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DEVELOPMENT OF PULSE FAULT SEQUENCE ANALYSIS APPLICATION WITH KSTAR DATA INTEGRATION SYSTEM*

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Abstract

The Korea Superconducting Tokamak Advanced Research (KSTAR) interlock related systems are configured with various system such as fast interlock, supervisory interlock, plasma control, central control, and heating devices using various types of hardware, software, and interface platforms. For each system, monitoring and analysis tools are already well-developed. However, for the analysis of system fault behaviour, these heterogeneous platforms do not help finding the relation of failure. When the interlock events are latched or pulse is stopped by PCS, events are transmitted to different actuators and it could make other events via various interface. In other words, it could lead another factor of fault causes on different systems. Through this application, we will figure out the sequence of fault factor during the pulse-by-pulse KSTAR operation. The KSTAR Data Integration System (KDIS) is configured with KSTAR event-driven architecture and data processing environment. This application has been developed on the KDIS environment and synchronized with KSTAR event. This paper will present the development of shot fault sequence analysis application and its environment configured with KDIS.

INTRODUCTION

Since 2008, KSTAR [1] has completed its 10th plasma experiment by 2017. As the stability of device operation increases, the requirements for accessing operational information through data have increased. As part of such a requirement, we have developed fault analysis application to improve operational efficiency.

BACKGROUNDS

KSTAR Interlock Related System

In order to analyse fault sequence, the study of KSTAR interlock events and actions related system should be proceeded. Interlock system is complicated because it has various dependencies and configurations. KSTAR interlock system is composed of Fast Interlock System (FIS) [2] [3] for heating system protecting PFC from heating beams and Supervisory Interlock System (SIS) [4]. In addition, there are related systems such as local interlock system, central control system, plasma control system, and plasma monitoring system. Focused on the central interlock system, the interface diagram between interlock related systems is drawn in Fig. 1.

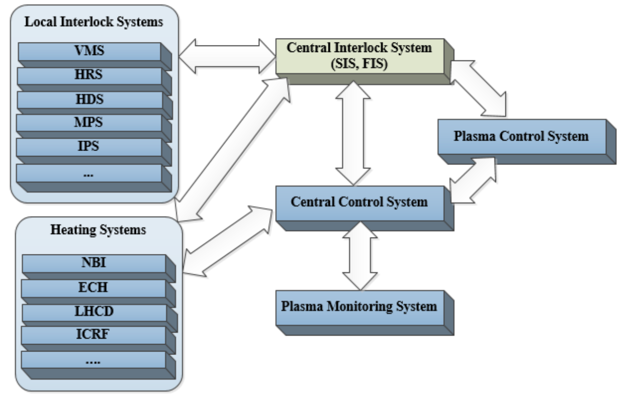

Figure 1: Interlock related system interface.

KDIS and Data Repository

The KDIS [5] has been developed as an integrated data system for KSTAR including scheduled processes on stream and batch data according to KSTAR events with a user interface service, hardware and software infrastructures, applications, and libraries under the open source architecture as shown in Fig. 2. The fault analysis application is developed and executed under the KDIS environment as a task. This application is launched by KDIS job scheduler according to an operational state of KSTAR.

In order to integrate data from the heterogeneous system, we use Channel Archiver [6], MDSPlus [7], and log files from the system. KDIS has all the interfaces between systems. KDIS provides an environment for integrating relevant data.

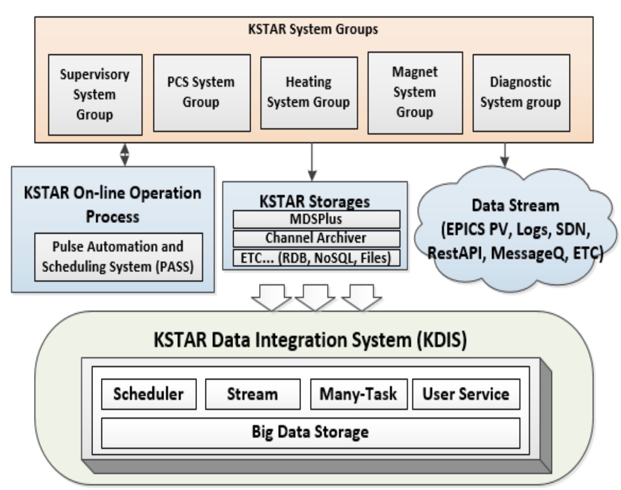

Figure 2: KSTAR system and KDIS.

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APPLICATION DEVELOPMENT

The main purposes of this application are generating and serving meaningful fault analysis data by providing information to the operator during pulse operation time, identifying cause and effect of the fault, and supporting statistical analysis through accumulated results.

This application is developed with python language and the flow of application can be divided into 4 stages. First, the application is launched by the scheduled event which is from the KDIS operation status scheduler. Second, this application is aggregating the data from various interface such as storage or memory. Third, backtracking the data by event groups. Fourth, archiving and providing analysed data to the operator and user.

Pre-processing Interlock Related Event

KSTAR is operated by automated pulse operation system named PASS [8]. Every pulse is operated by the sequence of stages as shown in Fig. 3. In order to decide the range of analysis, we dedicated the range of operation time is from 'Shot Start' to 'Termination' on purple marked stages of Fig. 3. The application extract and filter these bounded event data from unbounded archiving stream on each pulse by each system interface. Data is coming from various interface. These data will be sorted according to the timestamp. As data source of this application, EPICS channel archiver and MDSPlus interface have been used. Data from PLC based system and digitizer are integrated to EPICS and MDSPlus. Through these interfaces, the operation and experiment data of central interlock system, local interlock system, and related system are archived and stored. Those aggregated data will be divided as part of groups to be analysed. Therefore, even if the system or the interlock related functions are added, the application can be maintained in a scalable manner by adding to the data group.

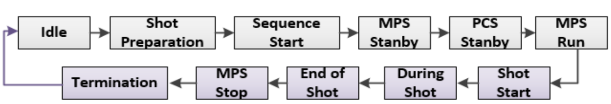

Figure 3: KSTAR operation Sequence

Application Logic

Based on the pre-processed data, the application performs analysis logic. The criterion of the analysis is the time stamp of the data, and the reference data is shown in Fig. 4 are grouped by pre-processing.

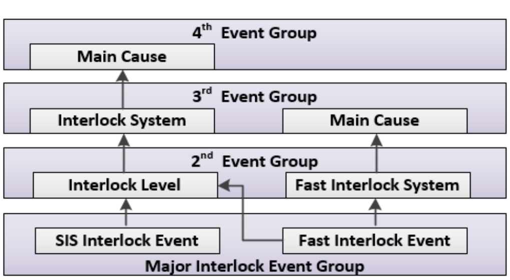

Figure 4: Grouped data for analysis.

Major Interlock events are latched by local interlock system or the other conditions. The beginning of the analysis is the search for the first major event. The major interlock events of KSTAR are divided into two types. The SIS interlock event operates with the following interlock level as shown in Table 1. On the other hand, fast interlock is an operation to prevent the damage of PFC from the heating system, and it operates depending on the condition of each system. The interlock operation below interlock level 4 has no direct effect on the interruption for experiments. Therefore, the event that stops the operation of the heating system and the level 3 or more is analysed in the main event group. It is divided into groups according to kinds of events and analysed in reverse order. Based on aggregated time based log, the application is composed of doing backtracking to find the factor which event stop the operation. Because this analysis should be started from the when the major event happens and divided into categories to find lineage for the main causes.

Table: 1 KSTAR Interlock Level

Interlock Level	Action
Level 1	TF fast discharge
Level 2	TF slow discharge
Level 3	Plasma discharge stop
Level 4	Next shot inhibit
Warning	Warning
Fast Interlock	Reducing damage to the plasma facing components (PFC) by heating beams off

In case of an event from the SIS system which has interlock level, it is easy to find root causes because our SIS system has logging interface with EPICS from PLC based system. On the other hand, fast interlock system is not so easy because this event could be from any system related. For example, if heating is stopped by PCS, the application need to process data by the result of causes. In addition, interlock event could occur chained by previous event and relation between SIS and Fast Interlock. Brief algorithm for analysis is as shown in Fig. 5.

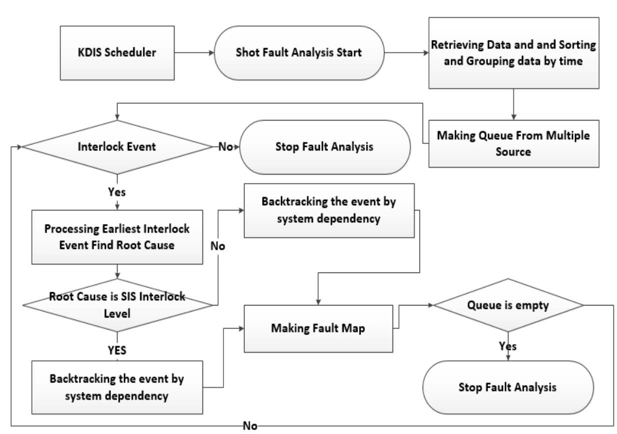

Figure 5: Application logic.

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Analysis Result and Data Archiving

The result of analysis and filtered pre-processed logs will go to the storage and operator as shown in fig 11.

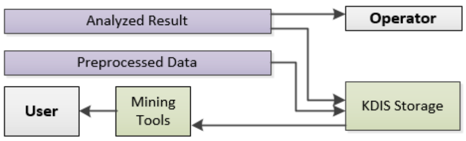

Figure 6: Usage of analysed data.

One of the operator's major concerns is to know why operation has failed between pulse operation times. The operator can watch result information as shown in Fig. 7 as soon as the pulse is terminated.

```
Shot Number = 18724, Shot Type = P-Shot
System Fault Log between (Seq Start : 2017/06/12 12:59:00 ~ Seq End : 2017-06-12 12:59:55 )

----------------------Root Fault Event--------------------
Heating Stop (NBI_FAULT [NB1_PLC_PS2_FLT] > PCS [SOFT_LANDING])
```

```
Shot Number = 18739, Shot Type = P-Shot
System Fault Log between (Seq Start : 2017/06/12 16:09:00 ~ Seq End : 2017-06-12 16:09:43 )

----------------------Root Fault Event--------------------
Interlock LV3 (MPS ['PF1 L3' Output DC over-voltage fault H/W])
> Heating Stop (CCS [CCS_SET_PCS_INTL_LV3] > PCS [PS_FAULT])
```

Figure 7: Examples of root cause log for the operators.

On the other hand, data will be archived to KDIS storage. These results can be served and used for other experimental or operational results and analysis. Users can access data with the file itself or tools on the KDIS for mining it like Fig 8.

```
Shot Number = 18739, Shot Type = P-Shot
System Fault Log between (Seq Start : 2017/06/12 16:09:00 ~ Seq End : 2017-06-12 16:09:43 )

-----------------Interlock Event Sequence----------------
2017-06-12 16:09:18.800637 Interlock LV3 (MPS[PF1 L3])
2017-06-12 16:09:18.850321 Heating Stop (CCS_SET_PCS_INTL_LV3  PS_FAULT)
2017-06-12 16:09:18.850323 Interlock LV4 (Fuel)
2017-06-12 16:09:18.850326 Interlock LV4 (MPS [IPS4, PF1, IPS1, IPS2, IPS3, IPS4, IRC5], GND)

-----------------Detailed Log----------------
2017-06-12 16:09:18.668644 PF1 Status :  Output DC over-voltage fault (H/W)
2017-06-12 16:09:18.892565 PF6U Status :  Forced quench
2017-06-12 16:09:18.906276 PF6L Status :  Forced quench
2017-06-12 16:09:18.924174 PF4L Status :  Forced quench
2017-06-12 16:09:19.050291 PF5L Status :  Forced quench
2017-06-12 16:09:19.220218 PF2 Status :  Forced quench
2017-06-12 16:09:19.331089 PF3U Status :  Forced quench
2017-06-12 16:09:19.423831 PF4U Status :  Forced quench
2017-06-12 16:09:19.597428 PF5U Status :  Forced quench
2017-06-12 16:09:19.673812 PF3L Status :  Forced quench
2017-06-12 16:09:19.716486 PF7 Status :  Forced quench
```

Figure 8: Example of archived data.

An example analysis case of result is as shown in Fig. 9. Based on the analysed case, we could know what causes the operation stopped and what happened as next event.

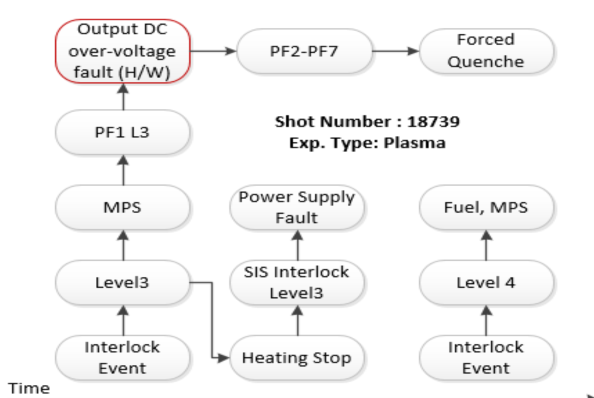

Figure 9: Example of analysed case.

SUMMARY

This application has been developed for the analysis of operational fault event for the KSTAR machine operator and operated during the 2017 KSTAR campaign. Because of this application, operators could know the reason without communicating the operators in charge of the system. Therefore, operation efficiency has been improved with making operation time shorter by saving fault detection time.

For the future work, we will consider more about the data and interface quality. First, log integration level is not enough for now. In order to perform deeper analysis related with all the system, we will try to generate and integrate more log and analyse detailed reason and relation. Second, we have to fix timestamp synchronization. Because the system is different, compensation methodology will be considered according to type of system. Third, visualization will be considered include alarming for convenience. Fourth, we need more performance to retrieve data from EPICS channel archiver. These current limit is that it is difficult to explain associations between sequential events.

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REFERENCES

[1] G.S. Lee, et al., "Design and Construction of the KSTAR Tokamak", Nucl. Fusion 41, 2001

[2] Hong, J., Lee, W., Lee, T., Han, H., Han, S. H., Park, K., & KSTAR Operation Research Team. (2016). Development and operation of fast protection for KSTAR. Fusion Engineering and Design, 112, 742-746.

[3] Myungkyu Kim, Taehyun Tak, and Jaesic Hong, "The Implementation of KSTAR Fast Interlock system using C-RIO" presented at the 16th Int. Conf. on Accelerator and Large Experimental Physics Control Systems. (ICALEPCS'17), Barcelona, Spain, December 2017, paper TUMPA04, this conference.

[4] Hong, J., Park, K. R., Park, M., Chu, Y., Kim, Y. O., Kim, K. P., ... & Kim, M. K. (2010). The operation result of supervisory interlock system for the KSTAR 1st campaign. Fusion Engineering and Design, 85(3), 500-504.

[5] Tak, T. Hong, J., Lee, W et al, "Conceptual design of new data integration and process system for KSTAR data scheduling," presented at the 11th IAEA Technical Meeting. (IAEATM'17), Greifswald, Germany, May. 2017, paper FUSENGDES-D-17-00283, unpublished.

[6] See http://www.aps.anl.gov/epics/docs/GSWE/start-tools/channelarchiver.htm.

[7] See http://www.MDSplus.org.

[8] Lee, Woongryol, et al. "Conceptual design and implementation of Pulse Automation and Scheduling System for KSTAR." Fusion Engineering and Design 96 (2015): 830-834.

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