Improvement for a Fast Corrector Power Supply in TPS

Content:

1. Introduction About the NSRRC
2. Upgrade the Fast Corrector Power Supply Project
3. Test and Result
4. Future Work
5. Conclusion

Chen-Yao Liu Power Supply Group NSRRC POCPA 2018
1. Introduction About the NSRRC

NSRRC: National Synchrotron Radiation Research Center

Chen-Yao Liu  Power Supply Group NSRRC  POCPA 2018
TLS : Taiwan Light Source

TPS : Taiwan Photon Source

Chen-Yao Liu    Power Supply Group NSRRC       POCPA 2018
The Structure of Storage Ring Beam Position Monitor (BPM), and Corrector Magnet in FOFB

(a) BPM, (b) fast corrector magnet, (c) dipole magnet, (d) quadrupole magnet, (e) sextupole magnet

Chen-Yao Liu    Power Supply Group NSRRC       POCPA  2018
The FCPS employs the full-bridge topology with the rated current/voltage of $\pm 10\text{A}$/$\pm 50\text{V}$
The Triangular Carrier Signal; $V_{SIN}$ and $V_{SIN_INV}$ are the Sinusoidal Reference Signals for the positive and Negative Bridge Output Voltages

Key Waveforms of the Full-Bridge FCPS

Operational Modes of the Proposed FCPS

Chen-Yao Liu    Power Supply Group NSRRC       POCPA  2018
MOSFETs’ Temperatures Measured by an Infrared Thermography

Measured Temperatures of MOSFETs $S_1$ and $S_4$ while MOSFETs $S_1$ and $S_2$ and MOSFETs $S_3$ and $S_4$ operated at output frequency and high frequency, respectively.

Chen-Yao Liu    Power Supply Group NSRRC       POCPA  2018
Indicates the Acceleration Factors of MOSFETS $S_1$ and $S_2$ Are Greatly High Than the Factors of MOSFETS $S_3$ and $S_4$ Due to the Exponential Acceleration Factor Function

Acceleration Factors w.r.t. Actual Use Temperatures for HPWM

Chen-Yao Liu  Power Supply Group NSRRC  POCPA 2018
2. Upgrade the Fast Corrector Power Supply Project

The MPWMS and MOSFETS’ Temperatures for the Proposed Average-Temperature Control

MPWMS and Temperatures for MOSFETs $S_1$ and $S_2$

MPWMS and Temperatures for MOSFETs $S_3$ and $S_4$

Chen-Yao Liu  Power Supply Group NSRRC  POCPA  2018
The Acceleration Factors w.r.t. Actual Use Temperatures of MOSFETS for MPWMS

Acceleration Factors w.r.t. Actual Use Temperatures for MPWMS

Chen-Yao Liu    Power Supply Group NSRRC       POCPA  2018
Implemented FCPS prototype and example of the PWM signals of the Proposed MPWMS for the MOSFETs $S_1$ and $S_4$

The time intervals $T_1$ and $T_2$ can be adjusted according to the actual requirements and are set as 125 s in the following experiments

Chen-Yao Liu   Power Supply Group NSRRC   POCPA 2018
Lists the MOSFETs’ Temperatures for the Different Operational Conditions and the Estimated Failure Rates for the Components Used in the Implemented FCPS Prototype

<table>
<thead>
<tr>
<th>Component</th>
<th>Failure Rate (per million hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MOSFETs $S_1 - S_4$ ($78.6 , ^\circ C$)</td>
<td>1.701</td>
</tr>
<tr>
<td>Low-pass Filter Inductance $L_{f1}, L_{f2}$</td>
<td>0.038</td>
</tr>
<tr>
<td>Low-pass Filter Capacitance $C_f$</td>
<td>0.87</td>
</tr>
<tr>
<td>Voltage Sensor</td>
<td>0.56</td>
</tr>
<tr>
<td>Current Sensor</td>
<td>0.5</td>
</tr>
<tr>
<td>Gate Drive</td>
<td>1.0</td>
</tr>
</tbody>
</table>

| Temperatures while MOSFETs $S_1$ and $S_2$ and MOSFETs $S_3$ and $S_4$ operated at output frequency and high frequency, respectively. |
|---|---|---|---|
| $S_1$ | $S_2$ | $S_3$ | $S_4$ |
| 90.9 C | 87.2 C | 67.9 C | 68.6 C |

| Temperatures while MOSFETs $S_1$ and $S_2$ and MOSFETs $S_3$ and $S_4$ operated at high frequency and output frequency, respectively. |
|---|---|---|---|
| $S_1$ | $S_2$ | $S_3$ | $S_4$ |
| 67.5 C | 69.3 C | 89.3 C | 86.9 C |

MOSFETs’ Temperatures under Different Operational Modes

---

Chen-Yao Liu  Power Supply Group NSRRC  POCPA  2018
3. Test

**Result:** Long Term Stability Test for FCPS

Measurement 15 hours: 5 ppm drift

Chen-Yao Liu  Power Supply Group NSRRC  POCPA 2018
Output Current Ripple for FCPS

Frequency: from 0 Hz to 1.6k Hz

Chen-Yao Liu    Power Supply Group NSRRC       POCPA 2018
Output Sine Wave Current

The output current has no current distortion due to positive and negative conversion.

Chen-Yao Liu    Power Supply Group NSRRC    POCPA 2018
4. Future Work

Full Digital Control by DSP TMS32028335 Add New MPWM Software Program in Real time System
## Selected New Power MOSFETs

<table>
<thead>
<tr>
<th></th>
<th>IXYS IXFK180N15P</th>
<th>IXYS IXFK250N10P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vdss</td>
<td>150V</td>
<td>100V</td>
</tr>
<tr>
<td>Current</td>
<td>180A</td>
<td>250A</td>
</tr>
<tr>
<td>rds(on)</td>
<td>11mΩ</td>
<td>6.5mΩ</td>
</tr>
</tbody>
</table>

Change all Power MOSFETs: Conduction Loss reduce 0.45w  
(Output Current: 10A)
5. Conclusions

1. A FCPS prototype rated as ±10A/±50 V controlled by HPWM and MPWMS was implemented.
2. The MOSFETs’ temperatures of the FCPS controlled by the HPWM and the proposed MPWMS.
3. The reliability indices under different PWM controls can then be assessed.
4. We can be observed that the reliability of FCPS using the proposed MPWMS can be effectively improved.
Reliability Assessment and Improvement for a Fast Corrector Power Supply in TPS

Kuo-Bin Liu, Chen-Yao Liu *, Bao-Sheng Wang, Yong Seng Wong

Chen-Yao Liu  Power Supply Group NSRRC  POCPA  2018

https://doi.org/10.1016/j.nima.2018.04.015

12 April 2018
Thanks Your Attention!