# Three Phase Power Supply

## 400Hz - 200V - 90kW

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## Nomenclature

Here the list of variables and parameters used along the document:

- $C_{Fu}$ $\Big[\mathrm{F}\Big]$: output filter capacitor;
- $R_{CFu}$ $\Big[\Omega\Big]$: resistance of the output filter capacitor;
- $L_{Fu}$ $\Big[\mathrm{H}\Big]$: output filter inductor;
- $C_{Fi}$ $\Big[\mathrm{F}\Big]$: DC-link capacitor;
- $u_{out}^{u}$ $\Big[\mathrm{V}\Big]$: output phase-u voltage;
- $u_{out}^{v}$ $\Big[\mathrm{V}\Big]$: output phase-v voltage;
- $u_{out}^{w}$ $\Big[\mathrm{V}\Big]$: output phase-w voltage;
- $i_{out}^{u}$ $\Big[\mathrm{A}\Big]$: output phase-u current;
- $i_{out}^{v}$ $\Big[\mathrm{A}\Big]$: output phase-v current;
- $i_{out}^{w}$ $\Big[\mathrm{A}\Big]$: output phase-w current;
- $i_{s}^{u}$ $\Big[\mathrm{A}\Big]$: stack (output leg) phase-u current;
- $i_{s}^{v}$ $\Big[\mathrm{A}\Big]$: stack phase-v current;
- $i_{s}^{w}$ $\Big[\mathrm{A}\Big]$: stack phase-w current;

# 1 Converter Layout Description

The power supply here reported concerns to the following characteristics:

- Output Stage:
  - Output System : Three phase system with neutral wire: four wires;
  - Output Voltage : Three phase with nominal $V_{out}^{nom} = 200.0\,\mathrm{V}$;
  - Output frequency : $f_{out}^{nom} = 400.0\,\mathrm{Hz}$;
- Input Stage:
  - Input Voltage : Three phase with nominal $V_{in}^{nom} = 400.0\,\mathrm{V}$;
  - Input frequency : $f_{in}^{nom} = 50.0\,\mathrm{Hz}$;

Figure 1 shows the layout, the power supply.

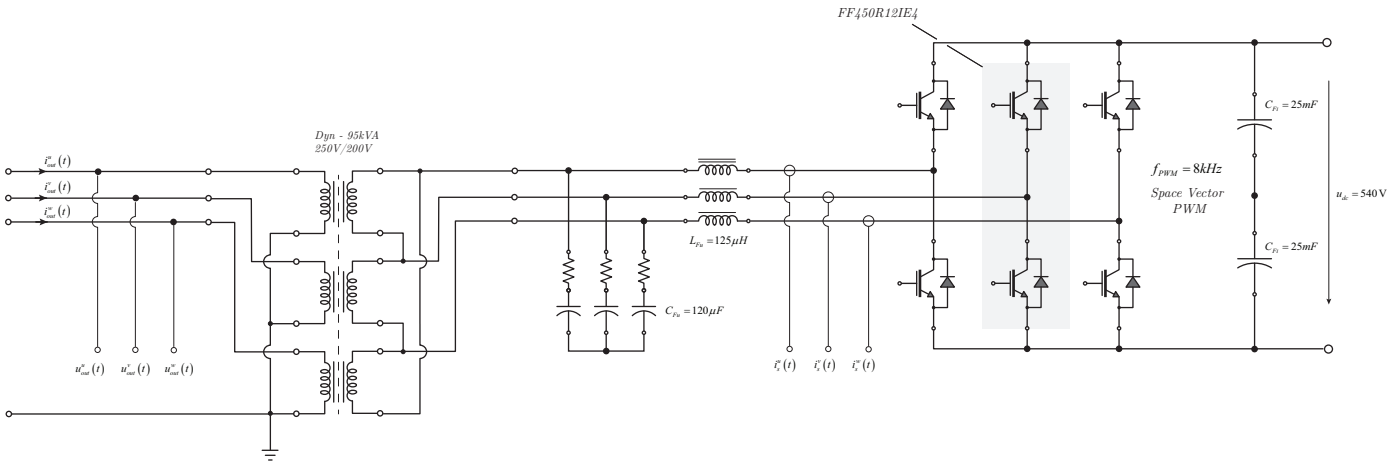



Figure 1: Electrical layout of the power supply.

# 2 Components Specification

## 2.1 Output Transformer

- Connection : Dyn;
- Nominal power : $P_n = 95\,\text{kV A}$;
- Nominal frequency : $f_n = 400\,\text{Hz}$;
- Nominal primary voltage : $V_1 = 250.0\,\text{V}$;
- Nominal secondary voltage : $V_2 = 200.0\,\text{V}$;
- Short circuit voltage : $V_{cc} = 4.0\,\%$;
- Voltage insulation : $V_{iso} = 3.0\,\text{kV}$;
- Ambient temperature : $T_a = 40.0\,^\circ\text{C}$;

## 2.2 Output Filter Inductor

- Connection : three phase inductor with three limbs;
- Nominal Positive Sequence Inductance : $L_{Fu} = 125\,\mu\text{H}$;
- Nominal Positive Sequence Current : $I_1 = 212\,\text{A}$ @ $f_1 = 400\,\text{Hz}$;
- Harmonic current - first PWM component: $I_{20} = 7.5\,\text{A}$ @ $f_{20} = 8\,\text{kHz}$;
- Harmonic current - second PWM component : $I_{40} = 7.0\,\text{A}$ @ $f_{40} = 16\,\text{kHz}$;
- Saturation current : $I_{sat} = 1.35\,I_1$;

– Voltage insulation : $V_{iso} = 3.0\,\mathrm{kV}$;

– Temperature Class : H.

– Ambient temperature : $T_a = 60.0\,^{\circ}\mathrm{C}$;

– Air Flow (speed): $v_a = 5.0\,\mathrm{m\,s^{-1}}$;

### 2.3 Output Filter Capacitor

– Nominal capacitance : $C_{Fu} = 120\,\mu\mathrm{F}$;

– Nominal current : $I_1 = 42\,\mathrm{A}$ @ $f_1 = 400\,\mathrm{Hz}$;

– Harmonic component current : $I_{20} = 7.5\,\mathrm{A}$ @ $f_{20} = 8\,\mathrm{kHz}$;

– Harmonic component current : $I_{40} = 7.0\,\mathrm{A}$ @ $f_{40} = 16\,\mathrm{kHz}$;

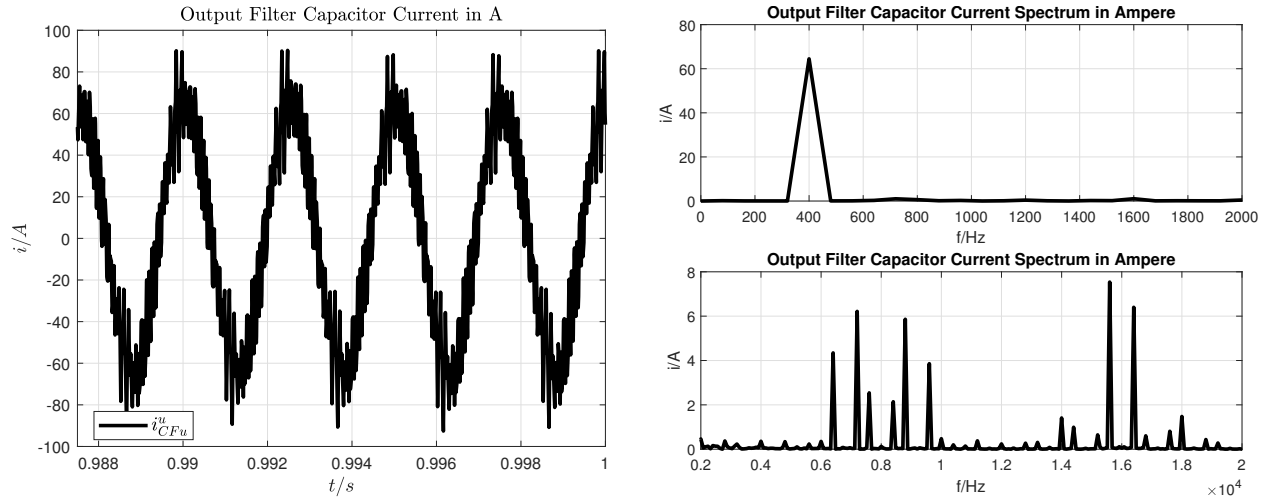
## 3 Simulation Results

### 3.1 Case scenario 1

– Input voltage : $u_{in} = 400.0\,\mathrm{V}$;

– Load characteristics : three phase balance resistive. System starts with $R^1_{load}$ and at time $t = 0.5\,\mathrm{s}$ switches to $R^2_{load}$, where $R^1_{load} = 1\,\Omega$, $R^2_{load} = 0.44\,\Omega$ (full load);

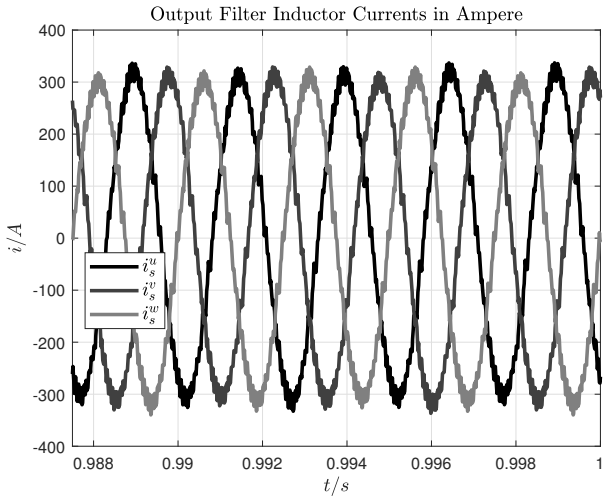
**Remark** - spectrum magnitude reports the amplitude of the harmonic components, while components data reports rms values.



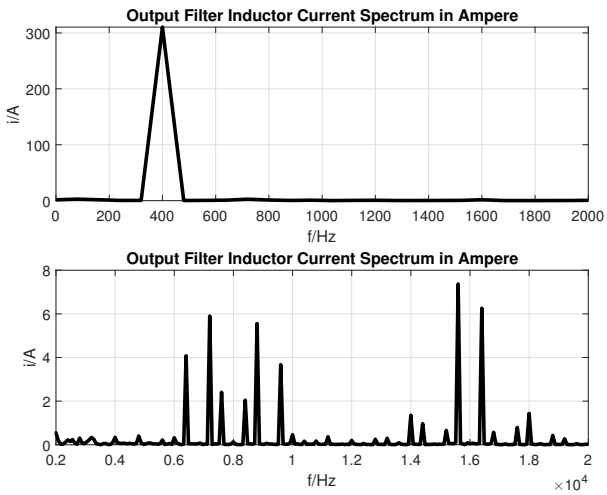

(a) Output filter capacitor current. Waveform trace at nominal power load.

(b) Output filter capacitor current spectrum. Data in Ampere.

Figure 2: Output filter capacitor ($C_{Fu}$) data for sizing.

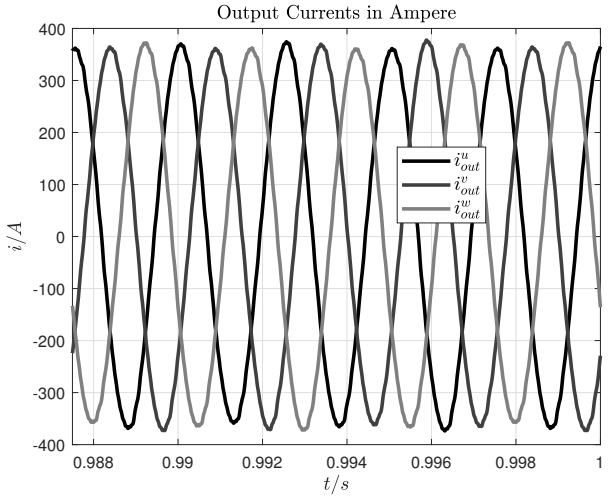



(a) Output filter inductor currents. Waveform trace at nominal power load.

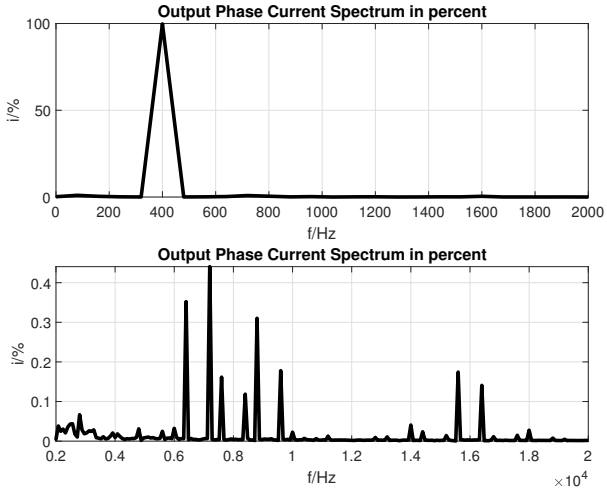



(b) Output filter inductor current spectrum. Data in Ampere.

Figure 3: Output filter inductor ($L_{Fu}$) data for sizing.

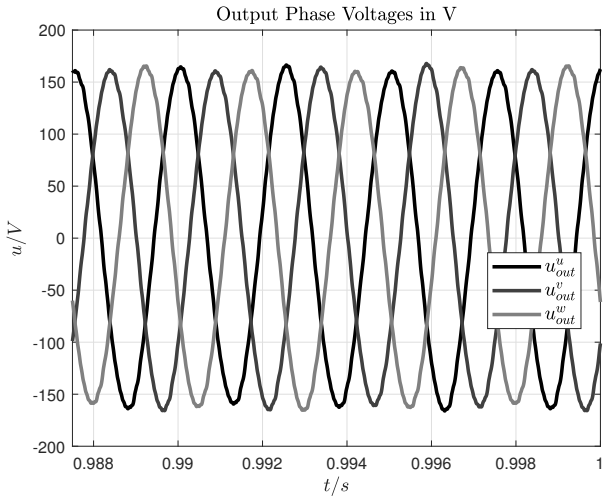



(a) Output phase currents. Waveform trace at nominal power load.

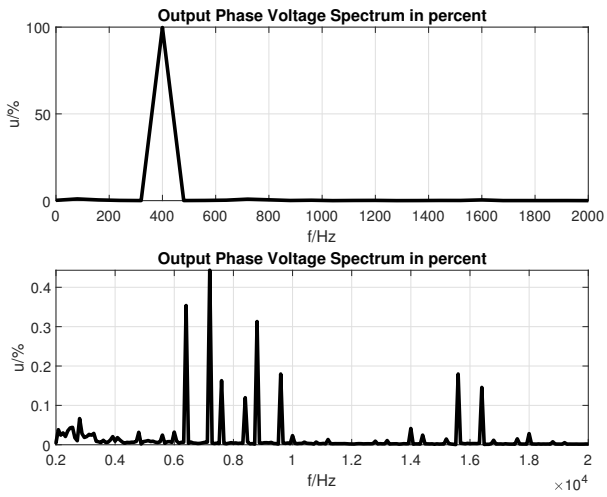



(b) Output phase current spectrum. Data in percent.

Figure 4: Output currents ($i_{out}^{uvw}$) for performance evaluation.




(a) Output phase voltages. Waveform trace at nominal power load.

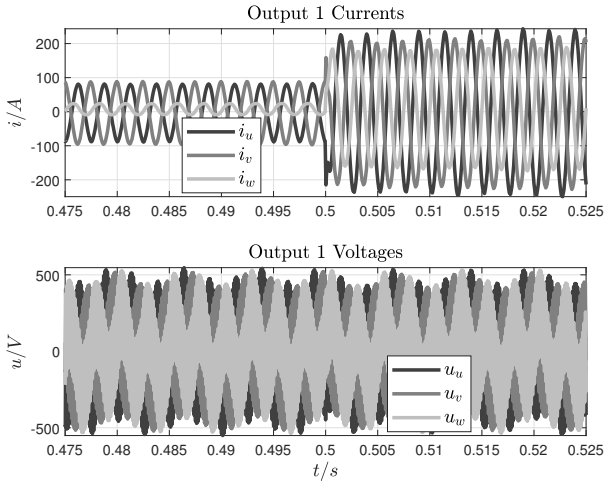



(b) Output phase voltage spectrum. Data in percent.

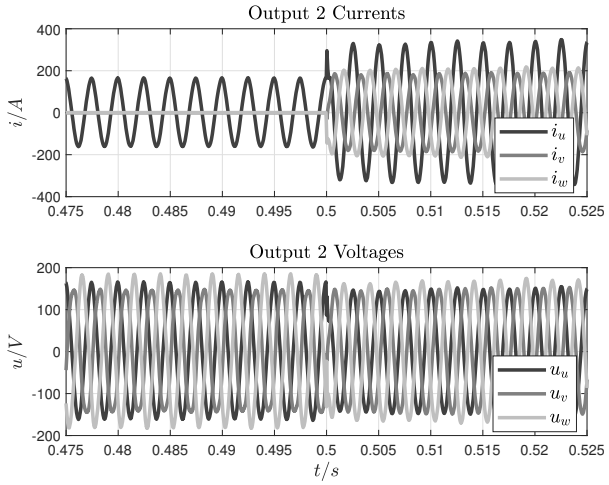
Figure 5: Output voltages ($u^{uvw}_{out}$) for performance evaluation.

## 3.2 Case scenario 2

- Input voltage : $u_{in} = 400.0\,\mathrm{V}$;
- Load characteristics : three phase unbalanced resistive.
- Load at time $t = 0\,\mathrm{s}$ :
  - $R^u_{load} = 1.0\,\Omega$
  - $R^v_{load} = \infty$
  - $R^w_{load} = \infty$
- Load at time $t = 0.5\,\mathrm{s}$ :
  - $R^u_{load} = 0.44\,\Omega$
  - $R^v_{load} = 0.8\,\Omega$
  - $R^w_{load} = 0.8\,\Omega$

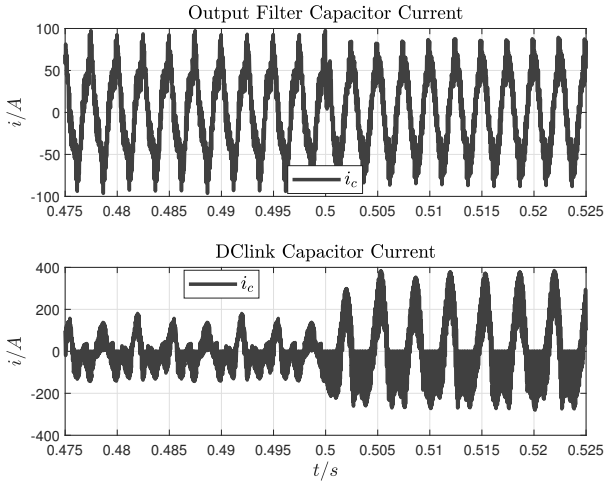



(a) Phase voltages and currents at primary side of the output transformer.

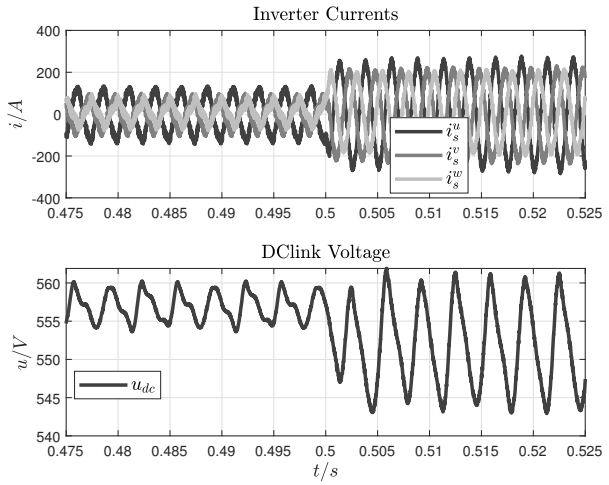



(b) Phase voltages and currents at secondary side of the output transformer.

Figure 6: Output voltages and currents ($u_{out}^{uvw}$, $i_{out}^{uvw}$) for performance evaluation.




(a) Output Filter capacitor phase current (top). DC-link current (bottom).




(b) Stack current (output of the leg) of the inverter top. DC-link voltage (bottom).

Figure 7: Components quantities.

# References