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DATABASE MIRRORING IN FAULT-TOLERANT CONTINUOUS TECHNOLOGICAL PROCESS CONTROL

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This paper describes the implementations of mirroring technology of the selected database systems – Microsoft SQL Server, MySQL and Caché. By simulating critical failures the systems behavior and their resilience against failure were tested. The aim was to determine whether the database mirroring is suitable to use in continuous metallurgical processes for ensuring the fault-tolerant solution at affordable cost. The present day database systems are characterized by high robustness and are resistant to sudden system failure. Database mirroring technologies are reliable and even low-budget projects can be provided with a decent fault-tolerant solution. The database system technologies available for low-budget projects are not suitable for use in real-time systems.

Key words: Continuous production; control; database mirroring; fault-tolerant system

INTRODUCTION

In the case of continuous processes, one of the important requirements is to ensure the robustness of the control system, i.e. deployment of fault-tolerant and disaster recovery solutions. Compared to the recent past, the production management is now increasingly dependent on information (or control) systems, which entails the ever-present emphasis on increasing labour productivity, increasing quality demands of customers, and pressure from the competition. The failure of an information system can have negative consequences both for the process control and for the quality assurance. In continuous process control the collection of data from production operation is fundamental and the data taken from the sensors by sampling represent a time series. Solutions falling into the category of fault-tolerant systems need to ensure continuity of such data.

Fault-tolerant solutions of information (or control) systems without the use of Enterprise level technologies are based on the existence of a backup (a secondary copy) of the system which will take over in the event of production system failure. The backup system must not only be an identical copy of the application software but also work with current data. The objective of research was to find solution of a database technology for ensuring data continuity at affordable costs.

EXAMPLES OF CONTROL OF CONTINUOUS PRODUCTION PROCESS IN METALLURGY

The technological processes in metallurgy or coke processing industry operate mostly continuously. This puts specific demands on the control and information systems providing real time feedback for the production management [1].

One of the information system tasks is acquiring data representing a time series, which are used for further calculations (trends, balances, forecasting). In the case of system failure the broken time series data would lose their relevance, therefore it is necessary to make such systems fault-tolerant.

An example of the control system, where securing the continuity of time series data is of paramount importance, is a production control system at ArcelorMittal Ostrava steelworks (formerly Nová Huť) – Figure 1. The MES system (Manufacturing Execution Systems) was designed and put into operation by company Real Time Software - R.T.S. cs s.r.o. (1993-present) [2]. It is a comprehensive system consisting of a wide range of modules and components, such as process data collection, dispatch control, technology monitoring, balance calculations, and data transfer to the corporate ERP system (formerly IBM, nowadays SAP). One of the modules is responsible for controlling the operation cycle of foundry ladles. When operating foundry ladles the temperature control is paramount in order to avoid undesired cooling-down. If the ladle contains molten metal and the temperature falls below a certain threshold, a stoppage may occur which may cause damage to the ladle. Prior to tapping the foundry ladles are heated to the desired temperature by high-temperature heating. During an operation cycle the foundry ladle goes through the following operating steps: high-temperature heating, tapping, transporting the molten steel, processing in ladle furnace, casting, open air cooling (before tapping or after casting the steel) and cooling below the lid. For all of these states of the ladle a mathematical model was constructed to calculate the enthalpy. The

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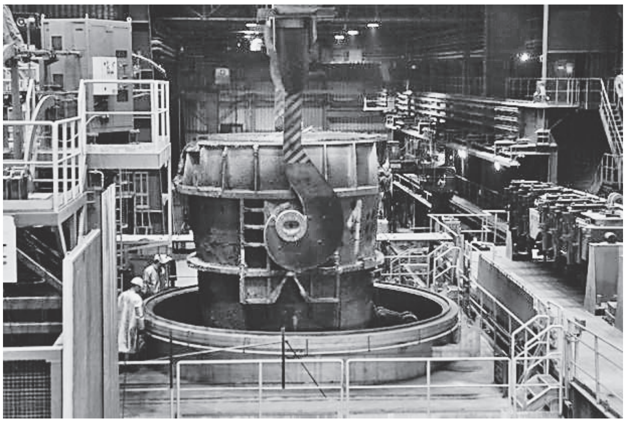

Figure 1 Foundry ladle – ArcellorMittal [5]

automated control system of the steelworks contains partial technological models monitoring the entire operating cycle of foundry ladles, namely the thermal state of the ladle lining. Based on the analysis of experimental measurements of surface and internal temperatures of the ladle and concurrent measurements of steel temperature during all operation steps with a filled ladle, model constants were created for ladle thermal state assessment. Enthalpy information available to the dispatchers describes temperature conditions in the ladle, allowing optimizing the production sequence. The heating time thus can be set to give the ladle sufficient enthalpy for tapping, and the ladle operation cycle can be optimized so that the ladle heat loss is minimized and at the same time the conditions for operation of alkaline ladle linings are met [3]. The calculation of the ladle enthalpy shows that it is unnecessary to heat the ladle for the whole time while it resides at the high-temperature heating station before the next tapping. To preserve the heat accumulated in the ladle lining it suffices to cover the ladle with a lid as soon as the casting is finished. Thus using the model of the foundry ladle thermal state in controlling the high-temperature ladle heating can turn into considerable savings of fuel gas. [4]

In order for the enthalpy calculation model to work the information system needs measurement data in the form of continuous time series. It is the critical component of the information system – if there is a loss of continuity in measurement data because of the database failure the enthalpy calculations cease to provide useful outputs.

RESEARCH OBJECTIVES

The aim of the research was to assess the suitability of database mirroring technology when controlling continuous production processes in metallurgy, coke production or mining. The research was restricted to solutions available in Standard category of the database systems. The reason for choosing Standard versions was to find a suitable technology without the necessity of heavy investments.

After initial analysis the current versions of the following database systems for testing and comparison were selected: Microsoft SQL Server, Oracle, MySQL and Caché.

Testing was performed in Microsoft Windows operating system environment. This constraint was introduced because one of the tested database platforms, Microsoft SQL Server, can run only on Windows systems, and also based on the fact that all potential clients in Moravia region in metallurgical or mining industry interested in deployment of this technology operate their information systems on the Windows Server platform.

Oracle is currently the leader in the database technologies and Oracle systems have been supplied with mirroring technology for many years. MySQL belongs among the most frequently used open-source database systems. Another major open-source platform PostgreSQL was considered but eventually excluded because PostgreSQL system is developed in Linux operating systems environment and its use in Windows systems is possible by porting it via Cygwin emulator. Last database platform included in tests was InterSystems Caché. It is an object-oriented database system with a high-quality database mirroring solution.

For database technology testing purposes has been assumed a model of an information system for continuous process control. Scheme of the model example of an information system is shown in Figure 2.

In this model, the MES information system is connected to the "production" network, which can to read

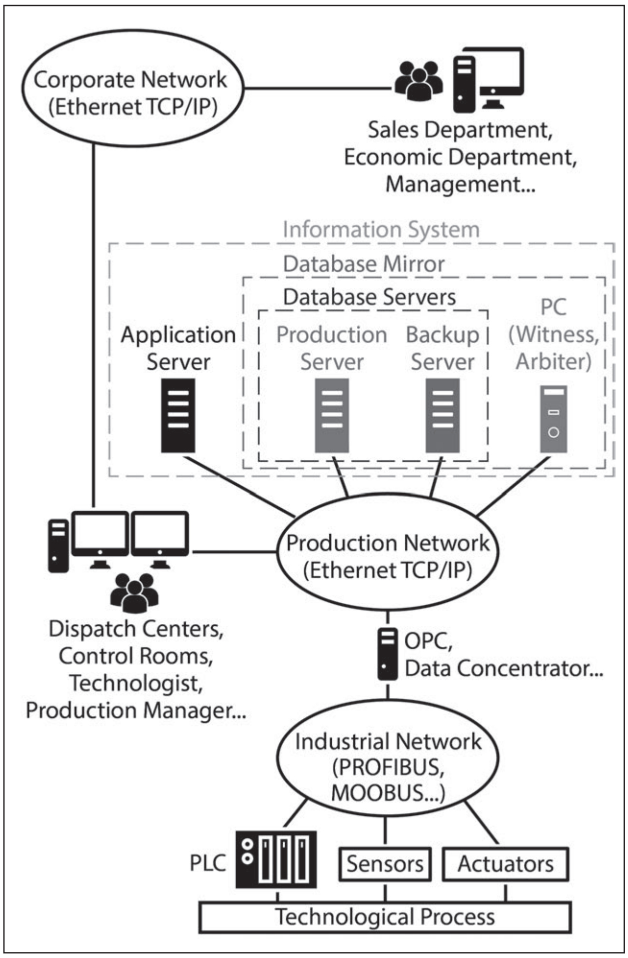

Figure 2 Model example of an information system for continuous process control. Source: own processing

data from the sensors, measuring devices, PLCs, controllers, and other elements of process automation [6]. For test purposes it is not important whether sensors are connected by current loops through data concentrator or if a fieldbus (Profibus, Modbus, etc.) and OPC server are used. The information system itself consists of the application server and the database server with a database instance labeled as a production database.

This instance is then mirrored to the backup database server, which is ready to take over the role of the production server in case of its failure. Role take-over can be either initiated by scripts or it is possible to use third server with a database instance in the role of witness (arbiter). Witness then automatically monitors the status of the production server ensures the activation of the backup server in case of failure.

RESULTS

For assessment of the database systems there was established the following categories:

a) Difficulty of deploying a database mirror
b) Controllability of systems using scripts
c) Speed of the transition to a mirror after failure (downtime duration)
d) Implementation costs
e) Reliability following crash tests

The Oracle database system was excluded from further testing at the very beginning. To ensure Disaster Recovery the Oracle database features a variety of technologies: Real Application Cluster, Data Guard or Oracle GoldenGate. These technologies, however, are only available in the Enterprise versions of the database and require greater investment in licenses.

Certain disadvantages can be noted as well when using the MySQL system. MySQL is publicly synonymous with an open source solution used “for free”, the licensing terms, however, clearly define the use of MySQL under the GPL license (information system using MySQL must be provided including source code) or you must purchase a license. Another disadvantage is the lack of technology equivalent to mirroring. MySQL does have a mechanism allowing database replication at the transaction log level. However, the method of connection and replication activation is different and it is not a trivial operation. After synchronization of the databases it is necessary to make a backup of the database, do a recovery at the receiving side of replication, and then read the new transactions start position address from the transaction log in order to initiate the replication. Deploying replication in fully automatic mode is quite difficult.

Based on the performed testing and feature comparison have been reached the following conclusions:

1. Microsoft SQL Server and Caché database systems provide comparable functionality at a comparable price, Oracle in comparably priced edition does not support mirroring. MySQL only provides replication that has comparable performance, but is inferior in terms of administration.
2. Solutions without a third server in the role of arbiter in case of failure must somehow ensure redirection of clients to the database backup server, Microsoft SQL Server database must be activated from the recovery mode by a script.
3. Using the third server in the role of arbiter on one hand greatly simplifies work with the system, on the other hand, it comprises another component that must be managed and the solution cost increases. The arbiter, however, can take care of redirecting clients through using virtual IP address without altering the configuration. The tests showed that even if the session between production and backup server is managed by the arbiter, a failure leads to some delay, during which data cannot be written in any system, and arbiter in itself does not provide any buffering of data write requirements. This delay depends on the system configuration and on the speed of transition of the migrated database to operating mode. The default setting will lead to a data dropout lasting tens of seconds. Within a real-time control, it is necessary to provide buffering of data write requirements at application level.
4. Crash tests conducted on all database systems confirmed their high robustness, damage to the database or incorrect behavior was recorded in none of the cases. The performed tests did not prove any database system to be significantly better.

CONCLUSION

The aim of the research project was to assess the database mirroring technology of major database system platforms to provide a low-cost solution. By studying existing information systems in metallurgy or coke industry and analysing the requirements, the model example of an information system for testing has been designed.

The results of the testing confirmed that present day database systems are characterized by high robustness and are resistant to sudden system failure. Database mirroring technologies are reliable and even low-budget projects can be provided with a decent fault-tolerant solution. Despite the abundance of information sources on the topic, deploying a database mirror is still not a trivial matter and requires extensive experience and researching of multiple information sources. The database system technologies available for low-budget projects are not suitable for use as real-time systems, in which case it is necessary to complement these technologies by providing software solutions for buffering or to invest in “enterprise” solutions.

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Note: The responsible translator for English language is PhDr. Pavel Král - Language services (translation, localisation and teaching), Olomouc, Czech Republic