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Anticipation of Deep Discharge of Batteries in Solar Panels Based on the Particle Swarm Optimization (PSO)Algorithm

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Abstract. Renewable energy is an alternative type of energy that can be used continuously without fear of environmental pollution. One of the things that can be used to get new renewable energy is using solar panels where later the electrical energy produced will be stored in batteries. A part from the advantages of a battery that can store electrical energy, but if it is used excessively and causes the battery to experience a deep discharge condition, steps are needed to over come it.This study uses the Particle Swarm Optimization method as an auxiliary method. And in this research it has been found that the auto switch system can charge battery 1 and battery 2 when the voltage level is below 11.88V or the DoD is already at 55% and stops charging when the voltage level is above 12.86Vfor battery 1 and batteries 2.

Keywords: Battery, Deep Discharge, Hybrid Generators, PSO Algorithm

1 Introduction

EBT or commonly known as New Renewable Energy is an alternative energy that can be used continuously without worrying that it will run out in the future. In addition, this type of renewable energy is a very clean type of energy because it does not produce pollutants that can pollute the environment. Examples of renewable energy sources include sun, wind, water, ocean waves, geothermal, and biomass. And wind turbines are also being developed to make it even better. In traditional power plants, it was only used as backup energy during power outages, but now it is developing into the main power source, replacing traditional solar and wind power plants Talking about solar panels, it can't be separated from the name batteries which are in charge of storing electrical energy produced by wind turbines or solar panels. One of the problems is using the battery regardless of deep discharge. Deep discharge itself is a condition when the battery energy is below the end discharge or when the battery is below 20%of the battery capacity when the SoC state is present. Many methods are available to predict deep discharge events and other conditions that can shorten battery life. One of them is an artificial neural network method which is better known as an artificial neural network.

2 Literature Review

2.1 Previous Research

Previous research is related to research related to the development of this automatics witch. According to Rimbawatietal in their research entitled Design of Automatic Transfer Switch. From this study it can be seen that when the battery voltage drops below 18 volts, the battery starts charging, but when the battery voltage is between 18 and 23 volts the voltage source switches to PLN, and above 23 volts the voltage source switches to PLN. switch to battery. In this study, PSIM software was used to control the PI using a lifetime charge and discharge and a modified signal conditioning device to achieve optimal results of the solar panel hybrid system.

2.2 EBT Generator

Generators EBT generators are electrical energy generators that use new renewable energy (EBT) sources from nature such as solar, wind, water and geothermal energy. EBT generator is a kind of clean energy and reduces pollution. And considering the amount of fossil fuels that could be lost in the next few years, NRE generators are an effective way to meet the energy demands of human life now and in the future.

2.3 Solar Panel

The sun is the substance that constantly illuminates the earth, sunlight has energy that can be used to generate electrical energy, and generating electrical energy requires tools that can do it, namely solar panels. A solar panel is a device that converts solar energy in to electrical energy, and the electrical energy produced by a solar panel is stored in a battery and used as a primary or back up power source for electronic devices. The solar panels themselves are often called photovoltaic modules or arrays. According to Rahmadhani (2018:2-2) A photovoltaic module is a module that converts solar radiation into electrical energy through haphoto electric process.

2.4 Battery

A battery in a solar panel system acts as a reservoir for the electrical energy successfully converted by the solar panel (array) so that it can later be distributed as a main power source or as a backup for electrical equipment. According to Ramadhani (2018), batteries act as a temporary energy store (buffer) to overcome the difference between power supply and power demand from solar modules. Regarding battery types, we again distinguish between:

a. Primary Battery
Battery This type of battery is not suitable for use as a battery as it is a single use type battery (disposable battery) and cannot be recharged (Sans power, 2021).Storage of electricity in photovoltaic systems. This is because this battery cannot store energy because the electro dematerial cannot reverse direction during discharge.

b. Secondary Battery
Battery This type of battery is a rechargeable battery (Sanspower,2021). It is a usable secondary battery that is suitable for storing power generated by solar panels. Lead-acid for this type of battery

2.5 Inverter

To meet power demand, devices are being developed to convert direct current to alternating current. This is because the excess direct current can be stored in the battery at the same time. This tool is also called an inverter. According to Rashid (inAdena,etal.,2018),inverters typically use a pulse width modulated (PWM) control signal to generate he AC output voltage. The inverter is called a voltage-fed inverter (VFI) when the input voltage is constant, and a current-fed inverter (CFI) when the input current is constant. This is because the inverters them selve shave different out putty pes.

Figure 1. Inverter Type Modified Sinewave 300 Watt (ElliesInverter Datasheet,2018)

2.6 Voltage Sensor

A voltage sensor also plays a role in solving this problem to avoid damaging the microcontroller board, which in this study use san Arduino board with a maximum input voltage of 5V. The sensor uses a DC voltage sensor, which features a 5-way voltage divider principle, so the maximum voltage going into the Arduino board is only 5V.

Figure 2. DC Voltage Sensor

Table1. Examples of DC Voltage Sensor Specifications

Specification	Description
Input Voltage Range	0- 25 VDC
Voltage Detection Range	0.02445- 25VDC
Voltage Analog Resolution	0.00489VDC

2.7 Current Sensor

It functions as a power reader for AC or DC power supplies and acts as a power failure protection. A current sensor type ACS712 is used in this study. According to Allegro(2020),current sensors are components that provide an economical solution for measuring AC or DC current in industry, commerce, or telecommunications. This makes this sensor very useful for measuring the amount of his AC or DC current in electrical circuits that are life support.

Figure 3. ACS712 Current Sensor

Table 2. Example Specifications of Allegro ACS712 Current Sensor

Specification	Description
Single Supply Operation	5 VDC
Output sensitivity	66 -185mV/A
Total output errors	1.5%at25ºC
Bandwidth	80 kHz

2.8 Buck-Boost Converter

ADC-DC converter is perfect for this task. According to Hart, a step-down converter is to add an LC low-pass filter after the switch in the basic converter circuit, allowing current in the inductor to flow through the diode and reverse when the switch is open. The buck converter it self in the circuit is designed to make the output voltage smaller than the input voltage, and the opposite happens in the boost converter circuit. The buck-boost converter can lower or increase the output voltage as needed.

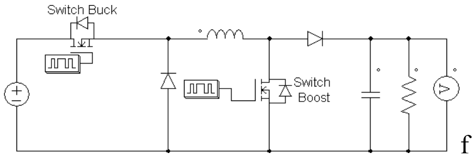

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Figure 4. (A) General Buck-Boost Converter Circuit

For the example in su This chapter will use the DC-DC BuckBoost ConverterXL6009 module which has the following structure and specifications:

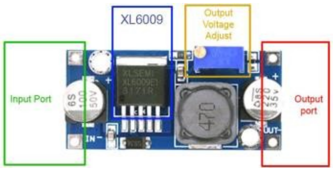


Figure 5. Buck-Boost Converter Series XL 6009

Table 3. Example of Hudson Technology 8 Channel Relay Specifications

Specification	Description
Input Voltage	5- 32 VDC
Output Current	Max.4 A
Maximum OutputVoltage	-0.3-60 VDC
Efficiency	92%
Max. Duty Cycle	0.9

2.9 Particle Swarm Optimization

This section describes the PSO (Particle Swarm Optimization) algorithm used as an optimization in this study so that the data are processed before the LVQ algorithm. The data is then processed by PSO.

2.10 Definition of PSO

This method was developed by James Kennedy and Russ Eberhartin 1995, and flocks of birds and fish were the inspiration for the development of the PSO method. As Isaid earlier, PSO is inspired by flocks of birds. So if you compare this particle to a bird in a flock of birds, the bird has its own intelligence and flock behavior.

According to Dongolan (2017:6) Inits simplest version, particle swarm-based optimization begins by randomly initializing a population of particles and searching for the best fit. Each particle in the PSO algorithm has his three abilities which can be explained as follows.

a The ability of particles to exchange information between particles.
b The ability of particles to remember the initial position/starting point of each particle.
c The ability of particles to make decisions using the information they receive.

Each PSO iterates until the expected result or state (best) is reached, after which the particles are updated with two values (the two best values). These two bests are the first, the highest achieved by each particle, called pbest (personal best), and the second, the overall highest of the particles int he population, It is called gbest (global best). Steps to compile the PSO algorithm:

a. Initialization of many particles, initial velocity of particles, initial position of particles, w (weight), c1,c2,r1,r2,maximum iteration, pbest, and gbest.
b. For each iteration, perform steps a to f as follows. Update the velocity (velocity) of each particle according to Equation.
    1. Update the velocity (velocity) of each particle according to Equation.
       $v_i(t)=v_i(t-1)+c_1r_1(x_{pi}-x_i)+c_2r_2(x_{si}-x_i)$
    2. Update the position of each particle according to Equation.
       $x_i(t)=x_i(t-1)+v_i(t)$

Description:
i=Particle Index.
v_i=Velocity of the i-thparticle.
x_i=Position Particle i.
x_{si}= Best position of all particles (gbest).
x_{pi}=Best position of all particles (pbest).

3 METHOD

3.1 Calculation Analysis

In this subsection, we manually calculate the input (Pin), output (Pout), and efficiencies of the solar panel, wind turbine, and battery capacity calculations used in this study, and check whether the calculated results match the results. Confirm negotiations will take place.

3.3.1 Calculations on Solar Panels

A solar panel calculation is performed to determine the input and output power produced by the solar panel using the following calculations:

a. Calculation of the received power or input solar panel(Pin) according to Equation.

$$P_{\text{in}}=Ir\,x\,A$$

Description:
Pin=Solar panel input power (watts).
Ir=Intensity of solar radiation(watt/m2).
A=Solar panel surface area(m2).

b. If the solar intensity is known in Lux units, it must be converted to watts/m2 Equation below.

$$1 lux=0{,}0079 watt/m2$$

c. Calculation of solar panel output(Pout)

1. Determination of total load power (EB) in Watt Hour (Wh).

$$E_{\text{B}}=\Sigma P_{\text{load}}\, x\, t_{solarcell}$$

Description:
EB=Total Load Power (Wh).
ΣP_{Load}= Total Load Power (Watts).
$t_{\text{solarcell}}$=Length of Use of Solar Panels(Hour)

2. Determination of System Load (EA) in Watt Hour (Wh).

$$E_{\text{A}}=33{,}3\%\, x\, E_{\text{B}}$$

Description:
EA=System Load (Wh).
EB=Total Load Power(Wh).

3. Determination of total energy use (ET) in Watt Hour (Wh) with the assumption of losses.

$$E_{\text{T}}= E_{\text{A}} + Losess E_{\text{T}} \quad =E_{\text{A}}+(15\%\, x\, E_{\text{A}})$$

Description:
ET = Total Energy Consumption (Wh).EA =System Load(Wh).
15%=Assumption of Losson the system due to the system is still new.

4. Determination of the output power (Pout) on the solar panel in Watt.

$$Pout = \frac{Et}{t\ panelsurya}\ x1{,}1$$

Description:
Pout = Solar Panel output power (Watts).
ET=Total Energy Consumption (Wh).
1.1 =Multiplier.

d. The efficiency of the solar panels can be calculated using the following Equation.

$$\eta=\frac{P_{\text{out}}}{P_{\text{in}}}x100\%$$

A 30Wp capacity solar panel is used in this study. Refer to the 30W psolar panel specifications in the table below to determine the Pin and Pout sizes and solar panel efficiency.

Table 4. SolarPanelSpecifications30Wp

No.	30Wp.SolarPanelParameters	ParameterValue
1.	*Maximum Power*(PMPP)	30W
2.	*Maximum Power Voltage*(VMPP)	17.8V
3.	*Maximum Power Current*(IMPP)	1.69A
4.	*Open Circuit Voltage*(VOC)	21.8V
5.	*Open Circuit Current*(IOC)	1.85A

Before calculating Pin and Pout for a 30Wp solar panel, we need to compare the solar cross section of the30Wpsolar panel with the calculation using equation.

A=pxl

A=350 mmx650 mmA=0,35mx0,65m

A=0,2275m^2

Based on the solar panel input power results, once the solar panel cross-sectional area is determined, the input Power calculation using the light intensity data can be calculated as follows:

a. Example of Calculation of Input on Day1
   P_{in}=132.000lux$x$ 0,2275m^2
   P_{in}=(132.000lux$x$0,0079watt/m^2)x0,2275$m^2$$P_{in}$=237,28watt
b. Example of Calculation of Input on Day2
   P_{in}=134.100lux$x$0,2275m^2
   P_{in}=(134.100lux$x$0,0079watt/m^2)x0,2275$m^2$$P_{in}$=376,19watt
c. Example of Calculation of Input on Day3
   P_{in}=129,900lux$x$0,3551m^2
   P_{in}=(129.900lux$x$0,0079watt/m^2)x0,3551$m^2$$P_{in}$=346,41watt
d. Solar panel load calculation:
   With load 1 piece ACLED lamp 9watts
   1. System Load
      EB=PLoad x tsolar panels EB=9 wattsx10hours
      EB=90Wh
   2. Total Load Power EA= 33.3% x EBEA=33.3%x90WhEA=29.97Wh
   3. Total Energy Consumption ET=EA+ (15%x EA)
      ET=29.97Wh+(15%x29.97Wh)
      ET=29.97Wh+ 4,495 Wh
      ET=34,465Wh
   4. Solar Panel Output Power
      Pout =3,4465Watt x1,1
      Pout =3,791 Watt
e. Efficiency

$$\eta=\frac{P_{out}}{P_{in}}x100\%$$

$$\eta=\frac{3,791watt}{307,401watt}$$

η=1,223%

3.2 VRLA Battery Calculation

This section describes the characteristics of the VRLA battery type 12V 18Ah battery used in this study. The specifications of the 12V18Ah VRLA battery are in Table (A)below.

Table 5. 12V18Ah VRLA Battery Specification

No.	12V18AhBattery BatteryParameters	ParameterValue
1.	*BatteryCapacity*(CBattery)	18 Ah
2.	*BatteryVoltage*(vbattery)	12V
3.	*CycleUse*	13.8 V - 14.4V

Table 6. (B) Lead Acid Battery SoC Characteristics

BATTERYSTATEOFCHARGE	
Lev	Voltage

el	
100%	13.00 V
90%	12.75 V
80%	12.50 V
70%	12.30 V
60%	12.15 V
50%	12.05 V
40%	11.95 V
30%	11.81 V
20%	11.66 V
10%	11.53 V
0%	10.50 V

The characteristics of the SoC it self are closely related to the DoD of lead-acid batteries. For example, if the SoC of a lead-acid battery is 80%, the DoD of the battery is 20%, or the battery capacity is used 20%. When the lead-acid battery SoC reaches amber level, the battery must stop supplying load or stop discharging. After that, the lead-acid battery life is shortened and the battery needs to be recharged. If the battery SoC is at the red level and the battery continues to discharge, the battery will enter an over-discharge state and will no longer be able to charge. Continuous excessive discharge of the battery can damage the battery or significantly shorten the battery life.

To calculate the time for the battery to discharge in the load, it can be calculated using the following formula:

a. Starting from equation 3.26 where the maximum power (PMax) of the battery will be sought below.

$$Pmax=60\%xCBattery\ x\ V\ battery$$

Description:
Pmax =Maximum Battery Power(Wh).
CBattery =Battery Capacity(Ah).
Vbattery =Battery Voltage(V).

b. The power used during loading will also be calculated to find out how much voltage limit the load can use.

$$Puse=(Vbattery-Vdrop)\ x\ CBattery$$

Description:
Puse = Power used Load (Wh).
CBattery =Battery Capacity(Ah).
Vbattery =Battery Voltage(V).
Vdrop =Lower Limit of Battery Voltage at the level of 11.95v

c. After knowing the maximum power of the battery, it can be calculated the length of use of 1 battery until the condition of the battery must be charged before being used again.

$$T_{Baterai} = \frac{(P\ max - P\ use)\sum \square}{P\ beban}$$

Description:
TBattery=Battery Usage Time.
Pmax= Maximum Battery Power (Wh).
PLoad=Load Power(W).

Single-phase AC loads are used as the loads shown in the table below, with two types of loads: fan loads and LED lights.

Table 7. (C) Load Calculation used for VRLA Battery

No.	**Load**	**Amount (Units)**	**Power Device (Watt)**	**Total Power (Watt)**
1	Miyako Fan	1	35	35
2	LEDLight	1	9	9
	Total(PLload)			44

After knowing the battery capacity that will be used and the load to be used, it can be calculated manually using Equation

a. PMax= 60% x CBattery x Vbattery
   PMax = 60% x 18 Ah x 12.95
   VPMax=139,86Wh
b. Puse= (Vbattery- Vdrop) x CBattery
   Puse=(12.95 -11.95)Vx18Ah
   Puse= 1V x18Ah
   Puse=18 Wh
c. $T = \frac{(Pmax-Puse)}{\sum Pbeban} = \frac{121,86\,Wh}{44W}$ = 2,7/Hours= 2 Jam 46 menit

3.3 PSO Method Test

To be able to compute the results of the PSO algorithm, we can use the formulas already presented in Chapter2. For example, the computation consists of computing the training results of the PSO algorithm using only inputs from the vertical wind turbine (TAV). Allows generation of new configuration values. To be able to compute the results of the PSO algorithm training, we need an objective equation(the fit equation). This will give us the PBest and GBest results and allow us to update the particle velocities so that we can also update the particle position results. Like wise.

3.4.1 PSO Goal Equation

Before computing the PSO algorithm, we need the objective equations (fitting equations) that allow us to determine the PBest and GBest results.

If 13,8≤ xv1≤13,9
For 11,95≤ xv2, xv3≤12,95
If 0≤ xi1≤1,2
For 0≤ $xi2, xi3$ ≤2,

3.4.2 Initial Particle Position

After obtaining the desired equation, the initial particles position (x0) is randomly generated along with the initial particle velocity (v0) and through the PSO algorithm he is used to find Pbest and Gbest.

Table 8. PSO Method Training Parameters

Parameter	Description
C1	2.2
C2	1.8
	0.9
N	30
Maxepoch	50

A. PSO initialparticles

PSO randomly generates the initial positions of the particles and the number of particles generated is 30 particles according to the information in the table. Each particle contains six variables:

1. 1st particle (f1) 3.28th particle (f28)
   x_{v11}(0)=13.84 (0)=13.81x_{v128}
   x_{v21} (0)=12.53 (0)=12.84x_{v228}
   x_{i21}(0)=2.73 (0)=0x_{i228}
   x_{v31}(0)=12.15 (0)=11.94x_{v328}
   x_{i31}(0)= 0 (0) =0x_{i328}
2. 16th particle(f16)
   $x_{v1\,16}$ (0)=13.86
   x_{i116}(0)=1.26
   x_{v216}(0)=12.06
   x_{i216}(0)=2.73

$x_{v316}(0)=12.59$
$x_{i316}(0)=0$

Up to the 30th particle (f30) and then from each particle position 1 (f1) to the 30th particle(f30), the Pbest and GBest values for each particle are determined using the desired equations.

$f1=f(x_{v1},x_{i1},x_{v2},x_{i2},,x_{v3},x_{i3})=13,84+2x1,25+3x12,53+4x2,73+5x12,15+6x0=125$
$f16=f(x_{v1},x_{i1},x_{v2},x_{i2},,x_{v3},x_{i3})=13,86+2x1,26+3x12,06+4x2,73+5x12,59+6x0=126$
$f28=f(x_{v1},x_{i1},x_{v2},x_{i2},,x_{v3},x_{i3})=13,81+2x1,26+3x12,84+4x0+5x11,94+6x0=112$

Calculate each particle using the Excel application using the example calculation above, and after the calculation is obtained as above, the particle PBest PSO used in the above calculation is the 1st iteration and GBest is obtained from the computation result. These produce a minimum value of 112 at the 28th particle count.

1. PBest1
   PBest1 1 =13.84
   PBest1 2 =1.25
   PBest1 3 =12.53
   PBest14 =2.73
   PBest1 5 =12.15
   PBest1 6 =0
2. PBest 16
   PBest16 1 = 13.86
   PBest16 2 = 1.26
   PBest16 3 = 12.06
   PBest16 4 = 2.73
   PBest16 5 = 12.59
   PBest16 6=0
3. PBest28 GBest=PBest28
   PBest28 1= 13.81
   PBest282 =1.26
   PBest283 =12.84
   PBest284 =0
   PBest285 =11.94
   PBest286 =0

B. PSO Initial Speed

Determine the initial velocity of each particle,1 through 30,as follows:
$v1(0)=v2(0)=v3(0)=v4(0)=v5(0)=v6(0)=0$

C. Updating Particle Speed and Position

Once we have PBest and GBest, the next step is to compute the particle velocity and position in the first iteration. PSO gets new particle position and velocity results.

$v_i(t)=\omega x v_i(t-1)+c_1r_1(x_{pi}-x_i)+c_2r_2(x_{si}-x_i)$

Then the computation for updating the velocity is taken from the computation of the first particle, for example: where r1 and r2 have values of 0.5 and 0.7and c1 have values of c2.

1. $v1\ 1(1)=0,9x0+2,2x0,5(13,84-13,84)+1,8x0,7(13,81-13,84)$
   $v_{11}(1)=-0,0378$
2. $v_{12}(1)=0,9\ x0\ +2,2x0,5(1,25-1,25)+1,8x\ 0,7(1,26-1,25)$
   $v_{12}(1)=0,0126$
3. $v_{13}(1)=0,9x0+2,2x0,5(12,53-12,53)+1,8x0,7(12,84-12,53)$
   $v_{13}(1)=0,3906$
4. $v_{14}(1)=0,9\ x0\ +2,2x0,5(2,73-2,73)+1,8x0,7(0-2,73)$
   $v_{14}(1)=-3,124$
5. $v_{15}(1)=0,9x0+2,2x0,5(12,15-12,15)+1,8x0,7(11,94-12,15)$
   $v_{15}(1)=-0,2646$
6. $v_{16}(1)=0,9\ x0+2,2x0,5(0-0)+1,8x0,7(0-0)$
   $v_{16}(1)=0$

Update the particle position using the following formula:

$$x_i(t)=x_i(t-1)+v_i(t)$$

And the computation that updates the particle's position on the first particle is the next computation.

1. $x_{11}(1)=13,84-0,0378$ $x_{11}(1)=13,8022$
2. $x_{12}(1)=1,25+0,0126$ $x_{12}(1)=1,2626$
3. $x_{13}(1)=12,53+0,3906$ $x_{13}(1)=12,9206$
4. $x_{14}(1)=2,73-3,124$ $x_{14}(1)=-0,394$
5. $x_{15}(1)=11,94-0,2646$ $x_{15}(1)=11,6754$
6. $x_{16}(1)=0+0$ $x_{16}(1)=0$

After receiving new particle positions and velocities, the particles are re-evaluated using the objective equations to see if the Pbest and GBest values have changed. You can also see the final results of her PSO training up to 50 repetitions.

4 Resul and Discussion

4.1 Test of Voltage Sensor and Current Sensor

This section presents the test results of four DC voltage sensors and four ACS20A current sensors tested to measure the voltage and current of a 12VDC dynamo load. Also, the experimental results for voltage and current sensors are shown below.

4.1.1 Voltage Sensor Test

After obtaining the test data for voltage sensor 1, use the circuit shown below. Then measure the voltage with a multimeter and a DC voltage sensor. The successfully determined data are then entered into the table below. This table contains the results of voltage measurements on his12Vdynamo using a voltage sensor and a multimeter.

Table 9. The First Test Result Data Voltage Sensor

Test	Sensor ADC Value	Voltage on Sensors(V)	Voltage on Multimeter (V)	*Error* (%)
1	550	13.43	13.70	2.01
2	537	13.13	13.70	4.34
3	557	13.60	13.70	0.74
4	546	13.35	13.70	2.62
5	552	13.50	13.70	1.48
6	550	13.45	13.70	1.86
7	545	13.33	13.70	2.78
8	554	13.55	13.70	1.11
9	548	13.40	13.70	2.24
10	554	13.55	13.70	1.11
		Average		2.03

From the table above, we can see that the highest error result is 9.22n, the lowest is 0.88n, and the average voltage sensor error is 2.41%

4.1.2 Voltage Sensor Test

After acquiring the test data for voltage sensor 2 in the circuit shown below. Then measure the voltage with a multimeter and a DC voltage sensor. Successfully determined data are entered into a table of voltage readings on a 12V dynamo with a voltage sensor and multimeter.

Table 10. The Second Voltage Sensor Test Result Data

Test to-	Sensor ADCV alue	Voltage on Sensors (V)	Voltage on Multimeter (V)	*Error* (%)

1	546	13.35	13.69	2.55
2	546	13.35	13.69	2.55
3	543	13.28	13.70	3.16
4	554	13.55	13.70	1.11
5	545	13.31	13.70	2.93
6	546	13.35	13.69	2.55
7	545	13.33	13.70	2.78
8	554	13.55	13.70	1.11
9	548	13.40	13.69	2.16
10	546	13.35	13.69	2.55
		Average		2.34

From the table above, we can see that the maximum error is 9.22n, the minimum is 0.88n, and the average error of the voltage sensor is2.41%.

4.1.3 Current SensorTest1

Once you have the current sensor test data, use the circuit shown below. Then measure the current with a multimeter and current sensorACS712 20A.

Table 11. The First Current Sensor Test Result Data

Test to-	Sensor ADC Value	Current on Sensors (A)	Current on Multimeter (A)	*Error*(%)
1	516	0.195	0.21	7.69
2	516	0.195	0.22	12.82
3	522	0.244	0.24	1.64
4	522	0.244	0.21	13.93
5	516	0.195	0.20	2.56
6	516	0.195	0.18	7.69
7	514	0.171	0.18	5.26
8	519	0.220	0.20	9.09
9	516	0.195	0.20	2.56
10	519	0.220	0.20	9.09
		Average		7.23

From the table above, we can see that the maximum error is 13.93n, the minimum is 2.56n, and the average error of the voltage sensor is 7.23%.

4.1.4 Current SensorTest2

After receiving the test data of the second current sensor having a circuit according to the circuit. Then measure the current with a multimeter and an ACS712 20Acurrent sensor.

Table 12. The Second Current Sensor Test Result Data

Test to-	Sensor ADC Value	Current on Sensors (A)	Current on Multimeter (A)	Error (%)
1	516	0.195	0.21	7.69
2	516	0.195	0.22	12.82
3	522	0.244	0.24	1.64
4	522	0.244	0.24	1.64
5	516	0.195	0.22	12.82
6	516	0.195	0.22	12.82
7	514	0.171	0.20	16.96
8	516	0.195	0.21	7.69
9	519	0.220	0.21	4.55
10	519	0.220	0.20	9.09
6	516	0.195	0.22	12.82

Average	8.77

From the table above, we can see that the maximumerroris16.96n, the minimum is1.64, and the average voltage sensor error is8.77%.

4.4 Integrated Testing

The test results are also presented in this section without the method, the LVQ method, the PSO method, and the LVQ-PSO method.

5.5.1 Test Without Method

Tests without methods are divided in to three tests. That is, tests with inputs from solar panels only, vertical wind turbines only, and solar panels and vertical wind turbines(EBT hybrid). This test ensures that when the battery is discharged, the battery is in an over-discharge state or his DoD (Depth of Discharge) state of the battery does not exceed 60%.

5.5.2 Testing with Input from Solar Panels

Current testing uses a 30Wp solar panel input used as a power source to charge the battery. The data obtained from the test results are presented in the table below. The test results use the battery 1 or battery 2 charge or discharge settings as shown in the table.

Table 13. Set Point for Battery Charge and Discharge with PV Input

No.	Parameter	SetPoint
1	VOutBuck-BoostPV	13.80V
2	IOutBuck-BoostPV	1.20 A
3	VChargemacBat1	12.95V
4	IBat1	2.70 A
5	VChargemacBat2	12.95V
6	IBat2	2.70A
7	VDischargemax Bat1	11.95V
8	VDischargemax Bat2	11.95V

After getting the set point as in the table above, the results of the input and output data from the solar panel which is used as a supply for charge and battery 1 and battery 2 are as shown in the table below.

Table 14. Solar Panel Input and Output Data Results

O'clock	Lux meter LightIntensity (Lux)	VIN PV(V)	IIn PV(A)	VOut Buck Boost PV (V)	IOut BuckBoostPV (A)
08.00	102,600	17.81	0.57	13.83	1.21
08.30	111,500	18.93	0.61	13.84	1.23
09.00	132,000	19,90	0.65	13.85	1.26

O'clock	Lux meter LightIntensity (Lux)	VIN PV(V)	IIn PV(A)	VOut Buck Boost PV (V)	IOut BuckBoostPV (A)
11.00	168.000	19.67	0.69	13.88	1.27
11.10	169,300	19.69	0.68	13.87	1.28
11.40	169,800	19.78	0.68	13.86	1.25
12.10	171,200	19.80	0.68	13.88	1.26
12.40	166,400	19.74	0.66	13.87	1.28
13.10	154,500	19.70	0.69	13.86	1.27
13.40	120,500	19.69	0.67	13.88	1.26
13.50	73,700	19.67	0.66	13.87	1.25
14.10	66,400	19.68	0.67	13.86	1.27
14.20	63,200	19.66	0.64	13.87	1.27
14.50	44,600	19.70	0.65	13.87	1.26
15.20	38.000	19.56	0.66	13.85	1.26
15.50	22,800	18.78	0.58	13.86	1.23
16.00	20,300	18.60	0.56	13.83	1.22

The VOut and IOut data of the buck/boost converter are reused in the table as the power source to charge the battery when the voltage drops below the 11.95V voltage level. See Battery 1 or Battery 2, which should be charged first. In the initial state, the voltage of the first battery is12.95Vandthevoltageof the second battery is 11.94V.

4.5 VRLA18AhBatteryTrial

This experiment describes a battery test where the battery is charged with a single-phase AC load, is a 35 Wattfananda9WattACLEDlamp.Thebatterytestalsoshowsdata from his SoC and DoD for batteries charged with 2direct loads. To load the data obtained after testing the battery, the data are shown in the table below.

Table 15. Battery Discharge Test Data

No	Load Power (Watt)	Battery Parameters		Loading Time (minute)	SoC (%)	DoD (%)
		Voltage (V)	Current (A)			
1	44	12.98	2.71	0	100	0
2		12.76	2.73	30	92	8
3		12.53	2.70	60	83	17
4		12.33	2.72	90	74	26
5	44	12.19	2.73	120	63	37
6		12.04	2.71	150	50	50
7		11.94	2.38	160	40	60

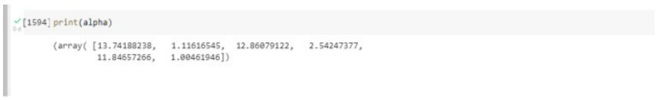
When the time reaches 166 minutes, the battery voltagedropsbelow11.95Vandonly40% of the battery SoC remains, so the battery should be disconnected. You can see that the battery voltage and current ratings continue to drop as the battery continues supply the 44 watt A Cload.

4.6 Testing with PSO Method

That is testing with input from solar panels only, test vertical wind turbines only, and solar panels and vertical wind turbines. This test uses the PSO algorithm method to prevent the battery from over-discharging or the DoD state of the battery when the battery does not exceed 60%.

4.6.1 Testing with Input from Solar Panels

Current testing uses a 30Wp solar panel input used as a power source to charge the battery. The data obtained the results are presented in the table below. Before running the experiment, new settings for battery charging and discharging a reset using the PSO algorithm.



```
[1594] print(alpha)

    (array( [13.74188238,   1.11616545,  12.86079122,   2.54247377,
              11.84657266,   1.00461946])
```

Figure 6. PSO Algorithm Learning Results with PV Input

Once the learning results are obtained, the new settings for Battery1or Battery2 are charged or discharged as shown in the following table

Table 16. LVQ Algorithm Learning Results with PV Input

No.	Parameter	*Set Point*
1	VOutBuck-BoostPV	13.74V
2	IOutBuck-BoostPV	1.12 A
3	VChargemacBat1	12.86V
4	IBat1	2.54 A
5	VChargemacBat2	12.86V
6	IBat2	2.54 A
7	VDischargemax Bat1	11.85V
8	VDischargemax Bat2	11.85V

Table 17. Solar Panel Input and Output Data Results with the LVQMethod

	Lux			**VOut**	**IOut**
O'clock	meter Light intensity (Lux)	VIN PV(V)	IIn PV(A)	Buck Boost PV (V)	Buck Boost PV (A)
08.00	110,600	17.81	0.57	13.83	1.21
08.30	119,500	18.93	0.61	13.84	1.23
09.00	123,000	19,90	0.65	13.85	1.26
09.30	131,000	19.86	0.67	13.84	1.26
10.00	144,100	19.77	0.66	13.85	1.28
10.30	156600	19.72	0.68	13.87	1.26
11.00	168.000	19.67	0.69	13.88	1.27
11.30	169,800	19.78	0.68	13.86	1.25
12.00	171,200	19.80	0.68	13.88	1.26
12.30	179,400	19.74	0.66	13.87	1.28
13.00	154,500	19.70	0.69	13.86	1.27
13.30	120,500	19.69	0.67	13.88	1.26
14.00	100,200	19.66	0.64	13.87	1.27
14.30	90,600	19.70	0.65	13.87	1.26
15.00	50,500	19.56	0.66	13.85	1.26
15.30	45,600	18.78	0.58	13.86	1.23
16.00	30,300	18.60	0.56	13.83	1.22

The VOut and IOut buck-boost converter data are reusedin the table as a power source for battery charging when the first battery voltage is below 11.85V and the second battery is below 11.85V.vertical wind turbines only, and solar panels and vertical wind turbines. This test uses the PSO algorithm method to prevent the battery from over-discharging or the DoD state of the battery when the battery does not exceed 60%.

5 Conclusions

The conclusions that can be drawn from this study are the buck boost converter modul estabilizes the input voltage of solar panels (PV) and vertical wind turbin (TAV) with an output voltage of 13.83V to 13.88V at an output current of 1.25A after testing and integrated test trials. You can 1..28A The PSO method charges the first battery and his second battery when the voltage level drops below 11.88V or when the DoD is already at 55. In the LVQPSO method, if the battery level is low and the voltage drops below 11.90V or the DoD is already 58, the second battery will be charged. The voltage level of the first battery is 12.88 Vand the voltage level of the second battery is12.90V.

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