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Position controlling of Sun Tracking System using optimization technique

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Abstract

The prime objective of this paper is to devise optimization technique for the position control of Sun Tracking System (STS). In order to control the position of this system, PID controller tuned by different methods such as Genetic Algorithm (GA), Particle Swarm Optimization (PSO) and Teaching Learning Based Optimization (TLBO) is used. These methods have been carried out to determine the most optimized and robust one for the position control. The simulated results for nominal and perturbed value of servo amplifier gain show that the PID controller tuned with TLBO technique gives most optimized and robust performance in comparison to other tuning techniques.

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Keywords: Sun-Tracking System; Teaching Learning Based Optimization Algorithm; Sun axis; Solar panel axis

1. Introduction

These days, scientists and researchers all over the world are sparing no efforts to replace conventional energy with renewable one. Conventional methods of energy generation play very pivotal role for causing the greenhouse effect and global warming [1,2]. Alternatively, solar photovoltaic (PV) systems can be used to generate electricity with nonpolluting process and abundantly available solar radiation. PV systems are very useful for the remotely located places which do not have grid connectivity [3].

A PV cell generates maximum output when light rays from the sun get directly incident over it. Generally, a sun tracking system (STS) is used to harness the energy of the sun to maximum extent [4]. These types of mechanisms are essential for applications like space vehicles. In STS, position of the solar panel is continuously aligned to the sun's axis. STS can be implemented either to operate in open loop or in closed loop. In first, usually predefined trajectory is followed by it, whereas in closed loop STS continuously solar panel is aligned towards

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| Nomenclature | |
|-----------------------|---|
| $P_{u,j}$ | newly produced population based on population P_j |
| teacher | global best individual in current population |
| <i>s</i> ₁ | real random number lies between 0 and 1 |
| tf | teaching factor |
| f (.) | cost function value of consistent solution |

the sun axis where sun axis is defined towards the direction of sun ray [5,6]. Most of the control problems can be conveniently handled by PID controllers and have simple design allowing easy implementation. But the selection of appropriate gains is always tedious and complex. Performance of the STS can be adversely affected by inappropriate gain selection. Prodigious artificial intelligent techniques have been used for the tuning of PID controllers such as genetic algorithm [7], particle swarm optimization [8], teaching learning-based optimization [9]. It is noting that GA and PSO are the classical PID parameter tuning technique whereas TLBO is the latest technique to improve the performance of system.

This paper is organized in such a way that the first section describes the introduction part. Section 2 describes the mathematical modelling of sun tracking system. Section 3 gives the various techniques for tuning the PID controller. Section 4 describes the simulation and result part of the paper. Section 5 ends with conclusion of the paper.

2. Sun tracking system modelling

Schematic of the sun tracking system considered in this work is shown in Fig. 1. A controller governs the servomotor position in accordance to the error signal generated. Error signal depends on the difference between sun axis and solar panel axis. Detailed modelling of the system under consideration is discussed in [10]. Values used for the parameters of the system are shown in Table 1 [11]. The open loop transfer function of the STS shown in Fig. 1 can be expressed in Eq. (1).

$$G_P(s) = \frac{\theta_s(s)}{\theta_r(s) - \theta_s(s)} = \frac{K_S R_F K_T K/n}{R_A J s^2 + K_T K_B s}$$
(1)

where, θ_r denotes the reference angle i.e. sun axis and θ_s represents solar panel axis. A conventional Proportional– Integral–Derivative (PID) controller is used to minimize the difference between the sun axis and the solar panel axis. Mathematically, output of the PID in terms of error signal can be expressed as [12]:

$$U(s) = E(s)\left(K_p + \frac{K_i}{s} + sK_d\right)$$
⁽²⁾



Fig. 1. Schematic of the sun tracking system.

| Symbol | Name | Value |
|----------------|------------------------------|------------------------------------|
| R _F | Amplifier resistance | 10,000 Ω |
| R_A | Armature resistance | 6.25 Ω |
| K_B | Back emf constant | 0.0125 V/rad/s |
| K_T | Torque constant | 0.0125 N m/A |
| K_S | Error discriminator constant | 0.1 A/rad |
| Κ | Servo amplifier gain | 1 (nominal value) |
| В | Viscous coefficient | 0 |
| J | Moment of inertia | 10 ⁻⁶ Kg m ² |
| n | Gear ratio | 800 |

Table 1. Parameter value of STS.

3. Tuning of PID controller using TLBO

Teaching Learning Based Optimization (TLBO) algorithm is designed by considering the influence of a teacher on the performance of learners in a given class [13]. Algorithm has two phases as 'Learner phase' and Teacher phase'. The cost function value (J) for this research work is formulated by combining Integral Absolute Error (IAE) and Integral Square Error (ISE) as:

$$I = w_1(IAE) + w_2(ISE)$$

(3)

where $w_1 = w_2 = 0.5$ are the weights. Goal is to minimize the objective function by selecting appropriate value of design variable (K_p , K_i and K_d) such that dynamic response can be improved. The population size and the number of iterations considered are 50. The flow chart for optimizing controller gains of STS by TLBO is shown in Fig. 2.

4. Results and discussion

In this section the results obtained from STS with PID controller in feedback control loop are illustrated. PID controller is offline tuned by GA, PSO and TLBO algorithms. Values obtained for controller gains from each of the algorithm are given in Table 2.

| Table 2. Gain parameter of uniferent optimized FID controller. | | | | | |
|--|--------|----------|--------|--|--|
| Controllers | K_p | K_i | K_d | | |
| GA PID | 0.9918 | 0.010 | 0.0126 | | |
| PSO PID | 1.000 | 0.000357 | 0.0166 | | |
| TLBO PID | 5.8861 | 0.100 | 0.100 | | |
| | | | | | |

Table 2. Gain parameter of different optimized PID controller.

Fig. 3 represents the convergence curves i.e. iteration wise variation of cost function value for GA, PSO and TLBO Optimization techniques. It shows that TLBO optimization gives the best cost function out of three techniques with same number of iterations.

Fig. 4(a) and (b) shows the response of STS with various techniques for nominal value of K (K = 1) under different reference of the panel axis position which shows that TLBO and PSO have very less overshoot whereas GA have large overshoot.

Transient and steady state performance obtained at fixed time interval are shown in Table 3, which indicate that TLBO has better performance in comparison to other optimization techniques.

Fig. 5(a)–(c) represent tracking response of STS for different value of K under parametric uncertainty by using PID controller tuned by GA, PSO and TLBO respectively. On comparison of the results under parametric uncertainty shown in Table 4, it is found that PID controller tuned by TLBO displays more robust performance in comparison to other techniques.

In context with the present STS, high oscillation and overshoots implies the non-alignment of panel axis with sun axis and hence the presence of error signal which will put the respective controller in action till these spurious things dies out. In doing so heavy energy loss takes place and by using PID controller tuned by TLBO, the energy consumption can be optimized to a great extent.



Fig. 2. Flow chart for optimizing controller gains of STS using TLBO.



Fig. 3. Iteration wise variation of cost function.

Table 3. Comparisons of different controller.

| Controllers | Rise time (s) | Settling time (s) | Overshoot (%) |
|----------------|---------------|-------------------|---------------|
| GA tuned PID | 0.0367 | 0.115 | 7.851 |
| PSO tuned PID | 0.0412 | 0.0941 | 3.5460 |
| TLBO tuned PID | 0.0355 | 0.0538 | 0.0120 |

5. Conclusion

The main objective of this paper is to find the best optimization technique for the position control of Sun Tracking System. In order to control the position of this system, PID controller is tuned by different methods such as GA,



Fig. 4. Position tracking response of STS; (a) step changes; (b) step and ramp change.



Fig. 5. Position tracking response with different value of K; (a) Tuned by GA; (b) Tuned by PSO; (c) Tuned by TLBO.

PSO and TLBO. These techniques have been carried out eventually to select the best method for PID tuning for regulating the position of sun tracking system. These methods have been carried out for nominal and perturbed value of servo amplifier gain to ascertain the most optimized and robust method for the position control. The simulated

| Controllers | Gain (K) | Rise time (s) | Settling time (s) | Overshoot (%) |
|----------------|----------|---------------|-------------------|---------------|
| GA tuned PID | K = 0.2 | 0.0965 | 0.2320 | 3.6460 |
| | K = 1 | 0.0367 | 0.1150 | 7.8510 |
| | K = 2 | 0.0278 | 0.0750 | 4.7370 |
| PSO tuned PID | K = 0.2 | 0.0871 | 0.2100 | 3.6460 |
| | K = 1 | 0.0412 | 0.0941 | 3.5460 |
| | K = 2 | 0.0345 | 0.0680 | 0.1510 |
| TLBO tuned PID | K = 0.2 | 0.0411 | 0.0680 | 2.1110 |
| | K = 1 | 0.0355 | 0.0538 | 0.0120 |
| | K = 2 | 0.0361 | 0.0538 | 0.0110 |

Table 4. Comparisons of different controller.

results for these two conditions indicate that the PID controller tuned with TLBO technique gives most optimized and robust performance in comparison to other tuning techniques.

References

- Sudhakar K, Srivastava T, Satpathy G, Premalatha M. Modelling and estimation of photosynthetically active incident radiation based on global irradiance in Indian latitudes. Int J Energy Environ Eng 2013;4(21):2–8.
- [2] Goura R. Analyzing the on-field performance of a 1-641 megawatt-grid -tied PV system in south India. Int J Sustain Energy 2015;34:1-9.
- [3] Kumar Shiva, Sudhakar K. Performance evaluation of 10 MW grid connected solar photovoltaic power plant in India. Energy Rep 2015;1:184–92.
- [4] Ponniran A, Hashim A, Ali Munir H. A design of single axis sun tracking system. In: 5th international power engineering and optimization conference. 2011, p. 107–10.
- [5] Fathabadi H. Novel online sensorless dual-axis sun tracker. IEEE/ASME Trans Mechatronics 2017;22(1):321-8.
- [6] Seme S, Štumberger G, Voršič J. Maximum efficiency trajectories of a two-axis sun tracking system determined considering tracking system consumption. IEEE Trans Power Electron 2011;26(4):1280–90.
- [7] Civelek Z, Çam E, Lüy M, Mamur H. Proportional-integral-derivative parameter optimisation of blade pitch controller in wind turbines by a new intelligent genetic algorithm. IET Renew Power Gener 2016;10(8):1220–8.
- [8] Gaing Zwe-Lee. A particle swarm optimization approach for optimum design of PID controller in AVR system. IEEE Trans Energy Convers 2004;19(2):384–91.
- [9] Qu D, Liu S, Zhang D, Wang J, Gao. Teaching-learning based optimization algorithm based on course by course improvement. In: 11th International Conference on Computational Intelligence and Security (CIS), 2015, p. 48–52.
- [10] Jha SK, Yadav AK, Gaur Prerna, Parthsarathy H, Gupta JRP. Robust and optimal control analysis of sun seeker system. J Control Eng Appl Inform 2014;16(1):70–9.
- [11] Kuo BC, Golnaraghi Farid. Automatic control system. 8th ed. John Wiley and Sons (Asia) Pte Ltd; 2003.
- [12] Rawat Anuj, Jha Shyama Kant, Kumar Bhavnesh. An overview of configuration strategies and control techniques for solar water pumps. In: International Conference on Sustainable Computing in Science, Technology & Management, 2019. http://dx.doi.org/10.2139/ssrn.3 352352.
- [13] Rao RV. Teaching-learning-based optimization algorithm. In: Teaching learning based optimization algorithm. Cham: Springer; 2016.