

Rawat, Anuj; Jha, S. K.; Kumar, Bhavnesh

Article

Position controlling of Sun Tracking System using optimization technique

Energy Reports

Provided in Cooperation with:

Elsevier

Suggested Citation: Rawat, Anuj; Jha, S. K.; Kumar, Bhavnesh (2020) : Position controlling of Sun Tracking System using optimization technique, Energy Reports, ISSN 2352-4847, Elsevier, Amsterdam, Vol. 6, Iss. 2, pp. 304-309, <https://doi.org/10.1016/j.egy.2019.11.079>

This Version is available at:

<https://hdl.handle.net/10419/243894>

Standard-Nutzungsbedingungen:

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

Terms of use:

Documents in EconStor may be saved and copied for your personal and scholarly purposes.

You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.

If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.



<https://creativecommons.org/licenses/by-nc-nd/4.0/>

The 6th International Conference on Power and Energy Systems Engineering (CPESE 2019),
20–23 September 2019, Okinawa, Japan

Position controlling of Sun Tracking System using optimization technique

Anuj Rawat^a, S.K. Jha^{b,*}, Bhavnesh Kumar^b

^a Netaji Subhas Institute of Technology, Dwarka, New Delhi, India

^b Netaji Subhas University of Technology (Formerly NSIT), Dwarka, New Delhi, India

Received 3 October 2019; accepted 22 November 2019

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.

© 2019 Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

Peer-review under responsibility of the scientific committee of the 6th International Conference on Power and Energy Systems Engineering (CPESE 2019).

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

* Corresponding author.

E-mail address: jhask271@gmail.com (S.K. Jha).

<https://doi.org/10.1016/j.egy.2019.11.079>

2352-4847/© 2019 Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

Peer-review under responsibility of the scientific committee of the 6th International Conference on Power and Energy Systems Engineering (CPESE 2019).

Nomenclature

$P_{u,j}$	newly produced population based on population P_j
$teacher$	global best individual in current population
s_1	real random number lies between 0 and 1
tf	teaching factor
$f(\cdot)$	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 worth 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).

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

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]:

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

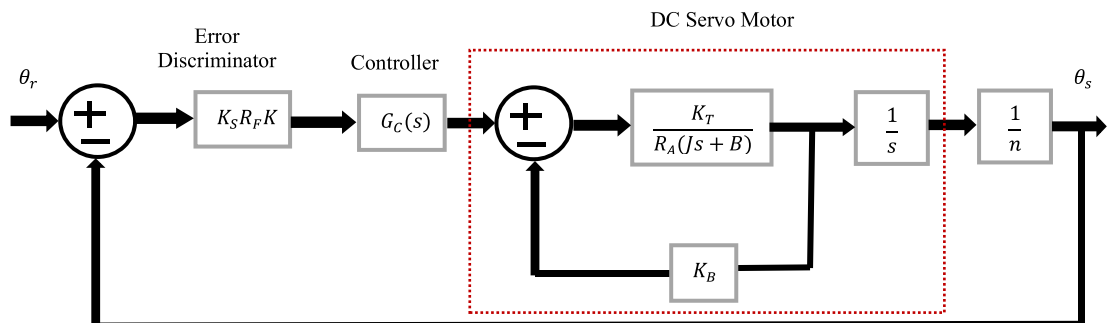


Fig. 1. Schematic of the sun tracking system.

Table 1. Parameter value of STS.

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
K	Servo amplifier gain	1 (nominal value)
B	Viscous coefficient	0
J	Moment of inertia	10^{-6} Kg m ²
n	Gear ratio	800

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:

$$J = w_1(IAE) + w_2(ISE) \quad (3)$$

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 different optimized PID 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

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.

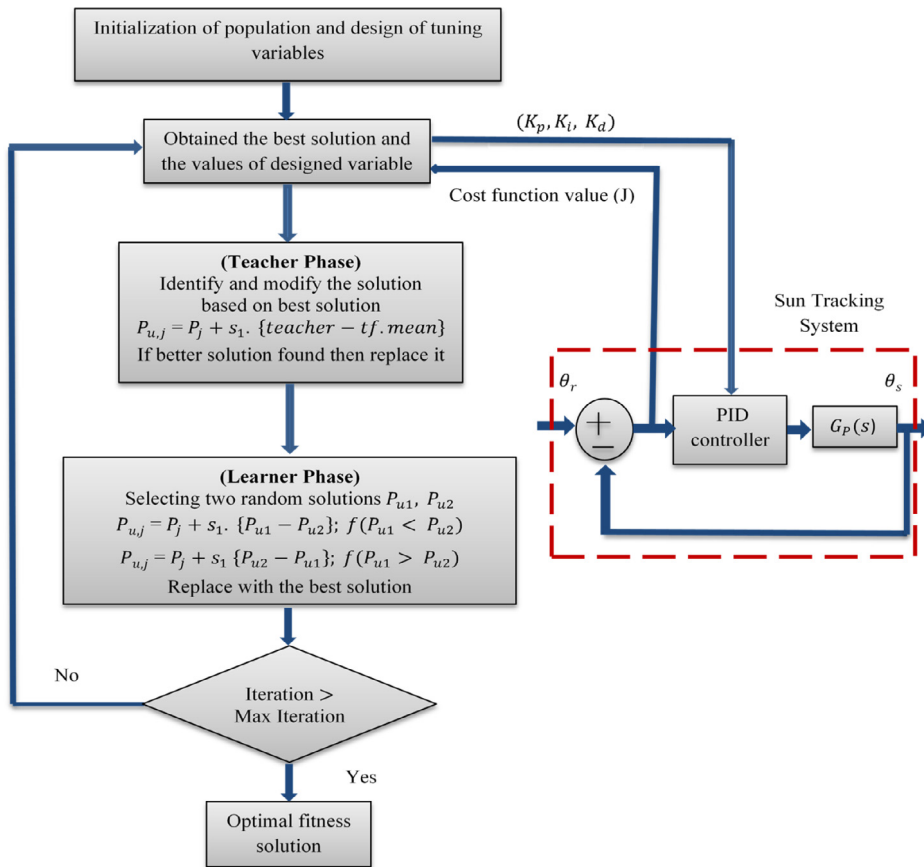


Fig. 2. Flow chart for optimizing controller gains of STS using TLBO.

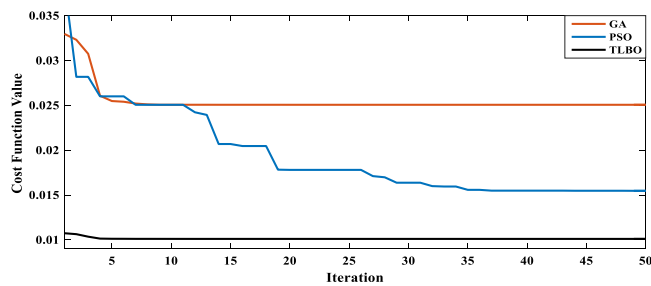


Fig. 3. Iteration wise variation of cost function.

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,

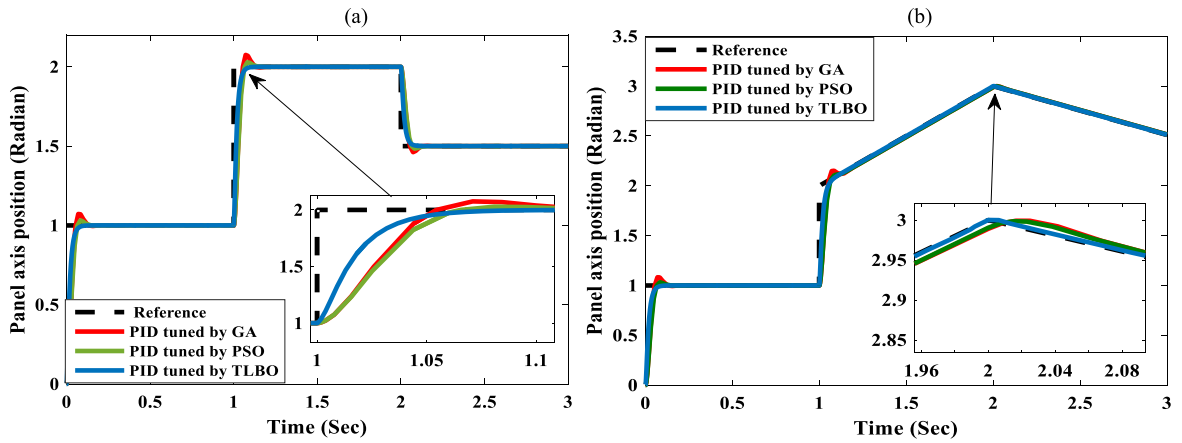


Fig. 4. Position tracking response of STS; (a) step changes; (b) step and ramp change.

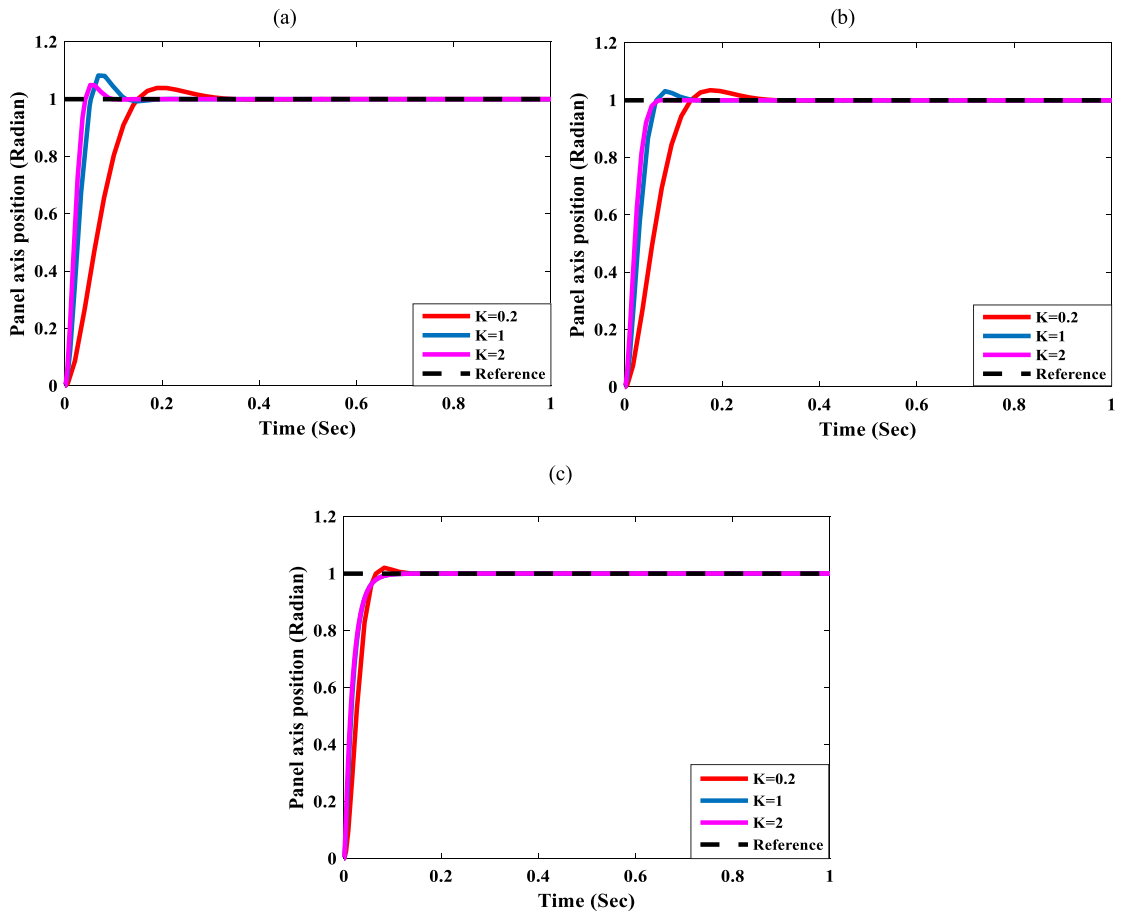


Fig. 5. Position tracking response with different value of K; (a) Tuned by GA; (b) Tuned by PSO; (c) Tuned by TLBO.

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

Table 4. Comparisons of different controller.

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

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

- [1] 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 Bhavnes. 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.3352352>.
- [13] Rao RV. Teaching-learning-based optimization algorithm. In: *Teaching learning based optimization algorithm*. Cham: Springer; 2016.