High performance intelligent power module for PWM rectifier application

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Abstract:

With the development of power electronics, there are more and more inductive load in power system and the pulse current result by inductive load will bring bad effect to the quality of the grid; On the other hand, when motor of load worked as a generator, the generated energy will be waste. Pulse width modulation(PWM) rectifier have a good performance in this circuit, which can make the input current work at sinusoidal state and improve the power factor; This paper showed the method how to design the PWM rectifier by using intelligent power module(IPM), which including topology selection, control method and power module selection, power losses calculation and prototype testing. At last, some pictures of testing waveform are given.

1. Functions of PWM rectifier

1.1. As a rectifier to transfer energy from AC to DC side and keep input current working at sinusoidal state ($\lambda=1$);
1.2. As a inverter to transfer energy from DC to AC side when motor of load worked as a generator and keep input current working at sinusoidal state ($\lambda=-1$).

2. Topology and control method selection

2.1. Topology

We select 3-phase bridge topology for our design; This topology is very popular especially for large power rating equipment. Fig.1 shows this topology:

![3-phase topology](image)

Fig.1. 3-phase topology

2.2 Control method selection

We adopted vector control method based on d-q axis, both out out voltage of PWM rectifier and current of input are monitored for system control, we can change power ratting and reference of current accoring the variation of Udc, and make input current follow the reference of current to achieve power factor control.
3. Power module selection

3.1. Features of IPM
In order to meet the demand of PWM rectifier, we select IPM for prototype because of the internal circuit of IPM is very suitable for 3-phase topology, and advantage protection circuit can enhance prototype more reliable. The features of IPM are as follows:

a) Adopting 5th generation IGBT(CSTBT) chip;
b) Detection, protection and status indication circuit for short-circuit, over-temperature and under-voltage(Fo available from all arm devices)

3.2. Power rating calculation
The parameter of prototype that we plan to make:
Power rating: 66kW; input: 3-phase AC 380V; output: DC 540V, Io=125A; fc=8kHz.
According to the above parameter we select PM450CLA120 for prototype, Fig.2 and Fig.3 shows the picture of exterior and internal circuit of PM450CLA120.

3.3 thermal design
To make sure IPM worked at safe temperature (Mitsubishi recommend Tj<125℃), we made a power loss simulation by software. We calculated the Tj (IGBT) under the condition of λ=1 as Fig.4, and get the Tj(IGBT) _ave =112.86 ℃.
We calculated the $T_j$ (Diode) under the condition of $\lambda = -1$ as Fig.5, and get the $T_j$ (Diode) $\text{ave} = 114.69 ^\circ C$.

![Fig.5. simulation for $T_j$ (Diode)](image)

The datas show the thermal performance of PM450CLA120 is OK. ($T_j$: junction temperature)

### 3.4. Interface between MCU and IPM

We designed a PCB and mounted it on IPM directly, the circuit of PCB was showed in Fig.6. PC1 is a high speed photo-coupler, which transfer PWM signals to IPM; PC2 is low speed photo-coupler, which send $F_o$ signal to MCU when protection circuit responded, then MCU will stop the PWM signals; $C_1$ and $C_p$ help IPM to improve noise immunity; We also set a capacitor between P and N terminal to minimize surge voltage when IGBT turn off; Meanwhile 6 isolated control power supplies are needed.

![Fig.6. interface circuit](image)

### 4. Prototype and test result

#### 4.1. Prototype

We made the prototype as 3-phase bridge topology by using PM450CLA120, Fig.7 and Fig.8 showed the exterior and internal pictures of prototype.
4.2 Testing result

We test the prototype at rectifier and inverter conditions by our test platform shown by Fig.9; When rectifier condition, prototype in picture will provide DC power supply to inverters to drive the motor; and in inverter condition, motor will as a generator and feed back the energy to grid through prototype.

Testing result showed both of them the input current working at sinusoidal state, Fig.10 shows the input wave form on rectifier condition, wave forms of voltage and current at the same phase; Fig.11 shows the input wave form on inverter condition, wave forms of voltage and current at the opposite phase.
5. Conclusion

PM450CLA120 is convenient to be used in PWM rectifier, the protect function and good thermal performance make the system more reliable, built-in drive circuit can help customer to shorten the development cycle. The testing result shows the PWM rectifier by using PM450CLA120 can make the input current work at sinusoidal state, improve the power factor well and feed back the energy to grid on inverter condition.

6. Literature

[1]: Datasheet of PM450CLA120 of Mitsubishi Electric.