HYBRID WOA-ALO ALGORITHM BASED MPPT CONTROLLERS FOR GRID-CONNECTED SOLAR PHOTOVOLTAIC SYSTEM

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Abstract: The environment and the world's energy system currently face formidable obstacles. In terms of energy, fuel cell vehicles and energy use are more environmentally friendly. For maintaining energy security, minimizing air pollution, or encouraging energy conservation and emission reduction, the synergies between electric vehicles and renewable energy in the smart grid are of major relevance. The combination of renewable energy and electric vehicles is fraught with difficulties because of the randomness, variable renewable, and electrical nature of renewable energy. This article focuses mainly on developing a fundamental theoretical model to analyze the resonant inductively coupled wireless power transfer system for battery charging of electric vehicle. Numerical simulations or innovative investigations are presented to demonstrate the suggested device's improved results.

Keywords: Electric Vehicle, FOPID, Ant Lion Optimizer Algorithm, Whale Optimization Algorithm

1. INTRODUCTION

The ever-growing need for electrical energy has prompted academics to look for alternate sources of energy, like those from solar, wind, fuel cells, as well as other sources, in leading to questions about carbon emissions from fossil fuels. These renewable energy sources may now be employed on a somewhat larger scale because to significant advances in the area of electrical machines, which has aided in the creation of microgrids. A microgrid is a collection of interconnected loads and DGs that, under explicitly defined electrical parameters, behave as a single entity with respect to the grid [1]. Both a grid-connected mode as well as an island mode are available for operation. Because micro sources like solar, wind, and fuel cells are so small, the grid controls much of the activities in the grid-connected phase. In the stand-alone configuration, the micro sources themselves control the device dynamics [1]. Droop based control method is the most widely utilized control mechanism in micro grids.

The robustness and speed of the system will be determined by the type of controller utilized. There are many different types of controllers, including hysteresis, dead beat, and proportional integral (PI) controllers, in both linear and non-linear contexts. Micro-grids frequently employ PI controllers, although due to their linearity, these are simplified. A significant number of research papers have been published in the literature to address this problem. Using PID controllers with fractional orders is one of the better solutions. FOPID controllers feature two extra parameters, fractional integrator order (a) and fractional derivative order (p), to manage in addition to proportional (Kp), integral (K1), and derivative (Kn), making them more adaptable [2]. FOPID controllers increase system accuracy and robustness. FOPID controllers improve the accuracy and robustness of the system. Numerous devices, including PSS and AGC, use FOPID controllers [3].

To get the best results, such as error minimization, TIID reduction, etc., the controller parameters should be correctly tuned. To the author's knowledge, only the PSO optimization method has been used to improve the FOPID parameters in a micro grid. Numerous optimization strategies have been used to design FOPID variables in other situations, including SRM push, AGC, and hydrothermal units. One of the more successful methods for this is ALO [4]. In order to accomplish more reliable performance & quick dynamic reaction, the FOPID controller parameters of the voltage source inverter are tuned in this article using the ALO method in an islanded microgrid. The method ALO was influenced by nature. The key stages of ALO are random ant walks, catching in antHon's pits, creating traps, sliding ants to antlion, capturing prey and repairing the pit, and elitism [5].

Rest of the work is arranged as follows. In section II describes the fractional order PID controller. Section III contains the proposed ALO algorithm for tuning of FOPID controller parameters. Section IV gives the literature Survey. Section V contains the problem formulation and objectives. Section VI contains the results and discussion part. Finally, section VII ends the paper with conclusion followed by references.

II. FOPID CONTROLLER

The various definitions and approximations for fractional order controllers include Rieman-Liouville, Grunwald-Letnikov, the Caputo expressions, Carlson approximation, Matsuda estimation, the continuous fraction expansion (CFE) technique. The fundamental transfer function of the FOPID controller is, as seen in equation (1),

$$G(s)= K_p + \frac{Ki}{s^{\alpha}} + K_d S^{\beta} \quad (1)$$

where a,f_J are the positive fractional orders and K_p, K_i and K_n are the proportionate gains. The use of S forces is extremely challenging since the differentiator or integration of the fractional order have infinite dimensions. Therefore, estimating the fractional powers is crucial. The most used approximate method for fractional order controllers is the oustaloup approximation, and so this article also makes use of this method [6-7]. It must first be modeled as a differentiator that use the Oustaloup approximation approach before being split by s to produce a fractional order integrator. The general expression for the approximation of the Oustaloup filter is

$$s^{\alpha} = K\prod_{k=-N}^{N}\frac{s+\omega'}{s+\omega}$$

$$\omega' = \omega_b\omega_u^{(2k-1-\alpha)/N}, \quad \omega = \omega_b\omega_u^{(2k-1+\alpha)/N}$$

$$K = \omega_h^{\alpha}, \quad \omega_b = 10^{-\alpha}$$

III. ALO ALGORITHM

The meta-heuristic method known as ALO was influenced by environment. Antlions emulate the bond among ants as well as ants. Antlions build traps to catch the ants that wander around in quest of food. A mathematical formalism could be used to describe how the ALO algorithms perform.

A. Random walks of ants and antlions

yt= [0, Csum (2r(t1)-1),Csum(2r (t2)-1),Csum (2r(tn)-1)

Here n is the set of iterations, a(t) is the random movement, c_{sum} is the entire sum, & t is the current iteration.

r(t)= 1 if rand > ½

0 if rand < 1/2

The position of ants and antlions are given by the following matrices.

$$M_A = \begin{bmatrix} A_{11} & A_{12} & \cdots & A_{1d} \\ A_{21} & A_{22} & \cdots & A_{2d} \\ \vdots & \vdots & \vdots & \vdots \\ A_{n1} & A_{n2} & \cdots & A_{nd} \end{bmatrix}$$

$$M_{AL} = \begin{bmatrix} AL_{11} & AL_{12} & \cdots & AL_{1d} \\ AL_{21} & AL_{22} & \cdots & AL_{2d} \\ \vdots & \vdots & \vdots & \vdots \\ AL_{n1} & AL_{n2} & \cdots & AL_{nd} \end{bmatrix}$$

Every ant or antlion's fitness is calculated using an optimal solution, and the results are kept in the arrays above.

$$M_{fA}=\begin{bmatrix} f(A_{11},A_{12},\cdots,A_{1d}) \\ f(A_{21},A_{22},\cdots,A_{2d}) \\ \vdots \\ f(A_{n1},A_{n2},\cdots,A_{nd}) \end{bmatrix}$$

$$M_{fAL}=\begin{bmatrix} f(AL_{11},AL_{12},\cdots,AL_{1d}) \\ f(AL_{21},AL_{22},\cdots,AL_{2d}) \\ \vdots \\ f(AL_{n1},AL_{n2},\cdots,AL_{nd}) \end{bmatrix}$$

Where in d is the dimension and n is the number of search agents. The minimum and maximum normalization approaches are used to standardize the position of each ant.

$$y_i^t=\frac{(y_j^t-a_j)*(d_j-c_j^t)}{(d_j^t-a_j)}+C_j$$

B. Trapping of ants in AntHon's pit

Antlion traps, which are interpreted as formulas in mathematics, have an impact on ants' random travels.

$$c_j^t=Antlion_k^t+c^t$$
$$d_j^t=Antlion_k^t+d^t$$

C. Ants sliding towards antlion

Antlions attempt to throw ants inside the trap by firing sand from the outside in. Below Equations show the behavior indicated previously.

$$c^t=\frac{c^t}{J}$$
$$d^t=\frac{d^t}{J}$$

D. Rebuilding of pits

The antlion starts digging a larger pit after eating an ant that accidentally falls into the pit's bottom. The position of the captured ant is then used instead of antHon's because of its greater optimal solution.

E. Elite

Elitism is one of the distinguishing traits of swarm intelligence. The greatest antlion up to that point is saved by Elitism after each repeat. As a consequence, the elite antlion as well as the antlion determined by the roulette wheel would both influence the ant population's random walk.

$Ant^t_j = Rw_a^i + RW_E^i/2$

IV. LITERATURE SURVEY

Munoz et al., (2020) presented the modeling, control model and simulation, resulting in a numerical simulator composed of detailed designs of the major elements: transmission system, induction motor, power electronics, control device, and vehicle dynamics. The simulation was established in MATLAB/Simulink and will allow the estimation of the energy consumption of an EV under specific configurations. Simulation outcomes demonstrate show the efficiency of the designed control. These simulations were carried out via the velocity profiles offered by the New Europe Drive Cycle (NEDC) [8].

Singh et al., (2020) suggested technique of current-controlled hill-climbing MPPT of the solar photovoltaic array for charging off-board electric vehicles using two sensors has been tested and simulated via MATLAB Simulink and steady charging current under the particular limit was maintained by suggested technique during the simulation of the device [9].

Padhay et al., (2018) proposed GWO in MATLAB simulation environment. GWO algorithm is proved better when contrasted with well known optimization approaches such as DE, PSO, GSA, and CMA-ES. Modified Grey Wolf optimization is proved superior to original Grey wolf optimization. The optimized variable values with PID controller in absence and presence of EV as well as with suggested controller Fractional order PID with derivative filter (FOPIDF) and EV are reported .The reported value presents the ITAE value for PID controller without EV is

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2.57with EV it is 1.908 and with the suggested controller FOPIDF it is least 0.3974 [10].

Pillai et al., (2019) a proportional–integral–derivative controller (PID or three-term controller) to enhance the efficiency of the electric vehicles (EVs) in the suspension device is applied. Initially, the mathematical modeling of the suspension system is established. This is simulated as an open loop system to acquire the suspension effect and the movement of the vehicle. Tuning is done using optimization techniques to identify the values of proportional, integral and derivative constants to minimize the displacement of the suspension system [11].

Eser et al., (2016) a novel electric vehicle charging model is utilize in a high spatial and temporal resolution optimal power flow simulation framework to assess the effects of enhanced penetration of electric vehicles on the central European power system. In 2030, electric vehicles are found to have only a moderate impact on reducing the curtailment of wind and solar power. The energy to charge the electric vehicles comes mainly from conventional power plants (coal and gas), whereas solar and wind power plants each provide only 4%. Consequently, the increased penetration of electric vehicles is acquired to result in an enhancement in CO2 emissions of up to 25% compared to the same number of gasoline vehicles [12].

Singh et al., (2020) a solar PV (Photovoltaic) array, a battery energy storage (BES), a diesel generator (DG) set and grid based EV charging station (CS) is utilized to provide the incessant charging in islanded, grid connected and DG set connected modes. The charging station is primarily designed to use the solar photovoltaic PV array and a BES to charge the electric vehicle (EV) battery. However, in case of exhausted storage battery and unavailable solar PV array generation, the charging station intelligently takes power from the grid or DG (Diesel Generator) set. However, the power from DG set is drawn in a manner that, it always operates at 80-85% loading to achieve maximum fuel efficiency under all loading conditions. Moreover, the PCC (Point of Common Coupling) voltage is synchronized to the grid/ generator voltage to obtain the ceaseless charging. The charging station also performs the vehicle to grid active/reactive power transfer, vehicle to home and vehicle to vehicle power transfer for increasing the operational efficiency of the charging station [13].

Das et al., (2016) A BDDDC is a dc to dc converter where the power can flows is in both the directions as supply end to load end and also load end to supply end. It has two modes of operation, buck mode & boost mode. Utilize PI and PID controller for triggering the IGBTs of DC to DC converter. The findings outcomes give that for both 24V and 48V input voltage the conventional boost converter efficiency is 55 % and for proposed boost converter the efficiency is 74% [30].

V. PROPOSED WORK

- **Problem Formulation**

The decrease of non-renewable energy sources and growing problem of environmental pollution, has forced us to look for better energy sources. The research being carried out on utilization of renewable energy such as solar energy, wind energy as soon has made it possible to utilize this abundant quantity of renewable energy sources in our day to day life more efficiently and economically. As it is known that solar energy is the most abundant renewable energy source at present in the world. The Distributed generation headed by the photovoltaic (PV) generation can solve all electrical power requirements in remote areas. Existing electricity supply system fails to meet peak power demand. This is a major cause of concern for many countries. The photovoltaic grid connected system greatly overcomes this problem. Solar energy is considered as the most popular source of renewable energy because of its round the clock availability during the day, easy commissioning, decreasing costs and increasing efficiency. The output power produced by the photovoltaic modules is intermittent in nature and depends on the intensity of solar radiation and temperature of solar cells. As the efficiency of the commercially available solar cells is low, it is important to track the maximum power point.

- **Problem Statement:**

The existing problem includes Whale optimization algorithm for MPPT but has its own limitations. Similar to other swarm-based algorithms, the recently developed whale optimization algorithm (WOA) has the problems of low accuracy and slow convergence. It is also easy to fall into local optimum. Moreover WOA and its variants cannot perform well enough in solving high-dimensional optimization problems. So that hybrid algorithm will be proposed. It also has FOPI controller but FOPI has less stability so that FOPID will be proposed.

- **Objective:**

1. To introduce hybrid of Whale optimization algorithm (WOA) and Ant Lion optimization (ALO) algorithm.

2. To replace FOPI to FOPID controller for better stability.

3. To perform comparative analysis.

Methodology:

1. Design simulink model of pv panel using power grid as load with fopid controller based MPPT algorithm
2. Define initial parameters of optimization algorithm like no of population , iteration etc
3. Define fitness function for optimization algorithm
4. Perform optimization algorithm for finding K_P , K_I, K_D of FOPID controller
5. Extract best K_p , K_I, K_D values and calculate final performance parameters
6. Perform comparative analysis of proposed system with existing one.

VI. RESULTS AND DISCUSSIONS

One of the most important forms of renewable energy in the future will be solar energy. PV system generates its greatest output power, make the usage of PV difficult in many climatic circumstances around the world & its nonlinear current-voltage (I-V) features, which result in a distinct Maximum Power Point (MPP) on its power-voltage (P-V) curve. In order to tackle the issue that arises when a PV module is coupled to a load and the operating point is not exactly at the MPP and MPPT methods are used in PV systems to extract the array's maximum output power. During in simulation utilising the MATLAB/Simulink software package, the suggested DC-DC boost converter-based fast charger is studied and its dynamic and transient performances are examined. To construct MPPT approach using Hybrid Whale Optimization and Ant Lion techniques is the goal of the presented design.Four different patterns of irradiance, current, power & temperature are used to test the proposed device. The three controllers IC-PI, IC-FOPID and HWOAALOFOPID are utilised in this suggested work.

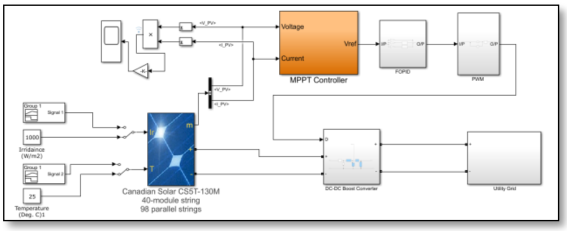

Fig 1: Proposed framework for MPPT Controller

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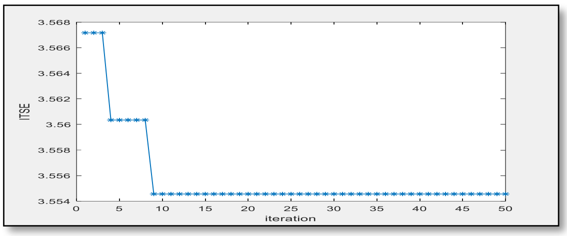

Fig 2: Convergence curve of Optimization Algorithm

As seen in the above figure 2, When the optimization process finds a solution, the target fitness function ITSE (Integral time square error) is taken into account. Convergence curve shows the difference between exact power and the power extract from the solar panel then error is minimized between both the power to tract a MPPT power.

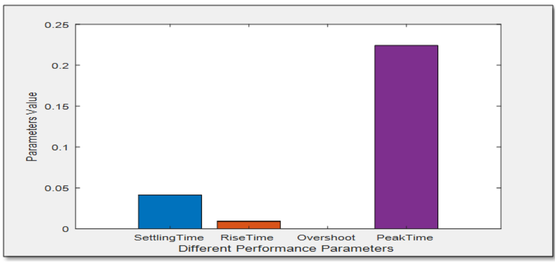

Fig 3: Graphical representation of Different parameters

Table 1: Different performance parameters

Parameter	Value
Settling Time	0.041262
Rise Time	0.009302
Overshoot	1.7764e-13
Peak time	0.3167

Settling time: With variations in the environment, the MPPT of PV voltage has a different settling time. Due to the fact that traditional linear controllers cannot ensure the same settling time for each irradiance value must be integrated into the system to prevent volatility.

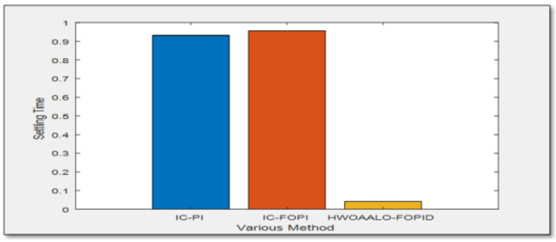

Fig 4: Settling time for various methods

From the fig 4, it is clear that the settling time for the proposed approach HWOAALO-FOPID controller decrease by 0.041262 as compared to other two methods which shows proposed method superior.

Rise Time: The amount of time it takes for a signal to cross from a predetermined low value to a specified high value is referred to as the rise time.

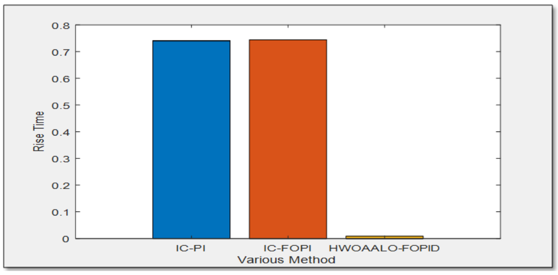

Fig 5: Rise time for various methods

From the fig 5, it is clear that the settling time for the proposed approach HWOAALO-FOPID controller increase by 0.009302 as compared to other two methods which shows proposed method superior.

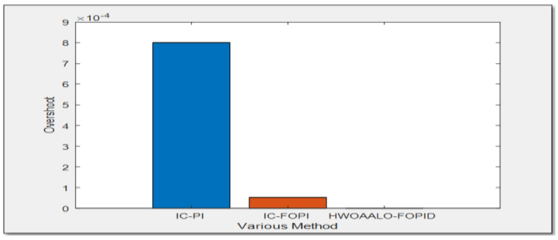

Fig 6: Overshoot for various methods

Table 2: Comparison of Parameters Values

Parameter	IC-PI	IC-FOPI	Value for proposed HWOALO
Settling Time	0.90123	0.981	0.041262
Rise Time	0.7512	0.7598	0.009302
Overshoot	8.000	0.987	1.7764e-13

The results presents the HWOAALO-FOPID controller increases the input voltage depending on the load requirement for renewable energy applications. The proposed approach showed Settling time 0.041262, Rise time 0.009302, Peak time 0.3167, which shows proposed values are better then the existing approach.

VII. CONCLUSION

This paper's goal is to create a FOPID controller for inverters in an islanded microgrid platform model on droop. The FOPID controller's settings have been adjusted using ALO and WOA to lessen voltage error. Switching reactive power loads or rectifier loads were utilized to analyze the efficiency of the controllers, as well as the findings for both ALO-based FOPID controllers and WOA-based FOPID controllers were evaluated. A hybrid ALO-WOA based FOPID controllers reduce oscillations, leading in more stable & dependable performance, Greater efficiently than current methods.

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