HIGH PRECISION TEMPERATURE MEASUREMENT SYSTEM USING SMARTLINK AT SPRING-8

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Abstract

We developed a high precision temperature measurement system using SmartLink within the SPring-8 standard control framework. In the storage ring of SPring-8, a stable magnet's temperature is essential to keep the beam orbit stable. The precise measurement of the magnet cooling water temperature with a resolution of 0.01˚C is a requested goal because 0.1˚C temperature deviation causes a few micron beam position distortions. The SmartLink is a general-purpose measuring instrument designed for network-based system. Its resolution is guaranteed 0.01˚C for thermocouples and 0.001˚C for resistive temperature detectors respectively. The system can be installed to any place along with the storage ring with the limited space. The temperature data from the SmartLink is taken by socket based network communication with a UNIX workstation and stored into the accelerator database system. In this article, temperature measurement system and results are presented.

1 INTRODUCTION

We developed a high precision temperature measurement system using SmartLink[1] within the SPring-8 standard control framework[1]. The compact form factor of SmartLink, as shown in figure 1, makes it easy to put them close to the signals or sensors being monitored.

Figure 1: View of SmartLink.

The poller and collector data-taking processes are running on the UNIX workstation. The poller process takes the data from the SmartLink by using a socket based network communication with bootp client protocol, and stores the data into a shared memory. The collector process reads the data from the shared memory and stores the data into the accelerator database system. We use type T thermocouples (TC's) to measure the magnet cooling water temperature and platinum resistive temperature detectors (RTD's) with 4 wire configuration to measure the underground temperature. The intervals of data taking are 10sec for the cooling water temperature and 60sec for the underground temperature.

In storage ring of the SPring-8, the cooling water systems consist in four zones. We measure the temperature of the water supplied to magnets, the outgoing water from magnets, and the air temperature of each zone. Even 0.1˚C temperature deviation of the cooling water causes a few micron beam position distortions[2]. So it is essential to request the precise measurement of the magnet cooling water temperature with 0.01˚C accuracy.

For the measurement of underground temperature, we installed the SmartLink with RTD's into the wave-guide pit for the RF cavities. Each RTD is set into the level of 3.6m below the storage ring medium plane (2.4m below the base plate) and 3m depth from sidewall of the pit. The SmartLink is covered by lead blocks to avoid radiation damage. Also we install the RTDs to measure the underground temperature around the storage ring with the depth of 0m, 0.5m, 3m, 5m and 10m below the surface.

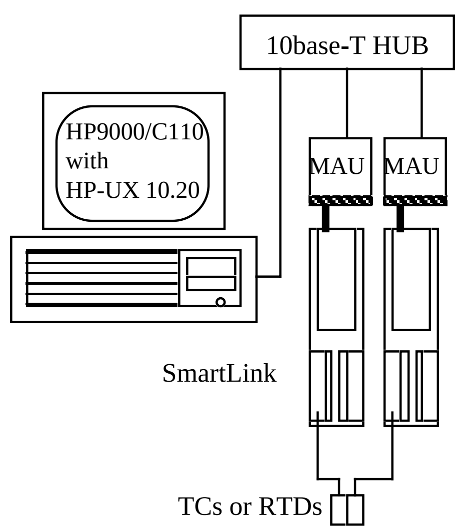

Figure 2: Schematic view of SmartLink testbench.

[1] SmartLink is a trademark of Keithley Instruments Inc..

2 PERFORMANCE ON THE TESTBENCH

2.1 Setup

On the testbench we use two SmartLinks and one UNIX workstation. In order to reduce the measurement systematic errors, the TC and the RTD are connected to both SmartLinks at the same time, and all sensors read the same temperature. The SmartLinks are connected to the workstation via 10base-T Ethernet. The poller process is running on the UNIX workstation to take the data. Figure 2 shows schematic view of SmartLink testbench.

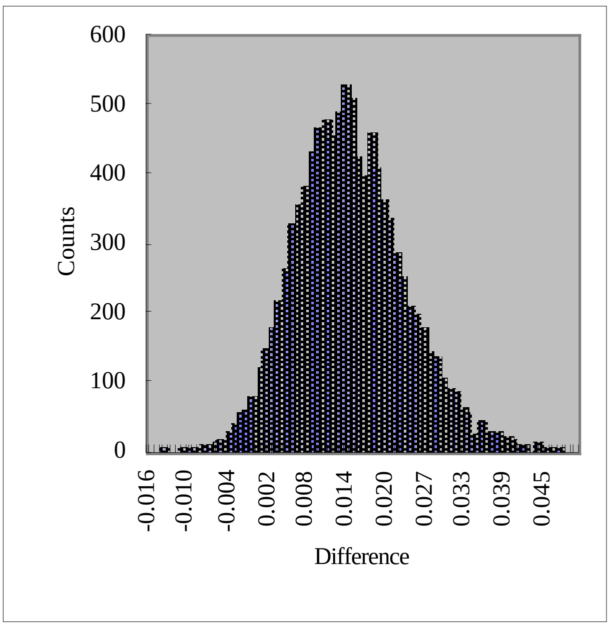

Figure 3: Difference of two RTD's.

2.2 Test Results

The SmartLink has the function of internal averaging up to 50 times. The data acquisition time and accuracy were measured for 1, 4, 10 and 50 averaging modes. Table 1 and 2 show the data acquisition time of each reading. This measurement includes the processing time at SmartLink, the propagation delay of network communication and the poller process time. The data acquisition time is almost proportional to the number of internal averaging and no difference is found between the TC and the RTD. A maximum value of the data acquisition time with no averaging is almost twice the average data acquisition time and we did not know the reason at this moment.

Figure 3 shows the distribution of the difference between the two RTD's with no averaging. The standard deviation is 0.0083˚C.

For estimation of accuracy we assume as follows:

- The error distribution is Gaussian distribution.
- Both SmartLink have the same accuracy.
- There is no correlation between two SmartLinks.

The relative accuracy $\sigma_{\text{SmartLink}}$ is given as,

$$\sigma_{Difference}{}^2 = \sigma_{SmartLink}{}^2 + \sigma_{SmartLink}{}^2.$$

It means

$$\sigma_{SmartLink} = \frac{\sigma_{Difference}}{\sqrt{2}}.$$

Table 1: Data acquisition time of TC

Int. Ave.	Average	Minimum	Maximum
1	118msec	109msec	229msec
4	372msec	368msec	385msec
10	965msec	925msec	997msec
50	4.75sec	4.70sec	4.79sec

Table 2: Data acquisition time of RTD

Int. Ave.	Average	Minimum	Maximum
1	109msec	104msec	168msec
4	378msec	376msec	394msec
10	825msec	795msec	876msec
50	4.02sec	3.95sec	4.49sec

Table 3 shows the accuracy of TC and RTD with 1,4,10 and 50 averaging.

Table 3: Relative accuracy of TC and RTD

Average	with TC	with RTD
1	0.0139	0.0059
4	0.0119	0.0038
10	0.0123	0.0039
50	0.0248	0.0022

The accuracy of RTD is proportional to the square root of averaging are up to 4 times. This means that the errors described as normal error distribution and systematic errors are dominating below 0.004˚C. On the other hand, the accuracy of TC is not proportional to the square root of averaging because the accuracy has reached the sensor resolution (0.01˚C).

3 PERFORMANCE WITH STORAGE RING

We started to measure the cooling water temperature and the underground temperature from the beginning of 1999. For the first few months, the data acquisition was unstable. The SmartLinks were hung-up every several hours. This was caused by the minor bugs of the network protocol stack of the SmartLink's firmware. However, the SmartLink with the new version of the firmware is relatively stable. Troubles like system hung-up have been recorded about three times in 5 months.

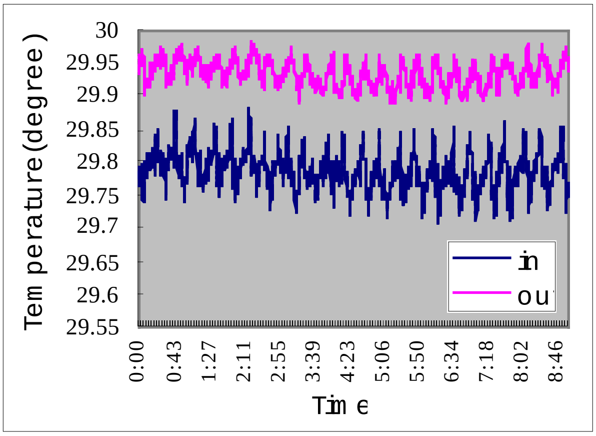

Figure 4: Difference of two TC's.

Figure 4 shows the supply and outgoing cooling water temperature with no averaging. A temperature of supply water is controlled within ±0.2˚C and a time constant is about 10 to 20 minutes. A hunching of cooling water is a character of the temperature control system and it will be improved in future. The difference between the temperature of the supplied and outgoing cooling water is caused by the heat load of pump system.

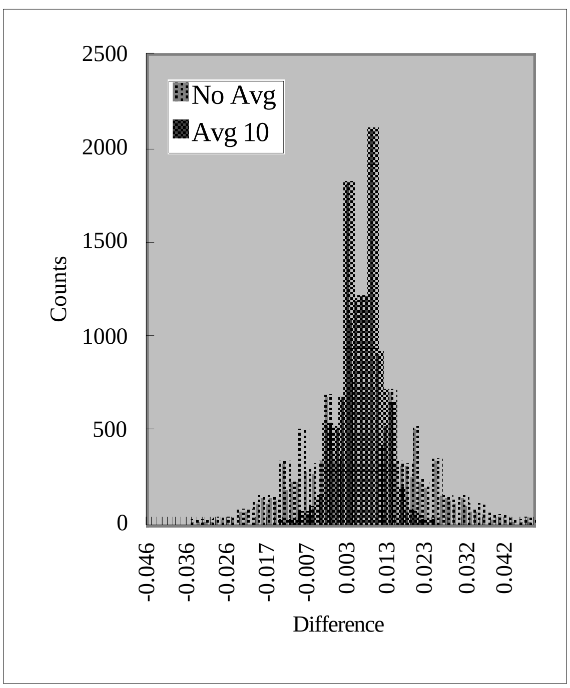

Figure 5: Difference of no average and 10 times averaging of RTDs.

If the heat load is constant, a difference between the supply and the outgoing cooling water temperature is constant. We selected as stable a condition as possible. The main magnets of the storage ring were not operated in this period, the heat load was negligibly small. The standard deviation of the difference was 0.0222˚C and relative accuracy was 0.017˚C. This is close to the requested value of 0.01˚C accuracy.

For the underground temperature measurement we use the two RTDs for each position. Figure 5 shows the difference between two RTDs with no averaging and 10 times averaging. The 10 times averaging is narrower than the no averaging.

Table 4: Relative accuracy of RTD

	σ
No Average	0.0103
10 times average	0.0035
10 times average after 5 month	0.0032

Table 4 shows the accuracy of no average, 10 times averaging and again 10 times averaging but 5 month. After 5 month the relative accuracy has not degraded.

4 SUMMARY AND CONCLUSION

We developed a high precision temperature measurement system using SmartLink within the SPring-8 standard control framework. The system has been operating for more than 5 months and performs very well the precise measurement of the magnet cooling water temperature and the underground temperature. On the testbench, the relative accuracy of TC is about 0.01˚C and the relative accuracy of RTD is less than 0.01˚C. The data acquisition time is about 100msec for no averaging and about 1sec for 10times averaging. This is good enough for the data taking intervals of 10 sec for the cooling water and 60sec for underground temperature.

At the storage ring environment, the relative accuracy of the system with TC is 0.016˚C. This is almost the same accuracy of the testbench and close to requested goal. The relative accuracy of the system with RTDs is 0.0103˚C with no averaging and 0.0032˚C with 10 times averaging. When compared to the testbench results, the accuracy is degraded. This is caused by the distance of the 3m extension from the RTD to the SmartLink. The accuracy of SmartLink is good enough for the measurement of the magnet cooling water and underground temperature.

REFERENCES

[1] R.Tanaka et al., Proc. of ICALEPCS'95, Chicago, USA, 1995, p.201.

[2] K. Kumagai et al., "Beam Orbit Distortion caused by Temperature Fluctuation of Cooling Water at SPring-8 Storage Ring", The 12th Sympo. on Accel. Sci. and Tech., Wako, Japan, 1999.(to be published)