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AN EFFICIENT MAXIMUM POWER POINT TRACKING CONTROLLER FOR SOLAR POWERED CARDIAC PACEMAKER

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Abstract
In modern healthcare technology, the cardiac pacemaker is utilized to maintain heart function with continuous monitoring and precision. Patients with serious heart conditions need an implantable cardiac pacemaker to survive.Hence, in this paper, a solar-powered cardiac pacemaker is designed toavoid the requirement of a battery and manage heart function. The solar power cardiac pacemaker consisting of Photo Voltaic (PV) system which is utilized to generate power from the sunlight energy. The PV may be affected because of environmental conditions. An effective Maximum Power Point Tracking (MPPT) controller is implemented in the implanted cardiac pacemaker to handle environmental circumstances. For maximum power point tracking (MPPT), the controller typically employs a Fractional Order Proportional Integral Derivative (FOPID) algorithm. The FOPID controller is given a boost in efficiency thanks to the use of the Chimp Optimization Algorithm (COA). The output voltage, output current, power, and convergence analysis are used to assess the effectiveness of the MATLAB/Simulink implementation of the suggested technique. Particle Swarm Optimization (PSO) and Grey Wolf Optimization (GWO) are contrasted with the proposed methodology.
Keywords: battery-free Cardiac Pacemaker, Chimp Optimization Algorithm, DC-DC converter, MPPT Controller, photovoltaic cell, and battery.

1. Introduction

Currently, implantablecardiac pacemakers are powered by low-limit batteries with limited power. Pacemaker replacement is natural as battery life ends, representing 25% of all implant techniques, and has restrictions [1]. This is a careful re-recommendation that will cost the patient, and there is a small risk of persistent complications (e.g. diseases, bleeding). Similarly, pacemaker size is indicated by battery size [2,3]. To overcome these obstacles, a strategy to store location energy within the human body would be attractive because it would allow the development of pacemakers without essential batteries and carefully reduce the amount of remediation. Various developments have been suggested for 'on location' intra-mortal energy collection [4]. However, these algorithms are experiencing the worst effects of significant deficiencies that were effectively experienced four to fifty years ago, [8] which has prevented the use of cardiac pacemakers as a powerhouse. In particular, the amount of energy stored may be too low, 2–5 implants may be too aggressive, 4,6,7 may prevent the effective use of unfamiliar physical responses, and require 2,4,6 or unreliable external fuel sources [5].

The purpose of this experiment is to explore whether sunlight can go as a hotspot as a select power source for pacemaker makers [6]. Photovoltaics, such as solar cells, can turn sunlight into electricity since it is a consistent and widely available fuel source. Solar cells are widely installed on buildings or utilised in power plants to convert solar radiation into electricity. Nevertheless, solar-based cells cannot be implanted in the body to regulate devices that are compatible with them but do not need power cords or induction transmissions due to safety and cosmetic concerns [7]. However, cells based on sunlight may exhibit energy whenever embedded in the body, because moderate amounts of light can enter human skin. In particular, close infrared light shows better skin penetration. B.V. Structure is a constant force property used to provide capacity to the heart pacemaker. B.V. The structure has various advantages, for example, the use of environmentally friendly energy [8, 9]. B.V. In the power age with boards, unprotected ozone has no harmful material exposures in these ways PV is harmless to the ecosystem. Solar-based energy is generally supplied energy, so it is free and abundant [10]. Environmental factors are crucial in the PV framework. It is planned for DC-DC converters to be included in the PV structure so that environmental factors can be controlled. Since then, the DC-DC converter's stable operation has necessitated the MPPT regulator's presence [11]. One such challenge is locating the largest key point (MPP), which moves due to the non-direct properties of current-voltage (IV) and force-voltage (PV) [i.e. temperature and radiation]. As a result, the MPP was determined after extensive written MPPT calculations [12]. Complexity, expense, necessary sensor type, implementation, and dependability are just some of the perspectives used in these calculations. The Perth and Observation (P&O) calculations are the most popular and widely used among these MPPT calculations [13] due to their ease of use and low level of complexity. Unfortunately, the standard P&O calculation often gets hung up on the MPP when used as a quick climate type. Multiple calculated enhancements to the standard P&O method have been developed to address this issue. PV. Neglects to carry out the best function in the structure [14], despite its accessibility to a wide variety of MPPT controllers, including PV. Particle swarm optimisation (PSO) [15], gravity search algorithm (GSA), and firefly algorithm (FA) are all AI methods developed recently in the FPV to implement the MPPT controller.

The paper's structure and primary contribution

- The solar-powered cardiac pacemaker was created to do away with the need for batteries.
- The solar power cardiac pacemaker is consisting of a PV system utilized to generate power from the sunlight energy.
- An effective MPPT controller is built into implanted cardiac pacemakers to handle environmental circumstances. The maximum power point tracking (MPPT) controller incorporates a FOPID that is used to draw out every last bit of energy from the photovoltaic array. COA is used to enhance the functionality of the FOPID controller.
- The output voltage, output current, power, and convergence analysis are used to assess the effectiveness of the MATLAB/Simulink implementation of the suggested technique. The proposed method is evaluated against industry standard procedures like PSO and GWO.

2. Literature Review

A PV-based cardiac pacemaker may be created in a variety of ways. This section discusses some of the approaches available.

Sara Azimi et al. [16] have created a battery-free cardiac pacemaker that draws power from the left ventricle's contractions using a biodegradable and flexible piezoelectric polymer-based nanogenerator (PNG). Poly (vinylidene fluoride) (PVDF) mixed nanofibers with zinc oxide (ZnO) and reduced graphene oxide (rGO) were used as a cross-sectional nanofiller in the PNG (RGO). An very high energy yield from hybrid nanofibers was recently achieved. Compared to the energy required to run a human cardiac pacemaker, the 0.487 J harvested by the Vivo integrated enhanced PNG with each beats is a significant improvement. Thanks to the producer of self-sustaining pacemakers' impressive display, polymer-based PNGs have entered the race to become self-regulating biomedical implants.

Chunhua Liu et al., [17] have a compulsive sandwiched wireless power transfer (WPT) framework derived to recharge the battery of miniature clinically advanced kinetics for a pacemaker. The main feature of the project is the use of fuzzy sandwich geography on both the transmitter and the collector coil, whose work is less than the WPT configuration expressed at 160 kHz repeatedly up to MHz. Also, the fitting receiver accepts the two-sided curl scheme, which can express more power within the restricted range. On average, with sandwich communication curls, the program accomplishes high reliability and adaptability of the controllable distance for a variety of miniature clinically advanced mechanics in patients. Therefore, the configuration can deliver up to 5 W of high power and up to 88% of transmission efficiency.

Adnan Mukhtar et al., [18] have presented Fractional Order PID controller(FOPID), Fractional Order PIcontroller (FOPI), TiltIntegral-Derivative controller (TID), Proportional-Integral-Derivative controller (PID)based on the heart rate control strategy of apacemaker.In this study, PID, TID, FOPI, and FOPID regulators with GA strategy aimed to control and control a patient's pulse to accomplish better yield reactions. In light of the yield reactions, the display displaying the FOPID regulator was better than the PID, TID, and FOPI controllers. Quantitative correlation of time-part details: i.e. best value, timing, static state error, ITAE respect, IAE respect with GA-FOPID demonstrate several key executions.

Munna Khan et al., [19] have promoted low-power sunlight-based powersupply for battery-operated cardiac biosensors. The primary focus of this paper is to generate power from a photovoltaic (PV) display set up under the skin to renew a depleted battery of compatible cardiac biosensors. The new approach separates the most intense energy from the embedded PV cluster from the external source approaching the infrared light (NIR) through the skin and depends entirely on the energy generated by the embedded PV exhibition for its operation. The proposed plot uses a voltage-based MPPT system that continuously controls the reserve using virtual open-circuit voltage. Execution uses the PV cluster proven in SPICE, which gives a capacity of 10-25mW for the current range of 6-14mA. The reproduction shows that the load-bearing cargo generates enough power and voltage to charge the battery of low-power cardiac biosensors such as the pacemaker.

Andreas Haeberlin et al., [20] have introduced the novel pacemaker (PM) inventions. Modern pacemakers are controlled by essential batteries. PM replacements are normal and expensive due to battery consumption and bear the risk of difficulties. Developed a strategy here to control

PMs using solar cells to stay away from the use of essential batteries. To control the BM environment, cells based on subcutaneous sunlight can be converted into electrical energy. This method will allow the battery to schedule fewer PMs; In these ways, PM alternatives can be avoided and the associated risks can be avoided. The battery can generate fewer PMs. Nevertheless, significant efforts must be made by the gadget business to effectively present a strategy that overcomes the need for essential batteries.

3. Proposed System Model

The cardiac pacemaker is utilized to manage the rhythmic action of the heart by continuous monitoring and precision in the healthcare industry.Normally, the cardiac pacemaker is designed with the help of a battery. The battery has a limited lifetime and, it is changed when a lifetime is existing in a battery. The battery replacement of a cardiac pacemaker is harmful to the patient health. Hence, in this paper, a battery-free cardiac pacemaker is designed with renewable energy resources. The PV system is selected to power the cardiac pacemaker. The PV system may be affected because of partial shading conditions. To extract the maximum power from the PV system, the MPPT controller is designed with the COA algorithm. The proposed controller is utilized to extract the maximum power which enhances the stable operation of the cardiac pacemaker. The complete proposed architecture is illustrated in Figure 1.

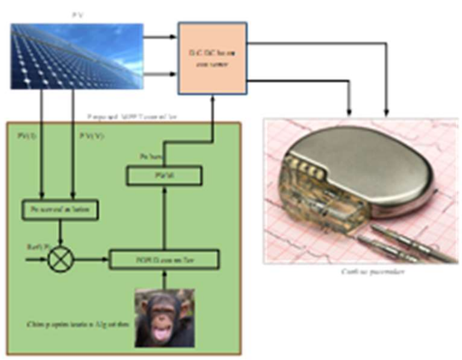

Figure 1: Complete Architecture of the proposed method

The main objective of the proposed methodology is to design a battery-free cardiac pacemaker with the help of a PV and MPPT controller.The proposed controller is utilized to manage the cardiac pacemaker monitoring. The MPPT controller is designed with a FOPID controller utilized to manage the monitoring of cardiac pacemakers. The FOPID controller is optimally tuned by COA. A detailed description of the PV system, FOPID controller, and COA is presented in the section.

3.1. Modelling of PV system

In the section, a normal mathematical formulation of the PV cell is given. The PV cells can be measured as electrical devices which generate electrical power from sunlight energy based on irradiance level. The sunlight energy is collected with the presentation of a PV panel which is named a sustainable energy source. The PV panel can be designed with the consumption of a semiconductor panel which absorbs photons of sunlight energy and omits the electrons which all taken n atoms based on behavior potential difference can be produced [21]. Associated with atoms' behavior, current flow can be processed and electricity generated which is utilized in many different applications. The MPPT controller must be designed to extract the highest power from PV by avoiding problems in environmental behavior. The general model of the PV system is presented in Figure 2.

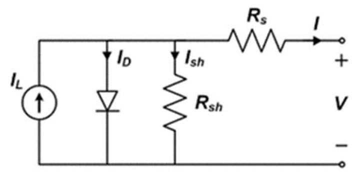

Figure 2: Equivalent circuit model of PV system

The current in addition voltage of a solar cell is formulated as the following,

$$I_c^{PV} = \frac{I_{ph}}{1 - C^{-d}}\left[exp^{\frac{V_{oc}}{a}}\left(\frac{qv + qr_v I}{NKT}\right) - 1\right] - \frac{V + R_s I}{R_{sh}} \qquad (1)$$

Where,

I^{ph} can be described as is the electric current of PV

I can be defined as a current of PV panel, $q = \left(1.6 * 10^{-19} C\right)$ can be considered as electron charge,

T can be considered as the temperature of each cell in the PV panel,

N can be defined as an ideal factor of PV

R_{sh} can be described as shunt resistance

R_s can be described as series resistance

V_{oc} can be described as open-circuit voltage

PV panels are designed based on the irradiation levels. In each solar panel, the various irradiance levels are considered to collect the database. The solar panel output power is changed because of irradiance level changes. The proper control signals generation is maintained in the constant irradiance with the DC-DC converter. The proper duty cycle (D) of the proposed converter is adjusted by the MPPT controller to keep the PV panel's specific operating points, typically at MPP. Here, a projected MPPT based controller can be designed intended for regulating the DC-DC converter duty cycle based on their inputs. In the MPPT controller, the maximum power is attained with the assistance of the PID controller. Sometimes, the environmental conditions may be affecting the generated power. For this reason, IMPPT is developed to manage the different weather conditions. In the proposed MPPT controller, the error power is computed which is corrected by providing the optimal pulses to the DC-DC boost converter. The optimal pulses are computed based on the FOPID controller. In the FOPID controller, the optimal pulses are selected with the help of the COA algorithm. A detailed description of the FOPID controller and COA is presented below section.

3.1. FOPID controller

The proposed integral controller, the FOPID controller is used to reduce the error of different parameters. Based on the differentiation and integration of non-integer order, the fractional-order controller may work based on fractional-order differential equations. The general PID controller has three different control parameters such as proportional, integral, and derivative modes. The PID controller performance may be improved with the consumption of adding two parameters and form a FOPID controller which increases two control parameters. The FOPID controller may be mathematically presented as follows. The main difference betweenthe PID controller and FOPID controller is, FOPID [22] controller has extra two control parameters and the derivation order are not an integer value. This behavior provides additional degrees of freedom for tuning the controller which encourages the best dynamic parameters with contrasted conventional PID controller. In recent years, compared with the PID controller, the FOPID controller hasthe best performance of controlling error values of the microgrid system. Thecontroller output is mathematically formulated and presented as follows,

$$U(t) = K_p E(t) + K_I D_t^{-\lambda} E(t) + K_d D_t^{-\mu} E(t) \qquad (1)$$

$$E(t) = \Delta P_{tie}(t) + B_i \Delta\omega_i(t) \qquad (2)$$

The transfer function of the FOPID controller is presented as follows,

$$G(s) = K_p + \frac{K_i}{S^\lambda} + K_d S^\mu \qquad (3)$$

The reference value is compared with the present value of PV power to compute error values which are denoted by E(t) and the control signal of the system is mentioned as U(t). The FOPID controller parameters have five parameters that provide the best results to improve the performance of the system. Different PID controller parameters tuning techniques are utilized for decentralized power system load frequency controllers. The universal progression procedure such COA algorithm has concerned the thought in the area of a parameter to controlling improvements. Because of thought utilizing hereditary administrators, the computational intricacy of this populace-based calculation is expanded [23]. The searching conduct is suitable for demonstrating and comprehension of transformative species, henceforth it is utilized as an advancement calculation as a part of recurrence action of a force microgrid system. In the COA algorithm, the step length in addition unit length of direction of that black widows can be defined randomly. In this way, the optimal solution convergence time is expanded for guaranteeing the given issue. In this paper, the COA algorithm is proposed to control the MPPT of the PV system and the proposed PV-based MPPT controller with an integrated system. The COA process is presented below section.

3.3. Chimp Optimization Algorithm

In this proposed methodology, COA is utilized to select the optimal gain parameters of the FOPID controller. The mathematical formulation of COA is presented as follows,

3.3.1. Inspiration

Normally, the fission-fusion society is a chimp's society. This is considered as one of the societies, the combination of society may be a time-variant function. Additionally, in society, each member has a specific duty and special ability that may change over time. From the consideration, the aim of independent concepts is developed in this algorithm. Hence, every group of chimpanzees separately attempts to find the search space with its singular characteristics intended aimed at specific duty. Generally, four types of chimps are presented such as attackers, chasers, barriers, and drivers. Based on these types, the behaviors of the chimps in the hunting process are changed for efficient hunt operation. In the chimp's algorithm, the drivers have collected the prey without doing the hunting process. Barriers residence themselves in plants to create a dam crossway the leakage route of the prey [24]. The prey is grabbed by chasers rapidly. At last, the attackers are identifying the escape route of the prey down into the inferior canopy. Attackers are required to have more efficient in identifying the proceeding change of prey. Moreover, the attackers have been collected with the meat larger piece after an efficient hunt.

In Chimp calculation, the attack method is strictly related to actual ability, intelligence, and age. Also, Sims can change practices during a particular chase or interact with their strategy as a whole. It is authorized by the chimps Chase to execute meat in exchange for social honors such as preparation and firm assistance. Henceforth, by opening another domain of interest and benefits. chimp may indirectly affect the chase. People use social motivation as chimps. In this way, the chimps have an advantage compared to other social predators. In addition to sexual motivation, start the sims to act turbulent as the last advance of the chase. Therefore, bulk chips drop the mistakes of obtaining meat independently. From the thinking of the social behavior of the Sims, it can be isolated into two primary stages, such as investigation and misuse. There is a way to track, prevent and drive prey in the investigation. Misuse is considered a prey attack. Details of misuse and investigation numbers are introduced as follows,

Driving and chasing the prey

In the COA, the prey can be hunted throughout the exploitation also exploration stages. The mathematical design of chasing also driving prey is formulated as follows,

$$D = \left| c.x^{prey}(T) - M.x^{chimp}(T) \right| \qquad (22)$$

$$x^{chimp}(T+1) = x^{prey}(T) - A.D \qquad (23)$$

Where, x^{prey}, x^{chimp} can be described as position vector of chimp and prey, T can be described as a number of current iterations, and $A, M\ and\ C$ can be described as coefficient vectors. The position vectors of the COA is computed based on the below equation,

$$A = 2.F.R^1 - a \qquad (24)$$

$$C = 2.R^2 \qquad (25)$$

$$M = Chaotic\ Value \qquad (26)$$

Where, R^1 and R^2 can be described as random parameters which in the variety of [0,1], F can be described as coefficient which decreased non-linearly from 2.5 to 0 by the iteration procedure (in both explorations also exploitation). M can be described as a chaotic parameter computed based on different chaotic maps. Hence, the vector describes the behaviour of sexual incentive of chimps in shooting behaviour.

Exploration phase

The attack behaviour of the chimp's mathematical model is designed as follows, firstly, the chimps can provide the location of the prey, and secondly, they can orbit it. Finally, predators are generally maintained by attackers. The chaser, barrier, and driver are usually involved in the hunt. At the research stage, there was no information about the optimal condition of the prey during the initial repetition. This state of the chaser, block and drive must be updated using the attacker's status. So, four optimal solutions can be saved and the other chimps are stopped to update the positions related to the locations of the best chimps. This creation is presented mathematically as follows,

$$d^{Attacker} = |C^1 X^{attacker} - M^1 D| \qquad (27)$$

$$d^{Barrier} = |C^2 X^{barrier} - M^2 X| \qquad (28)$$

$$d^{Chaser} = |C^3 X^{Chase} \ - M^3 X| \qquad (29)$$

$$d^{Driver} = |C^4 X^{driver} - M^4 X| \qquad (30)$$

$$X^1 = X^{Attacker} - A^1 (d^{Attacker}) \qquad (31)$$

$$X^2 = X^{Barrier} - A^2 (d^{Barrier}) \qquad (32)$$

$$X^3 = X^{Cha} \quad - A^3 (d^{Chase} \ ) \qquad (33)$$

$$X^4 = X^{Driver} - A^4 (d^{Driver}) \qquad (34)$$

$$X(T+1) = \frac{X^1 + X^2 + X^3 + X^4}{4} \qquad (35)$$

The search agent position is updated in the search space based on another chimp position. so, the chimp's final position is arbitrarily placed in the orbit which is described as drivers, chasers, barrier, and attacker positions.

Exploitation phase

As beforehand mentioned, the chimps will hunt the victim by attacking process while the prey stops running. In the attacking process of chimps, the value of f is linearly minimized. The vector of a also reduced in the manner of f vector. Additionally, the a is an arbitrary variable in the interval of [-2f,2f]. Additionally, COA chasing [25], blocking, and driving mechanisms have reinforced exploration capability and it may still be at the risk of local minima trapping conditions. Hence, the exploration is a required portion to achieve the best results. In COA, chimps deviate to attack the prey and converge to attack the prey. The vector a is located to mathematical design this characteristic so that inequality parameters. To avoid local optima entrapment, the chimps forced to diverge from prey which formulated as $|a|>1$. To achieve global optima, the chimps forced to converge at prey location which formulated as $|a|<1$.

Exploitation phase using the social incentive

In the COA, the social incentive and society of chimps which related to meat hunting. In the final stage of the chimp hunting process, the chimp may abort its hunting process. Hence, they chaotically attempt to grab hunting meat for social essences. These characteristics of the chaotic map are designed with chaotic maps which formulated as follows,

$$X^{chimp}(T+1) = \begin{cases} x^{prey}(t) - A.D & if \quad \mu < 0.5 \\ Chaotic\ value & if \quad \mu > 0.5 \end{cases} \tag{36}$$

Where μ can be described as an arbitrary number in the interval of [0,1]. Initially, they generate a random population of chimps. Secondly, all chimps are arbitrarily divided by different groups such as driver, chaser, barrier, also attacker. After that, every chimp position updates the f coefficients with the consideration of the own group method. The optimal prey location is identified in the iteration based on driver, chaser, barrier, and attacker. Then the distance from the prey, the positions are updated. Additionally, the optimal tuning of the m and c, the fast convergence rate and faster. Additionally, the value of f can be adjusted from 2.5 to 0 which empowers the process of exploitation. Finally, the condition of the divergence and iterations are checked which provides the optimal results to manage the results. With the help of COA, the optimal gain parameter is selected. After that, the proposed classifier is utilized to classify breast cancer from mammogram images.

4. Result and discussion

The performance of the proposed methodology is validated and justified in this section. The proposed method is implemented in MATLAB/Simulink and performances were evaluated. The proposed method is validated with the consideration ofthe proposed controller. The proposed method is implemented on 32 GB of RAM and a 4GHz intel core i78 system. The proposed controller is designed to manage the environmental conditions of a PV system, improve the voltage gain, and monitoring cardiac pacemakers. The proposed controller is utilized to empower the PV system with cardiac pacemaker performance during partial shading conditions. The partial shading conditions also, the PV system is managed to fulfill the required power of the cardiac pacemaker. The proposed method is compared with existing methods such as PSO and GWO. The proposed method's main objective is enabling stable operation by managing the cardiac pacemaker and environmental conditions of a PV system. The Simulink diagram of the proposed method and implementation parameters of presented in Figure 3 and Table 1.

Table 1: Implementation parameters of the proposed method

S. No	Description	Parameters
1	Capacitance (C)	$2.20E^{-04}$
2	Inductance (L)	$1.50E^{-04}$
3	Pe	$4.00E^{-05}$
4	Resistance (R)	$1.15E^{+02}$
5	Open Circuit Voltage (Voc)	6 V
6	Maximum Voltage (Vmp)	5V

7	Short Circuit Current (Isc)	0.008A
8	Maximum Current (Imp)	0.007A
9	Temperature Coefficient	0.061745 %/deg.c

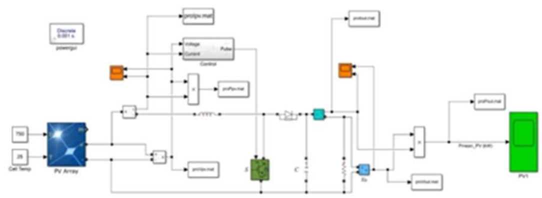

Figure 3: Proposed Simulink Diagram

The proposed methodology is tested with two different cases which mentioned as Stable Irradiance Condition, Changed Irradiance Condition

Case 1: Stable Irradiance Condition

In this case of analysis, the stable irradiance condition with a cardiac pacemaker is checked. The stable irradiance is analyzed with a proposed controller in a cardiac pacemaker. The cardiac pacemaker should be managing with the continuing power from the PV system. This condition, PV output current, output voltage, and PV output power are illustrated in Figure 4, Figure 5, and Figure 6. The power and voltage characteristics of a PV system are illustrated in Figure 7.

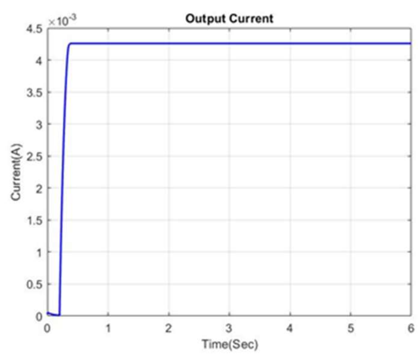

Figure 4:Output current of PV module

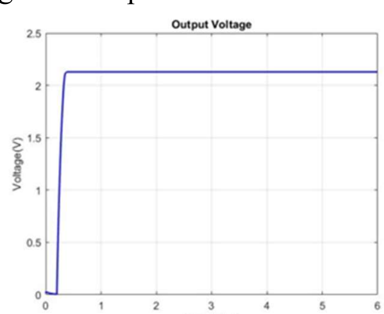

Figure 5: Output voltage of PV module

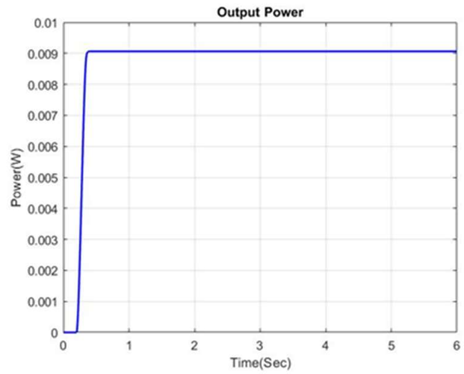

Figure 6: Output power PV model

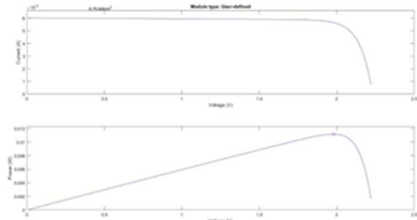

Figure 7: Analysis of P/I characteristics

In this case analysis, the constant irradiance of 0.75KW/m^2 is fixed at every time. At this constant irradiance level, the PV has generated the power is 0.01W. The output voltage and current of the PV are2.1V and 4.2*10^-3A. Generally, the above 2V is required to generate a pulse in a cardiac pacemaker. From the analysis, the proposed controller is generated the 1V at every time without any interruption. Hence, the PV system is suitable to design the cardiac pacemaker without a battery.

Case 2: Changed Irradiance Condition

In this case analysis, the changed irradiance condition with a proposed controller is checked. The varied irradiance is analyzed with a proposed controller in a cardiac pacemaker. The cardiac pacemaker should be managing with the continuing power from the PV system. The variable irradiance condition is illustrated in Figure 8.This condition, PV output current, output voltage, and PV output power are illustrated in Figure 9, Figure 10, and Figure 11. The power and voltage characteristics of a PV system are illustrated in Figure 12.

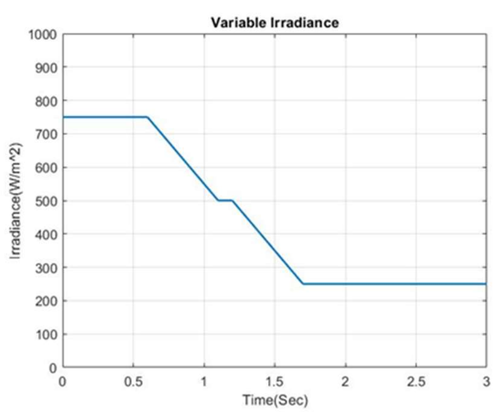

Figure 8: PV variable irradiance

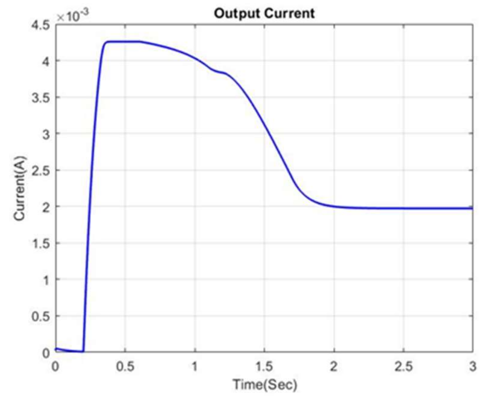

Figure 9: PV current

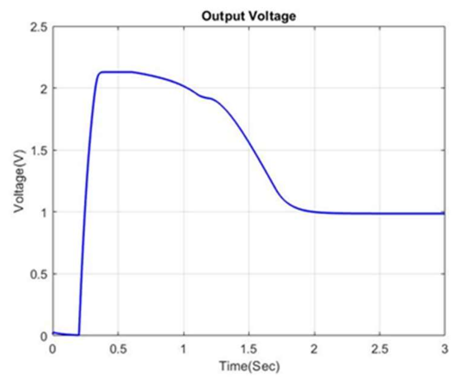

Figure 10: PV voltage

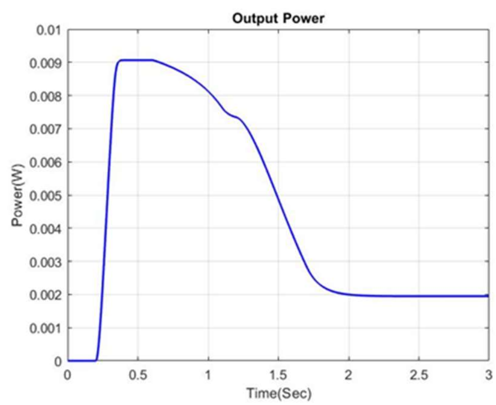

Figure 11: PV power

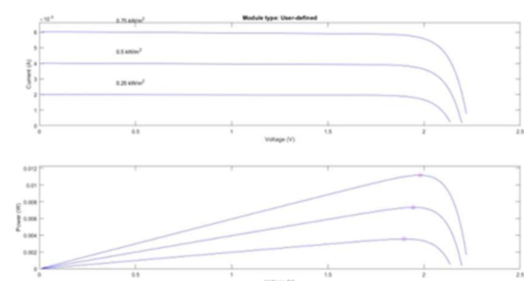

Figure 12: Analysis of P/I characteristics

In this case analysis, the variable irradiance of 0.75KW/m^2 is fixed at 0.65s, 0.50KW/m^2 is fixed at 0.75s and 0.25KW/m^2 is fixed at 1.65s. At this variable irradiance level, the PV has generated the power is 0.075W,0.050W, and 0.025W respectively. The output voltage and current of the PV is 2.1V,1.8V and 1V and 4.2*10^(-3) A,3.2*10^(-3) A and 1*10^(-3) A . Generally, the above 2V is required to generate a pulse in a cardiac pacemaker. From the analysis, the proposed controller is generated the 1V at every time without any interruption. Hence, the PV system is suitable to design the cardiac pacemaker without a battery.

4.1. Comparison Analysis

The comparison analysis is an essential part to validate the proposed methodology. To validate the proposed methodology, it is compared with the existing methods such as PSO and GWO. The proposed methodology is designed to manage the stable power to cardiac pacemaker continuously and provide power without battery connection. The PV system is utilized to provide the essential power in a cardiac pacemaker.

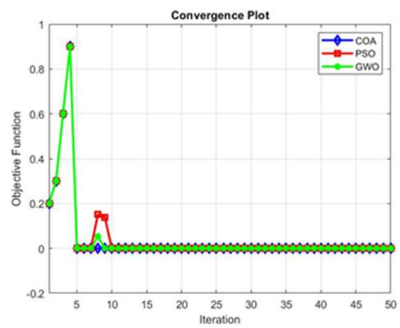

Figure 13: Comparison analysis of proposed method

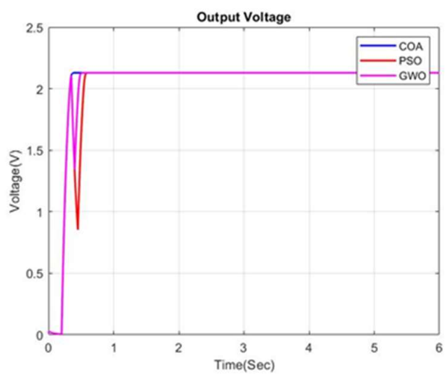

Figure 14: Comparison analysis of case 1

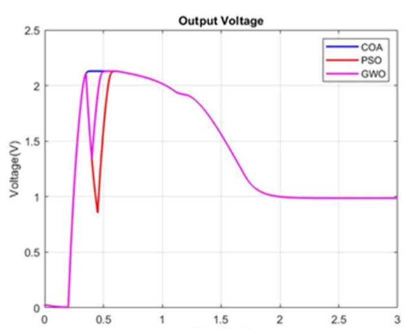

Figure 15: Comparison analysis of case 2

The convergence analysis of the proposed methodology is illustrated in Figure 13. The proposed methodology has been achieved the 0.01 fitness function. The PSO and GWO have been achieved fitness functionssuch as 0.152 and 0.174 respectively. From the analysis, the proposed methodology has been achieved the best results to maintain the stable power of the cardiac pacemaker. The comparison analysis of the case 1 output voltage is illustrated in Figure 14. The proposed methodology has been achieved stable output voltage at every time. The conventional methods of PSO and GWO have been achieved variable voltage at every time. From the analysis, the proposed methodology has been achieved the best results to provide stable power to a cardiac pacemaker. The comparison analysis of the case 2 output voltage is illustrated in Figure 15. The proposed methodology has been achieved stable output voltage at every time. The conventional methods of PSO and GWO have been achieved variable voltage at every time. From the analysis, the proposed methodology has been achieved the best results to provide stable power to cardiac pacemakers.

Table 2: Comparison Analysis of the proposed method

Description	Voltage in volts	Current in mA	Power in watts	Duty cycle (D)
Pacemaker requirement	2.1	0.005	0.001	0.5
Proposed algorithm	2.1	0.004	0.0084	0.5
PSO	1.7	0.002	0.034	0.7
GWO	1.5	0.001	0.0015	0.8

5. Conclusion

In this paper, a solar-powered cardiac pacemaker has been designed to avoid the requirement of a battery and manage heart function. The solar power cardiac pacemaker has been consisting of a PV system utilized to generate power from the sunlight energy. The PV may be affected because of environmental conditions. To manage environmental conditions, the efficient MPPT controller has been designed in the implantable cardiac pacemaker. In the MPPT controller, the FOPID has been designed which is utilized to extract the maximum power from the PV system. In the FOPID controller, COA has been utilized to empower the FOPID controller performance. The proposed methodology has been implemented in MATLAB/Simulink platform and it is evaluated by the output voltage, output current, power, and convergence analysis. The proposed methodology is compared with the conventional methods such as PSO and GWO respectively. From the analysis, the proposed methodology has been utilized as an efficient result to manage the stable operation of the cardiac pacemaker. In the future, the efficient cardiac pacemaker will be designed and validated with conventional methods.

6. References

- Xingqun Liang, Sylvia M. Evans, and Yunfu Sun. "Development of the cardiac pacemaker." Cellular and Molecular Life Sciences 74, no. 7 (2017): 1247-1259.
- Munna Khan, and Ajai Kumar Singh. "Modeling and simulation of solar boost converter to supply power for cardiac pacemakers." In 2013 IEEE International Symposium on Medical Measurements and Applications (MeMeA), pp. 187-190. IEEE, 2013.
- Dominique Méry, and Neeraj Kumar Singh. "Closed-loop modeling of cardiac pacemaker and heart." In International Symposium on Foundations of Health Informatics Engineering and Systems, pp. 151-166. Springer, Berlin, Heidelberg, 2012.

- Zhihao Jiang, Miroslav Pajic, SalarMoarref, Rajeev Alur, and Rahul Mangharam. "Modeling and verification of a dual chamber implantable pacemaker." In International Conference on Tools and Algorithms for the Construction and Analysis of Systems, pp. 188-203. Springer, Berlin, Heidelberg, 2012.
- Hugo Daniel Macedo, Peter Gorm Larsen, and John Fitzgerald. "Incremental development of a distributed real-time model of a cardiac pacing system using VDM." In International Symposium on Formal Methods, pp. 181-197. Springer, Berlin, Heidelberg, 2008.
- Fleur VY Tjong, and Vivek Y. Reddy. "Permanent leadless cardiac pacemaker therapy: a comprehensive review." Circulation 135, no. 15 (2017): 1458-1470.
- Geon-Tae Hwang, Hyewon Park, Jeong-Ho Lee, SeKwon Oh, Kwi-Il Park, Myunghwan Byun, Hyelim Park et al. "Self-powered cardiac pacemaker enabled by flexible single crystalline PMN-PT piezoelectric energy harvester." Advanced materials 26, no. 28 (2014): 4880-4887.
- Rubens Tofano de Barros, Sebastião Marcos Ribeiro de Carvalho, Marcos Augusto de Moraes Silva, and Juliana Bassalobre Carvalho Borges. "Evaluation of patients' quality of life aspects after cardiac pacemaker implantation." Brazilian Journal of Cardiovascular Surgery 29 (2014): 37-44.
- Jyoti Yadav, Asha Rani, and Girisha Garg. "Intelligent heart rate controller for cardiac pacemaker." International Journal of Computer Applications 36, no. 7 (2011): 22-29.
- Jongmoon Jang, Pradeep VallachiraWarriam Sasikumar, Fatemeh Navaee, Lorenz Hagelüken, Gurdial Blugan, and Juergen Brugger. "Electrochemical performance of polymer-derived SiOC and SiTiOC ceramic electrodes for artificial cardiac pacemaker applications." Ceramics International 47, no. 6 (2021): 7593-7601.
- Yuncong Jiang, Jaber A. Abu Qahouq, and Tim A. Haskew. "Adaptive step size with adaptive-perturbation-frequency digital MPPT controller for a single-sensor photovoltaic solar system." IEEE transactions on power Electronics 28, no. 7 (2012): 3195-3205.
- Bhukya Laxman, Anil Annamraju, and Nandiraju Venkata Srikanth. "A grey wolf optimized fuzzy logic based MPPT for shaded solar photovoltaic systems in microgrids." International Journal of Hydrogen Energy 46, no. 18 (2021): 10653-10665.
- Hai Tao, Mehrdad Ghahremani, Faraedoon Waly Ahmed, Wang Jing, Muhammad Shahzad Nazir, and Kentaro Ohshima. "A novel MPPT controller in PV systems with hybrid whale optimization-PS algorithm based ANFIS under different conditions." Control Engineering Practice 112 (2021): 104809.
- Mohammad Junaid and Khan. "A Novel Hybrid Maximum Power Point Tracking Controller Based on Artificial Intelligence for Solar Photovoltaic System Under Variable Environmental Conditions." Journal of Electrical Engineering & Technology (2021): 1-11.
- Ali M Eltamaly, M. S. Al-Saud, Ahmed G. Abokhalil, and Hassan MH Farh. "Simulation and experimental validation of fast adaptive particle swarm optimization strategy for photovoltaic global peak tracker under dynamic partial shading." Renewable and Sustainable Energy Reviews 124 (2020): 109719.
- Sara Azimi, AllahyarGolabchi, AbdolhosseinNekookar, Shahram Rabbani, MortezaHassanpour Amiri, Kamal Asadi, and Mohammad Mahdi Abolhasani. "Self-

powered cardiac pacemaker by piezoelectric polymer nanogenerator implant." Nano Energy 83 (2021): 105781.

- Chunhua Liu, Chaoqiang Jiang, Jingjing Song, and K. T. Chau. "An effective sandwiched wireless power transfer system for charging implantable cardiac pacemaker." IEEE Transactions on Industrial Electronics 66, no. 5 (2018): 4108-4117.
- Adnan Mukhtar, and Farhan Mukhtar. "Adaptive Fractional Order PID Controller Design of a Pacemaker based on Heart Rate Control Strategy." International Research Journal of Engineering and Technology (IRJET) (2020): 1681-1685.
- Munna Khan, Ajai Kumar Singh, and Syed Shakir Iqbal. "SPICE simulation of implantable solar power supply for sustainable operation of cardiac biosensors." International Journal of Biomedical Engineering and Technology 18, no. 2 (2015): 168-185.
- Andreas Haeberlin, Adrian Zurbuchen, Sébastien Walpen, Jakob Schaerer, Thomas Niederhauser, Christoph Huber, Hildegard Tanner et al. "The first batteryless, solar-powered cardiac pacemaker." Heart rhythm 12, no. 6 (2015): 1317-1323.
- Ayan Banik, Anurag Shrivastava, Ravindra Manohar Potdar, Sanjiv Kumar Jain, Santosh Gopal Nagpure, and Mukesh Soni. "Design, Modelling, and Analysis of Novel Solar PV System using MATLAB." Materials Today: Proceedings (2021).
- Mustafa SinasiAyas, and ErdincSahin. "FOPID controller with fractional filter for an automatic voltage regulator." Computers & Electrical Engineering 90 (2021): 106895.
- AyşenDemirören, Serdar Ekinci, Baran Hekimoğlu, and DavutIzci. "Opposition-based artificial electric field algorithm and its application to FOPID controller design for unstable magnetic ball suspension system." Engineering Science and Technology, an International Journal 24, no. 2 (2021): 469-479.
- M.Khishe, and Mohammad Reza Mosavi. "Chimp optimization algorithm." Expert systems with applications 149 (2020): 113338.
- M.Khishe, and M. R. Mosavi. "Classification of underwater acoustical dataset using neural network trained by chimp optimization algorithm." Applied Acoustics 157 (2020): 107005.