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MAE 119

HW4

Question 1

Using the code:

```matlab
clear;
close all;
clc;
addpath(genpath('pvlib'));
%for a typical electrical demand on day in Oct
hour = linspace(0,23,24);
demand=[5.1 4.9 5.1 5.3 5.6 6.7 8.0 8.6 8.3 7.6 7.2 6.7 6.2 5.9 5.9 5.9 6.5 7.2
7.9 8.1 8.1 7.4 6.4 5.6]*10^6; %W

fig = figure('units','inch','position',[5,5,6,5]);
hold on
plot(hour, demand, 'ko-')
xlabel('Hour of the Day')
ylabel('Electricity Demand (W)')
xlim([0,24])
hold off
print(fig,'Demand Vs. Time.png','-dpng','-r800');

%% Q1

peak_d = max(demand); % peak demand

% Nominal Capacity (Monthly)-31 days in Oct
diesel_nomcap = peak_d % Diesel ; eql to peak load on a typical day

btry=[sum(demand(20:end)) sum(demand(1:8))]; %Battery: Nighttime energy use only
battery_nomcap = max(btry)

% For solar Capacity
SurfTilt=10;
SurfAz=180;
TMYData=pvl_readtmy3('725905TYA.csv'); %Ukiah, CA site
TimeMatlab = TMYData.DateNumber;
Time = pvl_maketimestruct(TimeMatlab,
ones(size(TimeMatlab))*TMYData.SiteTimeZone);
dayofyear = pvl_date2doy(Time.year, Time.month, Time.day);
DNI = TMYData.DNI; % Read in for comparison with results
DHI = TMYData.DHI; % Read in for comparison with results
GHI = TMYData.GHI;
```

```matlab
Location = pvl_makelocationstruct(TMYData.SiteLatitude,TMYData.SiteLongitude,...
TMYData.SiteElevation); %Altitude is optional
pressure= TMYData.Pressure*100; %Convert pressure from mbar to Pa
[SunAz, SunEl, ApparentSunEl, SolarTime] = pvl_ephemeris(Time, Location);
SunZen=90-ApparentSunEl;
AM= pvl_relativeairmass(SunZen);
AMa=pvl_absoluteairmass(AM,pressure);

HExtra = pvl_extraradiation(dayofyear);
Ediffsky = pvl_perez(SurfTilt, SurfAz, DHI, DNI, HExtra, SunZen, SunAz, AMa);

ro_g = 0.2;
AOI = pvl_getaoi(SurfTilt, SurfAz, SunZen, SunAz);
Eb=0*AOI;
Eb(AOI<90)=DNI(AOI<90).*cosd(AOI(AOI<90));
GHI(isnan(GHI))=0;
Ediffground=pvl_grounddiffuse(SurfTilt, GHI, ro_g);
oct=6553:1:7296;

%POA
POA=Eb + Ediffsky + Ediffground;
Ediff=Ediffsky+Ediffground;
%for oct
doy=274:1:304;
POA=POA(oct); %actual generation in Oct

%monthly demand
Oct_demand = sum(demand)*31 %W

%Solar panel
DBfile = 'SandiaModuleDatabase_20120925.xlsx';
Module = pvl_sapmmoduledb(124, DBfile);


Tamb=TMYData.DryBulb(oct);
windspeed=TMYData.Wspd(oct);
a=Module.a_wind;
b=Module.b_wind;
deltaT=Module.delT;

Ee=POA*.98/1000;
Tcell = pvl_sapmcelltemp(Ee, 1000, a, b, windspeed, Tamb, deltaT);
Result = pvl_sapm(Module, Ee, Tcell);

%change MS and MP to get slr to equal Oct_damand, 5000 panels
MS=100; % #module in series
MP=50; % # number of parallel strings

Vdc=MS*Result.Vmp;
Vdc(Vdc<0)=0;
Idc=MP*Result.Imp;
Pdc=(Vdc.*Idc);
load 'SandiaInverterDatabaseSAM2014.1.14.mat';
Inverter = SNLInverterDB(441);

Pac=pvl_snlinverter(Inverter,Vdc,Pdc);
Pac(Pac<0)=0;
Oct_solar_generation=sum(Pac)
```
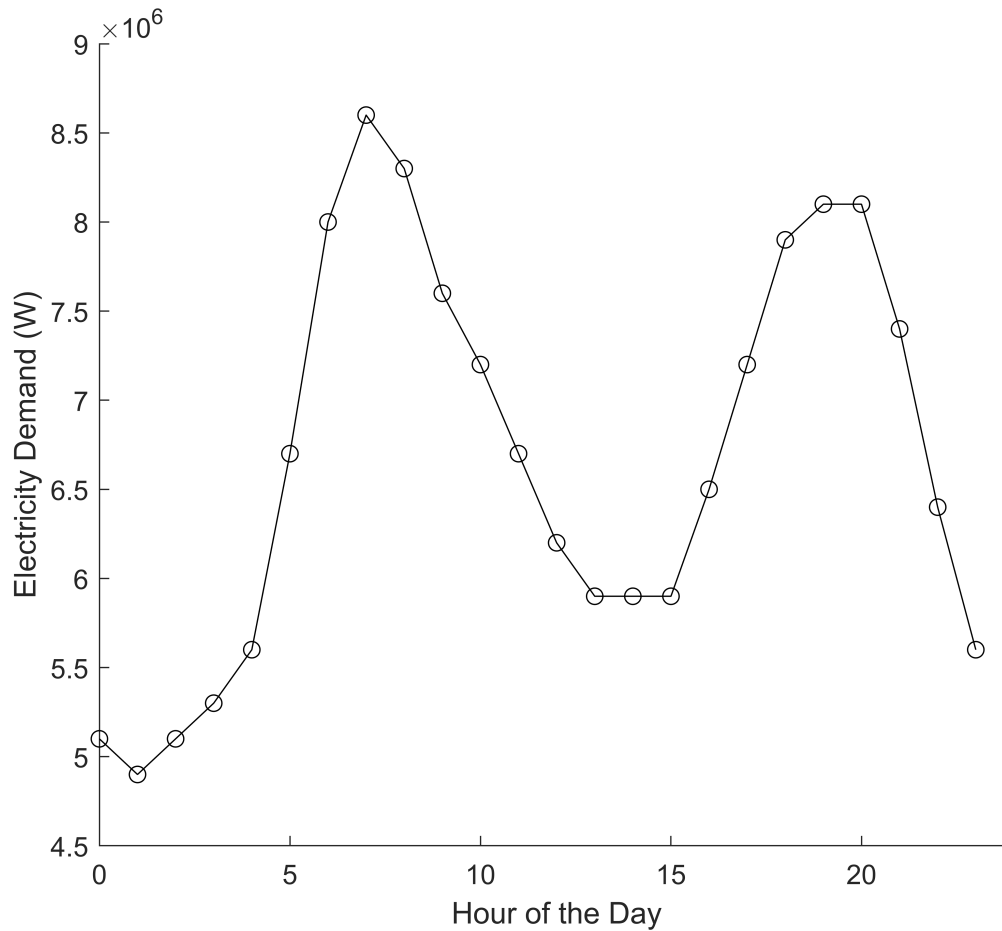
```
max_solarPwr=max(Pac);

Solar_array_nomcap = 10^6
Solar_arrays_req = ceil((Oct_demand/Oct_solar_generation))
```

We know that the the monthly electricity demand graph looks like:

We are also able to get that:

- The nominal capacity of the diesel generation is 8600000 W.
- The nominal capacity of the solar generation is 1000000 W.
- The number of solar trays required is 22.
- The nominal capacity of the battery is 49300000 W

Question 2

Based on the questions, the spreadsheet can be written as:

Diesel Balance Sheet

size (kW):	8600
20 day energy (kWh):	3204000
E_life (kWh):	64080000
investment:	$ 4,730,000.00
O&M:	$ 103.20
fuel:	$ 1,268,784.00
down payment:	$ 473,000.00
interest rate:	0.05
loan payment:	$ 341,592.69
inflation:	0.05
discount:	0.06

Deisel (Senario 1)

year	investment	loan	fuel	OnM	Net Cost	Discount
0	$473,000	$0	$0	$0	$473,000	$473,000
1	$0	$341,593	$1,268,784	$103	$1,610,480	$1,519,321
2	$0	$341,593	$1,332,223	$108	$1,673,924	$1,489,787
3	$0	$341,593	$1,398,834	$114	$1,740,541	$1,461,392
4	$0	$341,593	$1,468,776	$119	$1,810,488	$1,434,076
5	$0	$341,593	$1,542,215	$125	$1,883,933	$1,407,784
6	$0	$341,593	$1,619,326	$132	$1,961,050	$1,382,463
7	$0	$341,593	$1,700,292	$138	$2,042,023	$1,358,062
8	$0	$341,593	$1,785,307	$145	$2,127,044	$1,334,534
9	$0	$341,593	$1,874,572	$152	$2,216,317	$1,311,835
10	$0	$341,593	$1,968,300	$160	$2,310,053	$1,289,922
11	$0	$341,593	$2,066,715	$168	$2,408,476	$1,268,755
12	$0	$341,593	$2,170,051	$177	$2,511,820	$1,248,298
13	$0	$341,593	$2,278,554	$185	$2,620,332	$1,228,514
14	$0	$341,593	$2,392,481	$195	$2,734,269	$1,209,370
15	$0	$341,593	$2,512,106	$204	$2,853,903	$1,190,834
16	$0	$341,593	$2,637,711	$215	$2,979,518	$1,172,876
17	$0	$341,593	$2,769,596	$225	$3,111,414	$1,155,469
18	$0	$341,593	$2,908,076	$237	$3,249,905	$1,138,584
19	$0	$341,593	$3,053,480	$248	$3,395,321	$1,122,198
20	$0	$341,593	$3,206,154	$261	$3,548,007	$1,106,285
Total					$49,261,820	$26,303,357

LCOE ($/kWh):	0.410476859
LLC:	26303357.11

Deisel (Senario 2)

year	Investment	Fuel	O$M	Net Costs	Discounted
0	$4,730,000.00	$0.00	$0.00	$4,730,000.00	$4,730,000.00
1	$0.00	$1,268,784.00	$103.20	$1,268,887.20	$1,197,063.40
2	$0.00	$1,332,223.20	$108.36	$1,332,331.56	$1,185,770.35
3	$0.00	$1,398,834.36	$113.78	$1,398,948.14	$1,174,583.83
4	$0.00	$1,468,776.08	$119.47	$1,468,895.54	$1,163,502.85
5	$0.00	$1,542,214.88	$125.44	$1,542,340.32	$1,152,526.41
6	$0.00	$1,619,325.63	$131.71	$1,619,457.34	$1,141,653.52
7	$0.00	$1,700,291.91	$138.30	$1,700,430.21	$1,130,883.20
8	$0.00	$1,785,306.50	$145.21	$1,785,451.72	$1,120,214.49
9	$0.00	$1,874,571.83	$152.47	$1,874,724.30	$1,109,646.43
10	$0.00	$1,968,300.42	$160.10	$1,968,460.52	$1,099,178.07
11	$0.00	$2,066,715.44	$168.10	$2,066,883.54	$1,088,808.47
12	$0.00	$2,170,051.21	$176.51	$2,170,227.72	$1,078,536.69
13	$0.00	$2,278,553.77	$185.33	$2,278,739.11	$1,068,361.81
14	$0.00	$2,392,481.46	$194.60	$2,392,676.06	$1,058,282.93
15	$0.00	$2,512,105.53	$204.33	$2,512,309.86	$1,048,299.13
16	$0.00	$2,637,710.81	$214.55	$2,637,925.36	$1,038,409.51
17	$0.00	$2,769,596.35	$225.27	$2,769,821.62	$1,028,613.20
18	$0.00	$2,908,076.17	$236.54	$2,908,312.71	$1,018,909.30
19	$0.00	$3,053,479.98	$248.36	$3,053,728.34	$1,009,296.95
20	$0.00	$3,206,153.98	$260.78	$3,206,414.76	$999,775.28
Total				$46,686,965.92	$26,642,315.82

LCOE ($/kWh):	0.415766477
LLC:	26642315.82

Solar + Battery Balance Sheet

solar size (kW):	34000
battery size (kWh):	84900
20 day energy (kWh):	3204000
E_life:	64080000
solar investment:	$ 61,200,000.00
solar O&M:	$ 306,000.00
solar tax incentive:	$ 18,360,000.00
battery investment:	$ 50,940,000.00
battery O&M:	$ -
solar down payment:	$ 6,120,000.00
bat down payment:	$ 5,094,000.00
interest rate:	0.05
solar loan payment:	$ 4,419,761.70
battery loan payment:	$ 5,937,266.74
inflation:	0.05
discount:	0.06

Solar + Battery (Senario 1)

year	investment	loan	OnM	Tax Incentive	Net Cost	Discount
0	$11,214,000	$0	$0	-$18,360,000	-$7,146,000	-$7,146,000
1	$0	$10,357,028	$306,000	$0	$10,663,028	$10,059,461
2	$0	$10,357,028	$321,300	$0	$10,678,328	$9,503,674
3	$0	$10,357,028	$337,365	$0	$10,694,393	$8,979,219
4	$0	$10,357,028	$354,233	$0	$10,711,262	$8,484,323
5	$0	$10,357,028	$371,945	$0	$10,728,973	$8,017,313
6	$0	$10,357,028	$390,542	$0	$10,747,571	$7,576,613
7	$0	$10,357,028	$410,069	$0	$10,767,098	$7,160,735
8	$0	$10,357,028	$430,573	$0	$10,787,601	$6,768,274
9	$0	$10,357,028	$452,101	$0	$10,809,130	$6,397,907
10	$5,094,000	$10,357,028	$474,706	$0	$15,925,735	$8,892,847
11	$0	$10,357,028	$498,442	$0	$10,855,470	$5,718,526
12	$0	$10,357,028	$523,364	$0	$10,880,392	$5,407,222
13	$0	$10,357,028	$549,532	$0	$10,906,560	$5,113,421
14	$0	$10,357,028	$577,009	$0	$10,934,037	$4,836,135
15	$0	$10,357,028	$605,859	$0	$10,962,888	$4,574,430
16	$0	$10,357,028	$636,152	$0	$10,993,180	$4,327,425
17	$0	$10,357,028	$667,960	$0	$11,024,988	$4,094,288
18	$0	$10,357,028	$701,358	$0	$11,058,386	$3,874,237
19	$0	$10,357,028	$736,425	$0	$11,093,454	$3,666,531
20	$0	$10,357,028	$773,247	$0	$11,130,275	$3,470,472
Total					$215,206,751	$119,777,054

LCOE ($/KWh):	1.869179992
LCS:	-93473696.78

Solar + Battery (Senario 2)

year	investment	OnM	Tax Incentive	Net Cost	Discount
0	112140000	0	-18360000	93780000	93780000
1	0	306000	0	306000	288679.2453
2	0	321300	0	321300	285955.8562
3	0	337365	0	337365	283258.1594
4	0	354233.25	0	354233.25	280585.9126
5	0	371944.9125	0	371944.9125	277938.8757
6	0	390542.1581	0	390542.1581	275316.8109
7	0	410069.266	0	410069.266	272719.4825
8	0	430572.7293	0	430572.7293	270146.6571
9	0	452101.3658	0	452101.3658	267598.1038
10	50940000	474706.4341	0	51414706.43	28709703.53
11	0	498441.7558	0	498441.7558	262572.8991
12	0	523363.8436	0	523363.8436	260095.7963
13	0	549532.0358	0	549532.0358	257642.0623
14	0	577008.6376	0	577008.6376	255211.4768
15	0	605859.0694	0	605859.0694	252803.8214
16	0	636152.0229	0	636152.0229	250418.8797
17	0	667959.624	0	667959.624	248056.4374
18	0	701357.6052	0	701357.6052	245716.2824
19	0	736425.4855	0	736425.4855	243398.2042
20	0	773246.7598	0	773246.7598	241101.9948
Total				154838182	40536211.97

LCOE ($/KWh):	0.632587578
LCS:	-13893896.15

Solar + Diesel

solar size (kW):	10000
deisel size (kW):	8436
deisel energy (kWh):	153544
20 day energy (kWh):	3204000
E_life (kWh):	64080000
solar investment:	$ 18,000,000.00
solar O&M:	$ 90,000.00
solar tax incentive:	$ 5,400,000.00
deisel investment:	$ 5,061,600.00
deisel O&M:	$ 101.23
deisel fuel:	$ 60,803.42
solar down payment:	$ 1,800,000.00
deis down payment:	$ 506,160.00
interest rate:	0.05
solar loan payment:	$ 1,299,929.91
deis loan payment:	$ 589,950.32
inflation:	0.05
discount:	0.06

Solar + Diesel (Senario 1)

year	investment	loan	fuel	OnM	Net Cost	Discount
0	$2,306,160	$0	$0	$0	-$3,093,840	-$3,093,840
1	$0	$1,889,880	$60,803	$90,101	$2,040,785	$1,925,269
2	$0	$1,889,880	$63,844	$94,606	$2,048,330	$1,823,007
3	$0	$1,889,880	$67,036	$99,337	$2,056,253	$1,726,469
4	$0	$1,889,880	$70,388	$104,303	$2,064,571	$1,635,334
5	$0	$1,889,880	$73,907	$109,519	$2,073,306	$1,549,295
6	$0	$1,889,880	$77,602	$114,995	$2,082,477	$1,468,064
7	$0	$1,889,880	$81,482	$120,744	$2,092,107	$1,391,371
8	$0	$1,889,880	$85,557	$126,781	$2,102,218	$1,318,958
9	$0	$1,889,880	$89,834	$133,121	$2,112,835	$1,250,584
10	$0	$1,889,880	$94,326	$139,777	$2,123,983	$1,186,021
11	$0	$1,889,880	$99,042	$146,765	$2,135,688	$1,125,054
12	$0	$1,889,880	$103,994	$154,104	$2,147,978	$1,067,479
13	$0	$1,889,880	$109,194	$161,809	$2,160,883	$1,013,106
14	$0	$1,889,880	$114,654	$169,899	$2,174,433	$961,754
15	$0	$1,889,880	$120,387	$178,394	$2,188,661	$913,252
16	$0	$1,889,880	$126,406	$187,314	$2,203,600	$867,439
17	$0	$1,889,880	$132,726	$196,680	$2,219,286	$824,164
18	$0	$1,889,880	$139,363	$206,514	$2,235,756	$783,283
19	$0	$1,889,880	$146,331	$216,839	$2,253,050	$744,662
20	$0	$1,889,880	$153,647	$227,681	$2,271,209	$708,174
Total					$39,693,571	$21,188,898

LCOE ($/KWh):	0.330663207
LCS:	5114458.776

adjusted LCOE($/KWh):	$0.051
adjusted LCS:	$7,560,774.76

Solar + Diesel (Senario 2)

year	investment	loan	OnM (Combined)	Tax Incentive	Net Cost	Discount
0	$23,061,600	$0	$0	-$1,468,064	$21,593,536	$21,593,536
1	$0	$1,889,880	$90,101	$0	$1,979,981	$1,867,907
2	$0	$1,889,880	$94,606	$0	$1,984,487	$1,766,186
3	$0	$1,889,880	$99,337	$0	$1,989,217	$1,670,185
4	$0	$1,889,880	$104,303	$0	$1,994,184	$1,579,580
5	$0	$1,889,880	$109,519	$0	$1,999,399	$1,494,067
6	$0	$1,889,880	$114,995	$0	$2,004,875	$1,413,358
7	$0	$1,889,880	$120,744	$0	$2,010,625	$1,337,180
8	$0	$1,889,880	$126,781	$0	$2,016,662	$1,265,279
9	$0	$1,889,880	$133,121	$0	$2,023,001	$1,197,411
10	$0	$1,889,880	$139,777	$0	$2,029,657	$1,133,350
11	$0	$1,889,880	$146,765	$0	$2,036,646	$1,072,880
12	$0	$1,889,880	$154,104	$0	$2,043,984	$1,015,797
13	$0	$1,889,880	$161,809	$0	$2,051,689	$961,912
14	$0	$1,889,880	$169,899	$0	$2,059,780	$911,042
15	$0	$1,889,880	$178,394	$0	$2,068,275	$863,019
16	$0	$1,889,880	$187,314	$0	$2,077,194	$817,680
17	$0	$1,889,880	$196,680	$0	$2,086,560	$774,874
18	$0	$1,889,880	$206,514	$0	$2,096,394	$734,459
19	$0	$1,889,880	$216,839	$0	$2,106,720	$696,298
20	$0	$1,889,880	$227,681	$0	$2,117,562	$660,266
Total					$62,370,424	$44,826,265

LCOE ($/KWh):	0.699535963
LCS:	-18183948.68

adjusted LCOE($/KWh):	$0.108
adjusted LCS:	$15,737,632.70

The analysis is not capturing the full value of the solar because the solar energy collected during non-outage periods can also be used to sell to make profits. After the life cycle savings are adjusted, the LCOE dropped to 0.051 and 0.108 compared to previously 0.33 and 0.70.

Assume the solar energy can be resold:

solar resold:	
October energy (kWh):	1465426
Daily energy (kWh):	47271.80645
345 days energy (kWh):	16308773.23
Profit:	$2,446,315.98
solar life energy (kWh):	351702240
Adjusted E_life (kWh):	415782240