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Modelling and Analysis of Electric Vehicle DC Fast Charging Infrastructure

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Abstract

In this presentation, DC fast charging infrastructure model using PSIM is proposed. DC Fast charging infrastructure is modelled as a bidirectional three-phase PWM rectifier with constant output voltage control and unity power factor input current control. The specification of the DC fast charging infrastructure is a constant voltage charging mode with capacity of 50 kW. Using a proposed model,a simulation on various levels of State Of Charge (SOC) which are simplified to the battery voltage droplevels was also performed. Lithium ion batteries was used and modelled by Thevenin equivalent battery model. Analysis of the DC fast charging impacts to the grid seen from the input current Total Harmonics Distortion (THD) were conducted.

Outline

I • INTRODUCTION

II • DC FAST CHARGER MODELING USING PSIM 9.0

III • SIMULATION

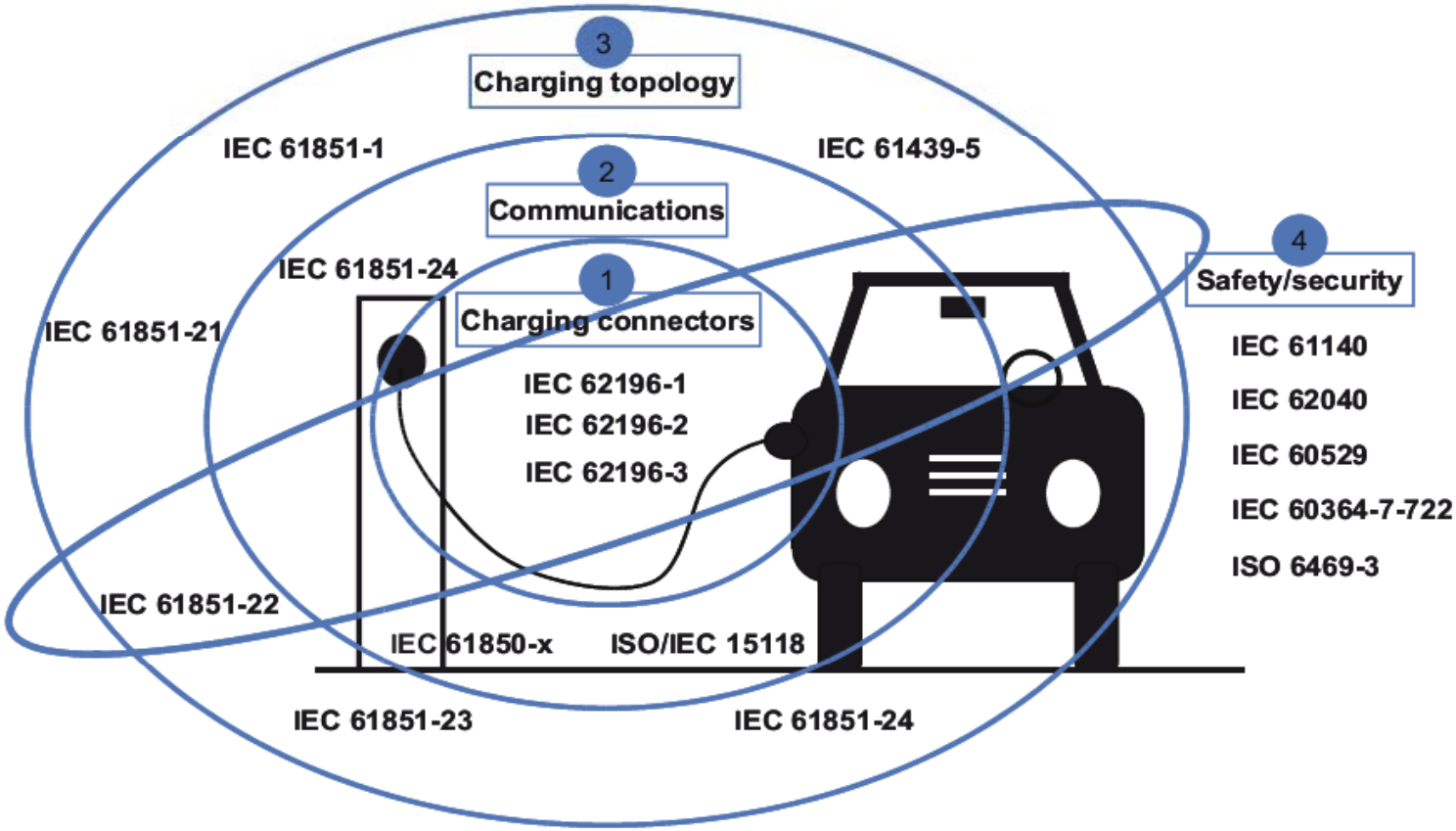
• SIMULATION ANALYSIS

• CONCLUSION

INTRODUCTION

1. Fossil energy limit and environmental issues
2. Internal Combustion Engine Vehicle transition to Electric Vehicle
3. Better performance of Electric Vehicle as battery technology and charging infrastructure developed
4. Rapid development of fast charging infrastructure for EV
5. Research of fast charging infrastructure is needed before it is implemented in Indonesia

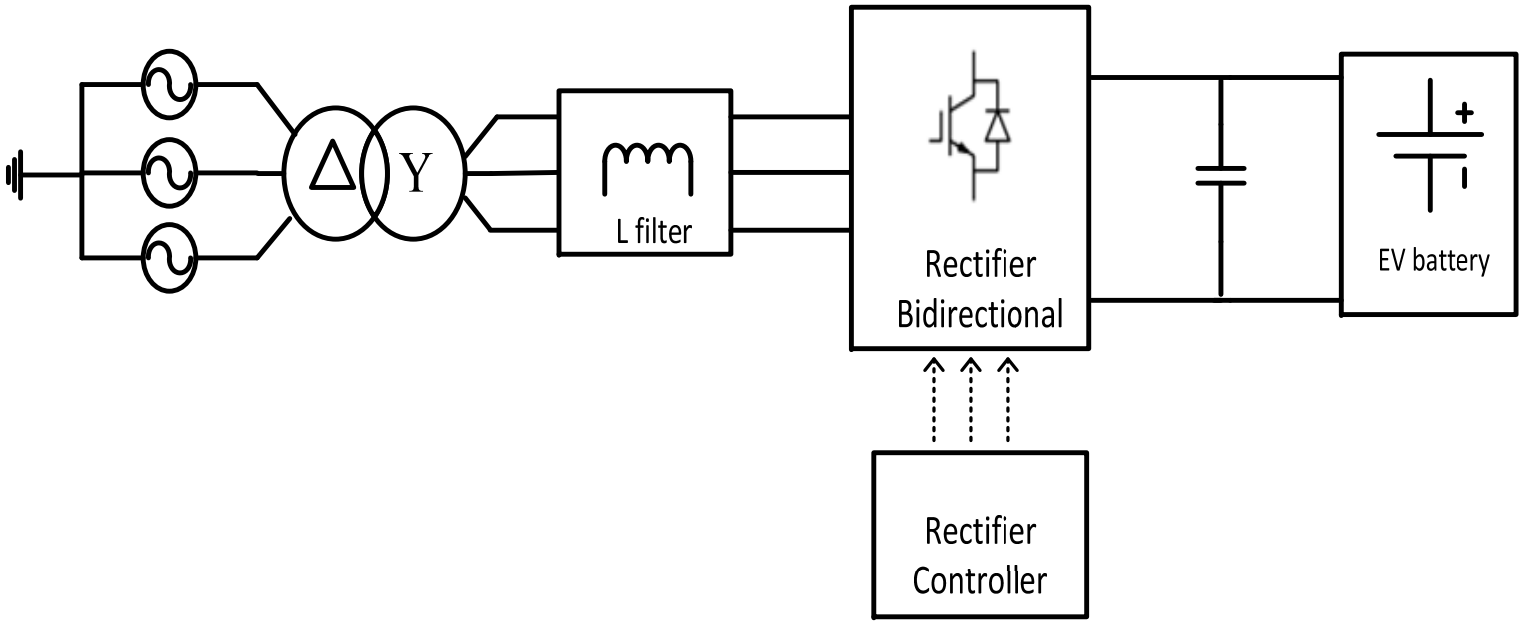
Charging System Covered on IEC Standard



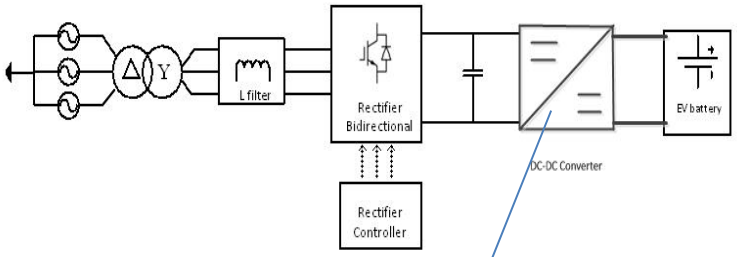
DC FAST CHARGER MODELING USING PSIM

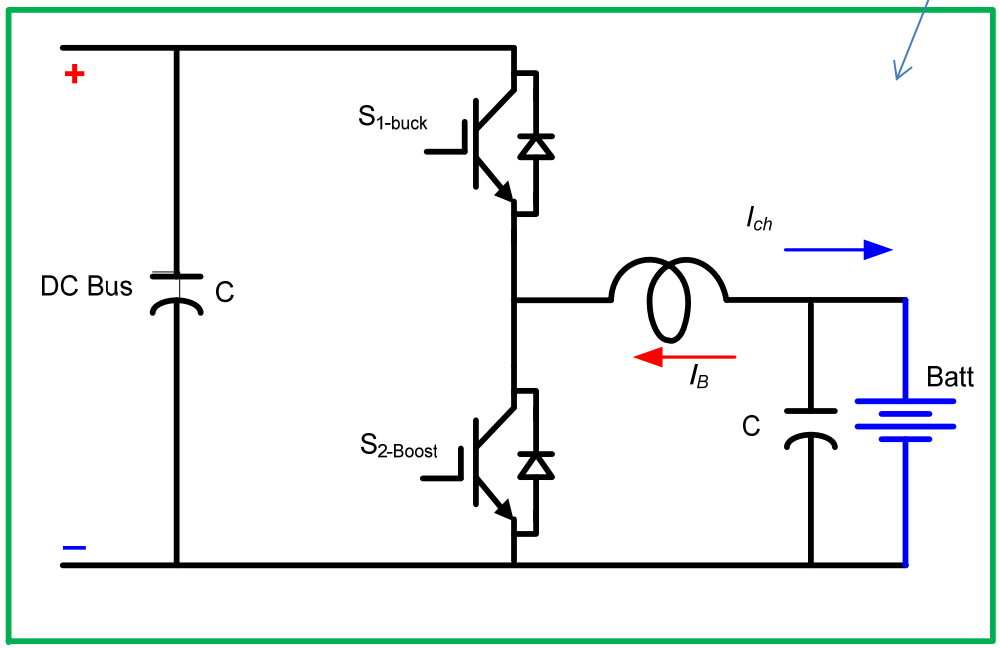
- *Fast charging mode that used is constant voltage and Constant Current mode*
- Fast charger that modeled have unity power factor input
- *Fast charger* that modeled is *bidirectional charger*
- Maximum Output Power of DC fast charger is 50 kW
- Charging voltage of DC fast charger is 600 V DC

Electric Car DC fast charger model



BUCK – BOOST CONVERTER

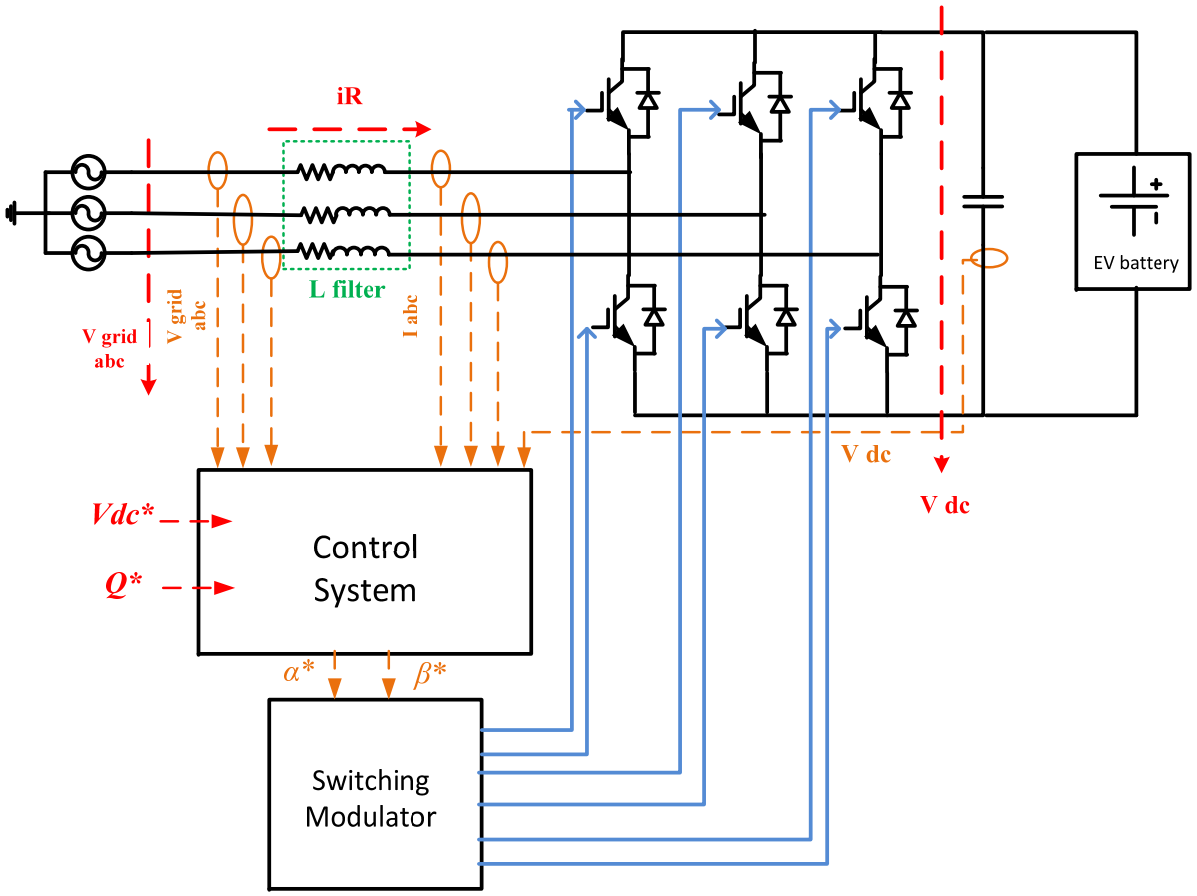




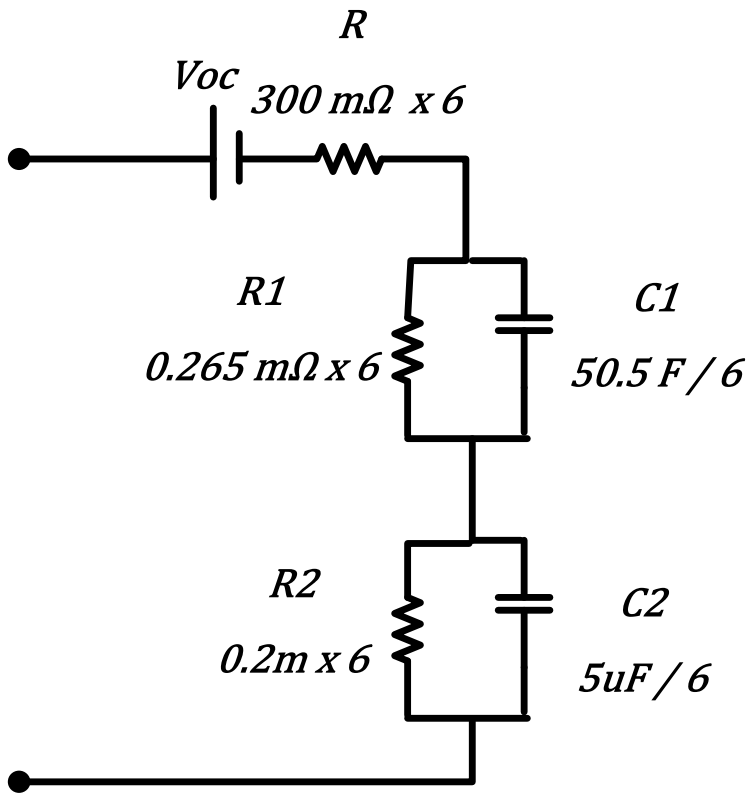
Buck-Boost Converter

- Maintained Constant current
- Bidirectional mode with separate buck or boost mode

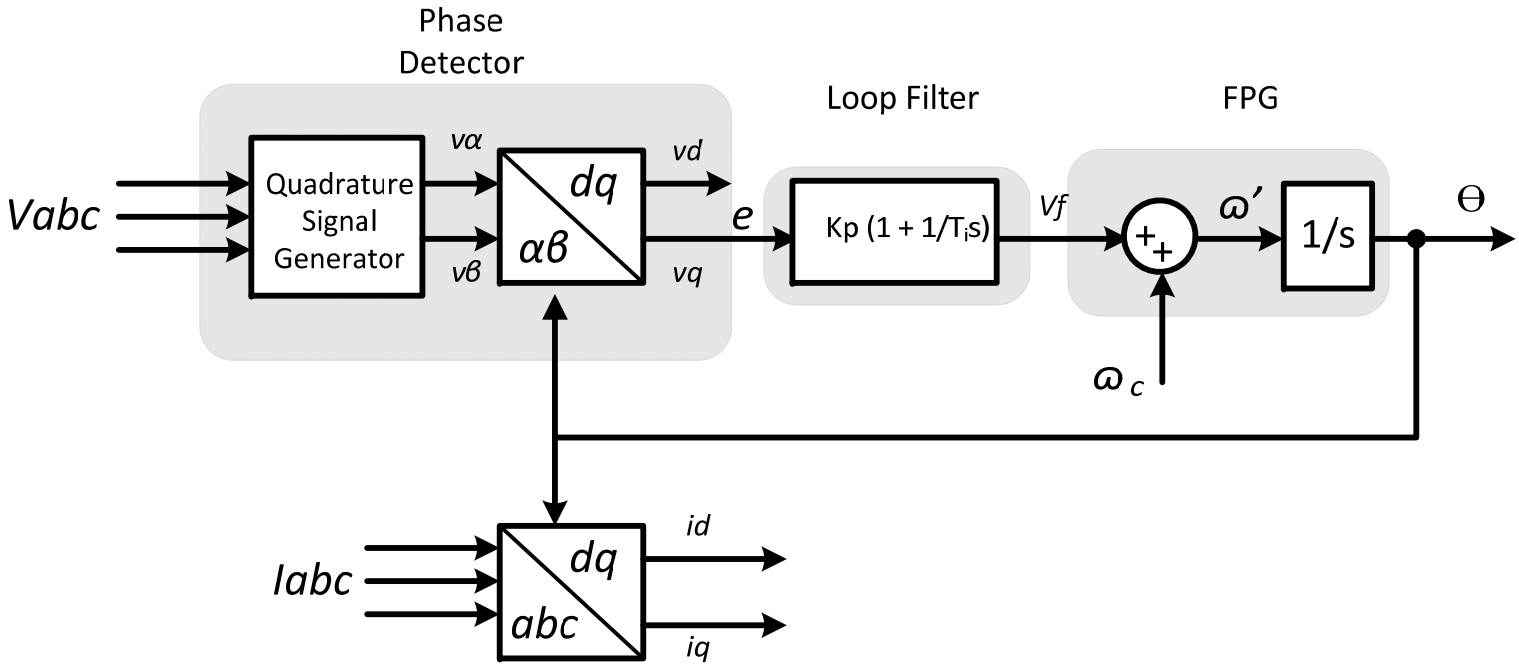
Three phase bidirectional PWM rectifier scheme



Battery model approach 600 V for 150 cells arranged series

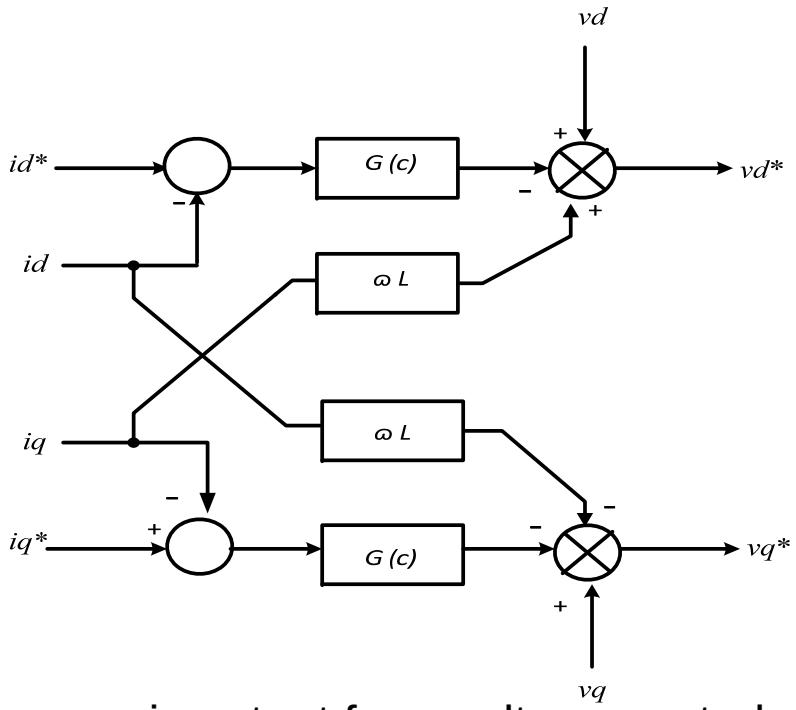


Angle Control Using PLL



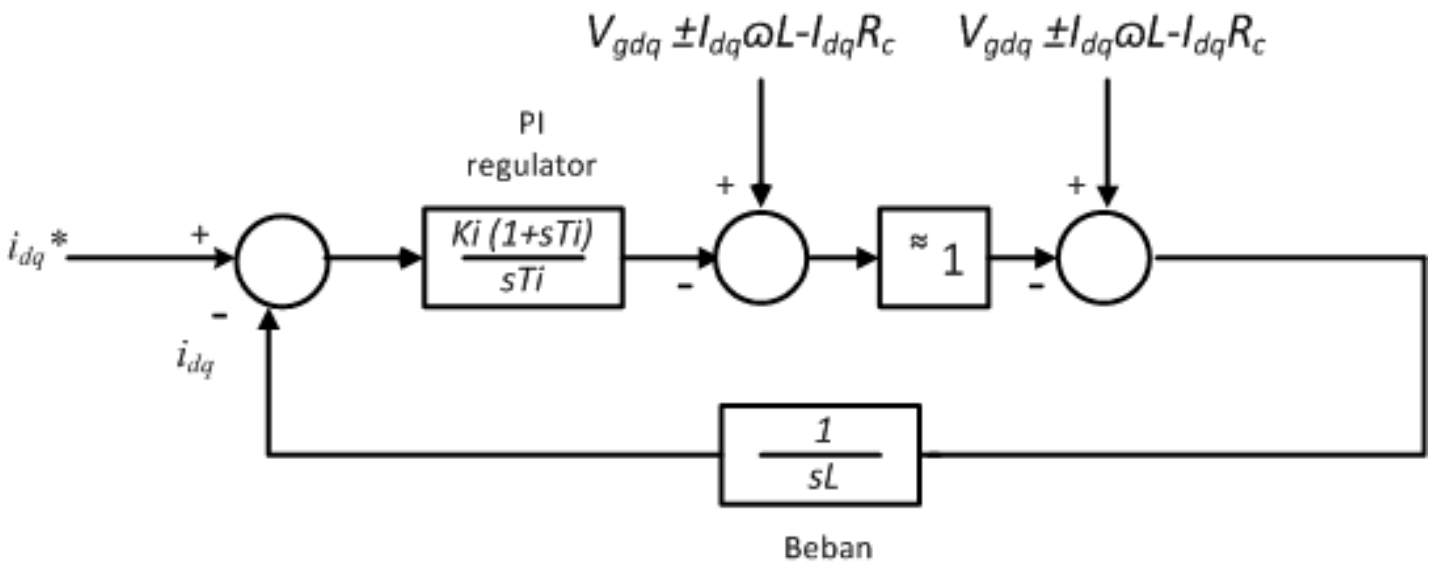
Current Control

Feed-forward current control scheme



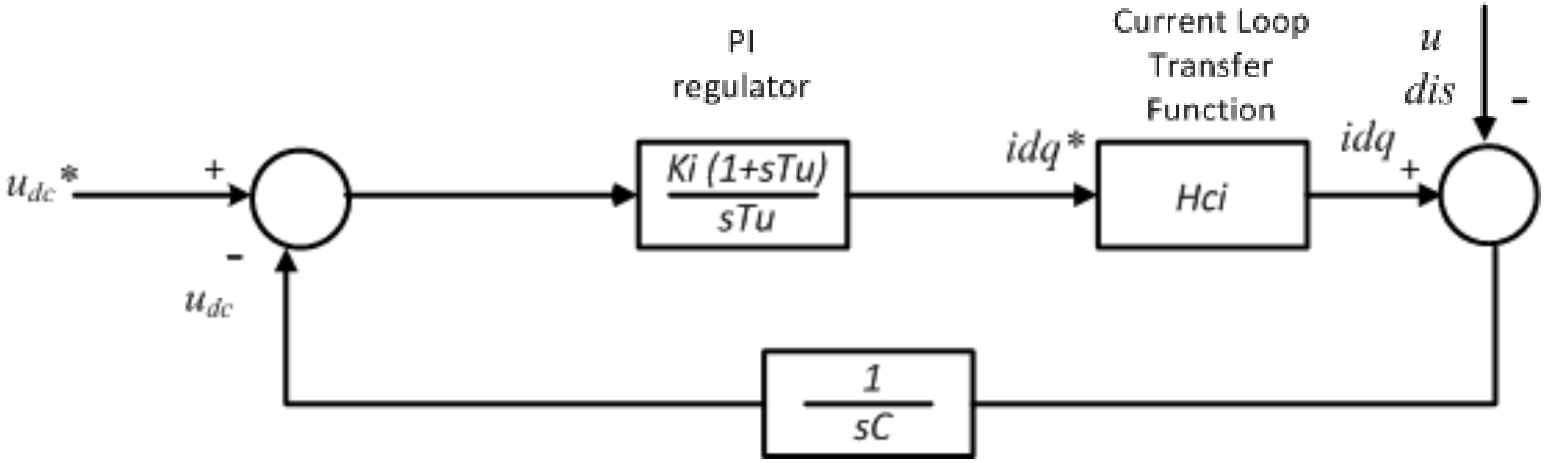
Id* current reference is output from voltage control
Iq* current reference is zero

Current Control



Feed-forward current control is used in order to compensate inductance coupling in rectifying current using synchronous reference frame.

DC Voltage Control

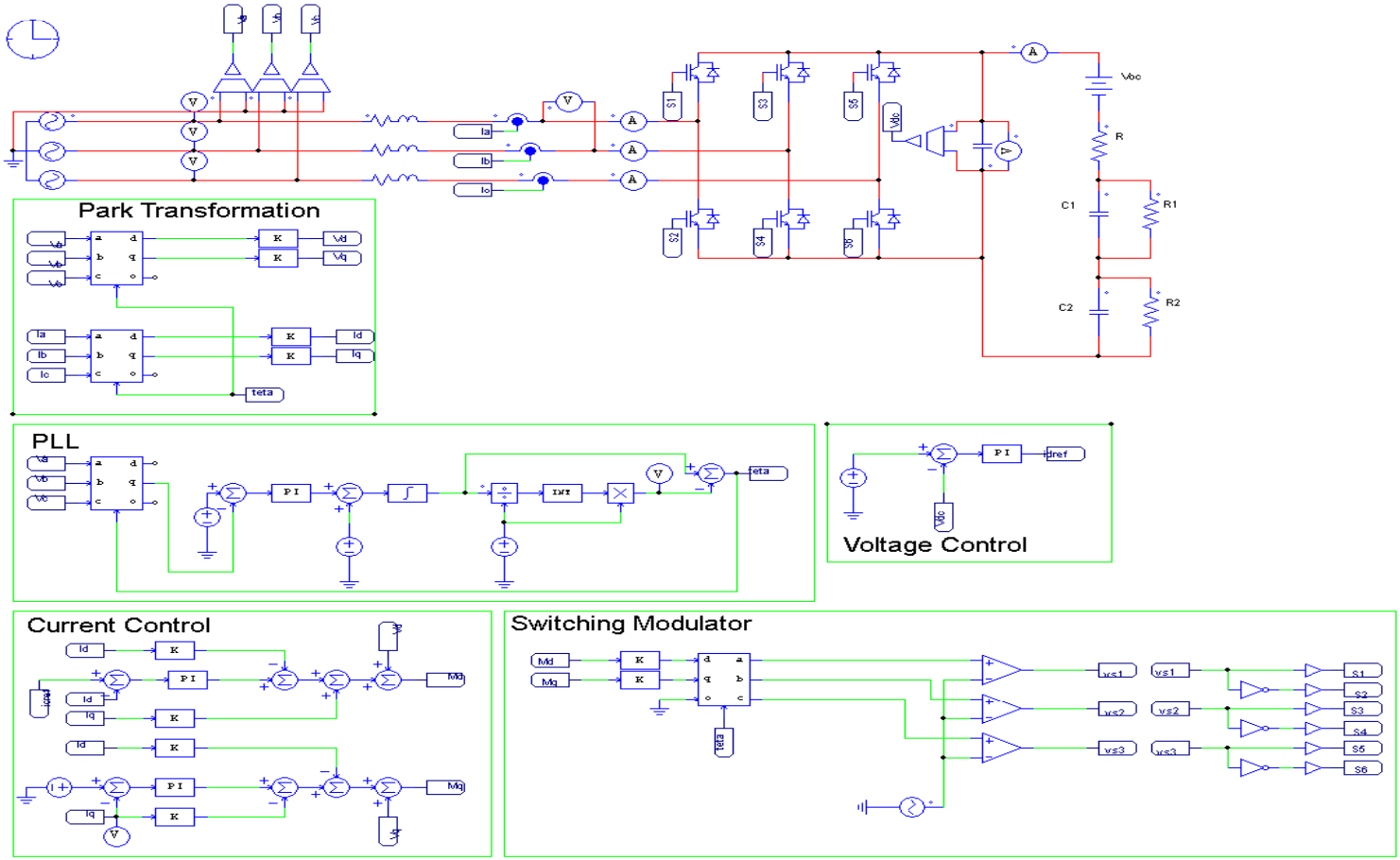


- PI control is used for controling DC voltage
- Output from voltage control will be used as id current reference

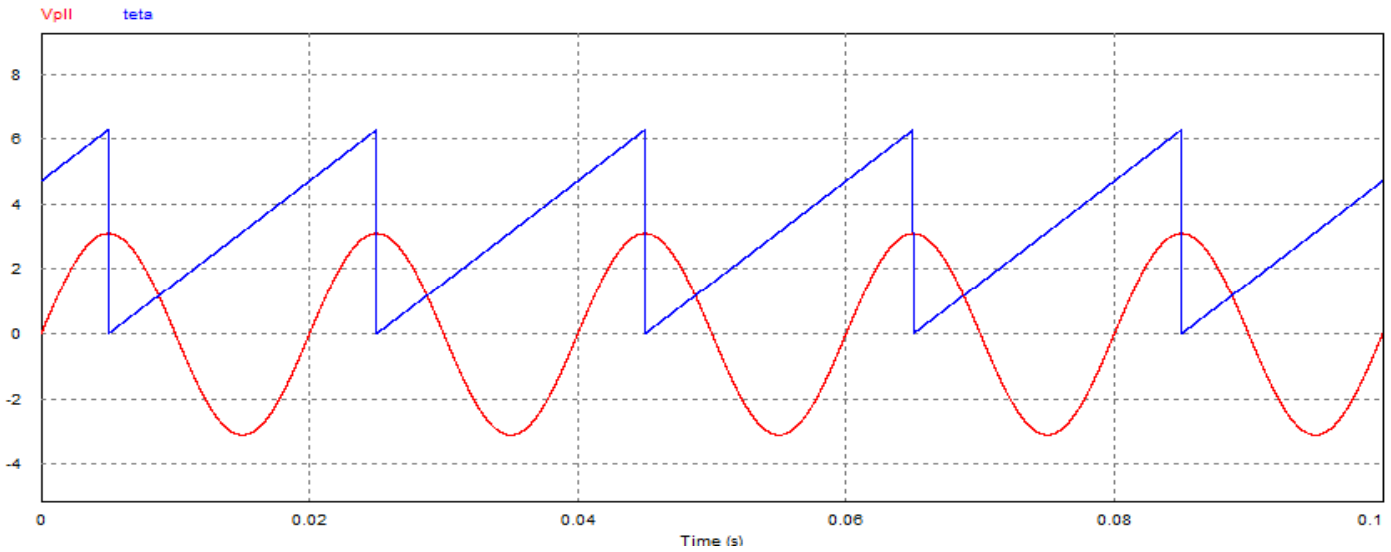
THE CIRCUIT SIMULATION PARAMETERS FOR DC FAST CHARGING INFRASTRUCTURE MODEL

Circuit Parameter	Value
Fast charging model capacity	50 kW
Charging voltage level	600 V dc
Source Voltage (V line-to-line) 50 Hz	380 V
Resistance R	0.12
Filter L	5 mH
Switching frequency	5 kHz
DC Link	330 uF
Control System	
PLL K_f Gain Constant	0.0707 rad/ V.s
PLL τ_f Time Constant	0.0628 s
Current Control Ki Gain Constant	2 A/V
Current Control Ki Time Constant	10 ms
Voltage Control Ku Gain Constant	0.165 V/A
Voltage Control τ_u Time Constant	5 ms
Battery Model	
Ohmic Resistance, R	1.8 Ω
Polarization Resistance, R_1	1.59 mΩ
Equivalent Capacitance, C_1	8.42 F
Polarization Resistance, R_2	1.2 mΩ
Equivalent Capacitance, C_2	0.83 uF

Simulation Circuit



PLL Simulation Result

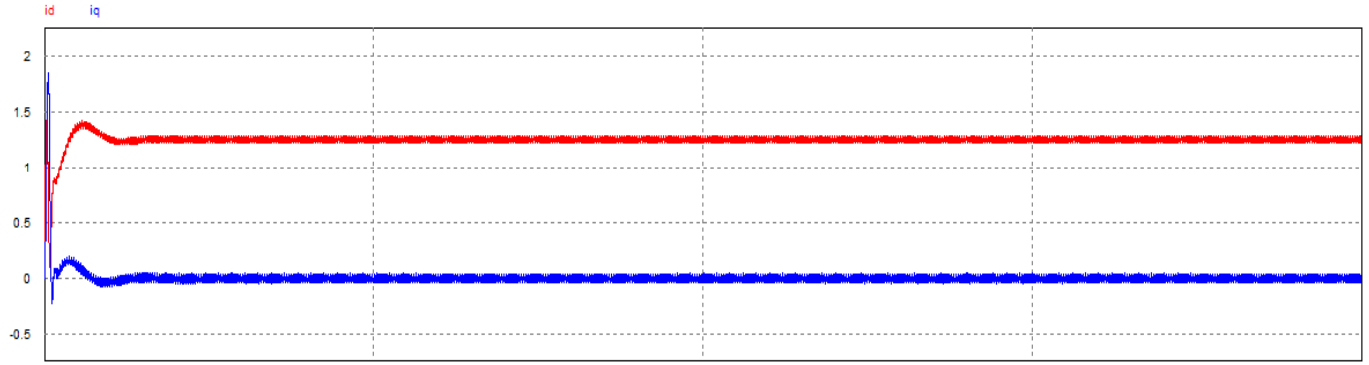


Angle reference(θ)

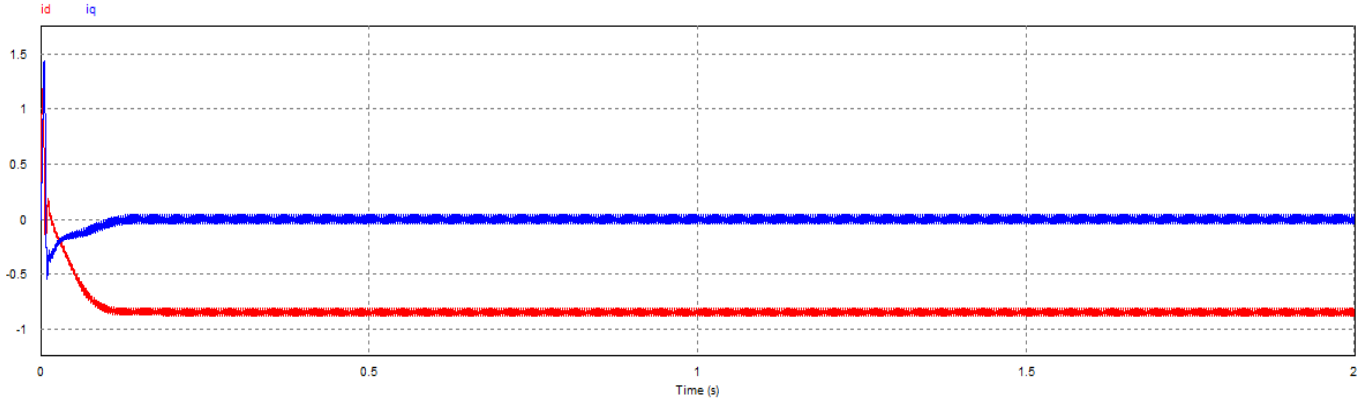
Voltage reference

There are 5 cycle in 0.1 s in angle reference, which is same with voltage reference

Simulation results of i_d and i_q input current control response

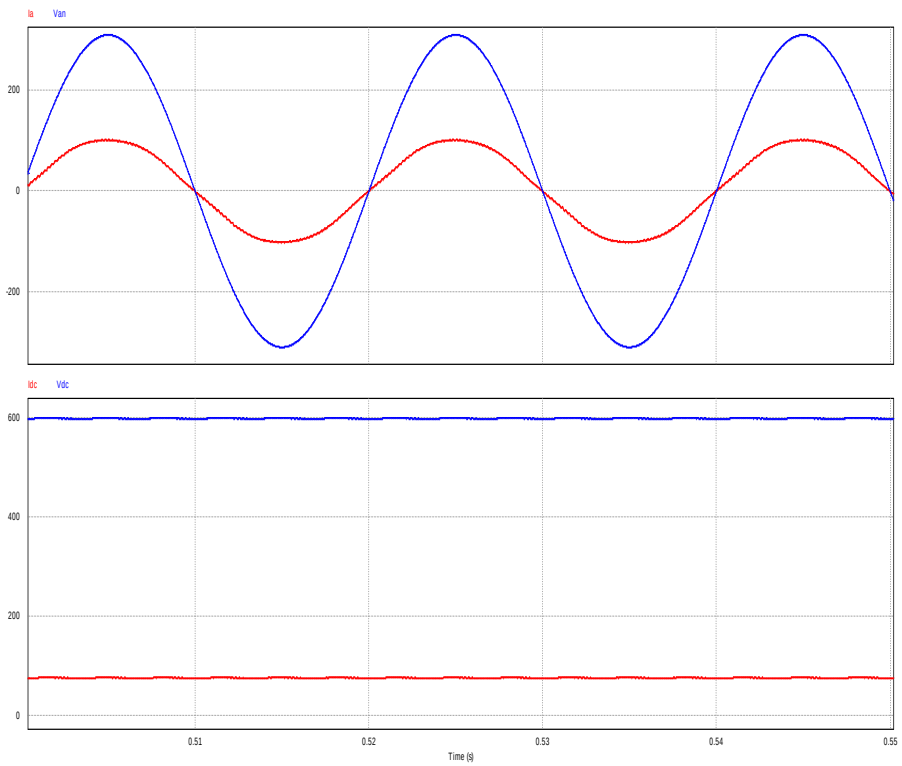


- **Rectifier mode**

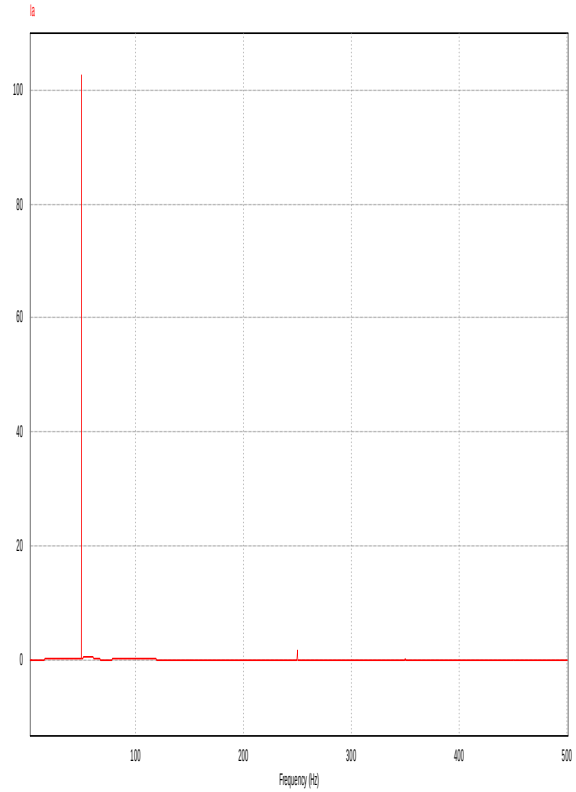


- **Inverter mode**

Simulation results at 77% nominal voltage (462 V)

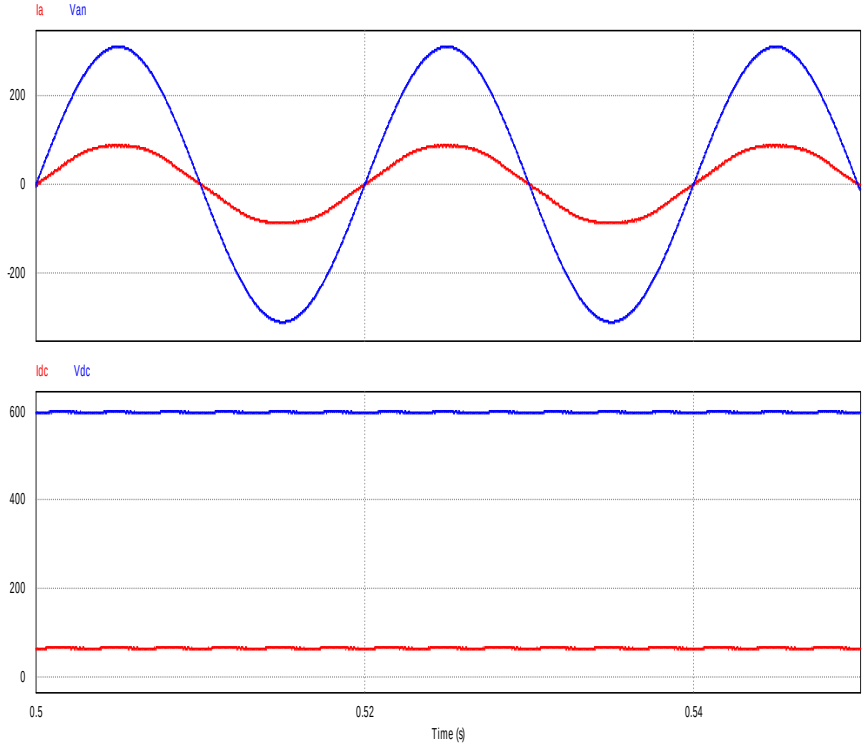


Input Voltage and Current (top), Output Voltage and Current (bottom)



Harmonic Spectrum of Input Current

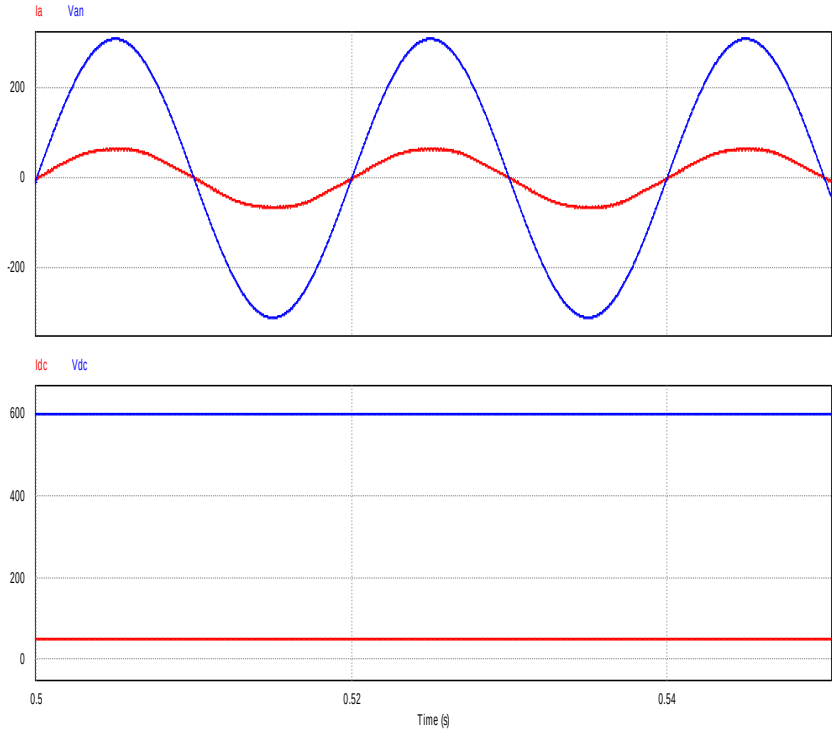
Simulation results at 80% nominal voltage (480 V)



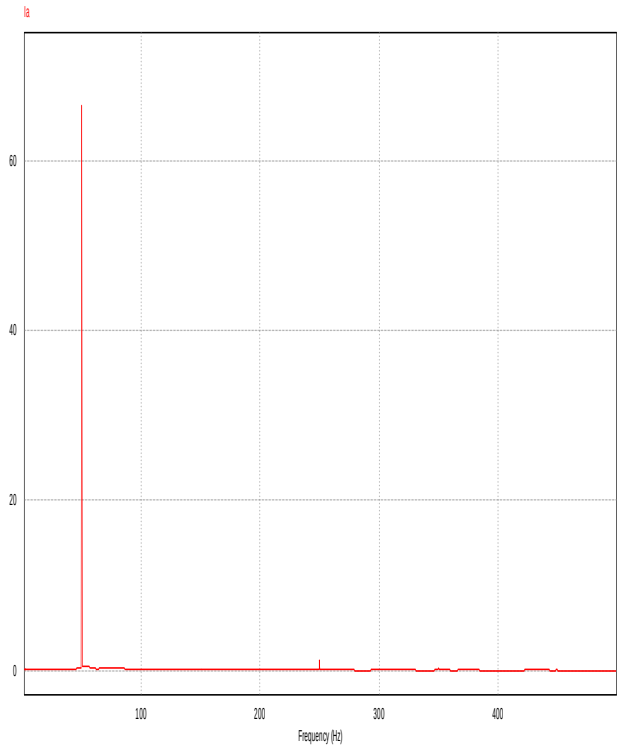
Input Voltage and Current (top), Output Voltage and Current (bottom)

Harmonic Spectrum of Input Current

Simulation results at 85% nominal voltage (510 V)

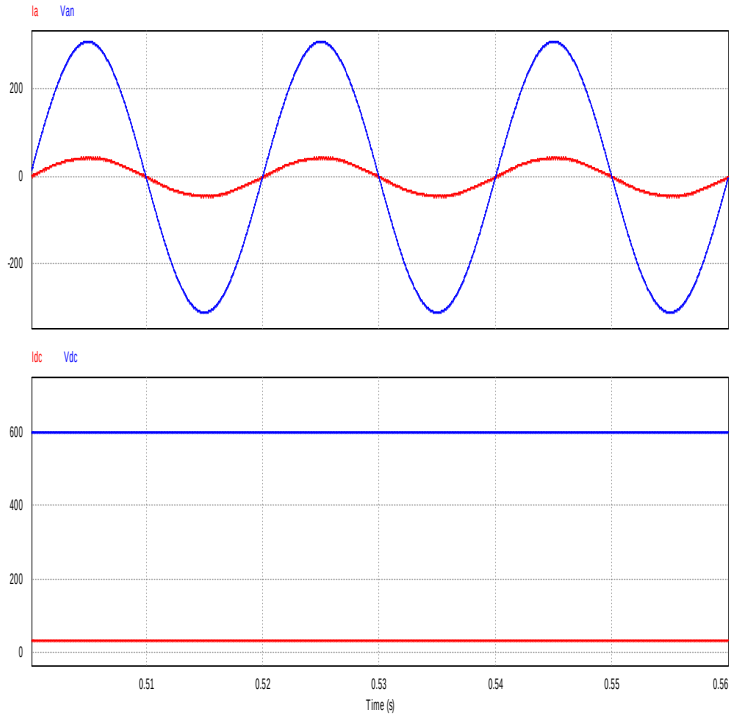


Input Voltage and Current (top), Output Voltage and Current (bottom)

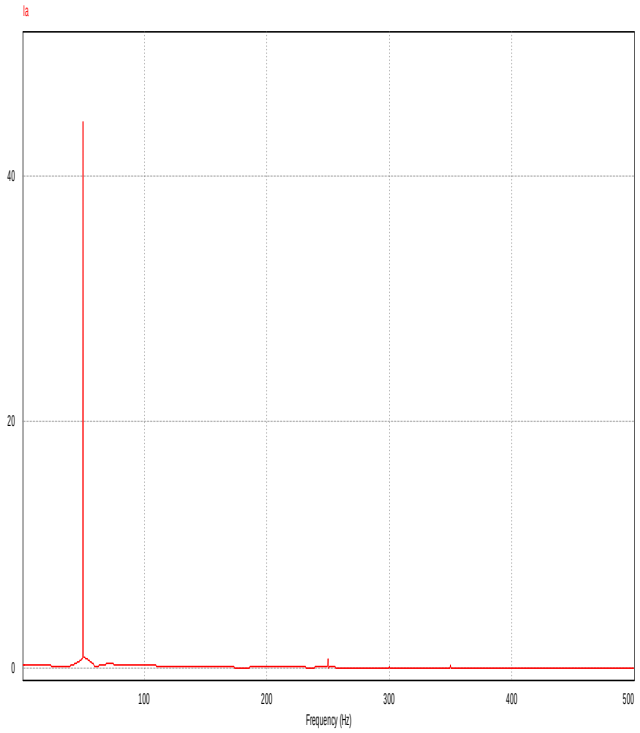


Harmonic Spectrum of Input Current

Simulation results at 90% nominal voltage (540V)



Input Voltage and Current (top), Output Voltage and Current (bottom)



Harmonic Spectrum of Input Current

AC POWER INPUT AND DC POWER OUTPUT ON DIFFERENT BATTEREY VOLTAGE LEVEL

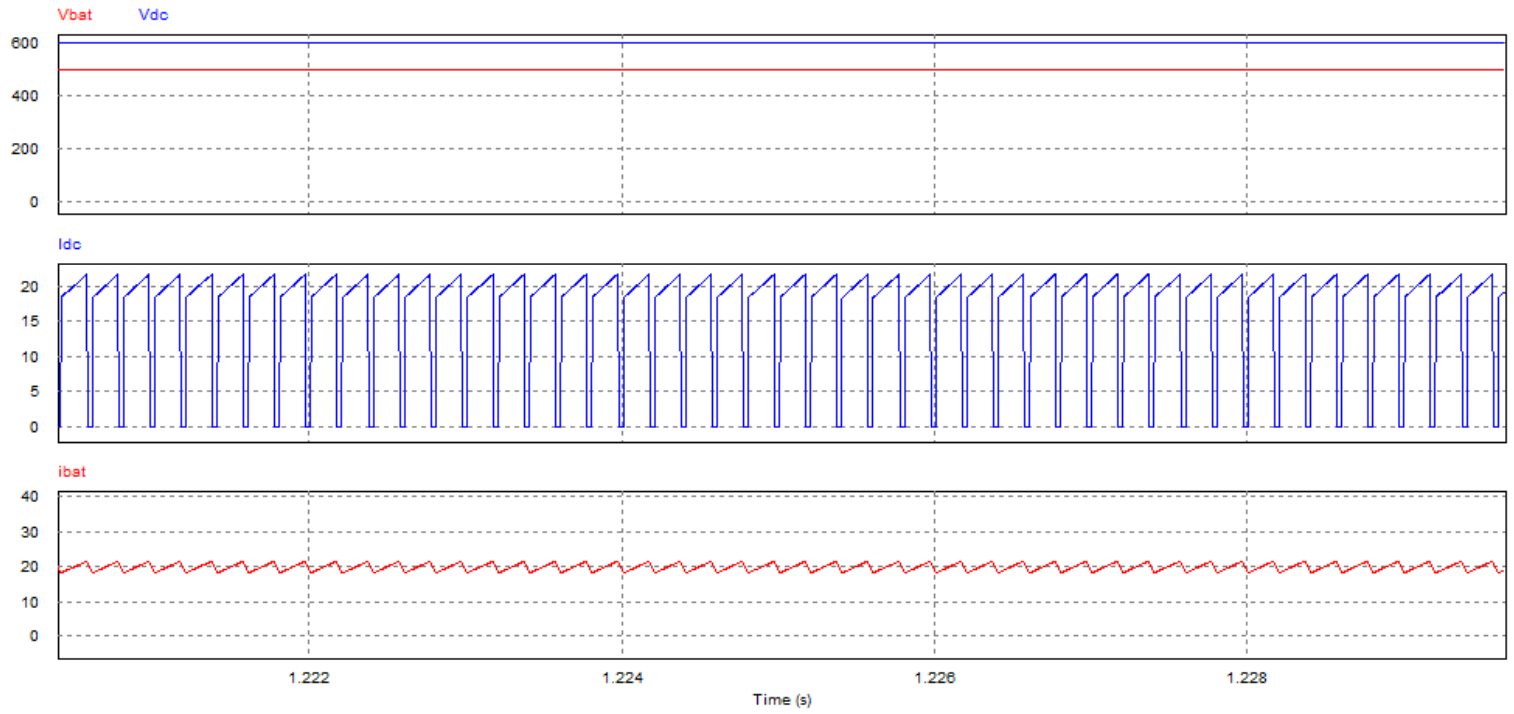
Battery Voltage Level (% V nominal battery)	V_{LL} *(V)*	I_L *(A)*	V_{dc} *(V)*	I_{dc} *(A)*	P_{ac} *(W)*	P_{dc} *(W)*
462 V (77%)	380	72.7	599	76.5	47862	45923
480 V (80%)	380	63.0	596	63.0	41498	37622
510 V (85%)	380	53.4	597	48.5	35159	29017
540 V (90%)	380	31.6	599	31.6	20844	18976

THD FOR VARIOUS KIND OF BATTERY VOLTAGE LEVEL

Battery Voltage Level	I_L (A)	THD (%)
462 V (77% V nominal battery)	72.72	2.36
480 V (80% V nominal battery)	63.05	2.65
510 V (80% V nominal battery)	53.42	2.67
540 V (90% V nominal battery)	31.67	3.18

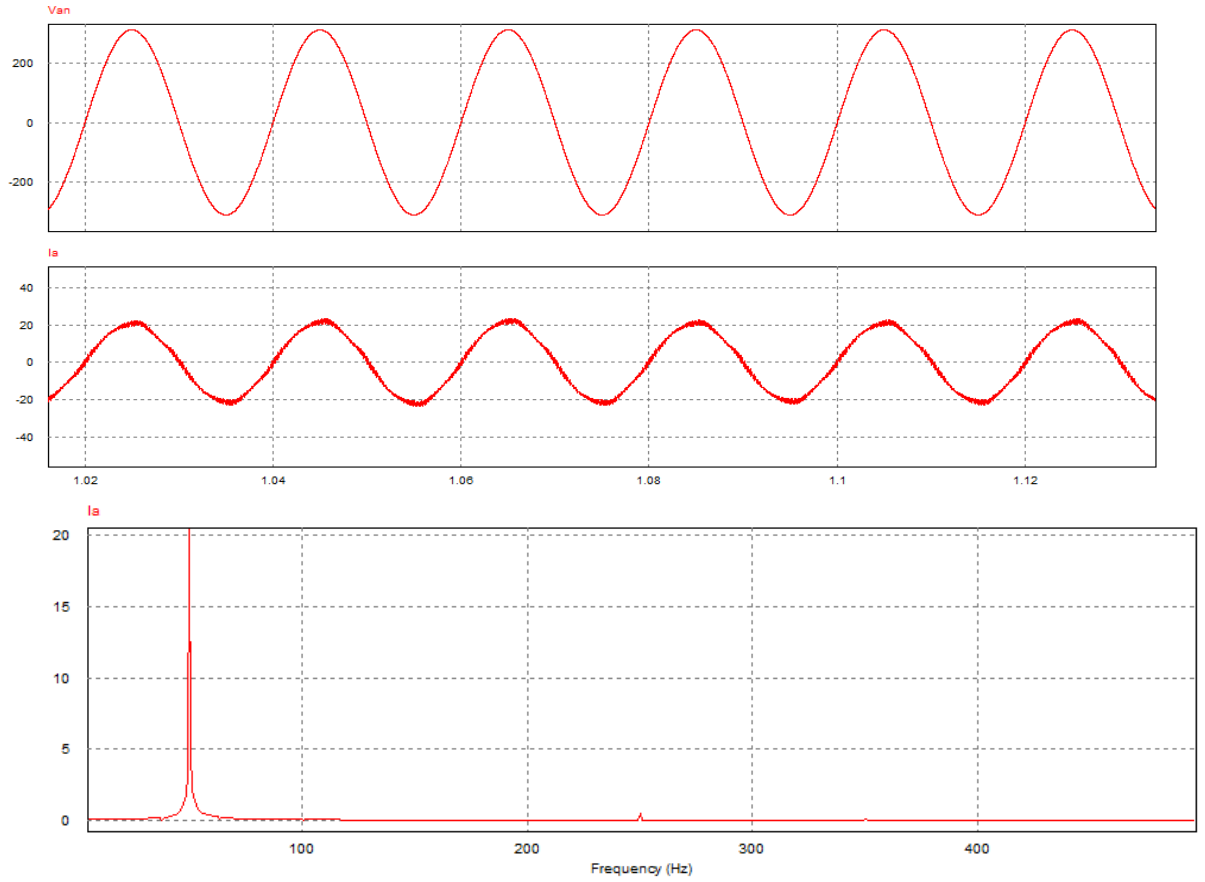
RECTIFIER MODE ON CC

77% from nominal Battery Voltage (462V)



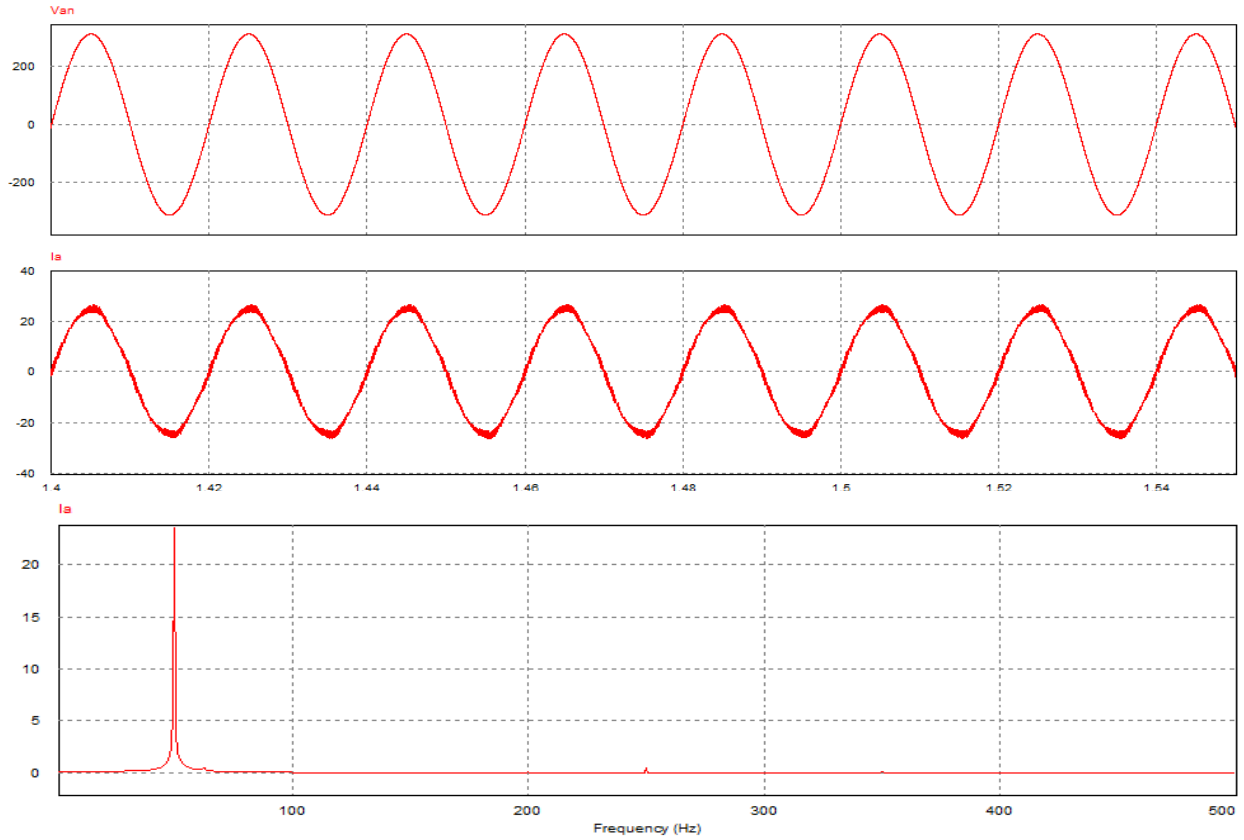
RECTIFIER MODE ON CC

77% from nominal Battery Voltage (462V)



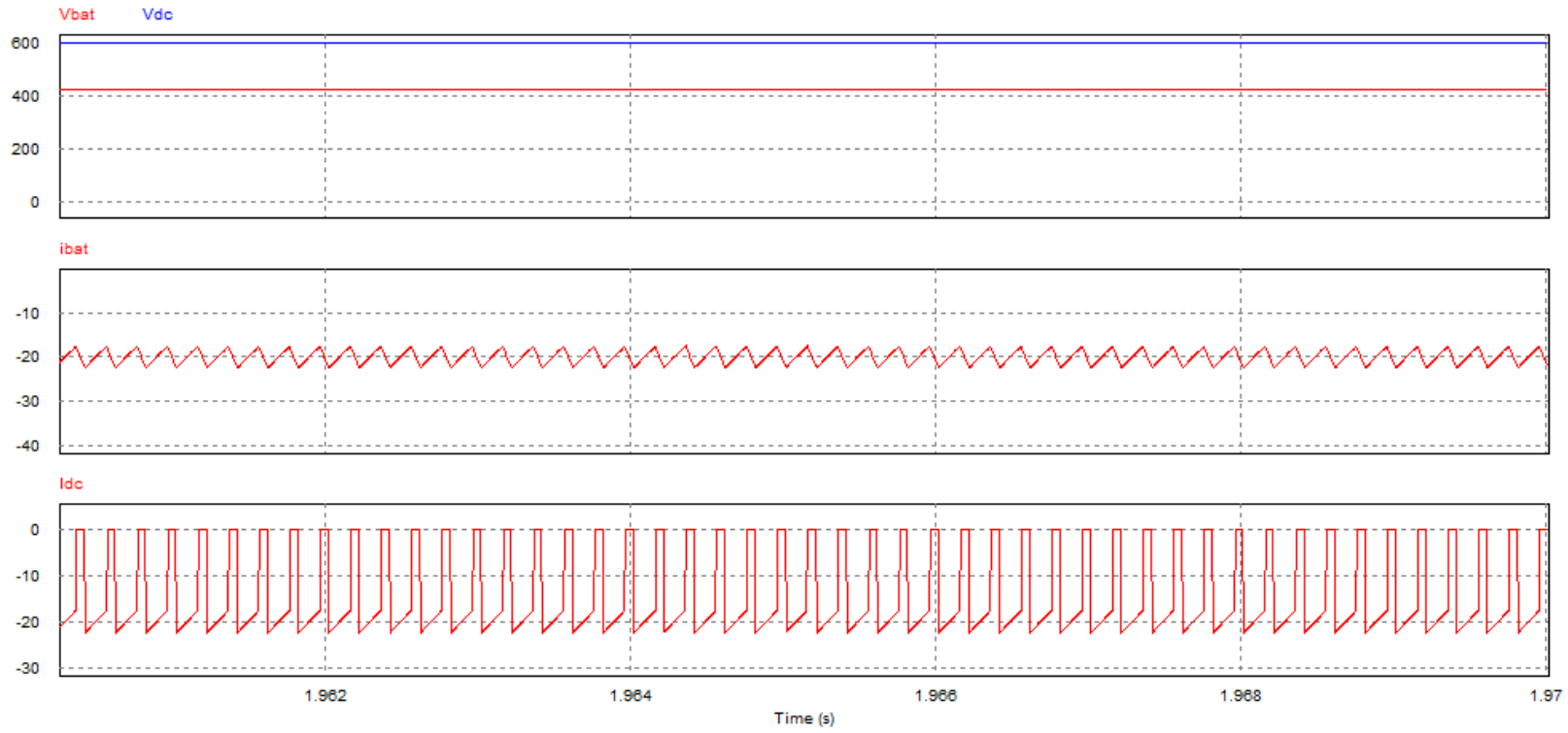
RECTIFIER MODE ON CC

90% from nominal Battery Voltage (540V)



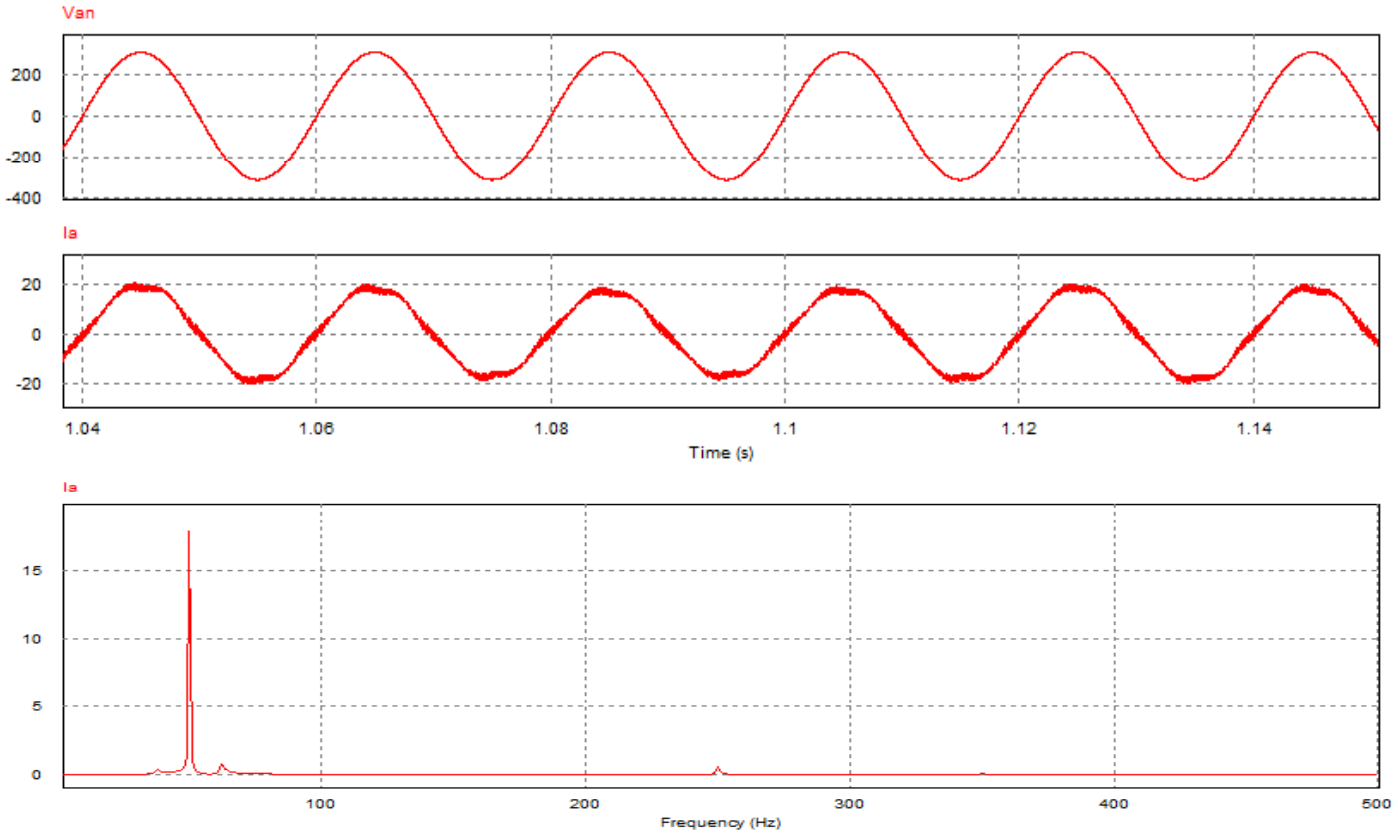
INVERTER MODE ON CC

77% from nominal Batterey Voltage (462V)



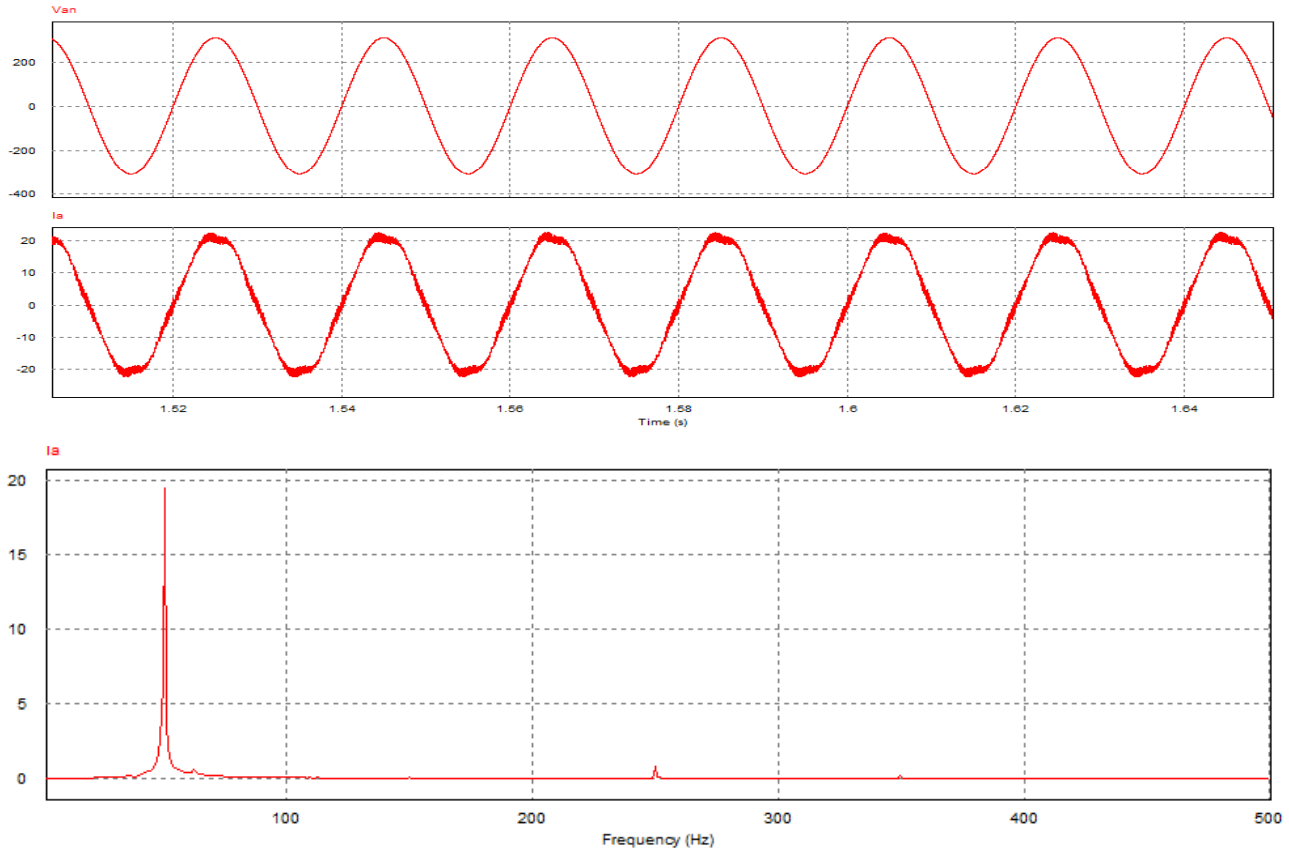
INVERTER MODE ON CC

77% from nominal Batterey Voltage (462V)



INVERTER MODE ON CC

90% from nominal Batterey Voltage (540V)



Input and Output Power with Different Batterey Voltage level (Current Control Mode)

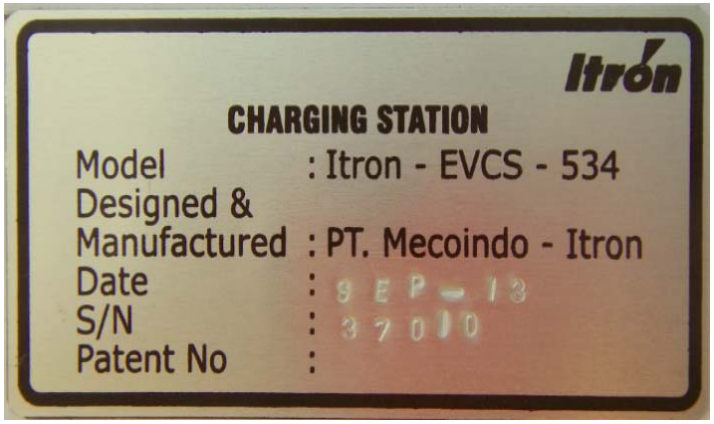
Battery Voltage level	Vll (V)	IL (A)	Vdc (V)	Vbat (V)	I2 (A)	Pac (W)	Pout (W)
462 V (77% from V nominal)	380	15.29	599.60	495.43	18.54	10063.56	9185.27
510 V (85% from V nominal)	380	16.76	599.56	543.10	18.36	11031.08	9971.32
540 V (90% fromV nominal)	380	17.67	599.54	572.90	18.24	11630.03	10449.70
595 V (99.2% from V nominal)	380	2.65	599.93	597.79	1.55	1744.18	926.57

CONCLUSION

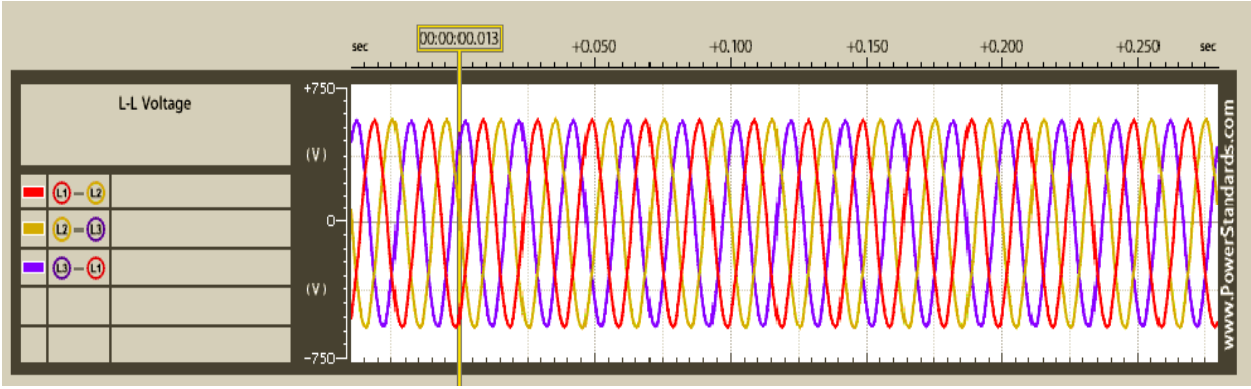
- Modelling of fast charging infrastructure as bidirectional three-phase PWM rectifier with dc output voltage control and current control input with simplified Lithium batteries models was successfully done using PSIM Simulation Software version 9.0.
- Analysis results shows that a proposed current and voltage control method successfully maintained unity power factor and THD of input current below 5% on various Battery voltage levels.

PILOT PLN EV NORMAL CHARGER IN NUSA DUA AREA

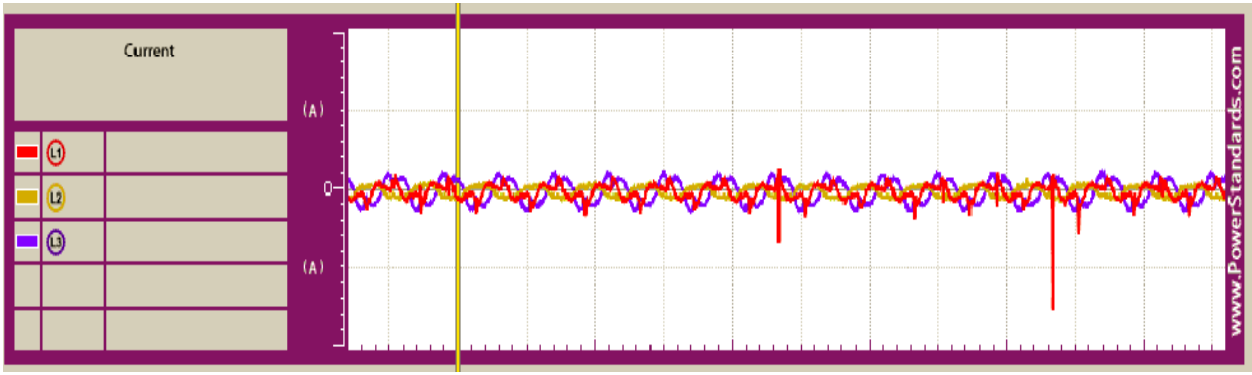
SAMPLE OF EV NORMAL CHARGER



THD FOR VARIOUS KIND OF BATTERY SOC



Tegangan yang terukur adalah $V_{l\text{-}l}$ sebesar 390 V



Arus maksimum yang terukur pada hari tersebut sebesar 10.2 A

Thank You