An-Najah National University

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"LOAD SCHEDULE AND MANAGEMENT FOR RELIABILITY IMPROVEMENT OF PV OFF-GRID SYSTEM"

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ABSTRACT

This project presents an energy management control strategy for reliability improvement of PV-standalone system.

The control algorithm is proposed to reduce the loss of load probability (LLP), for critical loads or load of high priority, on the other hand to keep the battery working under specific healthy conditions to extend the life span of the battery storage as it represents highly cost component in off grid PV-system.

The simulation results have been carried out by using MATLAB software to verify the effectiveness of the proposed control algorithm.

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1 INTRODUCTION

Nowadays, according to increase the fuel consumption and decline the fossil fuel sources, economic and political trends toward using the renewable a clean energy sources are getting more attention. In this case, some energy sources such as solar energy, wind are in top priority because of their accessibility and abundance. Stand-alone hybrid green power generation (SHGP) produce power at lower costs and/or higher reliability.

Renewable energy is the main source of energy in rural areas, especially solar energy. The matching between the load demand and the PV system can lead to critical problem in stability of the system, so must be cutoff loads due to no alternative sources exists, but this will reduce the reliability of the system, therefore the optimal control over system loads and the battery storage can be employed to reduce the loss of load probability, get better energy management efficiency and reduce the size of PV system. This tasks can be achieved using priority load control. Furthermore, with this type of control, the energy for critical loads can be guaranteed, given reliability to PV system.

In the literature, there are a few studies related to energy management of stand-alone PV system. Among them, Mahrane et al.[1], presented algorithm to management of the energy storage in stand-alone PV system. Groumpos and Papegeorgiou [2], proposed an optimum load management strategy for stand-alone PV systems. Guzman et al.[3], proposed a priority load control algorithm for optimal energy management in stand-alone PV systems. However, one of the previously cited works did not take into account priority load and priority battery SOC [1]. Others, adopted to increase reliability of the system on reduce the size of PV system, therefore this will reduce the total life cycle cost of the system.

This project presents energy management strategy based on the classification of loads into three categories depends on their priority and classification of battery SOC into three categories depends on priority levels, this strategy aims to increase the performance and the reliability of the system avoiding the need to change the size of PV system. And it's describes a stand-alone PV system used for the development of a priority load control algorithm using MATLAB programing, explains some significant problems of off-grid systems as when the power of PV are not enough to run all the loads then needs to scheduling system to do that at the same conditions, so the main goals to be achieved are the following:

- ✓ Optimize the energy supply to provide energy to highest priority loads.
- ✓ Reduce the loss of load probability (LLP) for critical demand.
- ✓ Increase the reliability of the stand-alone PV system.
- ✓ Make the system more stability.

2 MODELING OF STAND-ALONE PV SYSTEM

The stand-alone power system consists of some of main components like the following: PV array, charge controller, battery bank, inverter and the loads, the following figure showing the configuration of a stand-alone PV system. But in our design needs to model of PV and battery, and no needs to sizing for the other components.

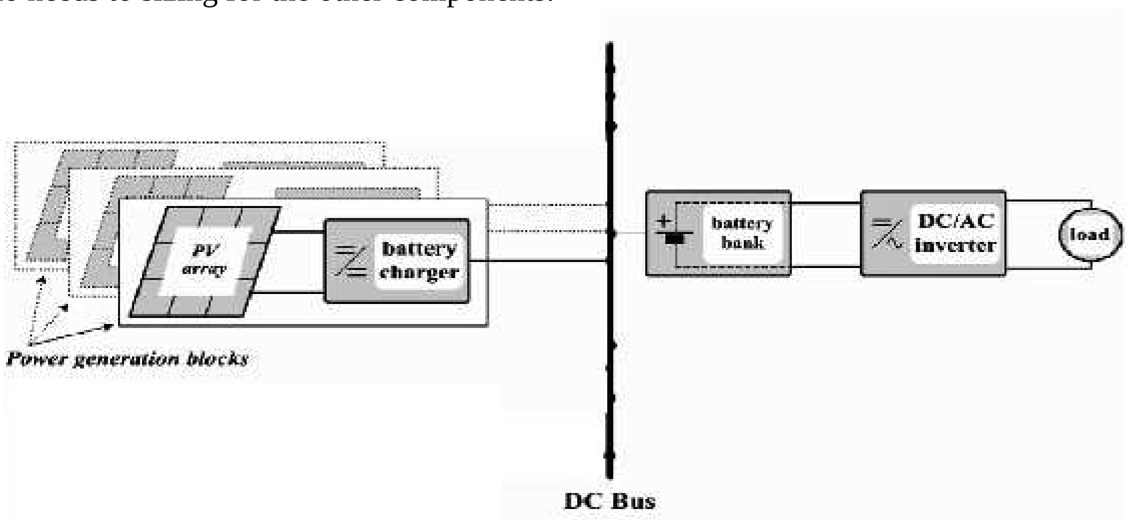


Fig.2.1: "Schematic of stand-alone pv system."

2.1|PV Model:

PV panels supply electricity based on the collected local solar radiation and temperature data hourly to meet loads.

The estimation power generated from PV array can be expressed as the following: [4][6]

$$= \ast (\frac{(\,)}{}) \ast [+ \ast (+ . \ast (\,) -)] \qquad (.)$$

h :

P , T : $hi\,h$ h ,
$i\,i$ i y.

$(\,)$: $i\,i$ $i\,i$ h i .

K_T: T $i\,i$.

T : A i .

2.2|Battery Models:

2.2.1|Charging model:

The charge capacity of battery bank of charging state can be exspresed as the following: [5][6]

$$( ) = (-) * (- \sigma) + [( ) - \frac{( )}{\eta}] * \eta \quad (.)$$

On the other hand, the battery bank is in discharging state, assumed the discharge effeciency of battery bank is 1.

2.2.2|Discharging model:

The charge capacity of a battery bank of dicharging state can be expressed as the following: [5][6]

$$( ) = (-) * (- \sigma) + [\frac{( )}{\eta} - ( )] \quad (.)$$

Where:

( )and (−) are the charge capacity of battery bank at ( ) and (−) respectively.

σ is hourly self discharge rate assumed is zero.

( ) i h y $y P$ y y h .

( ) is load demand at( )

η and η are the effeciency of the inverter and battery bank respectively.

3 SIZING OF SYSTEM COMPONENTS

The sizing objective of standalone PV system is a critical balance between energy supply and demand. Sizing of the PV array, inverter and battery bank for a stand- alone PV system is an important part of system design.

3.1|Load Estimation:

Estimating the electrical loads, it considered the first step in PV system to quantify the magnitude and duration of the electrical loads.

The daily energy requirement for the electrical loads is determined by product of the load power and operation time, expressed in units of watt-hours (WH).

Electrical loads vary with respect to the performance of the consumers.

3.2|PV Panel Sizing:

The size of PV panel must provide enough energy to meet the electrical loads plus system losses under the worst-case conditions.

The **Peak Sun Hours** (PSH) is calculated as the following equation: [8]

$$= \frac{\quad}{\quad} \qquad (.)$$

: $Th \quad iy \qquad i\ i\ i \quad iy\,[K\ /2-\ y]$.

: $Th \qquad i\ i\ i \quad iy = 1000\ /2$.

Considering a safety factor of SF, then the peak power of the PV generator (PPV) is calculated as the following equation: [6] [7]:

$$= \frac{*}{\eta * \eta *} (.)$$

:

: i h i y y i i [K h].

: i h h i [h].

η : i h i i y i .

η : i h i i y h .

: i h y i i i P –

.

3.3|Battery Bank Sizing:

Battery size is a design variable, and is generally based on the desired autonomy period, maximum allowable depth of discharge (DOD). The life of battery is a function of DOD. Similar to the load energy calculation, the amount of battery storage capacity is expressed in units of watt-hours (WH).

The watt-hour capacity (CWh) of the battery bank, necessary to cover the load demands for a day without sun, is obtained as in the following equation:

$$= \frac{[*]}{[\eta * \eta *]} (.)$$

h i y y h i i (y) y h y

y y h i h h i y i

h P . [6][7]

3.4|Charge Controller (Regulator) Sizing:

The voltage regulator is typically rated against amperage and voltage capacities. The voltage regulator is selected to match the voltage of PV array and batteries. A good voltage regulator must have enough capacity to handle the current from PV Array.

3.5|Inverter Sizing:

In sizing the inverter, the actual power drawn from the appliances that will run at the same time must be determined as first step. Also to allow the system to expand, we multiply the total power of the load value by a safety factor of range [1.2 – 1.3].

4 OPTIMIZATION AND FLOW CHRAT PROCEDURES

4.1|Approach to Optimization:

The loads are classified according their priority in three categories: very important (priority 1), semi-important (priority 2), and low important (priority 3).

The battery SOC classified into 3 priority levels: above or equal 0.75, above or equal 0.50 and less than 0.75, above or equal 0.22 and less than 0.50.

4.2|Reliability of stand-alone PV system:

4.2.1|Loss of power supply probability (LPSP): LPSP defined as being the fraction of the deficiency energy and that required by the loads, LPSP can be estimated by the following equation:[5]

$$= \sum_{=} ( ) / \sum_{=} ( ) \qquad (.)$$

:

$( ) = ( ) - [( ) + (-) -] * \eta$

$( )$: h .

$( )$: i h y yP y y h .

$( ) = ( ) * \eta$.

$(-)$: h h i i y h i (-1).

: h i i h i y y .

η: h i i y i .

4.2.2|Loss of load probability (LLP): LLP defined as the ratio between the power failure time (Tf) and power demand time (T) for each load. LLP of 0 indicates load will be completely satisfied by the power sources, and a LLP of 1 indicates load will not be satisfied any way, LLP can be estimated by the following equation:[5]

$$= \sum_{=} / \qquad \textbf{(4.2)}$$

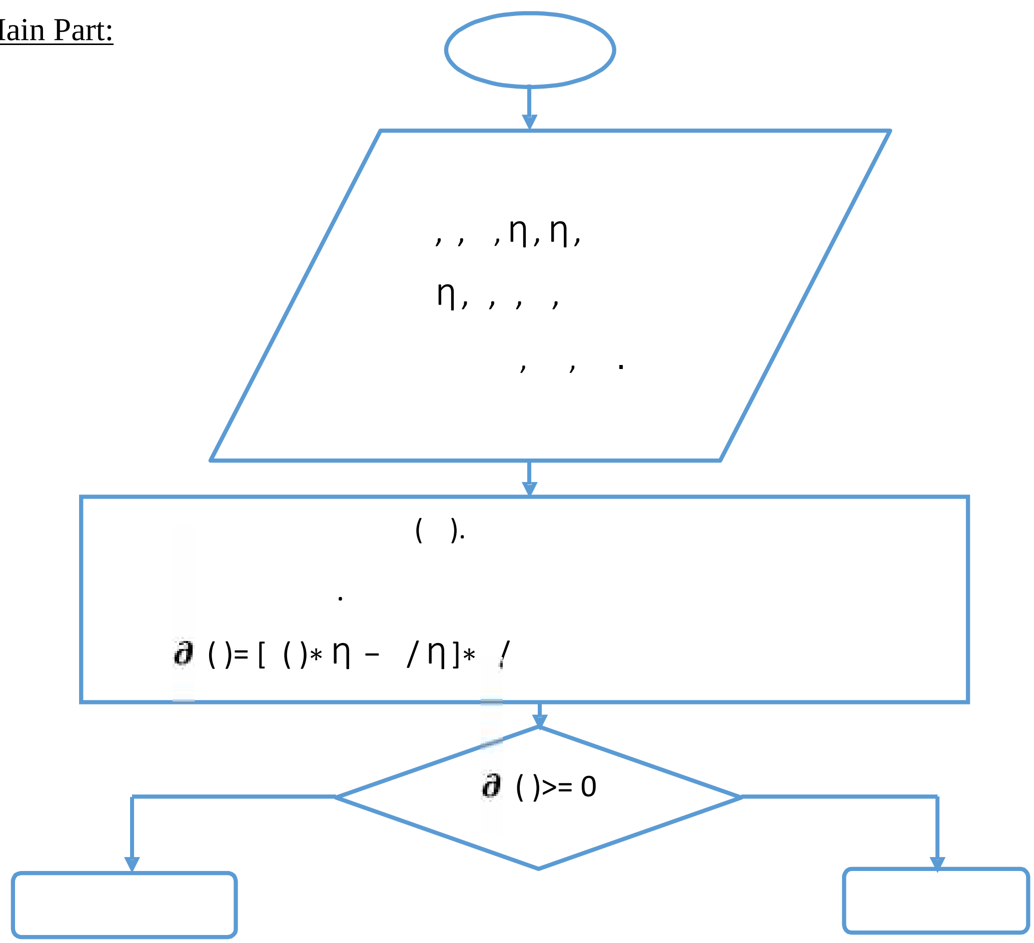
4.3|Energy Flow:

The presented operation flowchart is as follows:

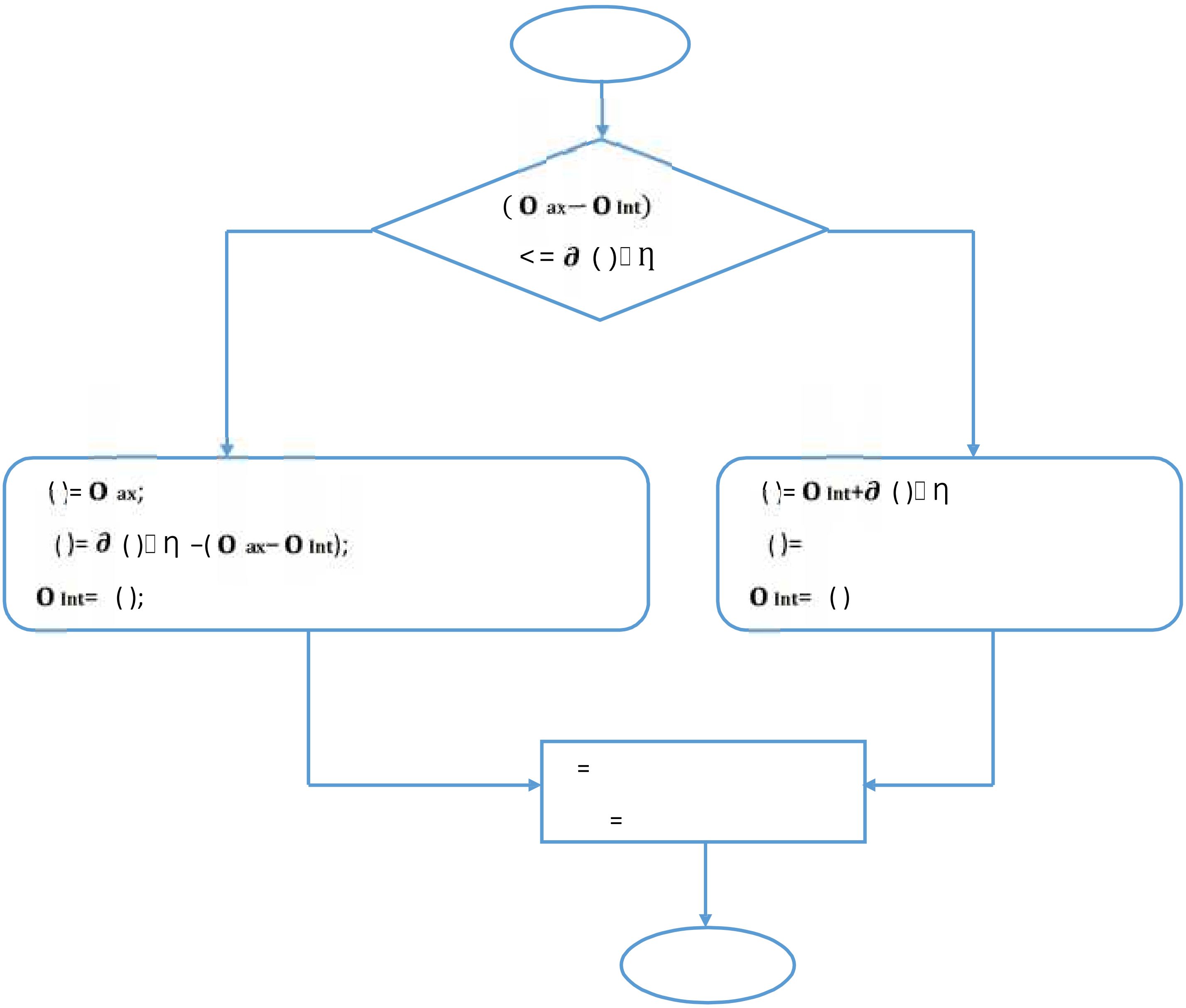
- If the power demand is less than the output power of the PV arrays, (*PL<PPV*), the charging process is happened. The excess energy is stored in battery, and new SOC will be calculated. The higher limit of the SOC is SOC_{Max}. If the battery SOC meets the SOC_{Max} then the surplus power will dump and the SOC value SOC_{Max}. In this situation the LPSP and LLP are equal to zero, because the sources could completely supply the demand.
- If the power demand is greater than the power output of the PV arrays, (*PL> PPV*), the discharging process will happen. In this condition, the priority load and priority SOC taking into account, if SOC above or equal 0.75 it is necessary to flow energy for all demand loads, else if above or equal 0.50 and less than 0.75 it is necessary to cut off all loads have low important priority, else if above or equal 0.22 and less than 0.50 it is necessary to cut off all loads have low and semi-important priority, else must be cut off all loads. New SOC will be calculated. It will be also checked not to getting out of the lower limit, SOC_{Min}. In this condition, the LPSP and LLP must be taken account by equations (1) and (2), because the sources could not supply the demand in all hours.

4.4| Flow Charts:

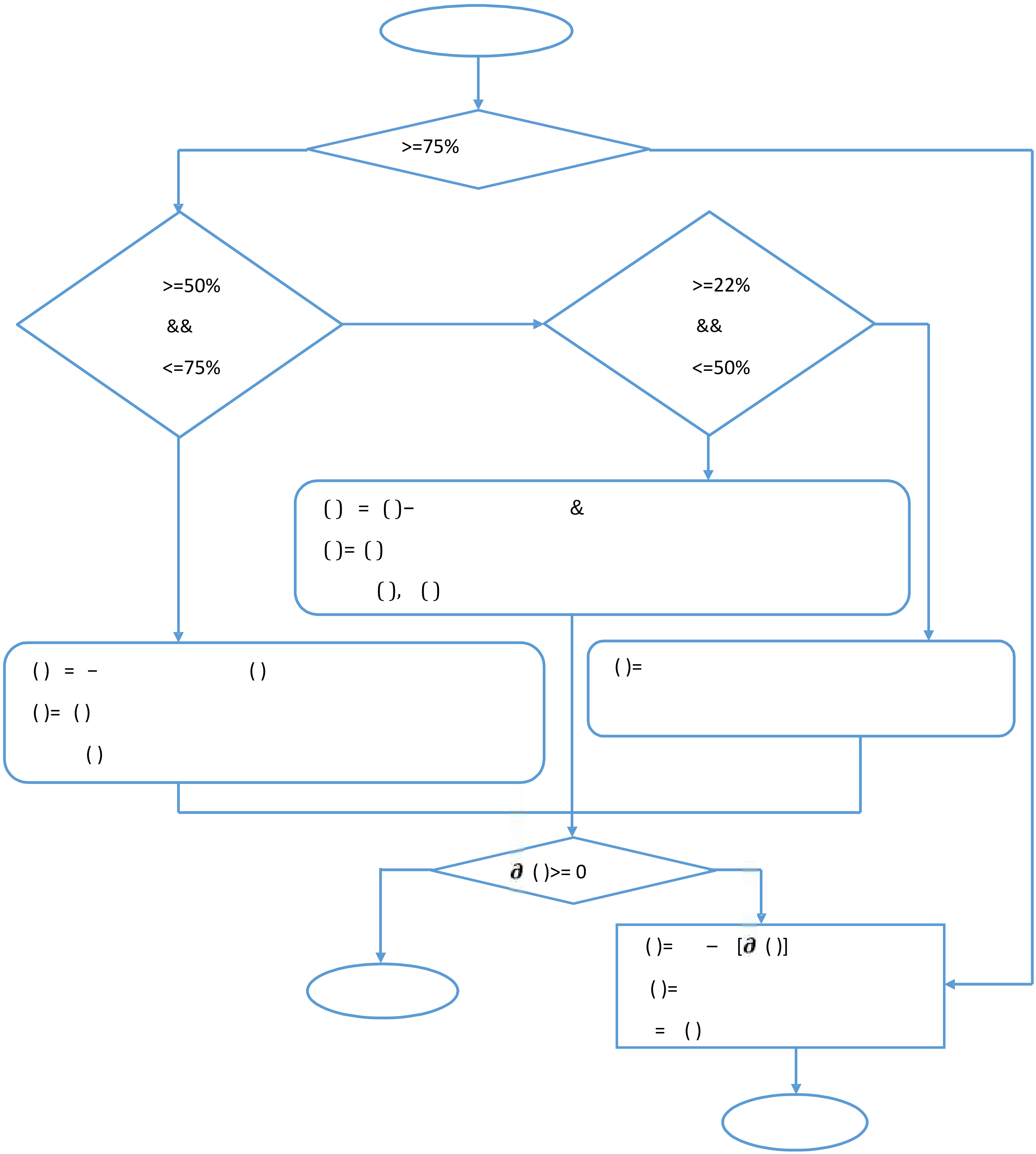
<u>4.4.1|Main Part:</u>



4.4.2|Charging Mode:



4.4.3|Discharging Mode:



5 DESIGN EXAMPLE AND THE RESULTS

5.1|Case Study And Sizing Calculations:

To test the algorithm, a stand-alone PV system matching with typical daily load curve as shown in figure 5.2.
We made a comparison between control and no control case to evaluate the algorithm; this completed by writing code on MATLAB program see appendix (1), and simulated the PV system over 8760 hour. In addition, we used PV-syst program to obtain irradiance and temperature for every hour see appendix (2).

<u>5.1.1|Average solar irradiance in Palestine:</u>

The following figure represent the average solar irradiance in Palestine, which is measured daily, distributed monthly and the annual average energy of 5.4 KWh/m2-day.

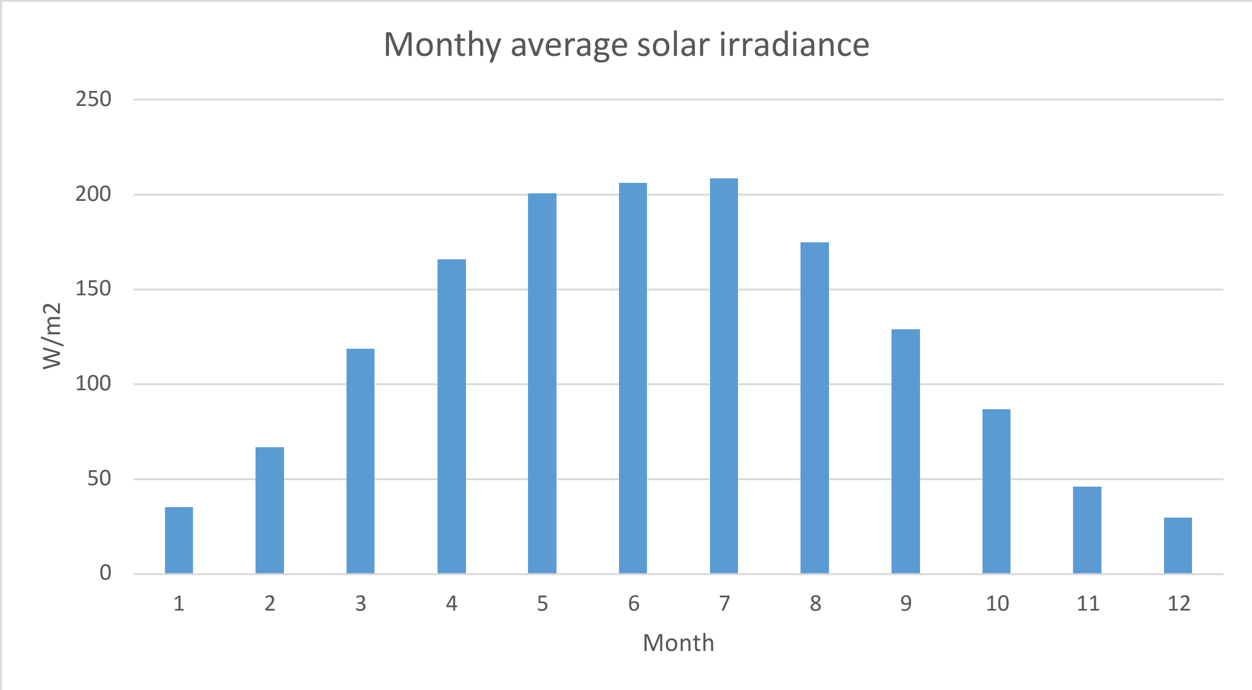


Fig.5.1"Solar irradiance in Palestine [W/m2], Ed = 5.4 KWh/m2-day". [8]

5.1.2|Load Estimation:

The following table showing that the estimated daily energy for a three different loads.

Table 5.1 The total energy of the load distributed-hourly:

H	EL1	EL2	EL3	ELT
1	500	0	0	500
2	500	0	0	500
3	500	0	0	500
4	500	0	0	500
5	500	0	0	500
6	500	0	0	500
7	500	500	0	1000
8	500	500	0	1000
9	500	500	0	1000
10	500	500	0	1000
11	500	500	500	1500
12	500	0	500	1000
13	500	0	500	1000
14	500	0	500	1000
15	500	0	0	500
16	500	0	0	500
17	500	0	0	500
18	500	500	0	1000
19	500	500	0	1000
20	500	500	0	1000
21	500	500	0	1000
22	500	0	0	500
23	500	0	0	500
24	500	0	0	500
Total	12000	4500	2000	18500

❖ Typical Daily Load Curve (DLC):

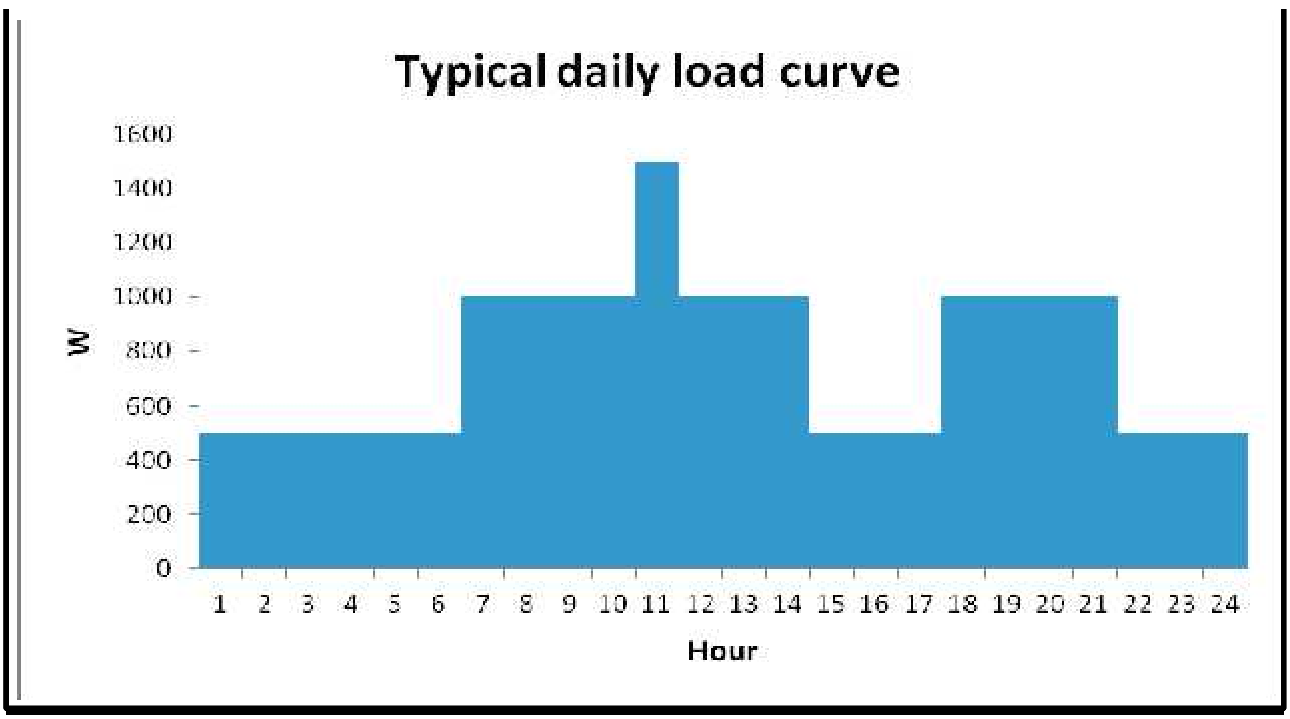


Fig.5.2." Typical daily load curve, ELT = 18.5 KWH/m2-Day".

5.1.3|Sizing Calculations:

- Determination of PV Array size:

Note that from figure 5.1 the daily solar energy = . —. and = —

Then the peak sun hour can be calculated by the following equation:

$$= \frac{. \; —}{——} = \; .$$

And from table 5.1 the daily load energy = . and assume η_{v} = . , η = .

The PV Array output power (PPV Array) can determine by the following equation:

$$= \frac{. \quad \square \; .}{. \; \square \; . \quad \square \; .} = \; .$$

The output power from PV array illustrated in the following figure:

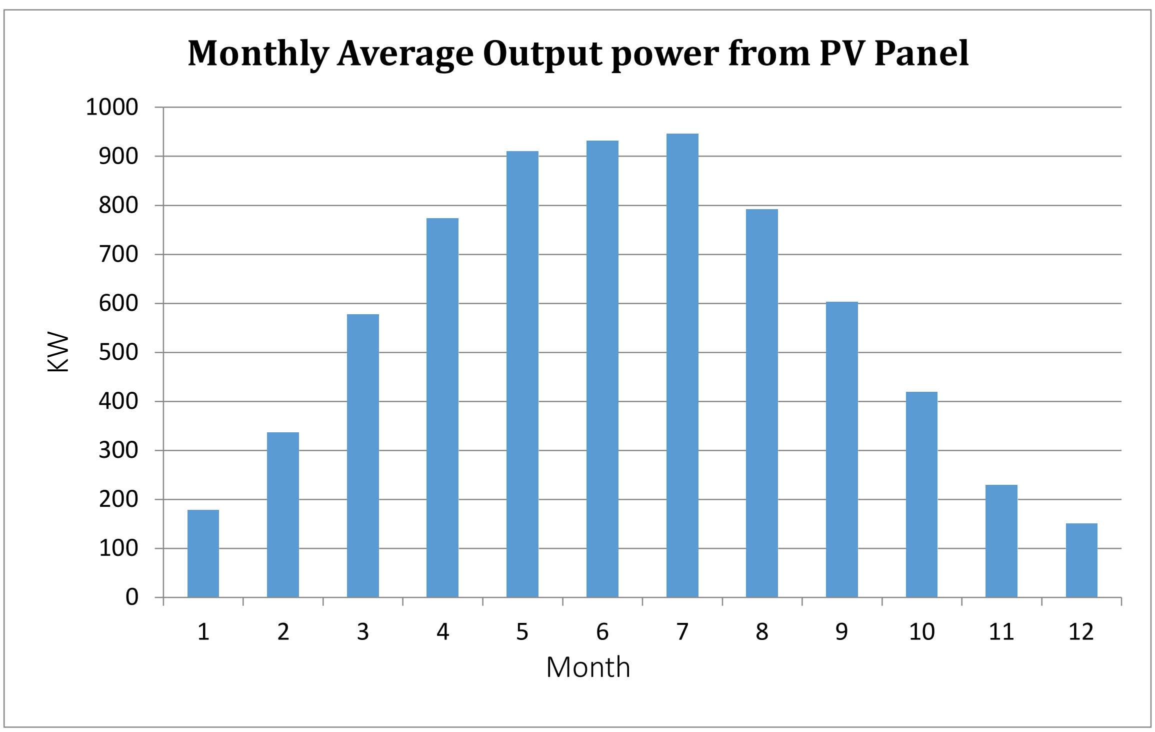


Fig.5.3." Average of PV Output Power".

- Determination of required battery bank capacity:

Batteries used in all solar systems are sized in ampere-hours under STC of 25˚C. The depth of discharge is a measure of how much of the total battery capacity has been consumed. In this design the days of autonomy [=] and maximum allowable depth of discharge [= %], theefficiency of the battery [η = .].

The battery bank capacity required [$C\ h$] can be calculated by the following equation:

$$= \frac{.\quad}{.\quad .\quad .} = \quad .$$

5.2|The Results of the Simulation:

The following results showing that two different cases according the MATLAB software, some of these results explain the original load, PV output power and SOC of the battery for those cases (control and no control).

Note: for more information about the software code then see appendices, page 22.

5.2.1|Battery State of Charge (SOC):

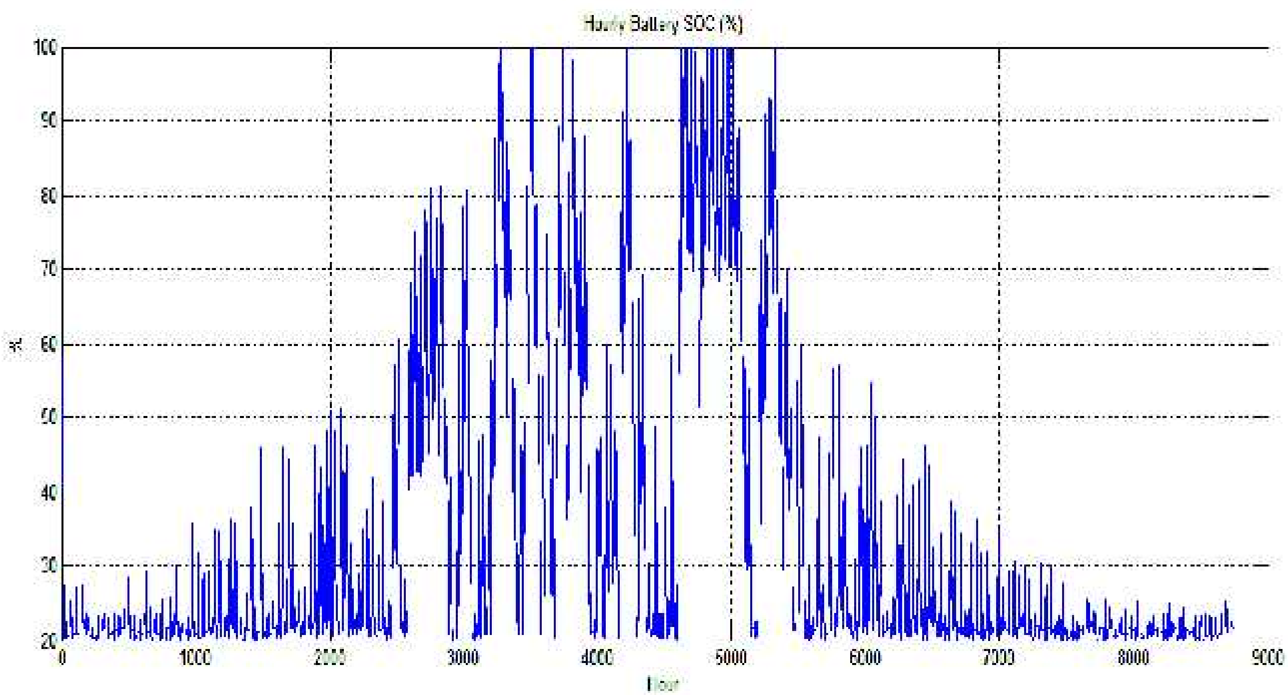


Fig.5.4: "Hourly battery SOC during the year for no control case (%)."

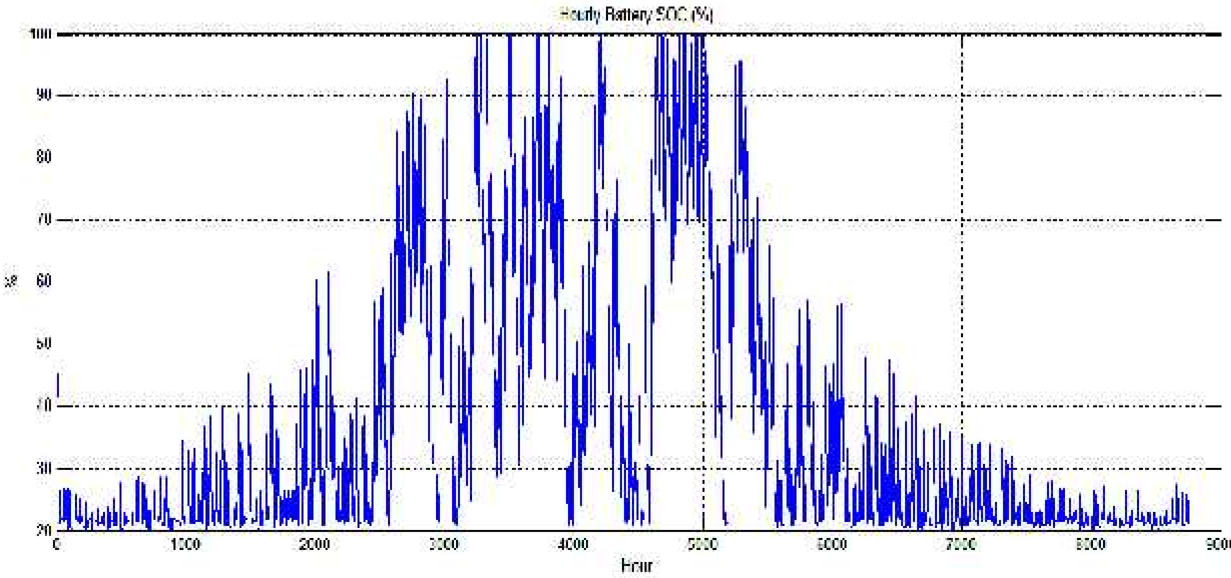


Fig.5.5: "Hourly battery SOC during the year for control case (%)."

5.2.2|Monthly Average (SOC):

In general, SOC is low especially in winter due to low solar radiation. In addition, note that hourly SOC for control case higher than for the no control case.

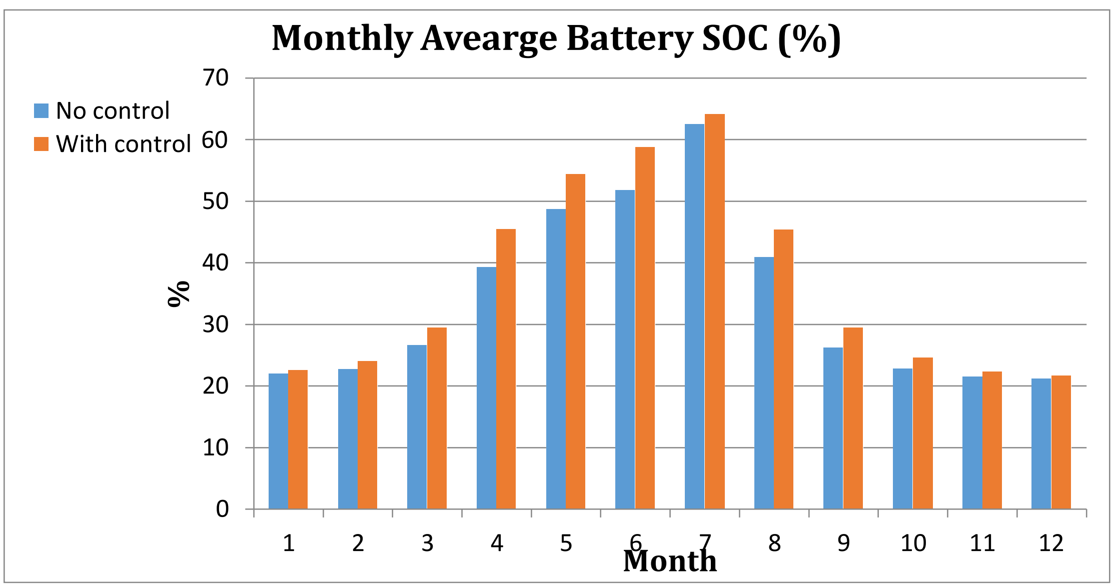


Fig.5.6: "Monthly average SOC (%)."

Monthly average SOC reaches minimum in November, and it reaches maximum in July. Overall, the no control case discharges the battery bank because it does not take into account the priority levels for SOC and priority of loads, while with control case SOC became the best.

5.2.3|Monthly Dump Energy:

Dump energy: is the energy generated from PV and lost without use in supplying load or charging battery.

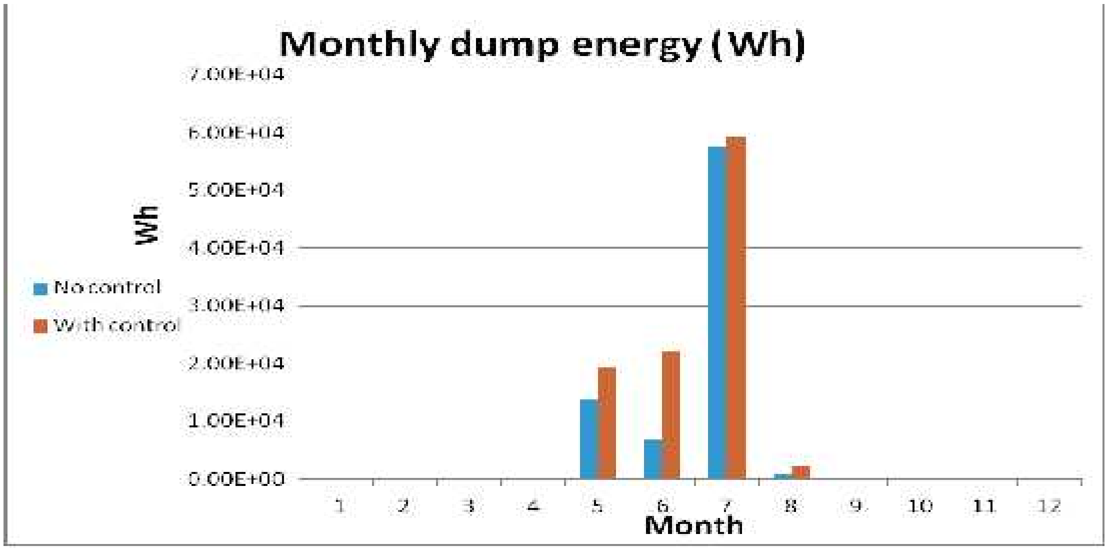


Fig.5.7: "Monthly dump energy (Wh)."

Dump energy for control case higher than for no control case, because the hourly SOC for control case reached to the maximum SOC, which is more than for no control case.

5.2.4|Output energy from stand-alone PV system:

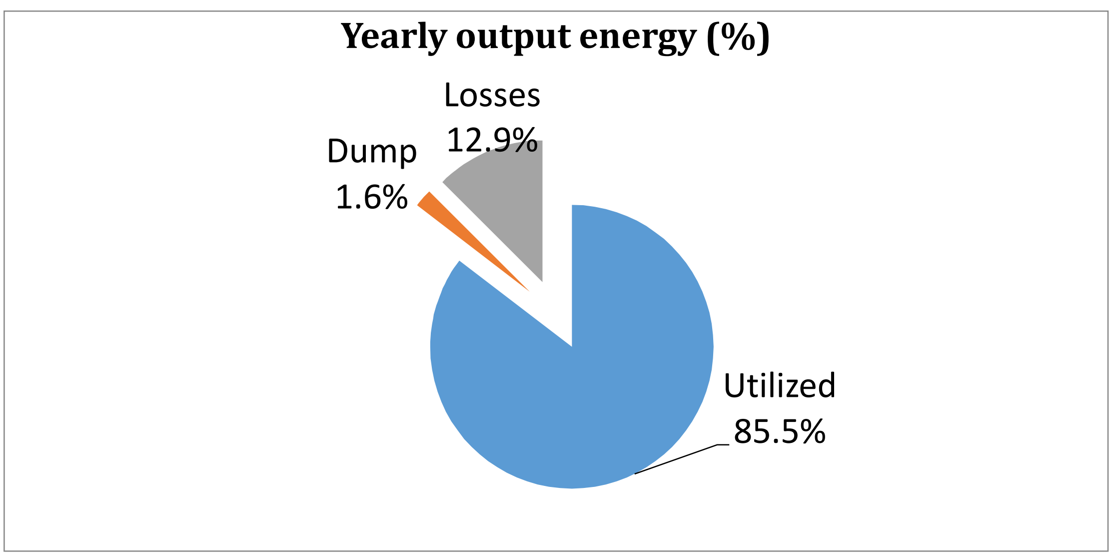


Fig.5.8: "Yearly output energy for no control case(%)."

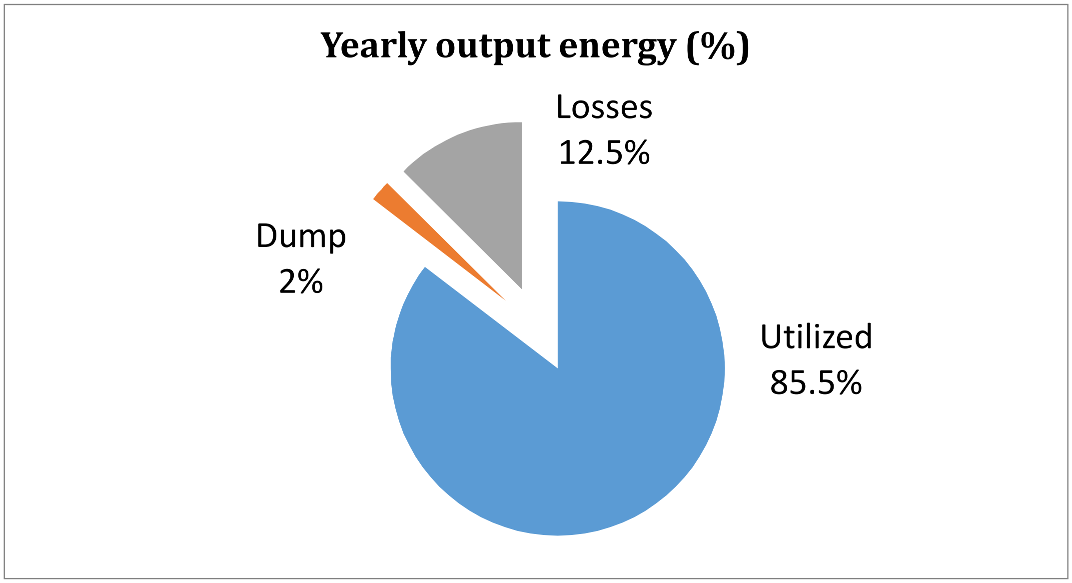


Fig.5.9: "Yearly output energy in with control case (%)."

Note that the total energy produced from the system is 5015 KWh, where 85.5% of this energy is used in two cases and 1.6% for no control , 2% for control case of it is not used (dump) and 12.9% for no control, 12.5% for control case is the amount of the losses, the losses comes from charge controller, battery bank and inverter.

5.2.5|Yearly percentage feeding load:

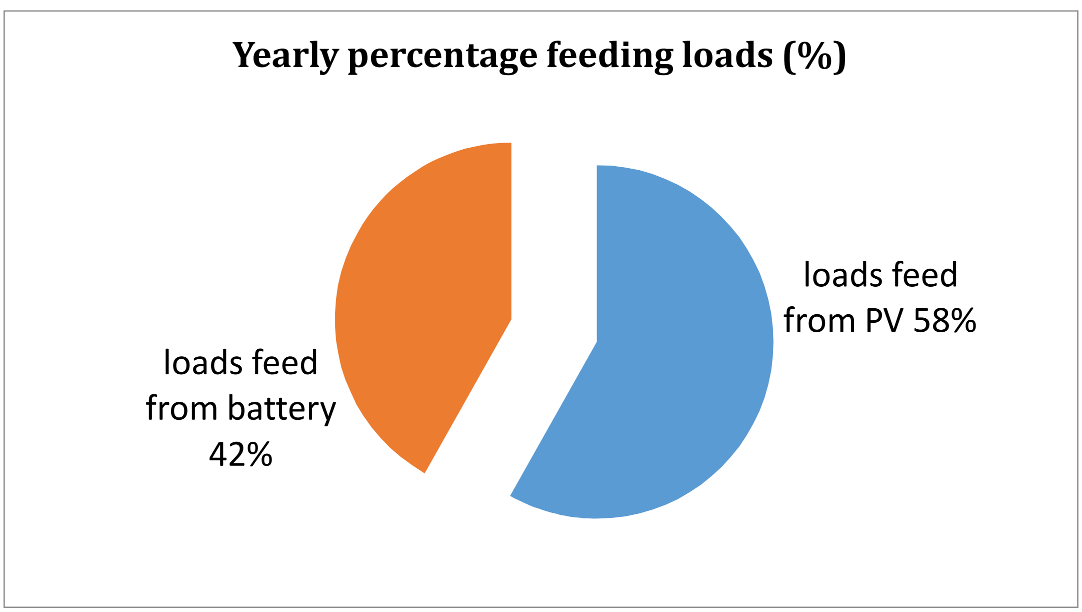


Fig.5.10: "Yearly percentage feeding load for no control case (%)."

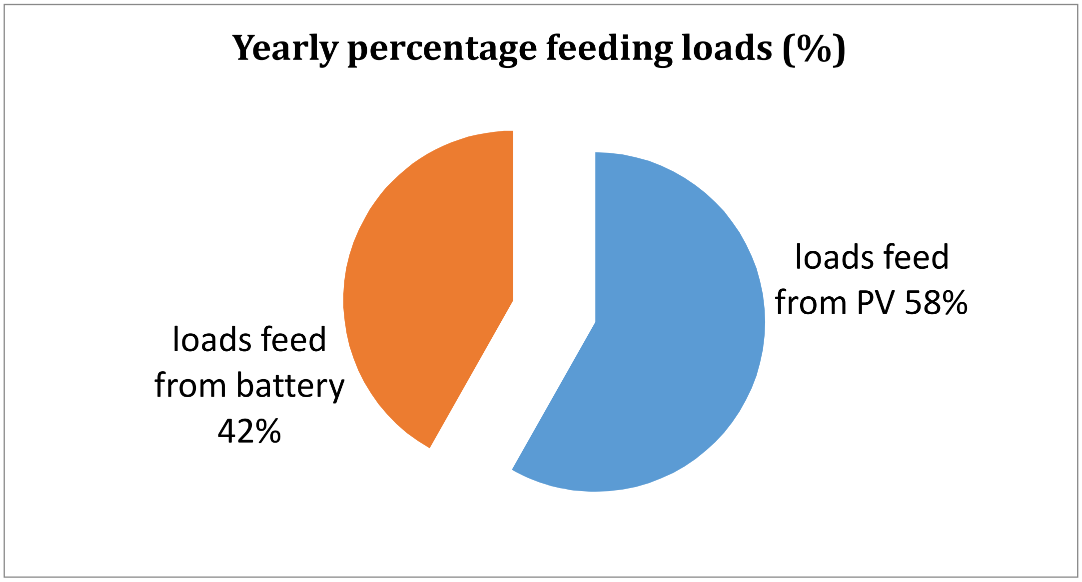


Fig.5.11: "Yearly percentage feeding load for with control case(%)."

5.2.6|Reliability of system:

We calculated LLP for each load and LPSP every month to quantify the effectiveness of the algorithm and the reliability of system.

Table 5.2: "LLP and LPSP for two cases."

Month	LLP1		LLP2		LLP3		LPSP	
	No control	With control	No control	With control	No control	With control	No control	With control
1	0.8	0.73	0.95	1	0.5	0.78	0.45	0.4
2	0.68	0.56	0.75	0.99	0.32	0.54	0.36	0.3
3	0.44	0.3	0.5	0.8	0.14	0.3	0.21	0.15
4	0.26	0.16	0.23	0.47	0.07	0.2	0. 96	0.05
5	0.14	0.06	0.13	0.32	0.04	0.2	0.06	0.02
6	0.09	0.03	0.07	0.22	0.03	0.2	0.04	0.01
7	0.14	0.08	0.13	0.25	0.06	0.2	0.05	0.02
8	0.21	0.12	0.22	0.44	0.09	0.2	0.08	0.04
9	0.42	0.26	0.43	0.8	0.12	0.27	0.2	0.12
10	0.62	0.5	0.62	0.9	0.18	0.38	0.3	0.23
11	0.78	0.7	0.91	1	0.033	0.65	0.44	0.36
12	0.84	0.79	0.99	1	0.53	0.85	0.52	0.044

The LLP for load 1(highest priority) it became less with control case especially in summer, but presenting worst LLP values for the lower priority loads. LPSP values became less due to energy management strategy.

6 CONCLUSIONS AND RECOMENDATIONS

- **Conclusions:**

- ✓ The energy management strategy, which based on two priorities, the first one is load priority, and other is SOC priority, and which is based on calculations such as SOC, LLP, LPSP and dump energy was implemented and simulated by using MATLAB program to achieve the objectives of the algorithm.
- ✓ The comparison between no control and control case according to SOC, LLP and LPSP, it is demonstrated the control algorithm has a better performance.
- ✓ The control algorithm clearly achieve the main goal, which is reducing the loss of load probability for the first load (highest priority), can be seen numerically that in table 5.2, and notice that the reliability of the system increased clearly. Also, obtained a higher SOC on the battery bank, as showing in Figure 5.5.
- ✓ Load scheduling make the design and use of electrical system more significant and economic, the size of the system will not need to expand as the load increased.
- ✓ Load schedule achieve the stability of power system.

- **Future Work:**

It is recommended that future work be focused on the practical implementation of the algorithm and travels to convert this idea by using a hardware system to the practical side, comparing between the theoretical and practical results, to take the efficiency and the reliability as an important topics into considerations.

A|Software code for the no control case:

```
clear all;
t=1:8760;
s=1:24;
m=1:3;
% Insert the input values
L1=500;L2=500;L3=500;% Values of Electrical Loads
E(1)=L1/(.92*.9);E(2)=L2/(.92*.9);E(3)=L3/(.92*.9);% Values of Electrical Loads before charge controller
Ebmax=30.2e3;Ebmin=.2*Ebmax;Ebint=.6*Ebmax;% The max, min and initial values of battery bank
Load(s)=[500 500 500 500 500 500 1000 1000 1000 1000 1500 1000 1000 1000 500 500 500 1000 1000 1000 1000
500 500 500 ]; % Values of demand distribution daily for each hour
L=repmat(Load,1,365);% Values of demand distribution annually for each hour
S(t)=L(t);
R(t)=L(t)/(.92*.9);% measure the demand load before the charge controller
% To show where every load turn-on or not
Lds(m,s)=[1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 ;
            0 0 0 0 0 0 1 1 1 1 1 0 0 0 0 0 0 1 1 1 1 0 0 0 ;
           0 0 0 0 0 0 0 0 0 0 1 1 1 1 0 0 0 0 0 0 0 0 0 0];
Ld=repmat(Lds,1,365);J=Ld;
G(t)=[the values obtain from PVsyst look appendix 3];% Values of solar radiation
z=1:365;
T(z)=[ the values obtain from PVsyst look appendix 3];% Values of temperature
% To make a constant temperature throughout the day
y=repmat(T',1,24);
l=1;
for h=1:365
for r=1:24
W(l)=y(h,r);
l=l+1;
if(l==8761)break;
end
end
end
%  To recalculate the calculation every hour take into account the new energy status of the system
for i=1:8760
Pout(i)=(4758.230453*G(i)/1000)*(1-.004*(W(i)+.0256*G(i)-25));% power generated from PV array
x(i)=Pout(i)-R(i);% calculate the energy difference between pv array and demand load
D(i)=x(i)*.92;% To make the difference after charge controller
if (D(i)>=0)) % To test the difference positive or not
% To test the battery full charge or not
if (D(i)*.85<=(Ebmax-Ebint))
Eb(i)=Ebint+D(i)*.85;
Ebint=Eb(i);
dump(i)=0;
else
% If the battery full charge then the surplus power will dump
Eb(i)=Ebmax;
Ebint=Eb(i);
```

```
dump(i)=D(i)*.85-(Ebmax-Ebint);
end
else
% Checking whether the battery can able to cover the deficit or not
if ((Ebint-Ebmin)>=abs(D(i)))
Eb(i)=Ebint-abs(D(i));
Ebint=Eb(i);
Else


% Cutoff all loads because the battery unable to cover the deficit
for u=1:3
Ld(u,i)=0;
L(i)=0;
x(i)=Pout(i);
D(i)=.92*x(i);
End
% After cutoff all loads, the energy difference will charge the battery
Eb(i)=Ebint+D(i)*.85;
Ebint=Eb(i);
dump(i)=0;
end
end
end
Soc(t)=(Eb(t)/Ebmax)*100; % state of charge for battery
figure;
subplot(2,2,1)
plot(t,S(t))
title('forcasting yearly load curve')
subplot(2,2,2)
plot(t,L(t))
title('scheduled load')
subplot(2,2,3)
plot(t,Soc(t))
title('battery SOC')
subplot(2,2,4)
plot(t,dump(t))
title('dump energy')

% All calculations
O=sum(Pout(t));% Total energy generated from PV panel
F=sum(dump(t));% Total dum energy
SOCint=60;
% To calculate how much energy delivered and consumed by the battery bank
for ui=1:8760
Z(ui)=(SOC(ui)-SOCint)*Ebmax/100;
SOCint=SOC(ui);
if(Z(ui)>=0)
Putb(ui)=Z(ui);
Putlb(ui)=0;
else
Putlb(ui)=Z(ui);
Putb(ui)=0;
```

```
end
end
PLPV=sum(L(t))-abs(sum(Putlb(t)))*.9;% To calculate how much PV panel contributed feed the loads
Putilized=PLPV+sum(Putb(t))/.85;% To calculate how much energy utilized from PV panel
Plosses=O-( Putilized+F); % To calculate how much energy losses
Ebint=.6*Ebmax;
% To calculate loss power supply over year
for los=1:8760
 EWR(los)=S(los)-(Pout(los)*.92+Ebint-Ebmin)*.9;
 Ebint=Eb(los);
 if(EWR(los)>0)
LPS(los)=EWR(los);
else LPS(los)=0;
end
end

% To calculate monthly loss load probability (LLP) and loss power supply probability (LPSP)
dayint=0;
day=[744  672 744 720 744 720 744 744 720 744 720 744];
for j=1:3
for c=1:12
Tdemand(j,c)=nnz(J(j,[dayint+1:day(c)+dayint]));
Tfailure(j,c)=nnz(Ld(j,[dayint+1:day(c)+dayint]));
LLP(j,c)=(Tdemand(j,c)-Tfailure(j,c))/Tdemand(j,c);
LPSP(c)=LPS([dayint+1:day(c)+dayint]);
dayint=day(c)+dayint;c=c+1;
end
dayint=0;
end
% To calculate yearly loss load probability (LLP)
A=nnz(J(1,:));B=nnz(J(2,:));C=nnz(J(3,:));
A1=nnz(Ld(1,:));B1=nnz(Ld(2,:));C1=nnz(Ld(3,:));
LLP1=(A-A1)/A;LLP2=(B-B1)/B;LLP3=(C-C1)/C;
```

B|Software code for the control case:

```
clear all;
t=1:8760;
s=1:24;
m=1:3;
% Insert the input values
L1=500;L2=500;L3=500;% Values of Electrical Loads
E(1)=L1/(.92*.9);E(2)=L2/(.92*.9);E(3)=L3/(.92*.9);% Values of Electrical Loads before charge controller
Ebmax=30.2e3;Socmax=100;Socmin=20;Socint=60;% The max, min and initial values of battery bank
Load(s)=[500 500 500 500 500 500 1000 1000 1000 1000 1500 1000 1000 1000 500 500 500 1000 1000 1000 1000
500 500 500 ]; % Values of demand distribution daily for each hour
L=repmat(Load,1,365); % Values of demand distribution annually for each hour
S(t)=L(t);
R(t)=L(t)/(.92*.9);% measure the demand load before the charge controller
% To show where every load turn-on or not
Lds(m,s)=[1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 ;
           0 0 0 0 0 0 1 1 1 1 1 0 0 0 0 0 0 1 1 1 1 0 0 0 ;
           0 0 0 0 0 0 0 0 0 0 1 1 1 1 0 0 0 0 0 0 0 0 0 0];
Ld=repmat(Lds,1,365);J=Ld;
G(t)=[the values obtain from PVsyst look appendix 3];% Values of solar radiation
z=1:365;
T(z)=[ the values obtain from PVsyst look appendix 3];% Values of temperature
% To make a constant temperature throughout the day
y=repmat(T',1,24);
l=1;
for h=1:365
for r=1:24
W(l)=y(h,r); l=l+1;
if(l==8761)break;
end
end
end

%  To recalculate the calculation every hour take into account the new energy status of the system
for i=1:8760
Pout(i)=(4758.230453*G(i)/1000)*(1-.004*(W(i)+.0256*G(i)-25));% power generated from PV array
x(i)=(Pout(i)-R(i))*100/Ebmax;% Energy difference between PV panel and demand loads
D(i)=x(i)*.92;% To make the difference after charge controller
if (D(i)>=0) % To test the difference positive or not
% To test the battery full charge or not
if (D(i)*.85<=(Socmax-Socint))
Soc(i)=Socint+D(i)*.85;
Socint=Soc(i);
dump(i)=0;
else
% If the battery full charge then the surplus power will dump
Soc(i)=Socmax;
Socint=Soc(i);
dump(i)=D(i)*.85-(Socmax-Socint);
end
```

```
else
% Checking whether the battery can able to cover the deficit or not
if (Socint-Socmin>=55)Soc(i)=Socint-abs(D(i));% To test if Soc above or equal 75%
Socint=Soc(i);
dump(i)=0;
else if(Socint-Socmin>=30&&Socint-Socmin<55) % To test if Soc above or equal 50% less than 75%
if(Ld(3,i)==1)
Ld(3,i)=0;x(i)=x(i)+(E(3)*100/Ebmax);
D(i)=x(i)*.92;
R(i)=R(i)-E(3);L(i)=L(i)-E(3)*(.92*.9);
end
if (D(i)>=0)
if (D(i)*.85<=(Socmax-Socint))
Soc(i)=Socint+D(i)*.85;
Socint=Soc(i);
dump(i)=0; else
Soc(i)=Socmax;
Socint=Soc(i);
dump(i)=D(i)*.85-(Socmax-Socint);
end
else
Soc(i)=Socint-abs(D(i));Socint=Soc(i);
dump(i)=0;
end
else if(Socint-Socmin>=2&&Socint-Socmin<30) % To test if Soc above or equal 22% less than 50%
for a=3:-1:2 if(Ld(a,i)==1)
Ld(a,i)=0;x(i)=x(i)+(E(a)*100/Ebmax);
D(i)=x(i)*.92;
R(i)=R(i)-E(a);L(i)=L(i)-E(a)*(.92*.9);
end
end
if (D(i)>=0)
if (D(i)*.85<=(Socmax-Socint))
Soc(i)=Socint+D(i)*.85;
Socint=Soc(i);
dump(i)=0; else
Soc(i)=Socmax;
Socint=Soc(i);
dump(i)=D(i)*.85-(Socmax-Socint);
end
else
Soc(i)=Socint-abs(D(i));Socint=Soc(i);
dump(i)=0;
end
% cutoff loads according to priority until the energy difference become positive or zero
else
for u=3:-1:1
if (Ld(u,i)==1)Ld(u,i)=0;
x(i)=x(i)+(E(u)*100/Ebmax);
D(i)=x(i)*.92;
```

```
R(i)=R(i)-E(u);
L(i)=L(i)-E(u)*(.92*.9);
% After cutoff loads, the energy difference will charge the battery
if(D(i)>=0) u=1;
Soc(i)=Socint+D(i)*.85;
Socint=Soc(i);
dump(i)=0;
else
Soc(i)=Socint;
Socint=Soc(i);
dump(i)=0;
end
end
end
end
end
end
end
end
figure;
subplot(2,2,1)
plot(t,S(t))
title('forcasting yearly load curve')
subplot(2,2,2)
plot(t,L(t))
title('scheduled load')
subplot(2,2,3)
plot(t,Soc(t))
title('battery SOC')
subplot(2,2,4)
plot(t,dump(t)*Ebmax/100)
title('dump energy')
% All calculations
O=sum(Pout(t));% Total energy generated from PV panel
F=sum(dump(t));% Total dum energy
SOCint=60;
% To calculate how much energy delivered and consumed by the battery bank
for ui=1:8760
Z(ui)=(SOC(ui)-SOCint)*Ebmax/100;
SOCint=SOC(ui);
if(Z(ui)>=0)
Putb(ui)=Z(ui);
Putlb(ui)=0;
else
Putlb(ui)=Z(ui);
Putb(ui)=0;
end
end
PLPV=sum(L(t))-abs(sum(Putlb(t)))*.9;% To calculate how much PV panel contributed feed the loads
Putilized=PLPV+sum(Putb(t))/.85;% To calculate how much energy utilized from PV panel
Plosses=O-( Putilized+F); % To calculate how much energy losses
Socint=60;
```

```
% To calculate loss power supply over year
for los=1:8760
 EWR(los)=S(los)-(Pout(los)*.92+Socint-Socmin)*.9;
 Socint=Soc(los);
if(EWR(los)>0)
LPS(los)=EWR(los);
else LPS(los)=0;
end
end
% To calculate monthly loss load probability (LLP) and loss power supply probability (LPSP)
dayint=0;
day=[744  672 744 720 744 720 744 744 720 744 720 744];
for j=1:3
for c=1:12
Tdemand(j,c)=nnz(J(j,[dayint+1:day(c)+dayint]));
Tfailure(j,c)=nnz(Ld(j,[dayint+1:day(c)+dayint]));
LLP(j,c)=(Tdemand(j,c)-Tfailure(j,c))/Tdemand(j,c);
LPSP(c)=LPS([dayint+1:day(c)+dayint]);
dayint=day(c)+dayint;c=c+1;
end
dayint=0;
end
% To calculate yearly loss load probability (LLP)
A=nnz(J(1,:));B=nnz(J(2,:));C=nnz(J(3,:));
A1=nnz(Ld(1,:));B1=nnz(Ld(2,:));C1=nnz(Ld(3,:));
LLP1=(A-A1)/A;LLP2=(B-B1)/B;LLP3=(C-C1)/C;
```

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