inverters causes improvement in torque ripple reduction.

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