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Optimized Speed Control Strategies for BLDC Motors in Solar-Powered Grass Cutting Applications Through Field-Oriented Control

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Abstract: Field-Oriented Control (FOC) of the Brushless DC (BLDC) motor is the main focus, with the goal of achieving accurate speed control and energy economy. The grass cutter is made more sustainable by the addition of a solar power source, which is in line with the growing need for environmentally friendly agricultural solutions. The first section of the study outlines the theoretical underpinnings of FOC and how it is used in motor control. The authors then go into detail on the BLDC motor control system's design and implementation, highlighting its use of solar energy. Experiments are conducted to assess the effectiveness of the suggested system and show that it can maintain the ideal speed even in the face of changing grass cutting conditions. The findings show that FOC plays a major role in improving speed control accuracy and stability, which in turn ensures the grass cutter's performance in various conditions. By providing a greener substitute for traditional grass-cutting techniques, this research has potential applications in agriculture. Combining FOC with solar power is a practical way to meet modern sustainability objectives and shows how technology innovation can be used to solve problems in the agriculture industry.

Keywords: Electrical Drive, BLDC Motor, SMC, PID, FOC, Solar Grass Cutter.

1. Introduction

A brushless DC (BLDC) motor controller is an electrical device that regulates the operation of BLDC motors. As the name suggests, a brushless DC motor uses no brushes to deliver power to the rotating motor shaft. Rather, a collection of immobile coils referred to as stator windings and permanent magnets on the rotor produce motion[1-4]. BLDC motors have several applications in robotics, electric cars, industrial automation, and consumer electronics due to their high efficiency, low noise, and long lifespan. To guarantee effective and seamless motor running, a BLDC motor controller carries out a number of tasks. In order to power the stator windings, it first converts a power supply's DC voltage to a three-phase AC voltage[5-9]. After that, the controller adjusts the AC voltage to produce a revolving magnetic field that interacts with the rotor's permanent magnets to provide torque and rotational motion. Second, using a sensor or a sensorless method, the controller tracks the rotor's position to decide when to power each stator winding. Sensored controllers locate the rotor using a variety of position-sensing tools, including Hall effect sensors. Conversely, sensorless controllers use mathematical methods to calculate the rotor position based on the motor's generated back-EMF voltage[10–14]. Third, in order to control the current passing through each stator winding, avoid overheating and damage, and ensure that the motor operates within its rated parameters, the controller employs pulse width modulation, or PWM, to alter the duty cycle of the AC voltage applied to the stator windings.

In addition, feedback signals from the controller can be received by the system control unit to monitor and control a number of parameters, such as motor speed and temperature[15-19]. In this paper a optimized speed control strategies for BLDC motor is developed in solar grass cutter using FOC. In this paper, section I and II covers the introduction and BLDC Motor controllers. Section III and IV describe how to build BLDC motor controllers and application area of brushless dc motors. Section V and VI covers the BLDC motors for solar grass cutter using FOC and conclusions.

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2. Related Work

BLDC Motor Controllers

There are various BLDC motor controller types available, each having pros and cons. Let's look at the most typical ones:

A. Sensored BLDC Motor Controllers

For BLDC motors, sensored motor controllers are the most used kind. They rely on information gathered from sensors that determine the rotor's position. Hall effect sensors are usually used to monitor the magnetic field of the rotor.

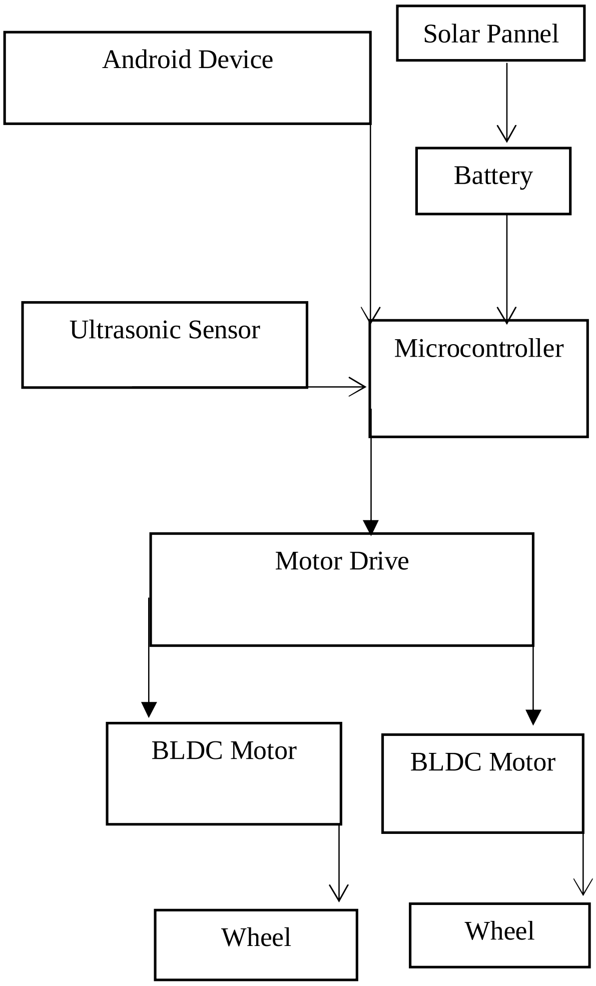

Figure 1. Block Diagram of BLDC Motor based Solar Grass Cutter.

The precise timing of the electrical switches that drive the motor is then determined by the controller using the data gathered from the sensors[20–25]. With sensored BLDC motor controllers, you can accurately control the motor's torque and speed since they provide accurate position information. They also provide more seamless functioning at all speeds and improved performance at low speeds. They need more wiring and parts, though, and are more costly than sensorless controllers. BLDC motor controllers that are sensorless seek to function without receiving input from sensors. Instead, to determine the rotor's position, they employ a method known as back-EMF sensing. When the rotor passes through the magnetic field of the stator, a voltage known as the back-EMF is produced. Since the voltage and motor speed are correlated, the voltage can be used to calculate the rotor's location. These controllers utilize fewer components and are less expensive than sensored controllers. Not only are they easier to install, but they also require less wiring. They might not, however, be able to manage speed and torque as precisely as sensored controllers. In addition, they may vibrate and make more noise when operating at low speeds.

B. Field-Oriented Control (FOC) BLDC Motor Controllers

The torque and speed of the motor are controlled using sensor-based field-oriented control (FOC) BLDC motor controllers using a mathematical model. First, the FOC controllers use the information collected from the sensors to determine the rotor's condition. They then determine the appropriate voltage and current to feed into the motor using a mathematical model. FOC controllers are used in high-performance applications like electric cars because they outperform other controllers in this regard. There are some advantages when comparing FOC controllers to other types of controllers [26–27]. They offer reduced vibration and noise levels, excellent efficiency, and precise torque and speed control. Additionally, they can be designed with various performance profiles and bidirectional motor control in mind. Compared to other controllers, FOC controllers require more complex programming and modification due to their higher level of sophistication.

C. Sinusoidal BLDC Motor Controllers

Sinusoidal BLDC motor controllers are FOC controllers that control the torque and speed of the motor using sinusoidal waveforms. A sinusoidal waveform is used by sinusoidal controllers to maintain a steady voltage and current supply to the motor. Smooth and effective operation is provided by the waveform's synchronization with the rotor position. Comparing sinusoidal controllers to other controller types, there are a number of benefits. They offer reduced vibration and noise levels, outstanding efficiency, precise control over speed and torque. They are frequently utilized in high-performance applications like robotics and electric cars and also offer smoother operation than other controllers.

D. Trapezoidal BLDC Motor Controllers

Using a trapezoidal waveform, sensorless controllers known as trapezoidal BLDC motor controllers manage the

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torque and speed of the motor. Trapezoidal controllers operate smoothly and effectively by using a waveform that is coordinated with the position of the rotor. Compared to other controllers, trapezoidal controllers use fewer components and are less expensive. Not only are they easier to install, but they also require less wiring. But their speed and torque control might not be as accurate as that of sensored controllers. It is also possible to experience problems with reduced performance at low speeds.

E. Hybrid BLDC Motor Controllers

The characteristics of sensored and sensor-less controllers are combined in a hybrid BLDC motor controller. Hybrid controllers employ sensors to locate the rotor when they are functioning at lower speeds; when they are operating at greater speeds, they cease using sensors. At low speeds, it enables the controller to transmit precise position data, while at high rates, it increases efficiency. There are some advantages when comparing hybrid controllers to other controller types. They offer reduced vibration and noise levels, outstanding efficiency, precise control over speed and torque[28-29]. In addition, their low speed performance is superior to that of sensorless controllers, and their cost is lower than that of fully functional sensored controllers.

Achieving the best possible motor performance for a given application requires careful consideration of the type of BLDC motor controller to be used. Although every sort of controller has benefits and drawbacks. Making an informed choice requires having a thorough understanding of the application's unique requirements. Sensored controllers, for example, might be more appropriate for applications requiring exact position control, whilst sensorless controllers might be more appropriate for applications that need to cut costs. Although they require more complex programming and may be more appropriate for high-performance applications, FOC and sinusoidal controllers provide superior performance. In contrast to hybrid controllers, which offer a compromise between cost and accuracy, trapezoidal controllers are a more affordable option. The performance of the system as a whole can be enhanced, vibration and noise levels can be decreased, and motor efficiency can be increased by carefully assessing the needs of the application and choosing the best BLDC motor controller.

BLDC Motor Speed Controller: A Difficult To Build

While there aren't many problems when using BLDC motors, designing and constructing the speed controller for them might be a complex undertaking. When designing, there are a few important considerations that you must make. These are some of the difficulties you might run into Regulating System. Because controlling algorithms directly govern motor speed, maintain stability, and reduce noise, they are the most difficult component of the task to perform accurately. You won't be able to fully regulate the speed until the controller accurately detects the location of the motor in order to control the torque output and speed of the motor[30].

A. Power Electronics

There's also the work of designing and building the power electronics that run the motor. In order to produce high-frequency AC signals, which directly affect the motor's production, it consists of gate drivers, power switches, and other functional parts.

B. Heat Management

Since BLDC motors can generate a lot of heat, effective heat management is crucial when designing speed controllers for BLDC motors. If the temperature rises too high, other system components may be harmed, which could reduce the lifespan of the controller and motor[31-33]. Therefore, in order to keep the controller from overheating, it is imperative to include appropriate cooling and thermal management methods.

C. Noise and Interference

The accuracy of the speed control may eventually be impacted by issues with the motor's operation caused by electrical noise and interference. For the controller to drive the BLDC motor precisely and responsively, it must be built to limit the effects of electrical noise and interference. It's crucial to create the controller correctly because it's what keeps the speed consistent[34].

D. System Integration

It might be difficult to make sure that various control systems, including power supply, microcontrollers, and sensors, work seamlessly together when BLDC motor speed controllers are integrated with them. Overall, it can be a difficult and protracted process.

E. Extra Cost

Every business favors affordable solutions over those that demand large sums of money. Here, the cost of constructing a BLDC motor speed controller can increase because it calls for premium parts, meticulous design, and testing. It can be difficult to create a controller that is cost-effective as a result. In general, a strong grasp of power electronics, control system architecture, and motor control theory is needed to construct a BLDC motor speed controller. A dependable and efficient method for regulating a BLDC motor's speed can be constructed by carefully weighing these difficulties and creating a well-

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thought-out controller.

Application Area Of Brushless Dc Motors

Brushless DC (BLDC) motor controllers are used in many applications that need high levels of dependability, accuracy, and efficiency. BLDC motor controllers are necessary to enhance the device's performance in the following areas.

A. Industrial Automation

Because of its effectiveness, dependability, and precise control over motor speed and torque, BLDC motor controllers are being used in industrial automation on a growing scale[35]. BLDC provides several benefits for industrial automation, including material handling equipment, CNC machines, robotics, conveyors, pumps, and fans.

B. Electric Vehicles

Electric car Utilizing a BLDC motor controller is essential to ensuring the vehicle operates dependably and effectively. They are used in electric cars, bikes, scooters, and other vehicles. The motor's speed and torque are controlled by the controllers to ensure efficient power consumption and seamless operation. BLDC motor controllers are used in electric vehicles (EVs) for power steering, propulsion, regenerative braking, motor protection, and battery management. The controller can be used to improve the longevity, range, and performance of the vehicle. It can also be used to start regenerative braking, precisely manage torque and speed of the motor, monitor the condition of the battery, and safely protect the motor.

C. Robotics

In robotics applications, BLDC motor controllers are frequently utilized. In this scenario, the BLDC motor controller plays a crucial role since it provides accurate and precise control over the motor speed and torque.

It is required because it ensures precise motion control, smooth functioning, and low power consumption—all essential to its operation. The main purposes of the BLDC motor controller in robotics are sensor integration, motor protection, motion control, battery management, and motor control. In robotics, controllers are generally considered indispensable since they ensure that the robot operates reliably and efficiently.

D. HVAC Systems

BLDC motor controllers are crucial components of HVAC (Heating, Ventilation, and Air Conditioning) systems because they regulate the speed of the motor that drives the air handler or fan. It's also critical to lower energy use and boost system performance. The BLDC motor controller is used in the vital HVAC system components of motor protection, energy savings, noise reduction, and variable speed control.

BLDC Motor In Solar Grass Cutter Using FOC

A. BLDC Motor based Solar Grass Cutter Specifications

Ultrasonic Sensors

Sonar and radar, which identify and detect features of a target by examining the echoes of radio waves or sound, respectively, operate similarly to ultrasonic sensors. When they possess both transmit and receive capabilities, they are commonly called transceivers. Ultrasonic sensors produce high-frequency sound waves and monitor the waves that are reflected back. Sensors determine an object's distance by measuring the delay between a signal being sent and an echo being received. Tank capacity, wind direction and speed, air or water speed, and antennas can all be measured using this technique. To measure direction and speed, a device makes use of many detectors. The speed is determined by measuring the separations between the particles in the air or water[36]. The sensor determines how far below the surface the liquid is in order to calculate the volume of liquid in a tank. Additional applications include sonar, humidifiers, medical ultrasonography, non-destructive testing, and burglar alarms. Transducers, which convert electrical energy into ultrasonic sound waves (beyond 18,000 hertz), are a component of most systems. After locating the echo and converting its waves back into electrical energy, sound can be quantified and visualized. The boundaries of technology are seen in surface forms and material consistency/density. Foam on the surface of a liquid in a tank, for example, could mislead a measurement.

b. Hardware AND Software Specifications for Solar Grass Cutter:

Hardware Specifications

- 8051 Family Microcontroller
- Solar Panel
- Motor Driver IC
- DC Motors
- Ultrasonic Sensor
- Batteries
- Robotic Body

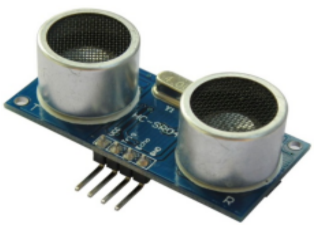

Figure 2: Ultrasonic Sensor Used in BLDC Motor for Solar Grass Cutter.

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C. BLDC Motor Specifications

This motor, which runs between 5000 and 12000 rpm, is better than a 24 volt DC motor, whose rpm exceeds 20000 rpm. The motor weighs 150.00g and requires 2.3 amps of current. This motor is needed for this project because of its great torque and power.

Power developed by the motor:

P = V*I = 24*2.3

P = 55.2 watts

Torque developed by the Motor:

$P = 2\pi NT/60$

$55.2 = 2*\pi*10000*T/60$

So, T = 18.97 N-M.

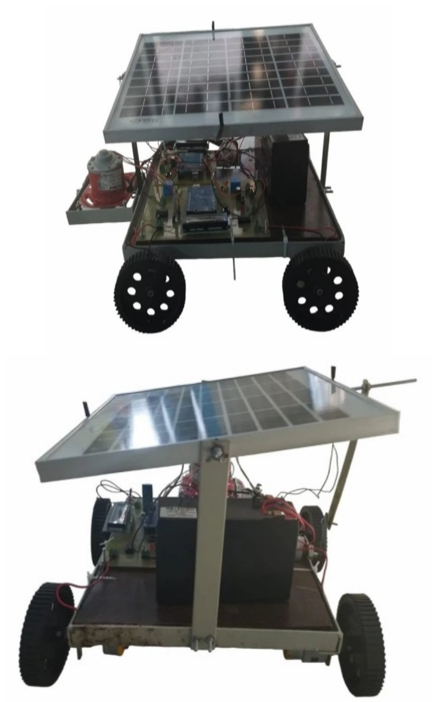

Figure 3: Model of BLDC Motor based Solar Grass Cutter Using FOC.

d. Motor Operating the Wheels

High torque, low speed 12 volt DC motor is needed for this application. At 300 rpm, this motor runs a current of 0.3 amp is needed. A total of 1.2 amps of electricity will be consumed by the four motors, each of which is used for a different wheel.

Power developed by 2 motors:

P = V*I = 12*1.2

P = 14.4 watts

Torque developed by 2 motors:

$P = 2\pi NT/60$

$14.4 = 2*\pi*300*T/60$

So, T = 0.45 N-M.

6. CONCLUSION AND FUTURE SCOPE

The present study concludes that a control circuit regulates the BLDC motor to maintain a consistent speed. Regardless of the applied load, the BLDC motor keeps its speed constant. The overall energy obtained from the sun much exceeds human energy consumption since it uses non-renewable resources. It was intended to be a low-effort, environmentally friendly substitute for the widely used, potentially harmful gas-powered lawnmower that also uses less energy. It is also easily handled by non-skilled individuals. It can be simply handled and controlled in a shorter amount of time by employing straightforward switches or by predetermining the code. Because it can identify obstacles and adjust course or stop operating in accordance with instructions, it is incredibly accurate and efficient. Thus, it is important to safeguard equipment against harm and lower human risk. Reducing weight, improving blade efficiency, and cutting costs will all contribute to this project's enhanced outcome. Booster and speed control circuits can be implemented for more dependable and steady operation. The machine can be utilized for room or garden lighting at night if a high-wattage panel is employed therefore we are able to retain more energy and at night, however, you set yourself apart. Therefore, this can be accomplished using the battery's power. We decided on renewable energy because of the demand for power. There are thus no operating expenses. The DC motor runs very efficiently on little power. The output voltage of the DC-DC converter is kept high and steady. Animals and the environment are unaffected by the sensors. The user will find it really helpful.

References

[1]. Prof. Saurabh Wanjari, Swapnil Nikam, Sunil Gaudase, Akshay Kuchekar, Sandip Radkar; “Design and Manufacturing of Fully Automated Solar Grass Cutter”, IJRASET, ISSN: 2321-9653, Volume 6 Issue 6, June 2018.

[2]. Vivek P Revi, Ajay Antony, Albin K Varghese, Rahul P R, Jaison K A; “Design and analysis of cutting blade for rotary lawn movers”; IJERT, ISSN: 2278-0181, Vol. 5 Issue 04, April-2016.

[3]. O’Dogherty, M.J., “A Review of Research on Forage Chopping”, Journal of Agricultural Engineering Research, 1982, 27(4), 267-289.

[4]. Basil Okafor, “Simple Design of Self Powered Lawn Mower”, Internatinal Journal of Engineering and Technology, OCT 2013,(Volume 3 No.10).

[5]. Vijay Raghunathan, A. Kansal, J. Hsu, J. Friedman, Mani Srivastava; “Design considerations for solar energy harvesting wireless embedded system”; IPSN 2005. Fourth International Symposium on Information Processing in Sensor Networks, 2005.

[6]. Indragandhi,V.,Selvamathi, R. and Subramaniyaswamy, V., 2022. Electric Motor Drives and their Applications with Simulation Practices. Academic Press.

[7]. Shankar, V.K.A., Umashankar, S., Paramasivam, S. and Hanigovszki, N., 2016. A comprehensive review on energy efficiency enhancement initiatives in centrifugal pumping system. Applied Energy, 181, pp.495-513.

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ISSN: 2582 - 4201(Online) , http://www.ijrdes.com/ , IJRDES, Vol. 6, Issue 4 , 2024 , https://doi.org/10.63328/IJRDES-V6RI4P4

[8]. Fu, L., 2020. Modeling and Design of an Electrical Mower Deck Control System. Purdue University.
[9]. Shankar, V.K.A., Umashankar, S., Paramasivam, S. and Hanigovszki, N., 2016. A comprehensive review on energy efficiency enhancement initiatives in centrifugal pumping system. Applied Energy, 181, pp.495-513.
[10]. Injection, C.S., 2009. 2008 Combined Subject Index IEEE Industry Applications Society Publications. IEEE Transactions on Industry Applications, 45(1), p.403.
[11]. Rodrigues, C.D.P., 2018. Design of a high-speed transmission for an electric vehicle.
[12]. Bar-Cohen, Y., Lee, H.J., Badescu, M., Sherrit, S., Bao, X. and Shalev, Y., 2021. 9 Specialized Drilling. Advances in Terrestrial and Extraterrestrial Drilling:: Ground, Ice, and Underwater, p.271.
[13]. Yedamale, P., 2003. Brushless DC (BLDC) motor fundamentals. Microchip Technology Inc, 20(1), pp.3-15.
[14]. Baldursson, S., 2005. Bldc motor modelling and control-a matlab/simulink implementation.
[15]. Sakunthala, S., Kiranmayi, R. and Mandadi, P.N., 2017, August. A study on industrial motor drives: Comparison and applications of PMSM and BLDC motor drives. In 2017 International Conference on Energy, Communication, Data Analytics and Soft Computing (ICECDS) (pp. 537-540). IEEE.
[16]. Patel, V.K.S. and Pandey, A.K., 2013. Modeling and performance analysis of PID controlled BLDC motor and different schemes of PWM controlled BLDC motor. International Journal of Scientific and Research Publications, 3(4), pp.1-14.
[17]. Amrutesh, P., Sagar, B. and Venu, B., 2014. Solar grass cutter with linear blades by using scotch yoke mechanism. International Journal of Engineering Research and Applications, 3(9), pp.10-21.
[18]. Ismail, F.B., Al-Muhsen, N.F., Fazreen, A.F. and Zukipli, A., 2019. Design and development of smart solar grass cutter. International Journal of Engineering and Advanced Technology, 9(2), pp.4137-4141.
[19]. Hariya, A., Kadachha, A., Dethaliya, D. and Tita, Y.D., 2017. Fully automated solar grass cutter. Int. J. Sci. Technol. Eng, 3.
[20]. Avinash Sahu and L. B. Prasad, "Load Frequency Control of Interconnected Five-Area Power System With PID Controller", Proc. of 2017 IEEE International Confrence on Information Communication Instrumentation and Control (ICICIC-2017), Aug. 17-19, 2017, Indore, India.
[21]. L. B. Prasad, B. Tyagi, and HO Gupta, "Fuzzy-PI based Automatic Generation Control of Two Area Interconnected Nonlinear Power System", International Journal of System Control and Information Processing, Vol. 2, no. 2, pp. 127-141, 2017.
[22]. S. Bennett, A History of Control Engineering 1930-1955, IEE Control Engineering Series 47, 1993.
[23]. S. Bennett, "Nicholas Minorsky and the Automatic Steering of Ships," IEEE Control Systems Magazine, vol. 4, no .4, pp. 10–15, 1984.
[24]. M. Araki, PID Control in Control systems, Robotics and Automation, vol II, edited by Heinz Unbehauen, Encyclopaedia of Life Support Systems (EOLSS), Developed under the Auspices of the UNESCO, Eolss Publishers, Oxford ,UK.
[25]. R. C. Eberhart & Y. Shi, Comparing Inertia Weights and Constriction Factors In PSO, IEEE 2000.
[26]. Angelina Jane Reyes Medina, Gregorio Toscano Pulido, José Gabriel Ramirez Torres, A comparative study of neighborhood topologies for Particle Swarm Optimizers, IJCCI 2009.
[27]. K. J. Astrom and T. Hagglund, PID controllers, Theory, design and tuning, 2nd edition, Instrument Society of America, 1995.
[28]. T. Hagglund and K. J Astrom, "Industrial Adaptive Controllers Based on Frequency Response Techniques," Automatica, vol. 27, no. 4, pp. 599-609, 1991.
[29]. J. G. Ziegler and N. B Nichols, "Optimum Settings for Automatic Controller," Transaction of ASME, vol. 64, pp. 759-768, 1942.
[30]. J. C. Cool, F. J. Schijff, T. J. Viersma, and Regeltechniek, Control Engineering, Delta Press, Amerongen, 1991.
[31]. C. S. Soh, C. Bi and K. C. Chua, "Direct PID Tuning For Spindle Motor Systems," Asia-Pacific Magnetic Recording Conference, Singapore, pp. 1-2, Nov-Dec.2006.
[32]. Juba ABERBOUR," Effect of cost function and PSO topology selection on the optimum design of PID parameters for the AGC System" 978-1-4673-6673-1/15/$31.00 ©2015 IEEE.
[33]. Amir Afroomand, Saeed Tavakoli, Mahdi Tavakoli, "An Efficient Metaheuristic Optimization Approach to the Problem of PID Tuning for Automatic Voltage Regulator Systems" 2016 IEEE International Conference on Advanced Intelligent Mechatronics (AIM).
[34]. Hossein Shayeghi," Anarchic Society Optimization Based PID Control of an Automatic Voltage Regulator (AGC) System" Electrical and Electronic Engineering 2012, 2(4): 199-207.
[35]. G. H. Cohen, and G. A. Coon,"Theoretical considerations of retarded control," Transactions of ASME, vol. 75, pp. 827-834, 1953.
[36]. Dong Hwa Kim, Tuning of PID Controller Using Gain/Phase Margin and Immune Algorithm, IEEE Mid-Summer Workshop on Soft Computing in Industrial Applications, Helsinki University of Technology, Espoo, Finland, pp. 6-74, 2005.

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