IJAREEIE

e-ISSN: 2278-8875
p-ISSN: 2320-3765

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

Volume 13, Issue 3, March 2024

INTERNATIONAL STANDARD SERIAL NUMBER INDIA

Impact Factor: 8.317

| e-ISSN: 2278 – 8875, p-ISSN: 2320 – 3765| www.ijareeie.com | Impact Factor: 8.317|| A Monthly Peer Reviewed & Referred Journal |

||Volume 13, Issue 3, March 2024||

|DOI:10.15662/IJAREEIE.2024.1303020 |

Comparative Analysis of Controller for Buck Converter to Improve Transient Response

Bhajanlal Vishnoi [1], Dr. M. K. Bhaskar[2], Manish Parihar[3]

M.E. Scholar, Dept. of EE, MBM University, Jodhpur, Rajasthan, India[1]

Professor, Dept. of EE, MBM University, Jodhpur, Rajasthan, India[2]

Ph.D. Scholar, Dept. of EE, MBM University, Jodhpur, Rajasthan, India[3]

ABSTRACT: The DC-DC buck converter is a low cost and efficient device but it suffers from problem of voltage regulation and high ripples in output. Further, due to disturbance in the input and load side of buck converter it goes under the unstable state some times and transient performance decreases drastically. So there is need of design of controller. This article deals with the design of PID controller whose tuning is done by conventional Ziegler-Nichols, LQR and LQG method. The Conventional Ziegler-Nichols method is simple but transient performance obtained are not up to the mark. The LQR (Linear Quadratic Regulator) controller is based on optimal control theory. Then LQG (Linear Quadratic Gaussian) controller is designed which is nothing but combi- nation of LQR and Kalman filter. The LQG controller provides better performance at the time of load disturbance. Transient performance is measured in terms of rise time, settling time, peak overshoot and steady state error. The MATLAB simulation study has been carried out to demonstrate the effectiveness of the proposed PID tuning methods.

KEYWORDS: PV cell, PID controller, DC-DC converter, Renewable Energy.

I.INTRODUCTION

A DC-DC converter is used to convert one level of de voltage to another. A linear DC-DC converter is uses resistive voltage drop to regulate output voltage but this method is not efficient due to large power loss. To avoid this switch mode DC-DC converters are used. Switch mode DC-DC converter uses power electronics devices and energy storing element which gives regulated de output voltage and higher efficiency [1]. The DC-DC converter is having low cost, small size and high efficiency but it contains large ripple in output and output voltage regulation is poor as compare to linear power supply. Thus a good con- troller is required to improve these performance parameters. PID (proportional-integral-derivative controller) controller can be used to improve output voltage regulation and ripple in output. MATLAB Simulink model of buck converter is shown below in Fig. 1

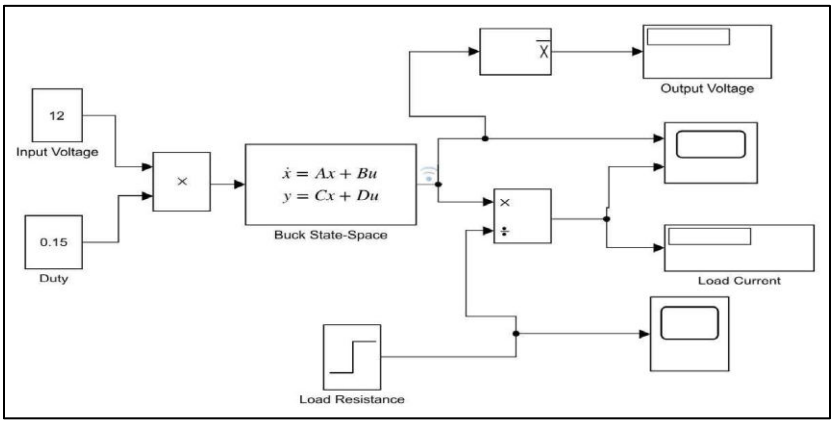


Fig. 1. Simulink Model of DC-DC Buck Converter

In general Trial and Error, Ziegler-Nichols, Tyreus-Luyben, Damped oscillation, C-H-R, Cohen- coon and internal mode control (IMC) methods are used for tunning of PID controller. This methods of tunning does not gives the optimal operation of PID controller. For optimization of PID controller Linear Quadratic Regulator (LQR) method is used for tunning of PID controller. LQR controller estimate kp, ki and kd to minimize cost function.

| e-ISSN: 2278 – 8875, p-ISSN: 2320 – 3765| www.ijareeie.com | Impact Factor: 8.317|| A Monthly Peer Reviewed & Referred Journal |

||Volume 13, Issue 3, March 2024||

|DOI:10.15662/IJAREEIE.2024.1303020 |

II. PID CONTROLLER DESIGN FOR BUCK CONVERTER

The PID controller generate a signal which is given to pulse width modulator. Pulse width modulator adjust the width of switching pulse such that the desired output voltage is achieved. PID controller performs proportional, integral and derivative action on error signal to get desired response. PID controllers are widely used in the industrial control applications. Error signal ia basically a difference between the real value and desired value [9]. By changing the proportional gain kp, integral gain ki and derivative gain kd the controller tries to minimize the error. The PID controller sometimes called three term control. These terms are Proportional (Present time dependency), Integral (Past error accumulation), Derivative (Future value prediction from present value). The block diagram of system with of PID controller is shown in Fig. 2.

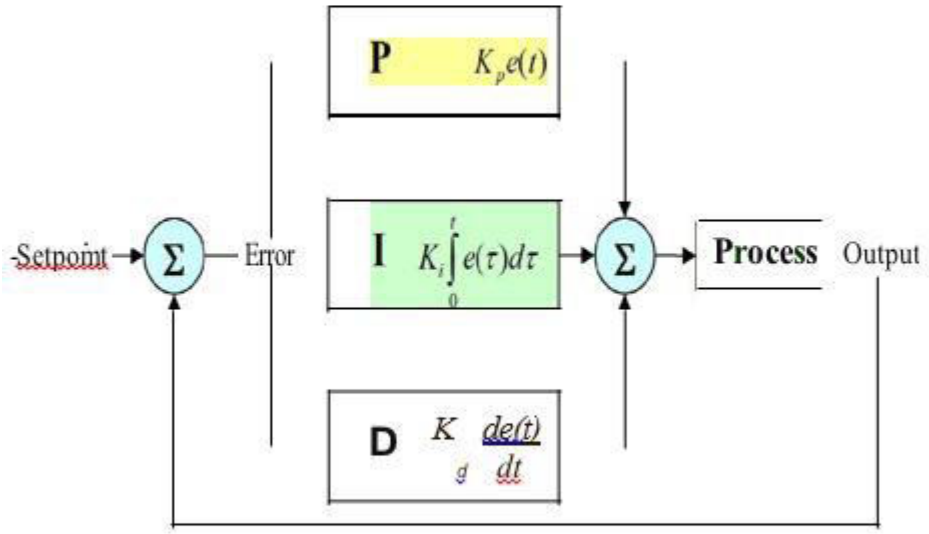


Fig. 2 Block Diagram of a System with PID Controller

For optimization of PID controller Linear Quadratic Regulator (LQR) method is used for tunning of PID controller. LQR controller estimate kp, ki and kd to minimize cost function [12]. LQR controller adjust weight matrices to get desired performance parameters. The weight matrices can be determined using trial and error method, algebraic solution method and genetic algorithm etc. That means LQR tunning method tune PID controller to minimize ripple in output and to improve output voltage regulation with minimum cost function. The LQR method also suppress the disturbance occurring in the system with better performance parameters.
We can also use Linear Quadratic Gaussian (LQG) method to tune PID controller. LQG con- troller is combination of LQR controller together with linear quadratic Estimator (LQE) for good voltage regulation in output, for the rejection of small disturbances and for the elimination of noise. In this method output measurements are assumed to be disturbed by Gaussian noise.

III. RESULT AND DISCUSSION

The tuning of PID controller was proposed in the previous sections. The conventional approach of designing a PID controller (Zeigler-Nichols) has been implemented but controller was not able to provide better transient performance and not able to compensate the change in input voltage and load. The LQR controller provided better transient performance and able to compensate the change in input voltage and load. The LQR weight matrices were obtained by trial error method, algebraic approach and genetic algorithm. To provide better performance with load disturbance LQG controller is proposed. The LQG uses LQR controller with kalman filter. Table 1 shows comparison of transient parameters obtain by different PID tuning methods.

| e-ISSN: 2278 – 8875, p-ISSN: 2320 – 3765| www.ijareeie.com | Impact Factor: 8.317|| A Monthly Peer Reviewed & Referred Journal |

||Volume 13, Issue 3, March 2024||

|DOI:10.15662/IJAREEIE.2024.1303020 |

TABLE 1: COMPARISON OF TRANSIENT PERFORMANCE OBTAINED EMPLOYING DIFFERENT METHODS

S.No.	Controller	Rise Time (Micro Sec)	Settling Time (Micro Sec)	Peak Overshoot (%)	Steady State Error (V)
1	Z-N	160.969	0.018	26.52	0.02
2	LQR-TE	3.747	0.0025	26	0
3	LQR-AA	3.225	0.00030	22.72	0.08
4	LQR-GA	3.869	0.00034	26	0.09
5	LQG-TE	3.274	0.003	26	0
6	LQG-AA	26.39	0.024	25	-0.05
7	LQG-GA	3.281	0.00028	8	0

Figure 3 shows the comparison of rise time for different PID tuning method. It is clear that LQR-AA provides minimum rise time.

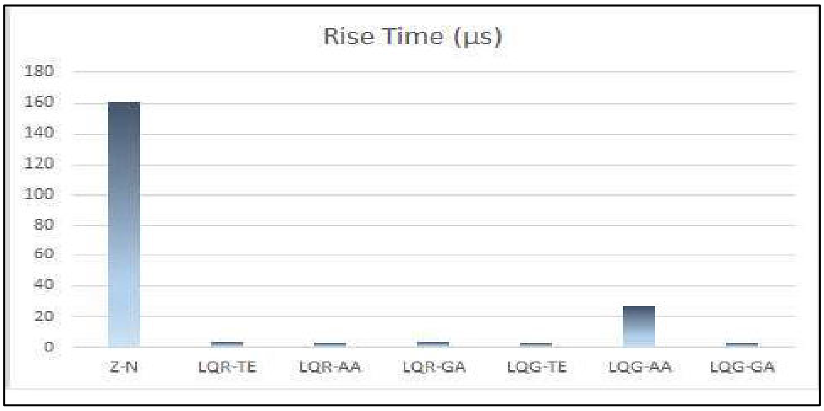


Fig. 3. Comparison of rise time obtain by different PID tuning methods

Figure 4 shows the comparison of settling time for different PID tuning method. It is clear that LQG-GA provides minimum settling time.

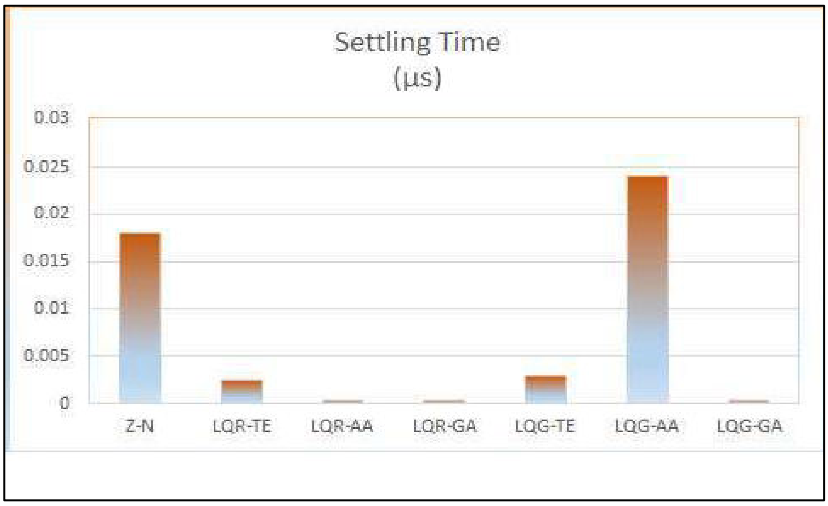


Fig. 4. Comparison of settling time obtain by different PID tuning methods

| e-ISSN: 2278 – 8875, p-ISSN: 2320 – 3765| www.ijareeie.com | Impact Factor: 8.317|| A Monthly Peer Reviewed & Referred Journal |

||Volume 13, Issue 3, March 2024||

|DOI:10.15662/IJAREEIE.2024.1303020 |

Figure 5 shows the comparison of peak overshoot for different PID tuning method. It is clear that LQG-GA provides minimum rise time.

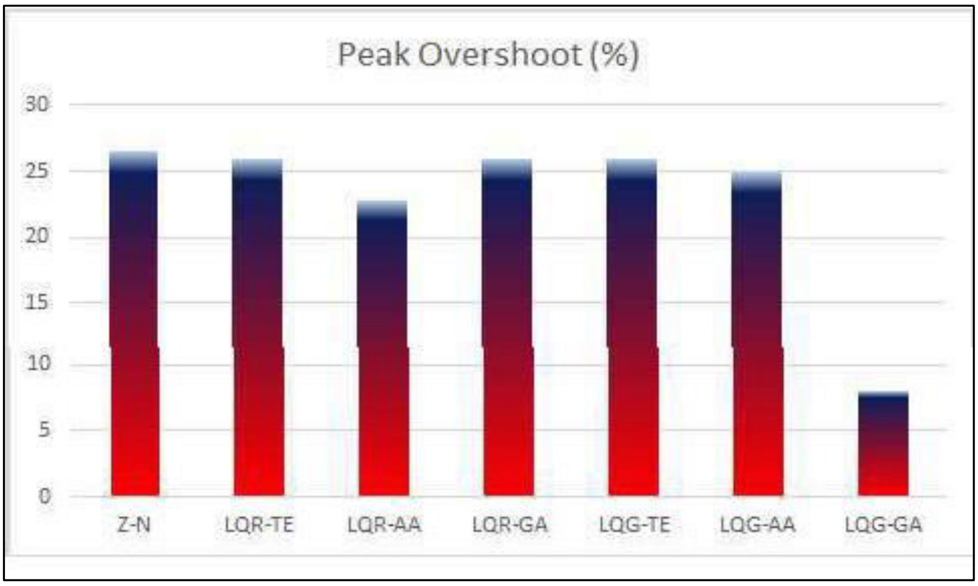


Fig. 5 Comparison of peak overshoot obtain by different PID tuning methods

Figure 6 shows the comparison of steady state error for different PID tuning method. It is clear that LQR-TE, LQG-TE and LQR-GA provides zero steady state error.

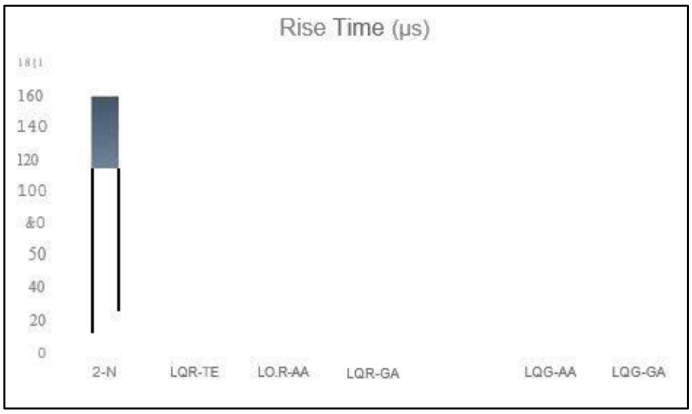


Fig. 6 Comparison of steady state error obtain by different PID tuning methods

If we compare result obtain by different methods it is found that LQG-GA provides best transient performance as compare to other methods.

IV.CONCLUSION

In this research article, Zeigler-Nichols, LQR and LQG methods of tuning PID controller was introduced. The LQR and LQG methods provides optimal design of PID controller. These tuning methods have been successful to provide improved transient parameter like rise time, settling time, peak overshoot and steady state error. The designed PID controller is capable of compensating the effect of change in input voltage and load disturbances. The state space modelling is also presented in this article The DC-DC buck converter is a non-linear system. The LQR and LQG methods are not applicable to non-linear system so linearized model of DC-DC buck converter is presented. The weight matrices Q and R were selected such that the cost function J becomes minimum. To select Q and R trial and error method, algebraic approach and genetic algorithm is used. LQG controller is designed by just adding a kalman filter

| e-ISSN: 2278 – 8875, p-ISSN: 2320 – 3765| www.ijareeie.com | Impact Factor: 8.317|| A Monthly Peer Reviewed & Referred Journal |

||Volume 13, Issue 3, March 2024||

|DOI:10.15662/IJAREEIE.2024.1303020 |

before LQR controller and system is provided white Gaussian noise. The result were satisfactory as the designed PID controller improves the transient performance and compensate any change in input voltage and load.

REFERENCES

[1] N. Mohan, T. M. Undeland, and W. P. Robbins, Power Electronics. Converters, Applications and Design, 3rd ed. John Wiley and Sons, Inc, 2003.

[2] S. Srivastava, Y. Kumar, A. Misra, S. K. Thakur, and V. S. Pandit, "Optimum design of buck converter controller using LQR approach," 2013 15th International Conference on Advanced Computing Technologies, JCACT 2013, 2013.

[3] S. A. Lindiya, K. Vijayarekha, and S. Palani, "Deterministic LQR controller for DC-DC Buck converter," 2016 - Biennial International Conference on Power and Energy Systems: Towards Sustainable Energy, PESTSE 2016, 2016.

[4] R. H. Tan and L. Y. Hoo, "DC-DC converter modeling and simulation using state space approach," 2015 IEEE Conference on Energy Conversion, CENCON 2015, no. 2, pp. 42-47, 2015.

[5] G. Q. Tan, Y. H. Chen, and L. Gu, "LQR Based Optimal PIO Control for Buck Converter," Applied Mechanics and Materials, vol. 687-691, pp. 3221-3226, 2014.

[6] L. Camacho-Solorio and A. Sarinana-Toledo, "I-LQG control of DC-DC boost converters," 2014 11th International Conference on Electrical Engineering, Computing Science and Automatic Control, CCE 2014, 2014.

[7] C. Kumar, S. Lal, N. Patra, K. Halder, and M. Reza, "Optimal controller design for inverted pendulum system based on LQR method," Proceedings of2Ul2 IEEE International Conference on Advanced Communication Control and Computing Technologies, ICACCCT 2012, no. 978, pp. 259-263, 2012.

[8] H. Li and X. Ye, "Sliding-mode PIO control of DC-DC converter," Proceedings of the 2010 5th IEEE Conference on Industrial Electronics and Applications, IC/EA 2010, pp. 730-734, 2010.

[9] Yun Li, Kiam Heong Ang, and G. C. Y. Chong, "PID control system analysis and design," IEEE Control Systems Magazine, vol. 26, no. 1, pp. 32-41, Feb 2006.

[10] Jamaludin, M. K., Manish Parihar, and Raghu Nath Singh Chouhan. "HVDC Test-Bed Designing Using Matlab/Simulink." (2018).

[11] M. B. Poodeh, S. Eshtehardiha, A. Kiyoumarsi, and M. Ataei, "Optimizing LQR and pole placement to control buck converter by genetic algorithm," ICCAS 2007 - International Conference on Control, Automation and Systems, pp. 2195-2200, 2007.

[12] A. Giovanni Beccuti, G. Papafotiou, and M. Morari, "Optimal control of the boost de-de converter," Proceedings of the 44th IEEE Conference on Decision and Control, and the European Control Conference, CDC-ECC '05, vol. 2005, pp. 4457-4462, 2005.

[13] K. Al-Hosani, A. Malinin, and V. I. Utkin, "Sliding mode PIO control of buck converters," pp. 2740-2744, 2018.

[14] N. S. Rathore, D. P. S. Chauhan, and V. P. Singh, "Tuning of PID controller for position control of de servo motor using luus-jaakola optimization," in 2015 International Conference on Computer, Communication and Control (JC4), Sep. 2015, pp. 1-5.

[15] R. Argelaguet, M. Pons, J. A. Maitin, and J. Quevedo, "A new tuning of PID controllers based on LQR optimization," in 1997 European Control Conference (ECC), July 1997, pp. 1855-1859.

[16] A. Jalilvand, H. Vahedi, and A. Bayat, "Tuning of the PID controller for a buck converter using bacterial foraging algorithm," 06 2010.

[17] Parihar, Manish, and M. K. Bhaskar. "Review of power system blackout." International Journal of Research and Innovation in Applied Science 3.6 (2018): 8-12.

[18] C. 0. Moreira, F. A. Silva, S. F. Pinto, and M. B. Santos, "Digital lqr control with kalman estimator for de-de buck converter," in 2011 IEEE EUROCON - International Conference on Computer as a Tool, April 2011, pp. 1-4.

[19] A. Mohammadbagheri, N. Zaeri, and M. Yaghoobi, "Comparison Performance Between PID and LQR Controllers for 4- leg Voltage-Source Inverters," vol. 7, pp. 230-234, 2011.

[20] K. Sirisantisamrid, N. Wongvanich, S. Gulpanich, and N. Tammarugwattana, "LQR / PID Controller Design of PLC-based Inverted Pendulum," vol. I, pp. 14-19, 2018.

[21] S. Das, I. Pan, K. Halder, S. Das, and A. Gupta, "LQR based improved discrete PID controller design via optimum selection of weighting matrices using fractional order integral performance index," Applied Mathematical Modelling, vol. 37, no. 6, pp. 4253-4268, 2013.

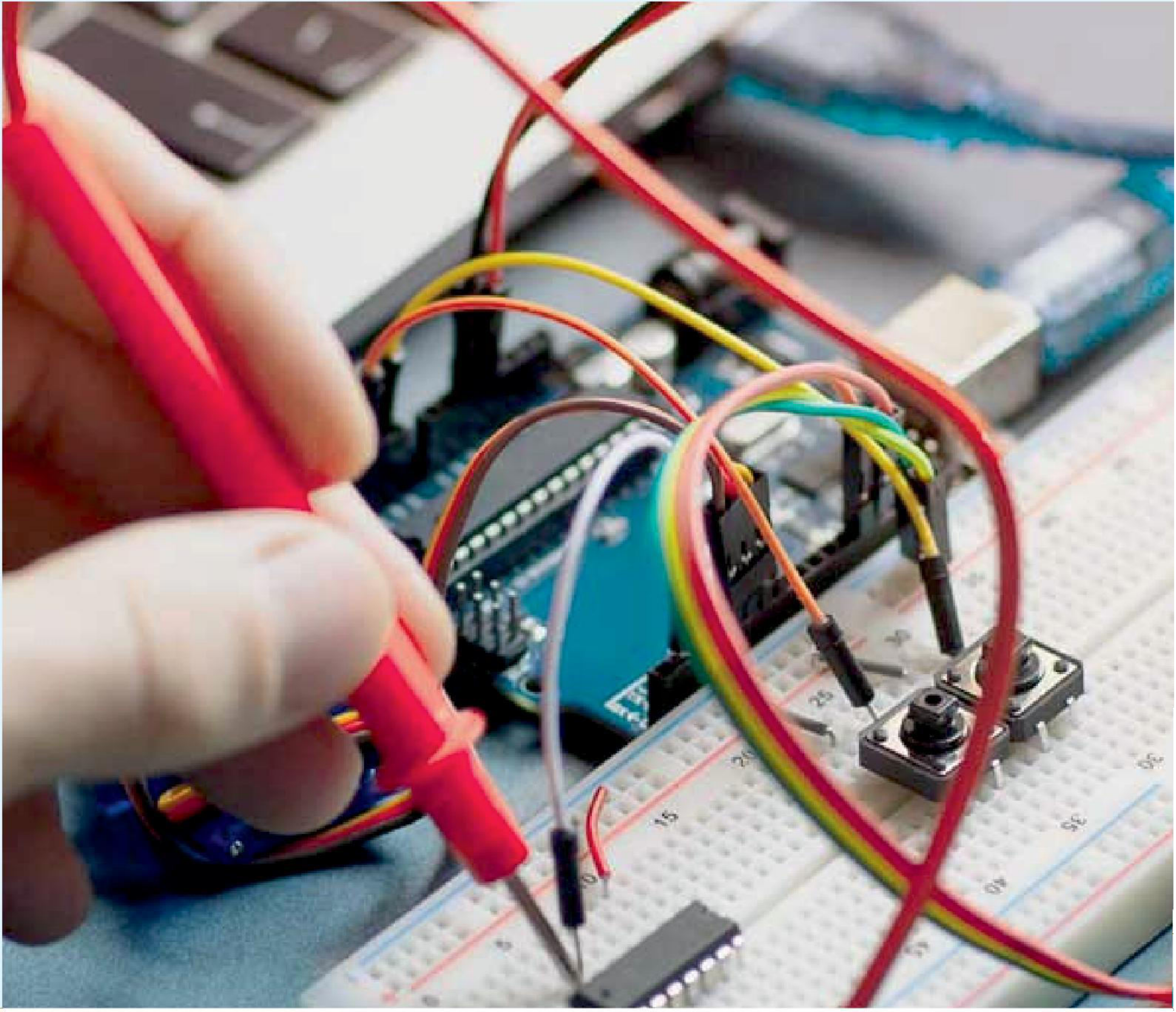
[22] H. Wu, W. Su, and Z. Liu, "PID controllers: Design and tuning methods," in 2014 9th IEEE Conference on Industrial Electronics and Applications, June 2014, pp. 808-813.

| e-ISSN: 2278 – 8875, p-ISSN: 2320 – 3765| www.ijareeie.com | Impact Factor: 8.317|| A Monthly Peer Reviewed & Referred Journal |

||Volume 13, Issue 3, March 2024||

|DOI:10.15662/IJAREEIE.2024.1303020 |

[23] P. V. G. K. Rao, M. V. Subramanyam, and K. Satyaprasad, "Study on PID controller design and performance based on tuning techniques," in 2014 International Conference on Control, Instrumentation, Communication and Computational Technologies (/CCICCT), July 2014, pp. 1411-1417.
[24] M. H. Moradi, "New techniques for PID controller design," in Proceedings of 2003 IEEE Conference on Control Applications, 2003. CCA 2003. vol. 2, June 2003, pp. 903-908 vol.2.
[25] A. O'Dwyer, "PI and PID controller tuning rules: an overview and personal perspective," in 2006 JET Irish Signals and Systems Conference, June 2006, pp. 161-166.
[26] M. Shamsuzzoha, M. Lee, and H. Seki, "Closed-loop PI/PID controller tuning for stable and unstable processes," in 2012 American Control Conference (ACC), June 2012, pp. 2368-2373.
[27] E. V. Kumar, J. Jerome, and K. Srikanth, "Algebraic approach for selecting the weighting matrices of linear quadratic regulator," in 2014 International Conference on Green Computing Communication and Electrical Engineering (ICGCCEE), March 2014, pp. 1-6.



International Journal of Advanced Research

in Electrical, Electronics and Instrumentation Engineering

9940 572 462 6381 907 438 ijareeie@gmail.com

www.ijareeie.com