Electric Car Project

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Abstract:-

The primary goal of this project is to design a electric car battery system. According to the project description and the requirements of the battery system, a DC power battery, a bidirectional DC/DC converter (Boost converter, a three phase DC/AC inverter , and Load which is eventually be used for the car to keep functioning. All these parts will use to for different purpose such as three phase different operation will determinate the load replacement. Power loss of the system has to be prioritize because excessive loss not profitable for the manufacturing companies.

DUTY RATIO RANGE:

$\frac{V_{out}}{V_{in}} = \frac{1}{1-D}$ $D = 1 - \frac{V_{in}}{V_{out}} = 1 - \frac{200}{600} = 0.667 = 66.7\%$ $V_{in} = 200 Volts$
For $V_{in} = 400\ Volts$
$\frac{V_{out}}{V_{in}} = \frac{1}{1-D}$
$D = 1 - \frac{V_{in}}{V_{out}} = 1 - \frac{400}{600} = 0.333 = 33.3\%$
Duty Range, $D = \varepsilon[33.3\%, 66.6\%$

INDUCTANCE:

$\Delta i = \frac{1}{L} V_{in} t_{on} = \frac{1}{L}(V_{out} - V_{in}) t_{off}$
$\Delta i = \frac{1}{L}(V_{out}(1-D)V_{out})(1-D)T_s$
$\Delta i = \frac{1}{L}\frac{V_{out}D(1-D)}{f_s}$
$L = \frac{V_{out}D(1-D)}{f_s \Delta i} = \frac{600*0.5*(1-0.5)}{5*10^3*100} = 3*10^{-4} = 300\ \mu H$

MODULATION INDEX OF THREE OPERATIONS:

$V_{rms} Values are$

$V_{an1} = \frac{P}{3[I_{rms}PF]} = \frac{75000}{3(160*0.8)} = 195.3125\ Volts$

$V_{an2} = \frac{P}{3[I_{rms}PF]} = \frac{50000}{3(120*0.8)} = 173.61\ Volts$

$V_{an3} = \frac{P}{3[I_{rms}PF]} = \frac{25000}{3(250*0.8)} = 41.66\ Volts$

Modulation Indexes are
$m_{an1} = \frac{2\sqrt{2}V_{an1}}{V_d} = \frac{2*195.3125*\sqrt{2}}{600} = 0.920$
$m_{an2} = \frac{2\sqrt{2}V_{an2}}{V_d} = \frac{2*173.61*\sqrt{2}}{600} = 0.818$
$m_{an3} = \frac{2\sqrt{2}V_{an3}}{V_d} = \frac{2*41.66*\sqrt{2}}{600} = 0.197$

POWER-LOSS CALCULATION(IGBT):

List of Equations to be used:

$P_{ss} = I_{cp}V_{ce(sat)}(\frac{1}{8} + \frac{D}{3\pi})$
$P_{sw} = E_{sw(ON)} + E_{sw(OFF)} * f_{sw} * \frac{1}{\pi}$
$P_{IGBT} = P_{sw} + P_{sw}$
$P_{dc} = I_{ep} * V_{ec}(\frac{1}{8} - \frac{D}{3\pi})$
$P_{rr} = 0.125 * I_{rr} * t_{rr} * V_{ce(P-K)} * f_{sw}$
$P_a = P_{ss} + P_{sw} + P_{dc} + P_{rr}$

CALCULATION(THREE OPERATIONS):

The following calculations have done using Matlab tool.

Matlab Code:

```matlab
clear
clc
disp('Author: Abu Sayed (50172775) and Nathan Chordas-Ewell(50121889)');
fprintf('\n');
% Duty Ratio Range
Vin1=200;
Vin2=400;
Vout=600;
D1=(1-(Vin1/Vout));
D2=(1-(Vin2/Vout));
disp('The DUTY RATIO RANGE:')
disp(D1);
disp(D2);
%Modulation Indexes For Three Operations:
P1=75000;
P2=50000;
P3=25000;
PF=0.8;
Irms1=160;
Irms2=120;
Irms3=250;
Vd= 600;
Van=(P1/(3*Irms1*PF));
Vbn=(P2/(3*Irms2*PF));
Vcn=(P3/(3*Irms3*PF));
disp('Vrms Values are:')
disp(Van);
disp(Vbn);
disp(Vcn);

% Calculation For WYE Parameters R and L :
Ipk1=226.27;
Ipk2=169.7;
Ipk3=353.55;
f1=400;
f2=800;
f3=40;
Omega1= 2* pi *f1;
Omega2= 2* pi *f2;
Omega3= 2* pi *f3;
Ran=  (Ipk1)^2 /P1;
Rbn=  (Ipk2)^2 /P2;
Rcn = (Ipk3)^2 /P3;
```

```
Lan=(P1*sqrt((1/PF^2)-1)/Omega1*Irms1);
Lbn=(P2*sqrt((1/PF^2)-1)/Omega2*Irms2);
Lcn=(P3*sqrt((1/PF^2)-1)/Omega3*Irms3);

%RESULTS:
fprintf('\n');
disp( 'FINAL RESULTS FOR Resistor and Inductance Value for WYE');
fprintf('\n');
disp('RESISTANCE Ran, Rbn, Rcn Values are in Ohm');
disp(['Ran = ' num2str(Ran)]);
disp(['Rbn = ' num2str(Rbn)]);
disp(['Rcn = ' num2str(Rcn)]);
fprintf('\n');
disp('RESISTANCE Lan, Lbn, Lcn Values are in uH ');
disp(['Lan = ' num2str(Lan)]);
disp(['Lbn = ' num2str(Lbn)]);
disp(['Lcn = ' num2str(Lcn)]);

%('For Modulation Index Mxn:')
Man= ((2*sqrt(2)*Van)/(Vd));
Mbn= ((2*sqrt(2)*Vbn)/(Vd));
Mcn= ((2*sqrt(2)*Vcn)/(Vd));
fprintf('\n');
disp('Results of Modulation Indexes are:')
disp(['Man = ' num2str(Man)]);
disp(['Mbn = ' num2str(Mbn)]);
disp (['Mcn = ' num2str(Mcn)]);
disp('POWER LOSS CALCULATIONS (IGBT):')
fprintf('\n');
disp('Operation #1')
%Steady-state loss:
Icp1=160*sqrt(2);
Icp2=120*sqrt(2);
Icp3=250*sqrt(2);
Vce1=1.5;
Vce2=1.4;
Vce3=1.75;
```

```
%D=Mxn Values
fsw=5000;
DTR=0.5; % Duty Ratio
EswON1=15E-3;
EswON2=12E-3;
EswON3=23E-3;
EswOFF1=20E-3;
EswOFF2=17E-3;
EswOFF3=31E-3;

%DIODE-LOSS CALCULATION:
Iep1=160*sqrt(2);
Iep2=120*sqrt(2);
Iep3=250*sqrt(2);
Vec1=1.7;
Vec2=2.0;
Vec3=2.5;

%Recovery Loss Perdiode:
Irr1=115E-9;
Irr2=105E-9;
Irr3=120E-9;
Trr1=190E-9;
Trr2=180E-9;
Trr3=205E-9;
VcePK=600;

%OPERATION # 1:
Pss1=Icp1*(Vce1)*((1/8)+(Man*PF/3* pi)); %PF = Cos(theta);
Psw1=EswON1+EswOFF1*fsw/pi; %Here is a little problem, doesn't give the correct answer.
%STEADY-STATE LOSS PER DIODE
Pdc1=Iep1*Vec1*(1/8-Man* PF/3*pi);
%Recovery Loss Per Diode:
Prr1=0.125*Irr1*Trr1*VcePK*fsw;
%Loss per Arm(SHADED PART):
Pa1=Pss1+Psw1+Pdc1+Prr1;
fprintf('\n');
disp('OPERATION#1:');
disp('The Steady State Loss');
disp(['Pss1 = ' num2str(Pss1)]);
disp('SWITCHING LOSS PER SWITCHING IGBT:');
disp(['Psw1 = ' num2str(Psw1)]);
disp('STEADY-STATE PER DIODE');
disp(['Pdc1 = ' num2str(abs(Psw1))]);
disp('RECOVERY LOSS PER DIODE');
disp(['Prr1 = ' num2str(Prr1)]);
disp('LOSS PER ARM (SHADED PART)');
disp(['Pa1 = ' num2str(Pa1)]);
fprintf('\n');
```

```
%OPERATION # 2:
Pss2=Icp2*(Vce2)*((1/8)+(Mbn*PF/3* pi));
Psw2=(EswON2+(EswOFF2*(fsw)*(1/pi))); %Here is a little problem, doesn't give the correct answer.
%STEADY-STATE LOSS PER DIODE
Pdc2=Iep2*Vec2*(1/8-Mbn*PF/3*pi);
%Recovery Loss Per Diode:
Prr2=0.125*Irr2*Trr2*VcePK*fsw;
%Loss per Arm(SHADED PART):
Pa2=Pss2+Psw2+Pdc2+Prr2;

fprintf('\n');
disp('OPERATION# 2:');
disp('The Steady State Loss');
disp(['Pss2 = ' num2str(Pss2)]);
disp('SWITCHING LOSS PER SWITCHING IGBT:');
disp(['Psw2 = ' num2str(Psw2)]);
disp('STEADY-STATE PER DIODE');
disp(['Pdc2 = ' num2str(abs(Psw2))]);
disp('RECOVERY LOSS PER DIODE');
disp(['Prr2 = ' num2str(Prr2)]);
disp('LOSS PER ARM (SHADED PART)');
disp(['Pa2 = ' num2str(Pa2)]);
fprintf('\n');
%OPERATION # 3:
Pss3=Icp3*(Vce3)*((1/8)+(Mcn *PF/3 *pi));
Psw3=(EswON3+(EswOFF3*(fsw)*(1/pi))); %Here is a little problem, doesn't give the correct answer.
%STEADY-STATE LOSS PER DIODE
Pdc3=Iep3*Vec3*(1/8-Mcn*PF/3 *pi);
%Recovery Loss Per Diode:
Prr3=0.125*Irr3*Trr3*VcePK*fsw;
%Loss per Arm(SHADED PART):
Pa3=Pss3+Psw3+Pdc3+Prr3;
fprintf('\n');

disp('OPERATION# 3:');
disp('The Steady State Loss');
disp(['Pss3 = ' num2str(Pss3)]);
disp('SWITCHING LOSS PER SWITCHING IGBT:');
disp(['Psw3 = ' num2str(Psw3)]);
disp('STEADY-STATE PER DIODE');
disp(['Pdc3 = ' num2str(abs(Psw3))]);
disp('RECOVERY LOSS PER DIODE');
disp(['Prr3 = ' num2str(Prr3)]);
disp('LOSS PER ARM (SHADED PART)');
disp(['Pa3 = ' num2str(Pa3)]);
fprintf('\n');
```

467Final.m | final.m | thermal.m

```
%Thermal Resistance
Rth_jc=0.053; %Thermal resistance per IGBT
Rth_jc=0.080; % Per FWDi
Rth_cf= 0.02;  % Case to Heatshink
Tc=125; %125 degree celcius
Ta=75;
Pa3=182.64;
%Tc=Ta+Pa3*(Rth_cf)+Rth_fa;  % Rth_fa = Thermal resitance of finge to ambian
% Pa3= is the highest Loss
Rth_fa=Tc-Ta-Pa3-Rth_cf;
disp('The Thermal Resistance of finge to ambian is:');
disp(['Rth_fa = ' num2str(abs(Rth_fa))]);

%Total Gate Charge:
Qgate=2000E-9;
Vge=15;
fs=5000;
Pdrive=Qgate*Vge*fsw;
disp(['Pdrive=' num2str(Pdrive)]);
```

Result:

```
Author: Abu Sayed (50172775) and Nathan Chordas-Ewell(50121889)

The DUTY RATIO RANGE:
    0.6667

    0.3333

Vrms Values are:
  195.3125

  173.6111

   41.6667


FINAL RESULTS FOR Resistor and Inductance Value for WYE

RESISTANCE Ran, Rbn, Rcn Values are in Ohm
Ran = 0.68264
Rbn = 0.57596
Rcn = 4.9999
RESISTANCE Lan, Lbn, Lcn Values are in uH
Lan = 3580.9862
Lbn = 895.2466
Lcn = 18650.9699

Results of Modulation Indexes are:
Man = 0.92071
Mbn = 0.81841
Mcn = 0.19642
```

```
POWER LOSS CALCULATIONS (IGBT):

Operation #1

OPERATION#1:
The Steady State Loss
Pss1 = 304.2258
SWITCHING LOSS PER SWITCHING IGBT:
Psw1 = 31.846
STEADY-STATE PER DIODE
Pdc1 = 31.846
RECOVERY LOSS PER DIODE
Prr1 = 8.1938e-09
LOSS PER ARM (SHADED PART)
Pa1 = 87.4491
```

```
OPERATION# 2:
The Steady State Loss
Pss2 = 192.5959
SWITCHING LOSS PER SWITCHING IGBT:
Psw2 = 27.0683
STEADY-STATE PER DIODE
Pdc2 = 27.0683
RECOVERY LOSS PER DIODE
Prr2 = 7.0875e-09
LOSS PER ARM (SHADED PART)
Pa2 = 29.3801
```

```
OPERATION# 3:
The Steady State Loss
Pss3 = 179.1507
SWITCHING LOSS PER SWITCHING IGBT:
Psw3 = 49.361
STEADY-STATE PER DIODE
Pdc3 = 49.361
RECOVERY LOSS PER DIODE
Prr3 = 9.225e-09
LOSS PER ARM (SHADED PART)
Pa3 = 193.553
```

Thermal Resistance

```
>> thermal

Rth_cf =

    0.0200

The Thermal Resistance of finge to ambian is:
Rth_fa = 132.66
Pdrive=0.15
```

OPERATION :

Table for gathered result using above equations and observation of CM400HA-24 A data-sheet

Table 1: Three Typical Operation Points

	Maximum power and maximum torque	High speed low torque	Low speed high torque
Inverter output power (W)	75000	50000	25000
Inverter based current (Ampere RMS)	160	120	250
Power factor	0.8	0.8	0.8
Fundamental frequency (Hz)	400	800	40

Resultant Data from the above Calculations are in a Table form

IGBT	OPERATION	$V_{ce(sat)}$	V_{ec}	$E_{sw(ON)}$ mj/pulse	$E_{sw(OFF)}$ mj/pulse	$V_{ce(PK)}$ Recovery	P_{ss}	P_{sw}	P_{dc}	P_{rr} nj	P_a
CH400HA-24A	1	1.5	1.7	15	20	600	304.22	31.84	31.84	8.19	78.72
	2	1.4	2.0	12	17	600	192.59	27.07	27.07	7.08	11.92
	3	1.75	2.5	23	31	600	179.15	49.61	49.36	9.2	182.64

IGBT	OPERATION	I_{CP}	PF	DUTY CYCLE	FREQUENCY(Hz)
CM400HA-24A	1	160	0.8	0.5	5000
	2	120	0.8	0.5	5000
	3	250	0.8	0.5	5000

CM400HA-24A DATA-SHEET:

This data-sheet have downloaded from Powerex to determine the characteristic, Conduction Loss, Switching Loss and Thermal Resistance.

Figure 1: Various Characteristic

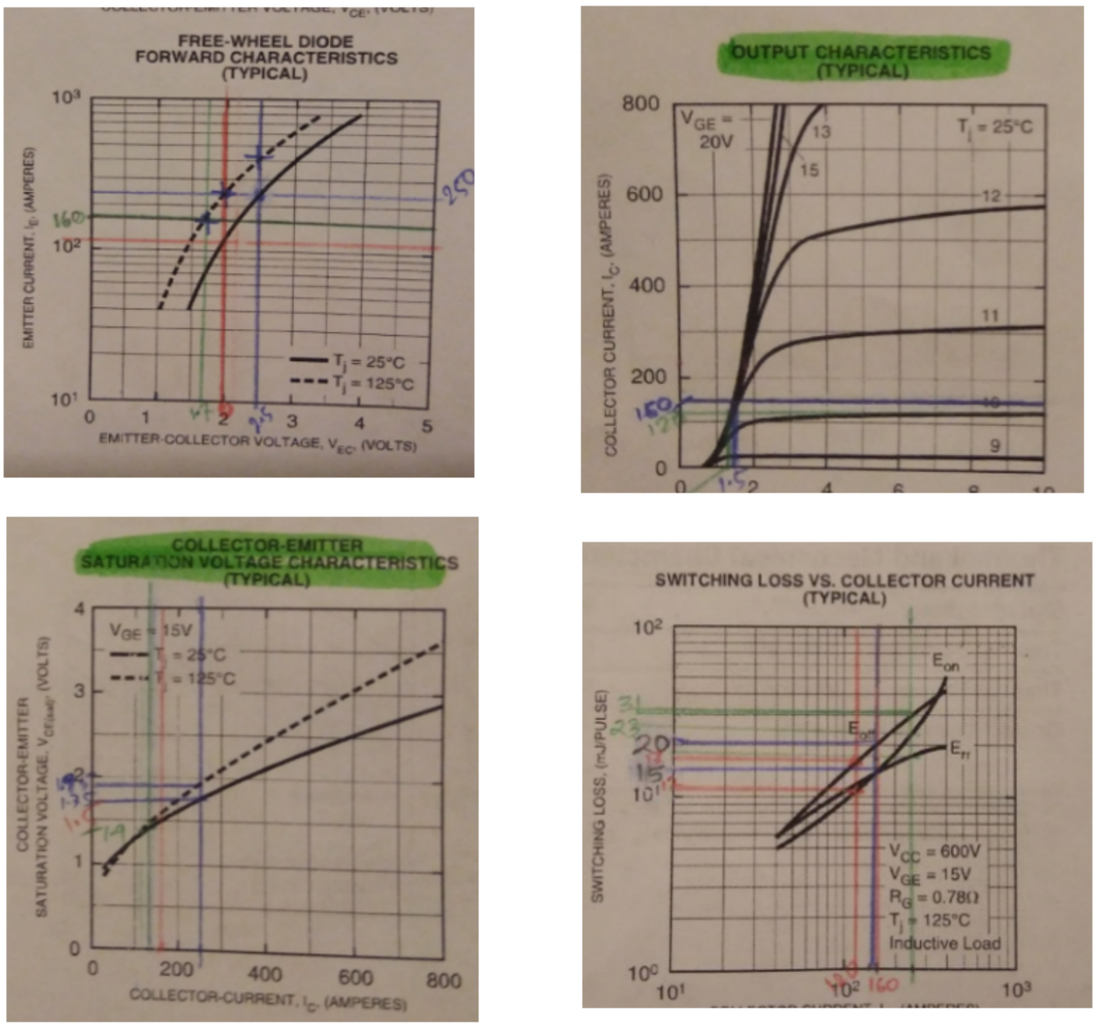


Figure 2: Electric Car Battery System

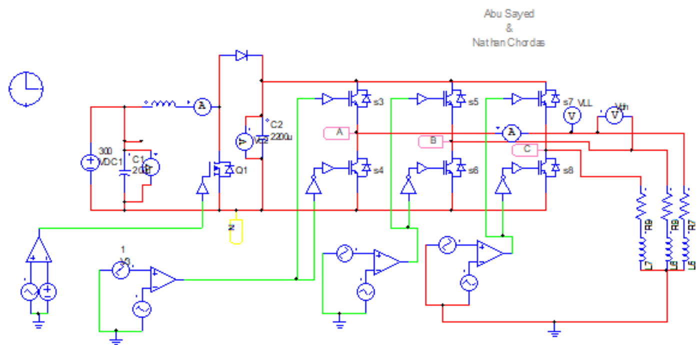


Figure 3: Input and Output Current Waveform

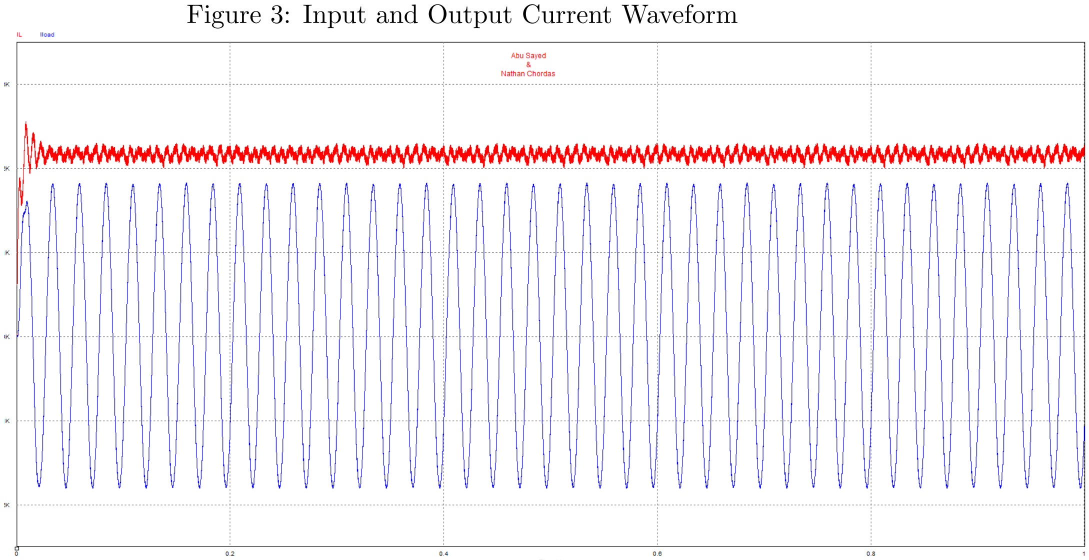


Figure 4: Load Side Output Voltage Waveform

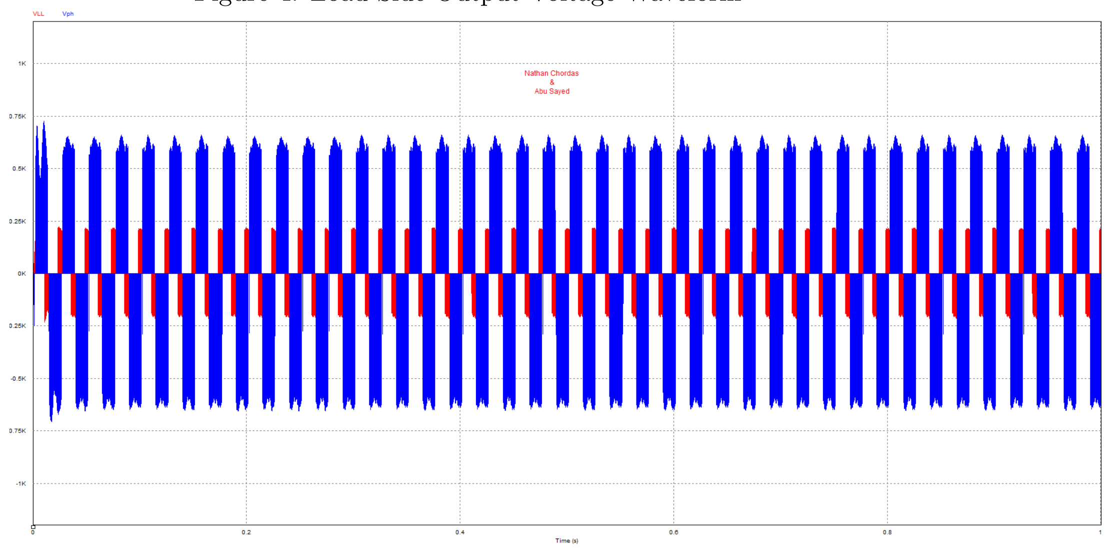


Figure 5: Capacitance Voltage Waveform

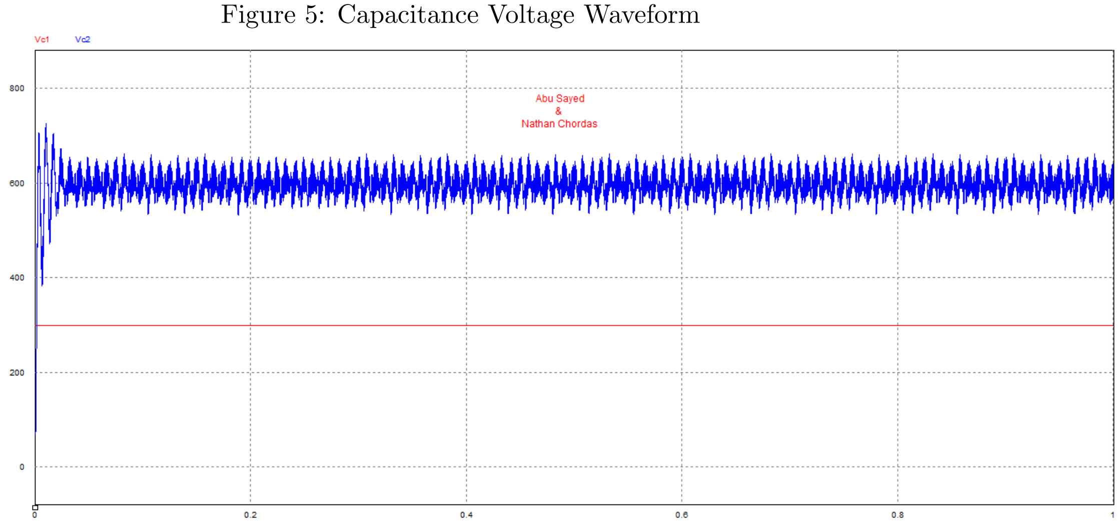
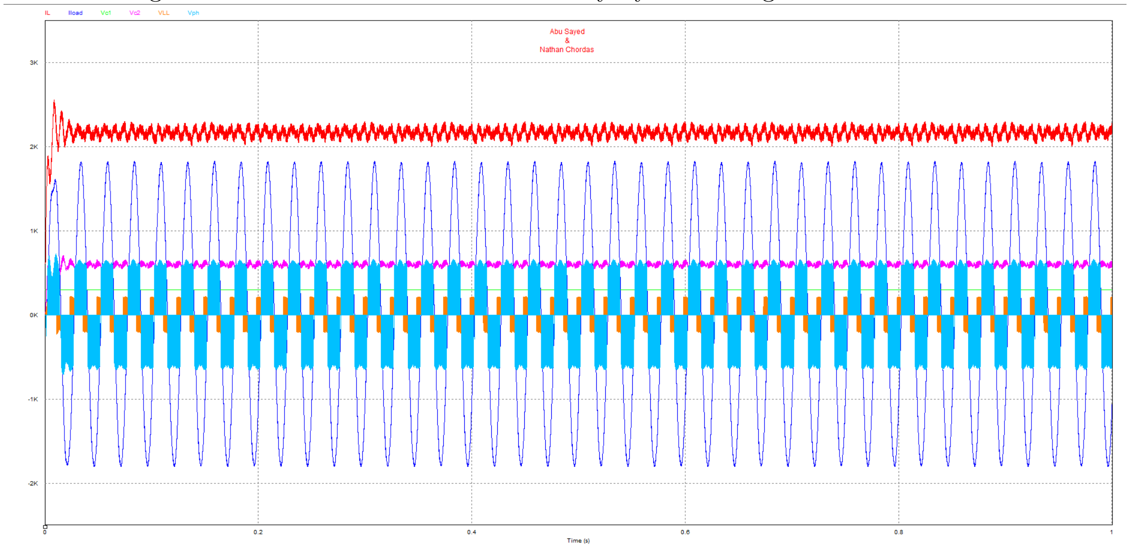


Figure 6: Combined Waveform of Battery System Design



Circuit Diagram:

Resultant Waveform of above Design:

CONCLUSION:

It has been determined after the simulation that the system is allowable to take the DC input and give an AC output at the load side, and with three different phases with 120 degree phase difference. The stable input has a great performance and gives a great output AC signal based on the calculated values, and the Minimum and Maximum torque has the great performance along with the three different operation conditions. Only the high value have observed during the steady state is the thermal resistance of the IGBT. It is quite high and which eventually is not good for this kind of battery system, it has to be lower and has to be lower as possible. According to gate drive power loss, it is good if it is low as expected, because the efficiency varies with the gate drive power loss.