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Enhancing PI controller performance in grid-connected hybrid power systems

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ABSTRACT

The optimal operation of a microgrid was buildup of both uncontrollable (solar, wind) and controllable (batteries, diesel generators) electrical energy sources are enclosed in this paper. By replacing controllers, the variations in wavering power supply caused by load fluctuations are managed. The objective of the research paper is to optimize these controller gain settings for effective use of electrical energy. In this paper integral time square error principle is combined along with the Cuckoo search algorithm (CSA) and particle swarm algorithm (PSA) to obtain the accurate, precise and appropriate results. It enhances the microgrid's steady-state sensitive responsiveness in comparison to trial-and-error techniques, assuring a stable supply of electricity to the load.

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1. INTRODUCTION

The paper elucidates an optimized power flow controller designed for a hybrid renewable energy system (HRES) linked to the utility grid. The controller intends to regulate the flow of real power and reactive power to the load while maximizing the utilization of available power from the HRES [1]-[5]. Two control loops, one for current, and other for power control are established using conventional PI regulators. Due to the unpredictable nature of renewable energy sources, a smart algorithm is employed to adapt the PI controller constants. The particle swarm optimization (PSO) algorithm is used to optimally tune the parameters of the proportional-integral (PI) regulators. Notably, search process occurs across a range of variable input parameters, often representing common values of sun radiation and wind speed in the region, eliminating the neccesity of an online search algorithm. The proposed method's validity is asserted through simulation results. The paper introduces an enhanced power flow controller for a HRES utility connected to the grid. The key goal is to regulate the real and reactive power flow to the load while maximizing the utilization of accesable power from the HRES. Two control loops, namely one current and other power control, are established utilizing traditional PI regulators. Due to the unpredictable nature of renewable energy sources, a smart algorithm is necessary to adjust a PI controller constant [6]-[10]. For best tuning of PI regulator parameters, PSO algorithm is employed. Notably, the PSO search process operates over a range of variable input parameters, commonly representing solar radiation and values of wind speed in the region. The resulting ideal value is appropriate for the specified input parameter range, which typically reflects the most frequently occurring conditions in the area. This approach eliminates the need for an algorithm used in online search. The viability of the suggested approach is substantiated through simulation results. The authors discuss the emerging trend of optimization control, where optimization techniques are employed to fine-tune controller parameters for a specific system. It contrasts optimization control with traditional adaptive control, highlighting the former's superiority. The research focuses on control stratagies for optimization applied to a photovoltaic (PV) system, introducing two techniques, PSO and CFA-PSO and Cuttlefish algorithm, for finding optimal gain values in a hybrid approach. Two controllers, PI and PIA stands for proportional-integral and proportional-integral acceleration, are considered. The study presents and analyzes various results to assess the dynamic efficacy of the suggested control stratagies [11]-[15]. Lastly, tests for robustness are conducted to demonstrate the controller's stability being implemented.

2. MICRO GRID MODELLING

Figure 1 shows the micro grid modelling-method. The isolated microgrid with a battery (6 Ahr), diesel generator (25 kva), wind source (11 kw) and power energy source (14 kW), that is completely self-sufficient in the subject of this paper [16]-[20]. With a total generation capacity of 2 kW from renewable and manageable sources, the battery is mostly utilized to provide power during brief outages. In order to maximize resource usage and reduce power oscillations in response to changing loads, the article uses CSA with PS as a control approach to use X_o operator.

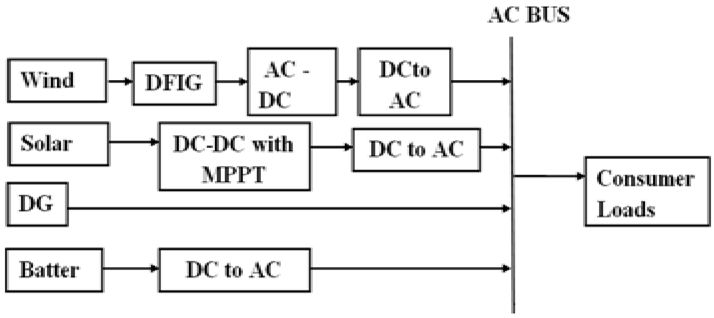

Figure 1. Block diagram of micro grid

2.1. Photo voltaic cell

A semiconductor device namely PV cell that uses the photovoltaic effect which transform solar energy into electrical energy. The output power is provided by:

$$Ppv = nP.C.S.Vdc - npIrs.Vdc.(e\alpha Vdc - 1) \quad (1)$$

Np=no. of PV strings connected in parallel, C=dc-link capacitance, S=solar insolation, Vdc=DC-link array voltage Irs=VSI-current reverse saturation. PV panel and microgrid are combined with PWM controller. In which 4-5 cycles input is transported to output, hence the PV panel transfer function along with MPPT with gain and time constants are provided by:

$$\Delta PS = Ks.\Delta S/1 + S.Ts \quad (2)$$

Ts=Constant converter controllers constant time
Ps=PV (power output)

2.2. Wind energy

With a modification of actual power generation in response to changing speeds of winds, the idea of controlling wind turbine seeks to maximize power output. In order to lessen the wind turbines' ratings, this scenario entails controlling both real power and reactive power generation, especially at wind speeds below their ratings. The equation specifies the maximum amount of wind energy that can be used.

$$PMMAX = ½\, \pi\rho R5\, CPMAX/\lambda 3OPT * \omega 3m \quad (3)$$

Where ρ=density of air, R=radius of blade, ωm=coefficient maximum power, λopt=optional speed ratio of tip.

Here maximum control in power, method is prevailed over by stall regulation in lessen to maintain a steady power output at wind speeds higher than the expected rated level. Therefore, contrary to optimizing for maximum power, the control mechanism switches to a stall regulation technique when wind speeds surpass the specified limit, where M is the maximum power coefficient, R is the radius of blade, Wopt is ideal tip speed ratio, and is air density. The maximum power control is prevailed by stall regulation in order to maintain continuous power at above wind speeds with rated value.

2.3. Diesel generator

Electricity is made easy generated with the help of diesel generators (DG). They are made composed of an electrical generator and a diesel engine. In order to acquire their output to fluctuations in power demand, DGs control is used with fuel supply. Additionally, the excitation of the synchronous generator, which in the context of a diesel generator may be characterized as a first-order transfer function, can be adjusted to regulate the voltage output of the generator.

$$Gg(s) = Kg(s)/1 + sTd(s) \tag{4}$$

Where, Kdg=gain to be thought as 1 and Tdg=DG-time constant and is being contemplating as 2 sec (4) representing the transfer function (governor) of a diesel generator.

A first-order transfer function with particular parameters serves as the governor transfer function when applied to diesel generators. The time constant (Tdg) is fixed at 2 seconds, and the gain (Kdg) is assumed to equal 1. These numbers describe how the diesel generator's governor adapts to fluctuations in power demand and adjusts output.

$$Gdg(s) \ = \ Kdg(s)/1 + sTstg(s) \ * \ Kg(s)/1 + sTg(s) \tag{5}$$

2.4. Battery

Electrochemical galvanic cells that transform chemical energy into electrical energy form a battery. Due to their affordability and simplicity, batteries have become a common power source in a variety of domestic, commercial, and economic applications.

$$Gb(s) \ = \ Kb(s)/1 + sTb\ (s) \tag{6}$$

Where, Kb is gain of battery, Tb is time constant of battery as 1 and 0.1 sec respectively.

2.5. Cuckoo search algorithm

Figure 2 shows the CSA diagram. In 2009 CSA was created by Xin-Shi and Saush Deb as a result of their observations of the obligate brood parasitism present in Cuckoo species. Cuckoo bird behavior served as inspiration for the met heuristic algorithm known as CSA [21]-[25]. The breeding habits of cuckoos and the Levy flight, a style of movement seen in some bird species, are both incorporated into this algorithm. The search process used by CSA is comparable to PSO, but it differs in that it uses a random walk through a Levy flight to more thoroughly explore new search spaces and ultimately produce superior overall results. Similar to how cuckoo birds lay eggs in nests of different bird species, the concept of CSA is akin to that. In this comparison, the cuckoo's female mate fertilizes the bird's eggs. Figure 3 shows the CSA.

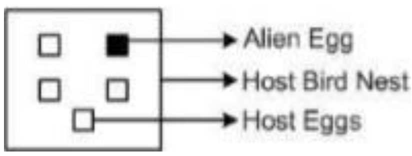

Figure 2. The semblance of CSA

Application of csa to microgrid
Step 1: consider system data and power boundaries fixed for, battery diesel generator and demand on load.
Step 2: consider parameters and constraints of CSA and N_d of nests.
Step 3: provoke and utilizing the provided nests with the random nests upto to 500 nests.
Step 4: iteration count to be fixed as 1, iter=0 and fitness value.

Step 5: by Levy aircraft behavior cuckoos are bought by utilising the random equation nest
(i -) = (Ub-Lb)* rand(Size (Lb)).
Step 6: calculate the value of fitness with no. of nests. By using the (7), ITSE value is computed.

$$ITSE \; = \; 0\int \; t.[\Delta f(t)]2 \, dt \; - \qquad (7)$$

Step 7: take the best fitness value best nest from all the fitness values and take the best nest variable values.
Step 8: iter = iter+1; Find value of fitness, if few <fmin, then sends the nest values to the new nest. Next Add the new values with the best values.
Step 9: find healthiness esteem, such that fnew<fmin, at that moment. Forward the estimations of nest to the new nest then we should update nest with best value and variables of kp, ki, and kf
Step 10: to get the best results and check if the iteration counter reaches the maximum iteration. If not then Go to step 7, else print best solution obtained.
Step 11: the nest which is best will gives the best solution for the gain values of PI controllers of Battery and PV System and outcomes being obtained.
Step 12: stop the process.

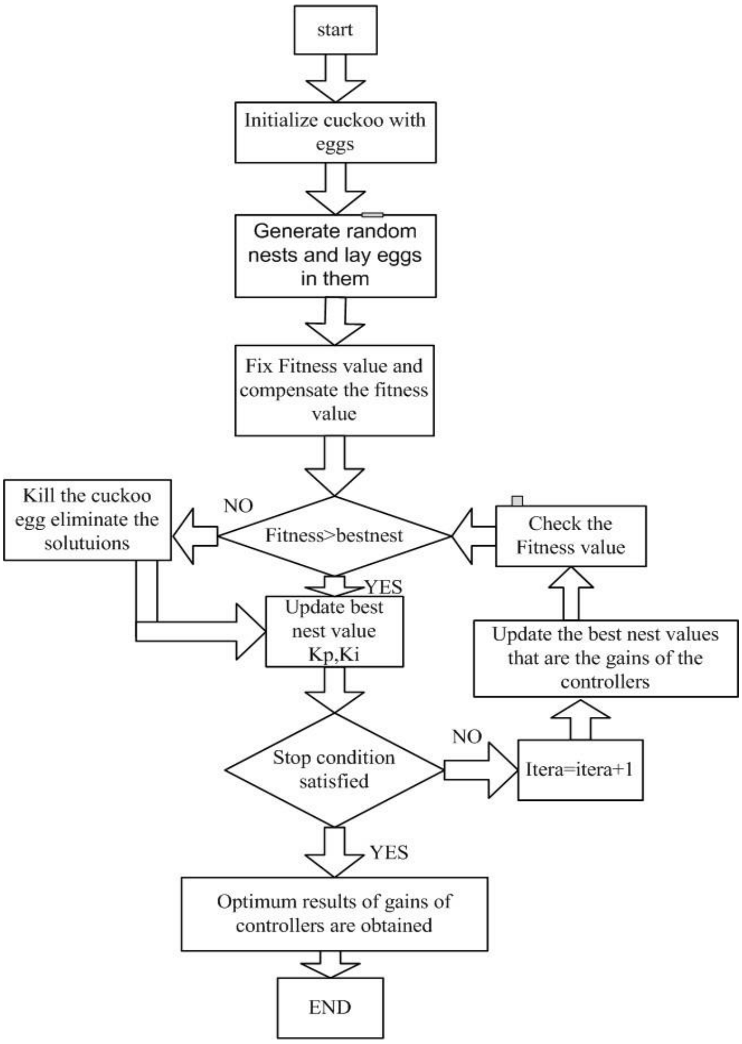

Figure 3. Cuckoo search algorithm

2.6. Pattern search algorithm

A relative algorithm namely pattern search (PS) algorithm is a recently developed algorithm. This PS algorithm has ascendancy it is facile to implement; its idea has simple concept for computation. PS algorithm utilizes a flexible and balanced operator; it enhances the worldwide search and also raises the ability to fine tune the local search. In this paper as a initiation, this algorithm starts its execution with an initial point 'X0' which is considering as the start point of the program execution. The Initial point is used by CSA algorithm. Now, the next iterations will begin at this range of values. It accompishes an improved objective function.

3. SIMULATION ANALYSIS AND RESULTS

A micro grid system consists of a diesel generator (25 kW), a battery (6 kW), wind (11 kW), and solar (14 kW) power sources. Additionally, the system suffers an increase in load demand (3 kW), which is met by the battery and the diesel generator. The objective is to optimize the micro grid system's controller parameters in order to meet certain performance goals, such as lowering operating costs, increasing energy efficiency, or assuring a steady supply of power. Both the traditional (trial and error) method and the CSA method were used for the analysis. The system ran for 60 seconds, and analysis was performed with 10 rounds of CSA optimization for different probabilities.

3.1. Case 1: if solar power decreases when wind power and load are constant

This paper describes a scenario in which solar power production suddenly drops while the load and wind power remain same. A diesel generator has been utilized to provide the extra power needed to fulfill the load demand in order to make up for the lack of solar electricity. Tabel 1 comparing gain values of case 1. This system's controller parameters are optimized utilizing CSA as well as more traditional techniques and Table 1 displays the outcomes. The CSA method has produced more optimal results.

Tabel 1. Comparing gain values of case 1

Parameter	Parameter	Conventional	Cuckoo	PSA(X0)
1	J	1.107 e+004	8210	-1.768
2	Kp (Solar)	40	57.5209	-1.6558
3	Ki (Solar)	35	50.8126	32.451
4	Kp (Battery)	0.2	2.3478	2.084
5	Ki (Battery)	15	52.9738	33.234

3.2. Case 2: when demand in load is higher than constant solar and wind power

Figure 4 shows the comparison of waveform of case 1. A diesel generator (DG) is utilized to make up the generation disparity and meet the load demand in circumstances where the load requirement is greater than the total capacity of wind and solar sources. But the DG cannot react instantly because synchronous machines have inherent inertia. A battery is used to provide electricity in order to fill this brief power gap. For both the solar and battery systems, the optimization method entails fine-tuning four values of gain (Kpb, Kib, Kps, and Kis). Both conventional techniques and the CSA are used for this optimization. Figure 5 shows the comparison of waveform of case 2. It's important to note that the CSA method outperforms traditional methods in terms of minimizing ITSE (integral of time-weighted squared error). This suggests that CSA manages the power supply during transient periods more effectively and with greater performance. Table 2 shows the comparison of gain value in case 2.

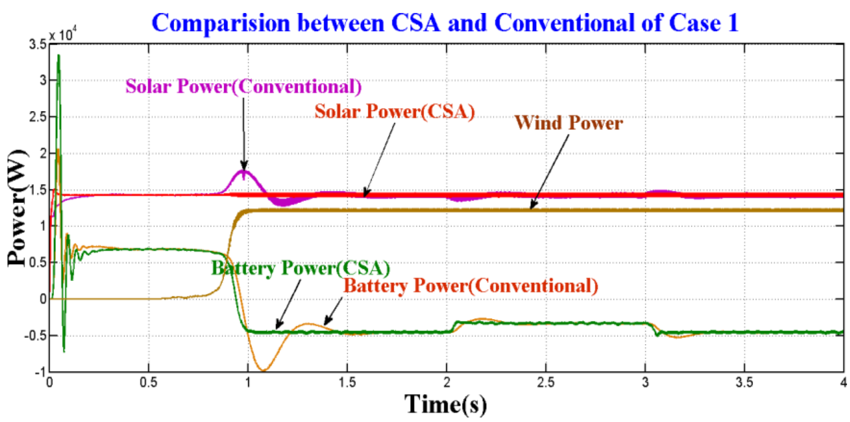

Figure 4. Comparison of waveform of case 1

Table 2. Comparison of gain value in case 2

S. No	Parameter	Conventional values	Cuckoo search algorithm
1	J	1.125 e+0.004	9679
2	Kp (solar)	10	93.3993
3	Ki (solar)	50	576.949
4	Kp (Battery)	4	7.5774
5	Kd (Battery)	35	111.469

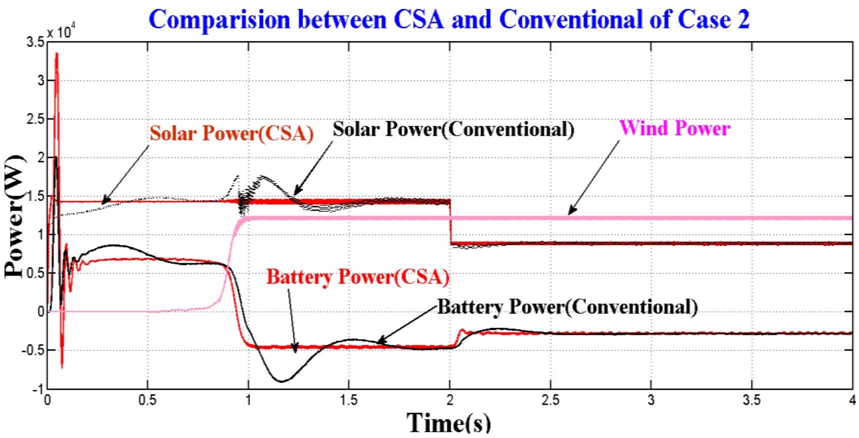

Figure 5. Comparison of waveform of case 2

3.3. Case 3: if wind power reduces load power and solar power are constant

Figure 6 shows the comparison of waveform of case 3. In the event of a rapid decline in wind power generation, with the load and solar power being constant, a diesel generator is used to make up for the loss in wind power. A standard approach and the CSA are both utilized to fine-tune the controller parameters for this system. The results of this parameter optimization process are displayed or reported, displaying how each approach succeeds in adjusting the controller parameters to make sure that there is a steady and dependable supply of electricity even when wind power encounters sharp swings. Table 3 shows the compare gain values of case 3.

Table 3. Compare of gain values of case 3

S.no	Parameter	Cuckoo	Conventional
1	J	7735	1.049 e+004
2	Kp (Gain of solar)	779167	40
3	Ki (Gain of Solar)	793.9091	35
4	Kp (Gain of Battery)	1.2991	0.2
5	Ki (Gain of Battery)	85.3235	15

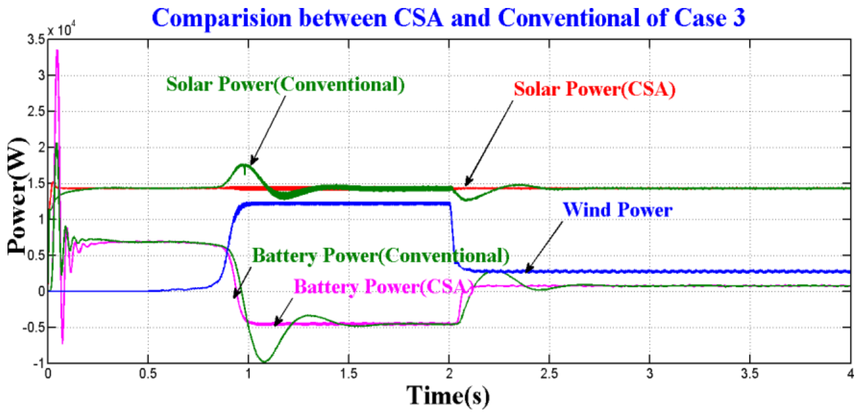

Figure 6. Comparison of waveform of case 3

3.4. Case 4: if wind power and solar power is more than demand of load

The diesel generator remains in a neutral or standby condition when both the solar and wind power sources are producing electricity at their maximum capacity, exceeding the present load requirement. In this case, extra energy produced by the wind and solar systems is stored in a battery for later use, ensuring effective use of the surplus energy when it is required or during times when the renewable sources may not be producing at their peak. This enhances energy efficiency and reduces reliance on the diesel generator. The gain calculus of PI controllers for the PV and battery systems can be ca using both conventional methods and the CSA method. The CSA approach, on the other hand, is used to deal with these problems. It offers assured gain values that prevent overshoots and oscillations and guarantee a steady stream of electricity. CSA is very helpful for enhancing the stability and response time of the control system while streamlining the gain adjustment procedure. In general, CSA aids in enhancing the control system's effectiveness for better power management.

4. CONCLUSION

In this paper Study presents, a hybrid system with a load of 20 kW that of solar, wind, batteries, and a diesel generator is simulated. MPPT trackers are constituted arranged to control maximum output from wind and solar systems, and PI and PID regulators are used to control flow of power between various systems. In order to stop these issues, gain levels should be tuned. Conventional PI controller will decrease the steady state error, because significant overshoots of peak and systems oscillations will still happen. CSA and the trial-and-error approach are both used for fine-tuning the gain values of the PI controller. The outcomes from the approach of trial and error were thoroughly contrasted with the CSA. The results that followed shown that the latter is more effective and best compared with another optimization.

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