5. Input Rectifier Circuit

5.1 Single phase input rectifier circuit
5.1.1 Input fuse
5.1.2 Noise filters
5.1.3 Rectifier (SS1)
5.1.4 Inrush current limiting
5.1.5 Filtering circuit (Filtering capacitor) (C1, C2)

5.2 Three phase input rectifier circuit
5.2.1 Three phase Y-connection and Δ connecting wires
5.2.2 Input fuse
5.2.3 Rectifier (SS1, SS2, SS3)
5.2.4 Inrush current limiting
5.2.5 Filtering circuit (Filtering capacitor) (C1)
5.1 Single phase input rectifier circuit

[Example]

Fig. 5.1.1
Single phase input filter
+ rectifier circuit

AC85 - 132V
/170 - 264V

Input

Noise filter

F1

200V

TH1

SS1

C1

R1

C2

R2

FG

DBS400B

Voltage doubler circuit : 100V : SW1 is ON
200V : SW1 is OFF

5.1.1 Input fuse

- To avoid any damage or failure, install either an input circuit breaker or a fuse. When selecting these parts, consider the continuous current and the inrush current. Use a normal-blow or slow-blow type fuse.

Table 5.1.1
Recommended value of AC fuse

<table>
<thead>
<tr>
<th>Input Voltage</th>
<th>Output power of module</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>200W</td>
</tr>
<tr>
<td>100V</td>
<td>10A</td>
</tr>
<tr>
<td>200V</td>
<td>5A</td>
</tr>
</tbody>
</table>

Table 5.1.2
Recommended value of DC fuse

<table>
<thead>
<tr>
<th>Output power of module</th>
</tr>
</thead>
<tbody>
<tr>
<td>200W</td>
</tr>
<tr>
<td>200V</td>
</tr>
</tbody>
</table>

5.1.2 Noise filters

- In order to reduce the conducted noise from the unit to the AC line and to increase the immunity level against the external noises, a noise filter should be installed. Refer to "Section 12 Noise Filter Design" for details.
5.1.3 Rectifier (SS1)

- It rectifies the AC input to DC. The rated voltage is 600V and the rated current is as follows.

<table>
<thead>
<tr>
<th>Output Power</th>
<th>The example of combination of a power supply</th>
<th>Current of Rectifier</th>
</tr>
</thead>
<tbody>
<tr>
<td>200W</td>
<td>DBS200B</td>
<td>4 - 6A type</td>
</tr>
<tr>
<td>400W</td>
<td>DBS200B x 2</td>
<td>8 - 10A type</td>
</tr>
<tr>
<td>600W</td>
<td>DBS200B + DBS400B</td>
<td>12 - 15A type</td>
</tr>
<tr>
<td>800W</td>
<td>DBS400B x 2</td>
<td>18 - 20A type</td>
</tr>
</tbody>
</table>

5.1.4 Inrush current limiting

- This rectification filtering circuit employs a capacitor input type. When input voltage is applied, an inrush current flows to charge the capacitor. To avoid the damage, an inrush current limiting is required. This resistance limits inrush current by the thermistor when the input is turned on, and resistance usually suppresses the lower loss due to the characteristic of thermistor (thermistor method).

- When temperature is low, the start-up time is getting longer due to characteristic of thermistor. Please select thermistor which can be used at actual.

- When the output power grows, inrush current protection circuit used to be build-in (SCR method and TRC method) using the thyristor or triac. Inrush current is limited by the resistance connected with thyristor or triac in parallel when the input is turned on. Then once input current goes to continuously, thyristor or triac is turned on to reduce power loss of resistor. In this circuit needed consideration about surge capacity of thyristor and add thermal fuse or use resistor which includes thermal fuse inside.

PC1 is the extra low trigger current opto coupler.

The inrush current can be calculated at the following formula.

\[
\text{Inrush current value (at AC200V)} = \frac{200 \times \sqrt{2}}{R}
\]

* Please note, input current protection might not be activated, if input ON/OFF interval is short.
5.1.5 Filtering circuit (Filtering capacitor) (C1, C2)

- The selection of the filtering capacitor depends on the output hold-up time and the ripple current flowing in the capacitor.

1. Obtain the capacitance \( (Ch) \) from the output hold-up time as follows

\[
Ch = \frac{2 \times Po \times Th}{(V1^2 - V2^2) \times \eta}
\]

- \( Ch \): Capacity of the filtering capacitor
- \( Po \): Output power of module
- \( Th \): Hold-up time
- \( V1 \): Input DC voltage = Input AC voltage (rms) x \( \sqrt{2} \)
- \( V2 \): Input DC voltage which can hold output voltage
- \( \eta \): Efficiency

**[Calculation example]**

1. DBS400B is used with AC200V.
2. The hold-up time is 20ms at AC200V.
3. The efficiency of DBS400B is 85%.

\[
Ch = \frac{2 \times 400W \times (20ms + 5ms)}{(200 \times \sqrt{2})^2 - (165V)^2} \times 0.85
\]

\[
= 446 \ \mu F
\]

* 5ms in the formula above is added considering the ripple voltage of the filtering capacitor.

2. Obtain the ripple current for selection of the capacitor as follows

**[Calculation example]**

\[
\text{Ripple current} = \frac{2.5 \times 400W}{200V}
\]

\[
= 5 \ A
\]

\( Po \): Output power of module
\( Vin \): Input voltage

<table>
<thead>
<tr>
<th>Table 5.1.4</th>
<th>Ripple current value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output power of module</td>
<td>Input voltage AC 100V</td>
</tr>
<tr>
<td>50W</td>
<td>1.25A</td>
</tr>
<tr>
<td>100W</td>
<td>2.5A</td>
</tr>
<tr>
<td>150W</td>
<td>3.75A</td>
</tr>
<tr>
<td>200W</td>
<td>5.0A</td>
</tr>
<tr>
<td>400W</td>
<td>10.0A</td>
</tr>
<tr>
<td>600W</td>
<td>15.0A</td>
</tr>
<tr>
<td>800W</td>
<td>20.0A</td>
</tr>
</tbody>
</table>
5.2 Three phase input rectifier circuit

5.2.1 Three phase Y-connection and Δ connecting wires

Do not use Y-connection (three phase four line type), because the peak rectified line voltage exceeds the maximum input voltage range of module.

The example of connection for "Three phase input rectifier circuit" is shown on Fig.5.2.2.

5.2.2 Input fuse

To avoid any damage or failure, install either an input circuit breaker a fuse. When selecting these parts, consider the continuous current and the inrush current. Use a normal-blow or slow-blow type fuse.

<table>
<thead>
<tr>
<th>Table 5.2.1</th>
<th>Recommended value of AC fuse</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Output power of module</td>
</tr>
<tr>
<td></td>
<td>200W</td>
</tr>
<tr>
<td>Current</td>
<td>2A</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 5.2.2</th>
<th>Recommended value of DC fuse</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Output power of module</td>
</tr>
<tr>
<td></td>
<td>200W</td>
</tr>
<tr>
<td>Current</td>
<td>3.15A</td>
</tr>
</tbody>
</table>
5.2.3 Rectifier (SS1, SS2, SS3)

- It rectifies the AC input to DC. The rated voltage is 600V and the rated current is as follows.

<table>
<thead>
<tr>
<th>Output Power</th>
<th>The example of combination of a power supply</th>
<th>Current of Rectifier</th>
</tr>
</thead>
<tbody>
<tr>
<td>200W</td>
<td>DBS200B</td>
<td>1 - 2A type</td>
</tr>
<tr>
<td>400W</td>
<td>DBS200B x 2</td>
<td>3 - 4A type</td>
</tr>
<tr>
<td>600W</td>
<td>DBS200B + DBS400B</td>
<td>4 - 5A type</td>
</tr>
<tr>
<td>800W</td>
<td>DBS400B x 2</td>
<td>6 - 7A type</td>
</tr>
</tbody>
</table>

5.2.4 Inrush current limiting

- When the output power grows, inrush current protection circuit used to be build-in (SCR method and TRC method) using the thyristor or triac. Inrush current is limited by the resistance connected with thyristor or triac in parallel when the input is turned on. Then once input current goes to continuously, thyristor or triac is turned on to reduce power loss of resistor. In this circuit needed consideration about surge capacity of thyristor and add thermal fuse or use resistor which includes thermal fuse inside.

![Inrush current limiting with SCR](image)

- The inrush current can be calculated from the following type.

\[
\text{Inrush current value (at AC200V)} = \frac{200 \times \sqrt{2}}{R}
\]

* Please note, input current protection might not be activated, if input ON/OFF interval is short.

5.2.5 Filtering circuit (Filtering capacitor) (C1)

- Becomes a calculation type same as the single phase input at three aspect input. The expression is shown in the following.
- The selection of the filtering capacitor depends on the output hold-up time and the ripple current flowing in the capacitor.
- The hold-up time of three phase input is almost the same as the single phase input. The expression in the single phase input is used this time.
(1) Obtain the capacitance (Ch) from the output hold-up time as follows

\[
Ch = \frac{2 \times Po \times Th}{(V1^2 - V2^2) \times \eta}
\]

Ch : Capacity of the filtering capacitor  
Po : Output power of module  
Th : Hold-up time  
V1 : Input DC voltage = Input AC voltage (rms) x \sqrt{2}  
V2 : Input DC voltage which can hold output voltage  
\eta : Efficiency

[Calculation example]

(1) DBS400B is used with AC200V.  
(2) The hold-up time is 20ms at AC200V.  
(3) The efficiency of DBS400B is 85%.

\[
Ch = \frac{2 \times 400W \times (20ms + 5ms)}{(200 \times \sqrt{2})^2 - (165V)^2} \times 0.85
\]

\[
= \frac{2 \times 400W \times 25ms}{((200 \times \sqrt{2})^2 - (165V)^2) \times 0.85}
\]

\[
= 446 \mu F
\]

* 5ms in the formula above is added considering the ripple voltage of the filtering capacitor.

(2) Obtain the ripple current for selection of the capacitor as follows

[Calculation example]

\[
\text{Ripple current} = \frac{2.5 \times 400W}{200V}
\]

\[
= 5 A
\]

Po : Output power of module  
Vin : Input voltage

<table>
<thead>
<tr>
<th>Output power of module</th>
<th>Input voltage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AC 100V</td>
</tr>
<tr>
<td>50W</td>
<td>1.25A</td>
</tr>
<tr>
<td>100W</td>
<td>2.5A</td>
</tr>
<tr>
<td>150W</td>
<td>3.75A</td>
</tr>
<tr>
<td>200W</td>
<td>5.0A</td>
</tr>
<tr>
<td>400W</td>
<td>10.0A</td>
</tr>
<tr>
<td>600W</td>
<td>15.0A</td>
</tr>
<tr>
<td>800W</td>
<td>20.0A</td>
</tr>
</tbody>
</table>