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The Design and Implementation of Fast Machine Protection System for CSNS

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Abstract

The high-quality of fast machine protection system(FPS) is one of the significant conditions for the stable and reliable operation of the Chinese Spallation Neutron Source (CSNS) accelerator. Based on the design concept of high availability, high reliability and high maintainability, we adopt the distributed architecture based on "high-performance Field Programmable Gate Array (FPGA) chip + Gigabit Transceiver with Low Power (GTP)+ VME bus read and write by real-time", which is demonstrated the superior performance to satisfy the requirements of the CSNS accelerator during commissioning and operation. The CSNS accelerator fast machine protection system has been put into operation for nearly five years with strong operability and availability, thorough traversal and response time-consuming tests.

INTRODUCTION

CSNS is a high power proton accelerator-based facility and its technical acceptance had been completed in March 2018.

Fig. 1: CSNS site.

According to the physics-related simulations and careful calculations of the CSNS accelerator, if equipment failure or beam current abnormality occurs during the operation of CSNS LINAC, the entire machine protection action must to be reliable, safe and effective to completed within 10μs to cut-off of the beam.

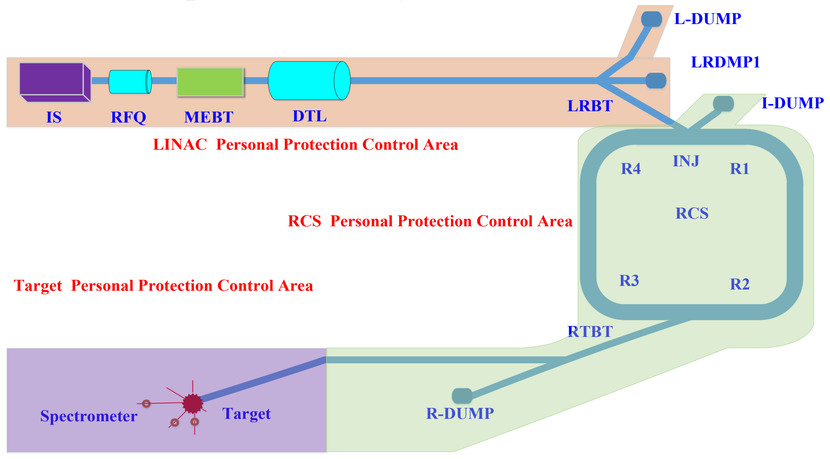

Fig 2: Schematic diagram of beam target and control area.

CSNS accelerator currently has a total of 6 accelerator beam targets: IS (Ion Source, IS), L-DUMP (LRBT Beam Dump, L-DUMP), LRDMP1 (LR Beam Dump, LRDUMP), I-DUMP (Injection Beam Dump, I-DUMP), R-DUMP (RTBT Beam Dump, R-DUMP) and target station. In order to further improve the operation safety, we adopted the architecture design plan of "RMS + two LPS based on PLC + FPS based on high-speed digital technology".

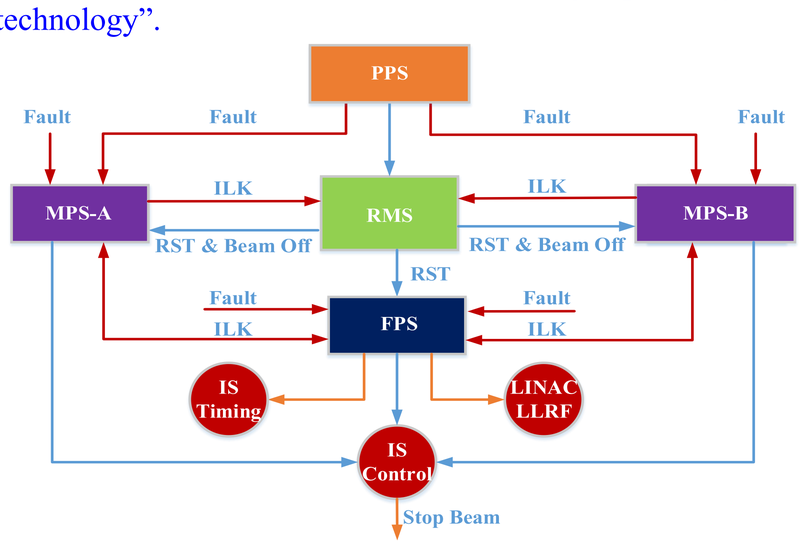

Fig. 3: Schematic diagram of the overall architecture

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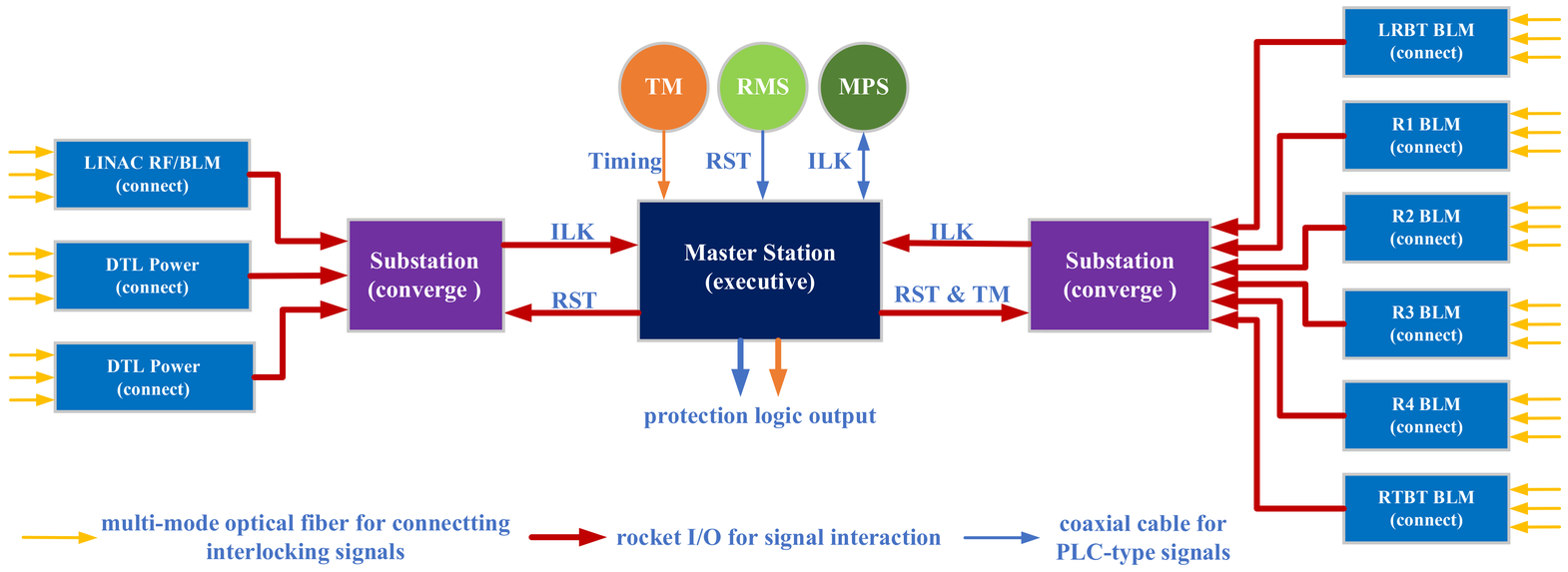


Fig. 4: Layout of CSNS fast machine protection system.

According to the main equipment and its distribution characteristics, FPS adopts the distributed architecture of "high-performance FPGA chip + high-speed Rocket I/O transmission + VME bus read and write", and "FPGA + Rocket I/O" is responsible for signal aggregation, logic processing, signal fan-out, etc.; VME is responsible for power supply and bus readout , backplane signal "line OR", etc., and also is designed a VME user-defined bus according to requirements.

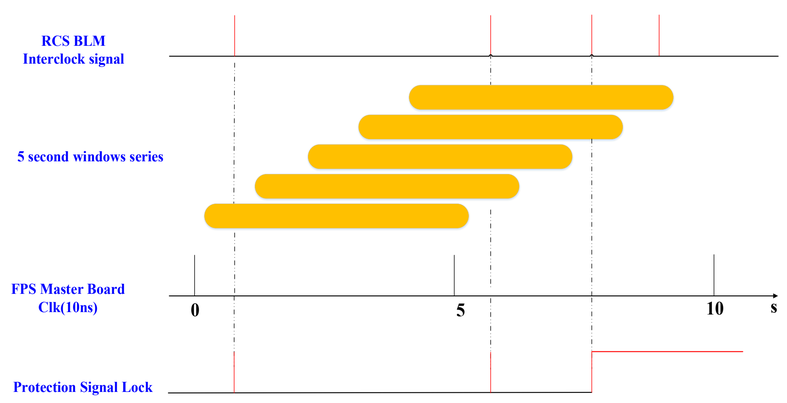
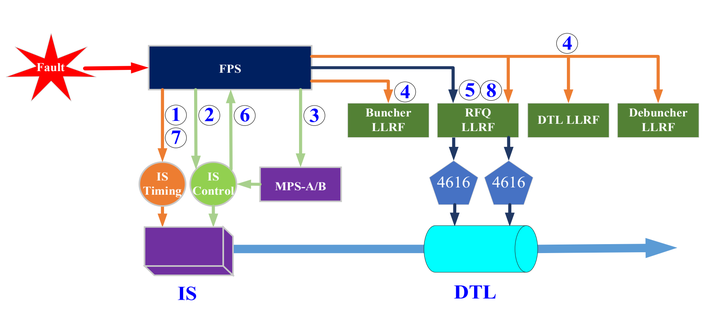


Fig. 5: Diagram of RCS BLM processing

In order to improve operating efficiency, FPS has developed a combination of instantaneous protection and permanent protection for LINAC RF system and the BLM. The operation results of FPS show that under the current equipment working conditions, this function can significantly improve the operation efficiency.



①stop the timing for the extract power supply of ion source
②drop down 50kV high voltage of ion source
③interlock with MPS-A/B
④stop the timing for LINAC LLRF Beam Gate
⑤drop down the RFQ power
⑥feedback "dropping down 50kV high voltage of ion source was Completed "
⑦sync recovery the timing for the extract power supply of ion source
⑧sync recovery the RFQ power

Fig. 6: Schematic diagram of permanent protection function

The architecture of FPS is divided into the interlocking signal collection layer, the interlocking signal summary and preliminary processing layer, and the interlocking signal logic processing and execution layer.

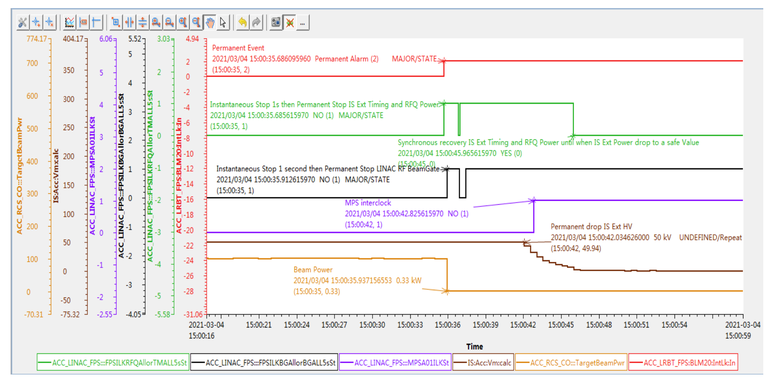


Fig. 7: Diagram of permanent protection for RCS BLM

On the basis of ensuring the safety of the machine, in order to improve the efficiency of the CSNS accelerator supply, according to the characteristics of the access interlock signal, FPS divides the faults caused by equipment failure : transient faults and permanent faults, for transient faults, the beam should be cut off immediately, and the beam should be restored automatically after the fault has passed; for permanent faults, the beam should be cut off immediately, and the beam can be restored manually after the fault is restored.

Fig. 8: Response time test for FPS.

It show that decided to independently design and develop a fast machine protection system (Fast Protection System, FPS) with a response time of less than 10μs to meet the rapid machine protection requirements of the CSNS accelerator.

CONCLUSION

The high-reliability, high-real-time, high-stability fast machine protection system is an extremely important equipment safety guarantee for the high-current proton accelerator in the process of beam adjustment and operation, and it is also one of the key subsystems. During the research and construction of the CSNS fast machine protection system, the research group and related research groups worked together, united and played a good team spirit, and successfully completed the construction. The operation of the past six years shows that the FPS of CSNS provides important guarantees for the safe operation of the accelerator, which has the advantages of compact system structure, easy maintenance, easy expansion, etc., and also including that "design is correct, the pre-research is sufficient, the implementation is reasonable, the function is complete, the operation is stable, reliable".

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