UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
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Faculty of Engineering, Built Environment and Information Technology

ENR 420

RESEARCH PROJECT

PRACTICAL 1: SIMULATIONS

Name and Surname	Student Number	Signature
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ENR 420 practical Topic 1 model

Brighton Chikomo (16071558)

I. Model Implementation

To optimize the operation cost of the Photovoltaic-Diesel-Battery(PVDB) hybrid power system three modules where considered. The modules include the PV module, the battery module and the diesel generator module(DG) [1]–[6].

A. Description of Control variables

The PV is modelled as a varying power source from zero maximum PV energy available for 24 hours. The battery bank was modelled as an energy storage bank with limited energy capacity. The DG is modelled as a varying power source in the range of minimum and maximum power. The models above lead to the following control variables [2].

$$P_1(t) - \text{control variable of energy flow from DG to the load at a given hour} \quad (1)$$

$$P_2(t) - \text{control variable of energy flow from PV to the load at a given hour} \quad (2)$$

$$P_3(t) - \text{control variable of energy flow from PV to battery at a given hour} \quad (3)$$

$$P_4(t) - \text{control variable of energy flow from battery to the load at a given hour} \quad (4)$$

B. Description of Objective function

The economic dispatch problem is to minimise the operation cost of the PVDB hybrid system at any given time. The operation cost of the DG was taken into consideration as a non-linear function. The operation cost of both the PV and the battery module was not considered in the optimization process. To minimize the operation cost of the PVDB hybrid system the following objective function (equation 5) is to be used

$$min\ C_f \sum_{t=1}^{N} \left(aP_1^2(t) + bP_1(t)\right) \quad (5)$$

$P_1(t)$ is the only control variable in the objective function (equation 5) since the only operation cost encountered are for the DG fuel. Control variables $P_2(t)$, $P_3(t)$ and $P_4(t)$ coefficients are zeros since there is no operation cost for the PV and battery models.

C. Description of Constraints

The PV generator is to meet the load demand. If the load demand is higher than the PV supply, the battery will be used to compensate for the required energy. If the load demand is lower than the PV supply, the surplus energy will be used to charge the battery up to its maximum capacity. At some point, both the power from the Pv and the battery bank can not meet the load demand. In this case, the DG will switch ON to compensate for the energy shortages to the load [2]. Whenever the PV and the battery are to meet the load demand, the DG switches off. Upon writing the PVDB hybrid system functionality described above mathematically, the constraints to the objective function proposed in equation 5 were obtained to be:

$$P_2(t) + P_3(t) \leqslant P_{pv}(t), \quad (6)$$

$$P_1(t) + P_2(t) + P_4(t) = P_L(t), \quad (7)$$

$$P_1(t) \geqslant 0,\ P_2(t) \geqslant 0,\ P_3(t) \geqslant 0,\ P_4(t) \geqslant 0, \quad (8)$$

$$P_i^{min} \leqslant P_i(t) \leqslant P_i^{max}, \quad (9)$$

$$B_c^{min} \leqslant B_C(0) + \eta_C \sum_{\tau=1}^{t} P_3(\tau) - \eta_D \sum_{\tau=1}^{t} P_4(\tau) \leqslant B_C^{max}, \quad (10)$$

D. Overal optimazation model

The model to be optimized consists of objective function, constraints and design variable. The objective function is to minimise [2]:

$$min\ C_f \sum_{t=1}^{N} \left(aP_1^2(t) + bP_1(t)\right)$$

subject to the constraints

$$\begin{aligned}
&P_2(t) + P_3(t) \leqslant P_{pv}(t),\\
&P_1(t) + P_2(t) + P_4(t) = P_L(t),\\
&P_1(t) \geqslant 0,\ P_2(t) \geqslant 0,\ P_3(t) \geqslant 0,\ P_4(t) \geqslant 0,\\
&P_i^{min} \leqslant P_i(t) \leqslant P_i^{max},\\
&B_c^{min} \leqslant B_C(0) + \eta_C \sum_{\tau=1}^{t} P_3(\tau) - \eta_D \sum_{\tau=1}^{t} P_4(\tau) \leqslant B_C^{max},
\end{aligned}$$

The design variables of this optimization problem are $P_1(t)$, $P_2(t)$, $P_3(t)$, and $P_4(t)$, respectively.

The table below provides useful constants to be used in solving the optimization problem proposed [2].

TABLE I
USEFUL CONSTANTS TO SOLVE THE OPTIMIZATION PROBLEM [2]

Parameter	Value
Nominal battery capacity, B_C^{max}	$54.5kWh$
Battery charging efficiency, η_C	85%
Battery discharging efficiency, η_D	50%
Battery allowable depth of discharge, DOD	50%
Diesel generator capacity, S	$5kVA$
PV array capacity	$4kW$
a	$US\$0.246/h$
b	$US\$0.1/kWh$
Fuel Cost, C_f	$US\$1.2/l$
PV array area, A_c	7-20m^2
PV generator efficiency, η_R	15%

II. SIMULATIONS OF THE MODEL

The nature of the objective function to be minimized is non-linear or quadratic hence the "quadprog" MATLAB function is to be used to solve the problem [2]. The MATLAB quadprog function is given by equation 11 and 12 below.

$$min\frac{1}{2}x^T Hx + f^T x \tag{11}$$

subject to constraints:

$$\begin{aligned} Ax &\leqslant b \\ A_{eq} &= b_{eq} \\ lb &\leqslant x \leqslant ub \end{aligned} \tag{12}$$

$$\begin{aligned} where: \quad H &- \text{Hessian matrix} \\ x &- \text{control variables} \\ f &- \text{vector matrix} \\ A,\ b &- \text{Inequality constraints matrix} \\ A_{eq},\ b_{eq} &- \text{equality constraints matrix} \end{aligned}$$

To solve the optimization problem the suggested objective function and the constraints are transformed into the MATLAB quadprg form shown in equation 11 and equation 12 respectively. The following subsections describe the formation of different matrix from the suggested energy optimization problem into a MATLAB quadprog form.

A. Transformation of the objective function to MATLAB quadprop form

Equation 5 is going to be transformed into equation 11 through the formulation of matrix H and matrix f.

Matrix H is a 96×96 matrix with:

1) diagonal entries of $2 \times C_f \times a$ from $H_{1,1}$ to $H_{24,24}$
2) All other entries are zeros

The framework of the H matrix is shown in matrix array 13

$$H = \begin{bmatrix} H_{1,1} & H_{1,2} & H_{1,3} & .. & .. & .. & H_{1,96} \\ H_{2,1} & H_{2,2} & H_{2,3} & .. & .. & .. & .. \\ H_{3,1} & H_{3,2} & H_{3,3} & .. & .. & .. & .. \\ .. & .. & .. & .. & .. & .. & .. \\ .. & .. & .. & .. & .. & .. & .. \\ .. & .. & .. & .. & .. & .. & .. \\ H_{96,1} & .. & .. & .. & .. & .. & .. \end{bmatrix} \tag{13}$$

Matrix f is a 96×1 matrix with:

1) First 24 row entries of $C_f \times b$
2) All other entries are zeros

The framework of matrix f is shown in matrix array 14

$$f = \begin{bmatrix} c_f \times b \\ c_f \times b \\ c_f \times b \\ .. \\ .. \\ .. \\ 0 \end{bmatrix} \tag{14}$$

B. Transformation of inequality constraints into MATLAB quadprog form

The inequality constraints in equation 6 and equation 10 are going to be transformed into first equation of equation array 12 to form the matrix A and matrix b as defined in equation 12. Matrix A is given by the coefficients of inequality constraint control variables ($P_2(t)$, $P_3(t)$ from equation 6 and equation 10. To fomulate matrix A three matrix namely A_a, A_b and A_c are going to be considered as sub matrix of A.

Matrix A_a is found from equation 6 as a 24×96 matrix with:

1) Two diagonal entries with ones from $A_{a1,25}$ to $A_{a24,48}$ and $A_{a1,49}$ to $A_{a24,72}$
2) All other entries are zeros

Matrix A_b and A_c are found from equation 10 as 1×96 matrices with: Equation 10 is separated into two parts to form A_b and A_c

$$\begin{aligned} A_b &: \eta_C \sum_{\tau=1}^{t} P_3(\tau) - \eta_D \sum_{\tau=1}^{t} P_4(\tau) \leqslant B_C(0) - B_c^{max} \\ A_c &: -\eta_C \sum_{\tau=1}^{t} P_3(\tau) + \eta_D \sum_{\tau=1}^{t} P_4(\tau) \leqslant B_C(0) - B_c^{min} \end{aligned} \tag{15}$$

$$where: \quad A_b = -A_c$$

η_C, η_D, B_C^{max}, DOB are given in table I

$$B_C^{min} = (1 - DOB)B_C^{max} \tag{16}$$

$$B_C^{min} \leqslant B_c(t) \leqslant B_C^{max} \tag{17}$$

Substituting values of DOB and B_C^{max} in equation 17, B_C^{min} was found to be 27.25kWh. After substituting constants from table I into equation 15 the following equations were obtained.

$$\begin{aligned} A_b &: 0.85 \sum_{\tau=1}^{t} P_3(\tau) - \sum_{\tau=1}^{t} P_4(\tau) \leqslant 27.25 \\ A_c &: -0.85 \sum_{\tau=1}^{t} P_3(\tau) + \sum_{\tau=1}^{t} P_4(\tau) \leqslant 0 \end{aligned} \tag{18}$$

From equation 18 matrix A_b can be found to be a 1×96 matrix with:

1) entries of 0.85 from entry $A_{a49,72}$ to $A_{a73,96}$
2) All other entries are zeros

To find A_c use equation 19 below

$$A_b = -A_c \tag{19}$$

matrix A is a 26×96 matrix with:

1) 24×96 top matrix as A_a
2) 1×96 matrix at row 25 as A_b
3) 1×96 matrix at row 26 as A_c

The frame work of the matrix A is shown in matrix array 20

$$A = \begin{bmatrix} A_a(24 \times 96) \\ A_b(1 \times 96) \\ A_c(1 \times 96) \end{bmatrix} \tag{20}$$

Matrix b is obtained from the coefficients of $P_{pv}(t)$ and the values $(B_c 0 - B_C^{min})$ and $(B_c^{max} - B_C(0))$ shown in equation 15. Using equation 18 b_b is 27.25 and b_c is 0. Matrix b_a are coefficients of $P_{pv}(t)$. To calculate $P_{pv}(t)$ left hand side of table II and sets of equations below were used [2].

$$\eta_{pv} = \eta_R \left[1 - 0.9\beta \left(\frac{I_{pv}}{I_{pv,NT}} \right) (T_{C,NT} - T_{A,NT}) - \beta(T_A - T_R) \right] \tag{21}$$

$$P_{pv} = \eta_{pv} A_c I_{pv} \tag{22}$$

$$\begin{aligned} where: \eta_R &= 15\% \\ A_C &= 10m^2 \times 4 \\ &= 40m^2 \end{aligned}$$

From table I A_C has a value of $7 - 20m^2$. A value of $10m^2$ was chosen and multiplied by the PV array capacity(4kW) to get the total power produced by the PV array of $10m^2$ [2].

TABLE II
RESULTS FOR $P_{pv}(t)$ [2]

Time	$I_{pv}(Wh/m^2)$	$T_A(C)$	η_{pv}	$P_{pv}(kW)$
00:30	0.00	24.86	0.1500	0.000000
01:30	0.00	24.17	0.1505	0.000000
02:30	0.00	23.46	0.1509	0.000000
03:30	0.00	22.58	0.1515	0.000000
04:30	0.00	21.88	0.1519	0.000000
05:30	16.35	21.51	0.1518	0.099289
06:30	164.72	22.77	0.1486	0.978821
07:30	255.99	23.32	0.1467	1.502028
08:30	352.40	23.58	0.1449	2.042584
09:30	644.89	25.74	0.1387	3.577166
10:30	624.82	27.73	0.1378	3.444462
11:30	832.56	29.67	0.1331	4.434166
12:30	798.66	31.23	0.1328	4.241990
13:30	711.53	31.23	0.1344	3.825667
14:30	752.34	32.79	0.1326	3.991322
15:30	416.75	32.79	0.1387	2.311551
16:30	165.09	31.60	0.1433	0.945993
17:30	47.74	23.54	0.1501	0.286574
18:30	10.90	23.77	0.1506	0.065642
19:30	0.11	23.99	0.1506	0.000663
20:30	0.00	24.62	0.1502	0.000000
21:30	0.00	24.25	0.1505	0.000000
22:30	0.03	23.40	0.1510	0.000181
23:30	0.00	21.86	0.1519	0.000000

b matrix is a 26×1 matrix with:

1) 24×1 top matrix as b_a(co-coefficients of P_{pv} as shown in table II)
2) 27.25 as b_b
3) 0 as b_c

The frame work of the matrix b is shown in matrix array 23

$$b = \begin{bmatrix} b_a(24 \times 1) \\ b_b(1 \times 1) \\ b_c(1 \times 1) \end{bmatrix} \tag{23}$$

C. Transformation of equality constraints into MATLAB quadprog form

The equality constraints in equation 7 is going to be transformed into second equation of equation array 12 to form matrix A_{eq} and matrix b_{eq} as defined in equation 12. Matrix A_{eq} is given by the coefficients of equality constraint control variables $(P_1(t), P_2(t) and P_4(t))$ from equation 7. Matrix b_{eq} is given by coefficients of $P_L(t)$ in equation 7.

Matrix A_{eq} is a 24×96 matrix with:

1) Three diagonal entries with ones from $A_{eq_{1,1}}$ to $A_{eq_{24,24}}$, $A_{eq_{1,25}}$ to $A_{eq_{24,48}}$ and $A_{eq_{1,73}}$ to $A_{eq_{24,96}}$
2) All other entries are zeros

Matrix b_{eq} is a 24×1 matrix with entries $P_L(t)$ as shown in table III below.

TABLE III
WEEKDAY AND WEEKEND DEMAND PROFILES [2].

Time	Winter load (kW)		Summer load (kW)	
	Weekend	Weekday	Weekend	Weekday
00:30	1.5	1.5	1.5	1.5
01:30	1.5	1.5	1.5	1.5
02:30	1.5	1.5	1.85	1.85
03:30	1.5	1.5	1.95	1.95
04:30	1.5	1.5	1.85	1.85
05:30	1.95	1.65	1.5	1.5
06:30	1.95	1.65	1.65	11.5
07:30	1.65	13.5	1.65	1.25
08:30	1.35	1.35	1.7	1.3
09:30	3.25	3.0	1.75	1.32
10:30	3.25	3.0	1.75	1.35
11:30	2.15	1.95	1.75	1.32
12:30	2.15	1.95	1.25	1.25
13:30	2.15	1.95	1.32	1.32
14:30	2.15	1.95	1.35	1.35
15:30	2.15	1.95	1.35	1.35
16:30	2.15	1.65	1.45	1.45
17:30	1.8	1.65	2.1	2.15
18:30	2.31	3.25	2.4	2.31
19:30	3.81	3.25	3.8	3.25
20:30	2.31	2.31	3.8	3.25
21:30	2.31	2.15	2.0	2.0
22:30	2.31	2.15	1.95	1.95
23:30	1.35	1.35	1.65	1.65

D. Boundaries

UB(Upper boundary) is a 96×1 matrix which is given by the capacities of the DG, PV and battery respectively.

UB matrix is a 96×1 matrix with:

1) entries 1 to 24 as DG capacity
2) entries 25 to 72 as PV capacity
3) entries 73 to 96 as battery capacity

The frame work of matrix UB is shown in matrix 24

$$UB = \begin{bmatrix} \text{DG capacity (5kVA)} \\ \text{PV capacity (4kW)} \\ \text{Battery capacity (54.5kWh)} \end{bmatrix} \tag{24}$$

LB(Lower boundary) matrix is given by equation 9 and 10.

LB is a is a 96×1 matrix with all entries as zeros.

The frame work of matrix UB is shown in matrix 24

E. Optimization problem solution

The quadprog function of MATLAB was used to solve the energy optimization problem described by the matrix above. Only data for winter weekends and weekdays(Table III) was analysed and plotted as shown in the results section.

III. RESULTS

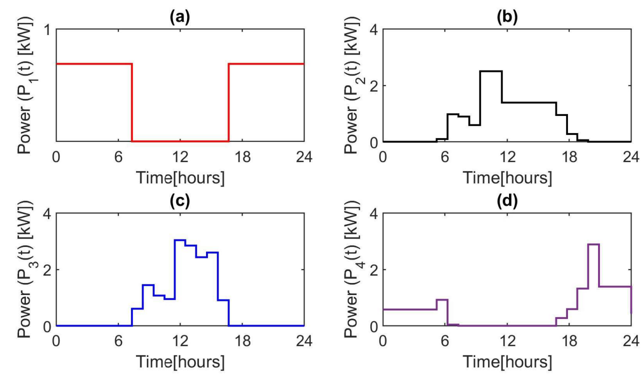

Fig. 1. Winter weekend power flow.

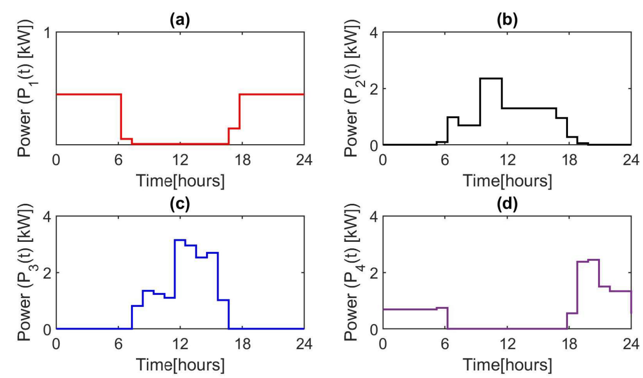

Fig. 2. Winter weekday power flow

IV. ANALYSIS OF PREDICTIONS FROM THE MODEL

Fig.1 and 2 show the flow of energy for 24hrs during the winter weekdays and weekends respectively. From time 0:00 to approximately 08:00 and from 18:00 to 0:00 the load demand is met by the DG and/or the battery bank. At these times, the DG switches ON only when the PV and/or the battery is not able to meet the load demand

Fig.1(c) and (d) and Fig.2(c) and (d) shows the charging and discharging processes of the battery bank respectively. The battery bank charges during the day and discharge (supply energy to the load) during the night when the PV can not provide enough energy to the load.

PV, battery bank and DG provides energy to the load during the early hours of the day. The DG switches ON only when the PV and/or the battery bank is not able to provide enough energy to the load. Whenever the PV and/or the battery bank is able to meet demand, the DG switches OFF to reduce the fuel costs and hence operation cost of the PVDB system. The ON time of the DG depends on the battery's state of charge(SOC) and the energy the PV array can supply(size of the PV array). The DG is ON for more hours if the PV and/or the battery bank provides less energy.

From plots in Fig.1 and Fig.2, the fuel cost saving can be deduced and the total cost to the proposed PVDB system can be obtained. If summer graphs where plotted, the seasonal variation in PV energy supply to the load is deduced. In general, the PV supplies more energy in summer than in winter hence the DG runs for a short time in summer than in winter.

From the two sets of graphs(weekend and weekdays energy flow plots) in Fig.1 and Fig.2 it can be deduced that the energy demand is higher during the weekend than during the weekdays. This is because during the week people living in remote areas will be busy in the fields and with other different outside home activities but during the weekend they will be at home using various electrical appliances.

In this optimization model, the battery is only charged by the PV and the DG only supplies energy to the load when it is switched ON. This model configuration ensures low operation cost since the DG ON time is limited. For this optimization energy problem, the optimization solution is obtained by computing the difference between the DG operating cost(fuel cost) for a stand-alone DG system and the PVDB hybrid system. The simulation results show that PVDB system achieves more saving than the stand-alone DG. This indicates the proposed optimization model has the capacity to reduce the operation cost for the PVDB system.

V. Conclusion

The cost of operating the PVDB system was optimized using the quadprog MATLAB function. The results of the energy optimization problem were plotted as shown in Fig.1 and Fig.2. Only the results for June weekends and weekdays were considered. To further analyse the validity of the proposed minimum cost solution to PVDB hybrid, summer energy demand should be considered and analysed.

References

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VI. Appendix A: MATLAB Code

The following code was used to optimize the energy problem in MATLAB.

```
%-----------------------------------------------------------------------------
%BRIGHTON S CHIKOMO
%ENR PRACTICAL PRACTICAL 1 FOR TOPIC 1
%MINIMUM COST SOLUTION
%LAST EDITED: 10/09/2019      TIME:0133hrs
%-----------------------------------------------------------------------------

%variables
cf = 1.2;
a = 0.246;
b = 0.1;

%---------- THE HESSIAN MATRIX FORMULATION-------------

%Big matrix 96*96
big_H = zeros(96);

%creating small matrix to fit in a big matrix
sm1_H = 2*cf*a*ones(1,24);
small_H = diag(sm1_H);


% Specify upper left row, column of where
% we'd like to paste the small matrix.
row1_H = 1;
column1_H = 1;
% Determine lower right location.
row2_H = 24;
column2_H = 24;


% It will fit, so paste it.
big_H(row1_H:row2_H, column1_H:column2_H) = small_H;
H = big_H;
%----------------END OF HESSIAM MATRIX FORMULATION-----------------

%---------- THE f MATRIX FORMULATION-------------


big_f = zeros(96,1);
%creating small matrix to fit in a big matrix
small_f = b*cf*ones(24,1);


% Specify upper left row, column of where
% we'd like to paste the small matrix.
row1_f = 1;
column1_f = 1;

% Determine lower right location.
row2_f = 24;
column2_f = 1;

% It will fit, so paste it.
```

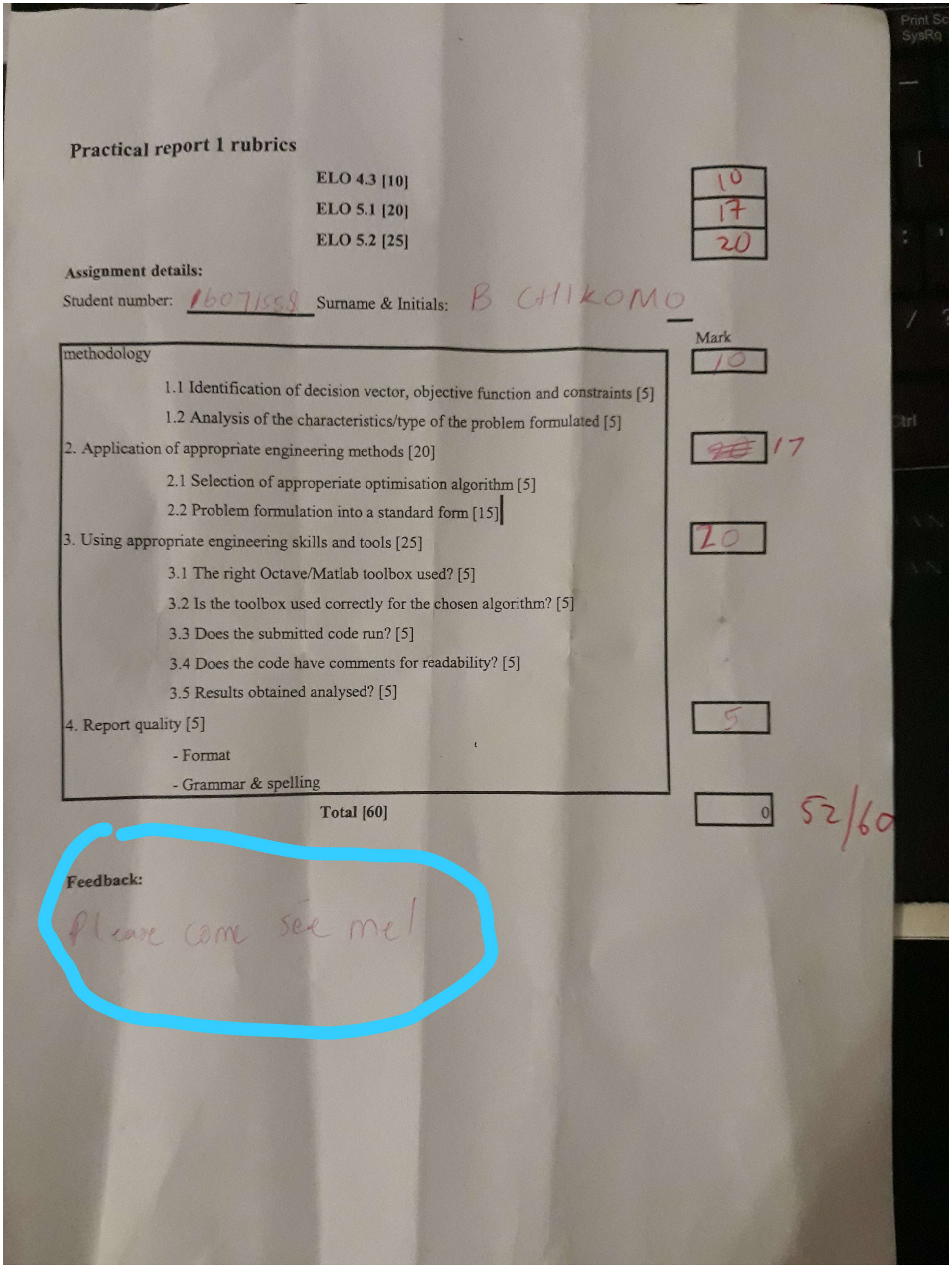
```
big_f(row1_f:row2_f, column1_f:column2_f) = small_f;
f = big_f;

%----------------END OF f MATRIX FORMULATION-----------------


%---------- THE Aeq MATRIX FORMULATION-------------

big_Aeq = zeros(24,96);
%creating small matrix to fit in a big matrix
sm_Aeq = ones(1,24);
small_Aeq = diag(sm_Aeq);

% Specify upper left row, column of where
% we'd like to paste the small matrix.
row1_Aeq1 = 1;
column1_Aeq1 = 1;
% Determine lower right location.
row2_Aeq1 = 24
column2_Aeq1 = 24

% Specify upper left row, column of where
% we'd like to paste the small matrix.
row1_Aeq2 = 1;
column1_Aeq2 = 25;
% Determine lower right location.
row2_Aeq2 = 24
column2_Aeq2 = 48

% Specify upper left row, column of where
% we'd like to paste the small matrix.
row1_Aeq3 = 1;
column1_Aeq3 = 73;
% Determine lower right location.
row2_Aeq3 = 24
column2_Aeq3 = 96

% It will fit, so paste it.
big_Aeq(row1_Aeq1:row2_Aeq1, column1_Aeq1:column2_Aeq1) = small_Aeq;
big_Aeq(row1_Aeq2:row2_Aeq2, column1_Aeq2:column2_Aeq2) = small_Aeq;
big_Aeq(row1_Aeq3:row2_Aeq3, column1_Aeq3:column2_Aeq3) = small_Aeq;
Aeq = big_Aeq;
%----------------END OF Aeq MATRIX FORMULATION-----------------

%---------- THE A MATRIX FORMULATION-------------

big_A = zeros(26,96);
%creating small matrix to fit in a big matrix
sm_A1 = ones(1,24);
small_A1 = diag(sm_A1);

sm_A2 = -1*sm_A1;
sm_A3 = 0.85*ones(1,24);
sm_A4 = -0.85*ones(1,24);



% Specify upper left row, column of where
```

```
% we'd like to paste the small matrix.
row1_A2 = 1;
column1_A2 = 25;
% Determine lower right location.
row2_A2 = 24;
column2_A2 = 48;

% Specify upper left row, column of where
% we'd like to paste the small matrix.
row1_A3 = 1;
column1_A3 = 49;
% Determine lower right location.
row2_A3 = 24;
column2_A3 = 72;

%matrix fitting
row1_A4 = 25;
column1_A4 = 49;
row2_A4 = 25;
column2_A4 = 72;

%matrix fitting
row1_A5 = 25;
column1_A5 = 73;
row2_A5 = 25;
column2_A5 = 96;

%matrix fitting
row1_A6 = 26;

% It will fit, so paste it.
big_A(row1_A2:row2_A2, column1_A2:column2_A2) = small_A1;
big_A(row1_A3:row2_A3, column1_A3:column2_A3) = small_A1;
big_A(row1_A4:row2_A4, column1_A4:column2_A4) = sm_A3;
big_A(row1_A5:row2_A5, column1_A5:column2_A5) = sm_A2;
big_A(row1_A6:row1_A6, column1_A4:column2_A4) = sm_A4;
big_A(row1_A6:row1_A6, column1_A5:column2_A5) = sm_A1;
A = big_A;
%----------------END OF A MATRIX FORMULATION-----------------


%---------- THE b_eq MATRIX FORMULATION-------------

%winter weekend b_eq
beq1 =[1.5; 1.5; 1.5; 1.5; 1.5; 1.95;
     1.95; 1.65; 1.35; 3.25; 3.25; 2.15;
     2.15; 2.15; 2.15; 2.15; 2.15; 1.8;
     2.31; 3.81; 2.31; 2.31; 2.31; 1.35];  %winter weekend



%winter weekday b_eq
beq2 =[1.5; 1.5; 1.5;1.5; 1.5; 1.65;
       1.65;1.35; 1.35; 3.0; 3.0; 1.95
       1.95; 1.95; 1.95; 1.95; 1.65; 1.65
       3.25; 3.25; 2.31; 2.15; 2.15; 1.35]; % winter weekday
```

```
%summer weekend b_eq
beq3 = [1.5; 1.5; 1.85; 1.95; 1.85; 1.5;
    1.65; 1.65; 1.7; 1.75; 1.75; 1.75;
    1.25; 1.32; 1.35; 1.35; 1.45; 2.1;
    2.4; 3.8; 3.8; 2.0; 1.95; 1.65]% summer weekend

%summer weekday b_eq
beq4 = [1.5; 1.5; 1.85; 1.95; 1.85; 1.5;
        1.15; 1.25; 1.3; 1.32 ; 1.35; 1.32;
        1.25; 1.32; 1.35; 1.35; 1.45; 2.15;
        2.31; 3.25; 3.25; 2.0; 1.95; 1.65;]%summer weekday





%----------------END OF b_eq MATRIX FORMULATION---------------


%---------- B MATRIX FORMULATION-------------


B = [0; 0; 0; 0; 0; 0.099289033;
    0.978821256; 1.502028173; 2.042584404; 3.577165653;
    3.444461772; 4.434166272; 4.241990345; 3.825667164;
    3.991322068; 2.31155128; 0.945992816; 0.286574412;
    0.065641571; 0.000662658; 0; 0; 0.000181151; 0 ;27.25; 0];
%----------------END OF B MATRIX FORMULATION-----------------

%---------- BOUNDARY MATRIX FORMULATION-------------

%Bounderies
%1) lower boundary
lb = zeros(96,1);

%2) upper boundary
UB_big = zeros(96,1);
UB_sm1 = 5*ones(24,1);
UB_sm2 = 4*ones(48,1);
UB_sm3 = 54.5*ones(24,1);

row1_ub1 = 1;
col_ub = 1;
row1_ub2 = 24;

row2_ub1 = 25;
row2_ub2 = 72;

row3_ub1 = 73;
row3_ub2 = 96;

UB_big( row1_ub1:row1_ub2, col_ub:col_ub)= UB_sm1;
UB_big( row2_ub1:row2_ub2, col_ub:col_ub)= UB_sm2;
UB_big( row3_ub1:row3_ub2, col_ub:col_ub)= UB_sm3;
ub = UB_big;
%----------END OF BOUNDARY MATRIX FORMULATION-------------
```

```
%------------------MAIN CODE TO PLOT---------------------------
[x,fval] = quadprog(H,f,A,B,Aeq,beq1,lb,ub);

t = linspace(0,24,24);
%t = hours(1):hours(1):hours(24);

p1= x(1:24,1);
p2= x(25:48,1);
p3= x(49:72,1);
p4= x(73:96,1);

p_1 = (p1)';
p_2 = (p2)';
p_3 = (p3)';
p_4 = (p4)';



%h = suptitle({'Winter power flow chart',''})
%set(h,'FontSize',25);


s(1)=subplot(2,2,1);
h1 = stairs(s(1),t,p_1);
h1.Color = 'red';
h1.LineWidth = 3.5;
title('(a)', 'FontSize', 20);
hy1 = ylabel('Power (P_1(t) [kW])');
hx1 = xlabel('Time[hours]');
hy1.FontSize = 30;
hx1.FontSize = 30;
ax = gca;
ax.FontSize = 30;
ax.LineWidth = 2;

s(2)=subplot(2,2,2);
h2 = stairs(s(2),t,p_2);
h2.Color = 'black';
h2.LineWidth = 3.5;
title('(b)', 'FontSize', 20);
hy2 = ylabel('Power (P_2(t) [kW])');
hx2 = xlabel('Time[hours]');
hy2.FontSize = 30;
hx2.FontSize = 30;
ax = gca;
ax.FontSize = 30;
ax.LineWidth = 2;

s(3)=subplot(2,2,3);
h3 = stairs(s(3),t,p_3);
h3.Color = 'blue';
h3.LineWidth = 3.5;
title('(c)', 'FontSize', 20);
hy3 = ylabel('Power (P_3(t) [kW])');
hx3 = xlabel('Time[hours]');
```

```
hy3.FontSize = 30;
hx3.FontSize = 30;
ax = gca;
ax.FontSize = 30;
ax.LineWidth = 2;

s(4)=subplot(2,2,4);
h4 = stairs(s(4),t,p_4);
h4.Color = [0.4940, 0.1840, 0.5560];% deep purple colour
h4.LineWidth = 3.5;
title('(d)', 'FontSize', 20);
hy4 = ylabel('Power (P_4(t) [kW])');
hx4 = xlabel('Time[hours]');
hy4.FontSize = 30;
hx4.FontSize = 30;
ax = gca;
ax.FontSize = 30;
ax.LineWidth = 2;

%---------------axis settings----------------------------------------------
axis([s(1)],[0 24 0.753 1]);
yticks(s(1),[0 1]); %winter weekend

%axis([s(1)],[0 24 0.653 1]);
%yticks(s(1),[0 1]);    %winter weekday

axis([s(2) s(3) s(4)],[0 24 0 4]);
xticks([s(1) s(2) s(3) s(4)],[0 6 12 18 24]);
yticks([s(2) s(3) s(4)],[0 2 4]);
ax = gca;
ax.FontSize = 30;
ax.LineWidth = 2;
ax.LineWidth = 2;

%---------------THE END: THANKS TO MATLAB TEAM-----------------------------
```


Practical report 1 rubrics

ELO 4.3 [10] 10
ELO 5.1 [20] 17
ELO 5.2 [25] 20

Assignment details:
Student number: 16071558 Surname & Initials: B CHIKOMO

	Mark
methodology	
1.1 Identification of decision vector, objective function and constraints [5]	10
1.2 Analysis of the characteristics/type of the problem formulated [5]	
2. Application of appropriate engineering methods [20]	~~20~~ 17
2.1 Selection of approperiate optimisation algorithm [5]	
2.2 Problem formulation into a standard form [15]	
3. Using appropriate engineering skills and tools [25]	20
3.1 The right Octave/Matlab toolbox used? [5]	
3.2 Is the toolbox used correctly for the chosen algorithm? [5]	
3.3 Does the submitted code run? [5]	
3.4 Does the code have comments for readability? [5]	
3.5 Results obtained analysed? [5]	
4. Report quality [5]	5
- Format	
- Grammar & spelling	
Total [60]	0 52/60

Feedback:
Please come see me!

Fig. 3. Marking attach for this paper"ALL THE BEST!!"

DONT WORRY ABOUT THE SEE ME ON THE MARKING, THE LECTURER CALLED ME BECAUSE I WAS THE HIGHEST AND WANTED TO SEE ME SINCE I SCORED AND WROTE THE PERFECT REPORT!!!!!!!!!!!!!!!

#THATS HOW WE DO IT!!
THANK THE LORD