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# The Use of Multi Agent System for Monitoring and Control of the Smelting Process in the Mining Metallurgical Sector

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Abstract - *This paper is focusing on the development of intelligent agent technology and application of that technology to the mining and metallurgical sector. We have shown how networks of communicating and cooperating intelligent software agents can be used to implement complex distributed systems. In the mining and metallurgical industries there are processes which cannot tolerate interruption, such as some sequential line chemical processes. Most of the time large production losses may occur due to voltage dips. Poor quality issues have been a major concern for the mine and metallurgical sectors. There is a need for equipment that supports production units to ride through the voltage dips so that the electrical networks are controllable and the voltage dips can be monitored. The paper proposes an application of the intelligent agent technology in creating an efficient data acquisition and expert fault tolerant system in the smelting process.*

## I. INTRODUCTION

Most of the time the power quality events such as voltage sags, swells, switching transients, notches, flickers and harmonics have become far more problematic and dangerous from application point of view than before. This is because of the increased use of sensitive electronic loads like variable speed drives and computers [1]. To improve the immunity or ride through ability of the equipment through these events, the waveform event features of the equipment operating characteristics will be very useful for analysis [2]. The benefits include enhanced coordination between the system and the equipment to the events, which improves the coordination between the system and the equipment.

Various types of events, the event features need to be defined. IEEE P1159.2 has proposed the list of parameters for characterizing sag events based on digitally sampled data [3]. However, a complete characterization of other types of events appears not to be unavailable in the literature.

This paper contributes to the automatic control and the solution of the power quality problem in the smelting g processes. The agent software has been introduced to control and monitor the smelting processes, where the hierarchic architecture of the agent software control has been designed and proposed as a powerful tool for the power quality problem in this process.

In the mines, there are different processes running, and in each process, there are some sensitive equipment that can get damaged due to power quality problems. Some processes and the associated equipments are sensitive equipment are:

- Mining process – Conveyor programmable Logic Controller ( PLC), motor), Shovel (PLC, DC inverter), Crushers (motor, control equipment), Haul truck (motor, rectifier)
- Smelter process – Furnace (PLC, motor), Converter (PLC, motor), Compressor (motor, control equipment)
- Concentrator process – Auto-Mills (PLC, motor), Crushers (motor, control equipment).

The paper is organized as follows: in the introduction a brief overview of some mining processes are discussed. Because voltage sags cause most of the problems in the mines, we briefly discuss this topic in section II. And in section III we introduce the agent and the hierarchic architecture, section IV the application of agent in power systems and section V will have the conclusion.

## II. VOLTAGE SAGS

Voltage sag is one of the prime elements causing the power quality problem so, it is important to explore different aspects of voltage sags.

### *II.A Causes of Voltage Sags*

Voltage sags are typically the result of what is known as a fault condition, large motor starting, or due to interaction between motor operations, faults and also due to system overloading conditions. Fault conditions that result in voltage sags can occur within the plant or in the utility system. The voltage sag continues a protective device clears the fault from which the condition resulted. In plants, such protective devices are typically the fuses or plant feeder breakers, whilst in a utility system of a fault a branch, a fuse or a substation breaker would typically clear the condition.

### *II.A.1 Voltage sags due to faults*

Voltage sags due to faults can be severe and therefore are of major concern. They cause problems to a large number of customers as they propagate through the system. The magnitude of this type of voltage sag at a certain point in the system depends mainly on the type of the fault, the distance to the fault, system configuration and the fault resistance. Its

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duration depends on the protection that is used, and varies between a half-cycle to a few seconds.

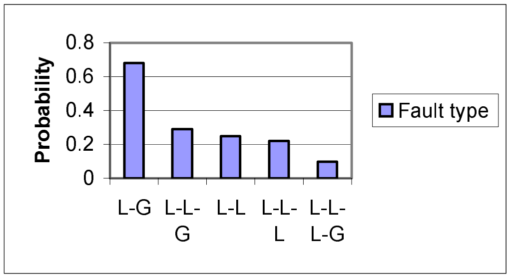


Fig. 1: Probability occurrence of the different faults

Faults are either symmetrical (three phase short circuit or three phase to ground faults) or non symmetrical (single phase to ground or double phase short circuit or double phase to ground faults). Depending on the type of fault, the magnitudes of the voltage sags of each phase might be equal (symmetrical fault) or unequal (non symmetrical faults).

The faults considered in figure 1 are three-phase short circuit (L-L-L), three-phase to ground (L-L-L-G), line-line short circuit (L-L), single line to ground (L-G) and double line to ground (L-L-G) faults. The probabilities associated with a fault type depend upon the operating voltage and can vary from system to system. A typical probability distribution of fault occurrence is as shown in figure 1. The effect of voltage sag due to any of these faults on the voltage waveform is shown in figure 2.

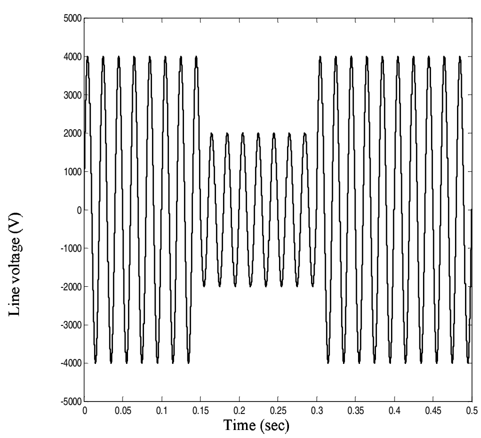


Fig. 2: Voltage Sag due to the faults

*II.A.2 Voltage sags due to induction motor starting*

During starting, motors draw approximately five times their full load running current at a very low power factor. This starting current causes shallow voltage sags. The magnitude of the voltage sags depends on the characteristics of the induction motor and the strength of the system at the point that the motor is connected. The voltage sags due to induction motor starting is manifested as shown in figure 3.

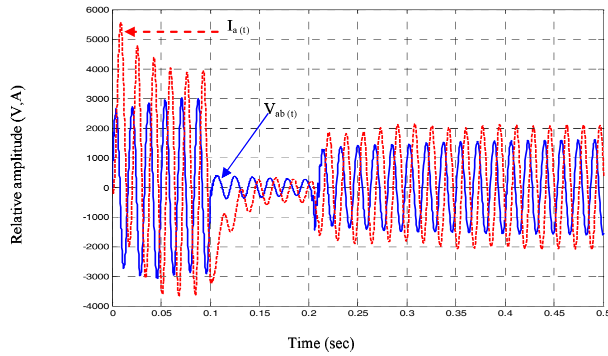


Fig. 3: Voltage sags due to induction motor starting

*II.A.3 Multistage voltage sag*

Multistage sag is due to faults, but present different levels of magnitude before the voltage returns back to normal. The steps in the voltage sag magnitude can be due either to change in the system configuration while the protection system tries to isolate the fault, or changes in the nature of the fault itself. A typical situation is a fault in the transmission system that is not cleared during the operation of zone 1 distance protection but only during the zone 2 operations.

*II.A.4 Voltage sags due to self-extinguishing faults*

Voltage sags due to self extinguish faults are the ones that disappear before the fastest possible breaker opening time.

*II.B. Solutions to Voltage Sags*

The possible solutions must be evaluated in accordance with the system perspective in order to determine the most economically viable solution. As a general rule the most economic alternative usually involves protection closest to the sensitive equipment or within the design of the equipment

There are ranges of solutions available for mitigation of voltage sags at the component, equipment, or plant entrance level. Some devices use energy storage technologies such as capacitors, batteries, or flywheels to provide energy to ride-through the sag event in the same manner as when there is an outage. More recently, these devices do not require energy storage; instead they use a series voltage injection principle, utilizing either transformer coupling or novel power electronic circuitry to achieve the voltage injection function.

Additional component level solutions have been recently introduced such as coil hold up devices that can be added to contactor coils to provide additional hold up time, thereby enable them to ride-through sags [3].

The ride-through of AC drives can be achieved by adding storage energy to the DC bus capacitors to enable sag ride through. Santoso and Parson [4] have undertaken studies relating to the size of DC bus capacitor. It should be noted that phase controlled DC drives have no DC bus, thus cannot benefit from DC bus hold up systems, and require input side devices to enable ride-through of sags.

Additional solution are the Embedded Solutions, in general these solutions involve fixing the individual weak link components of a tool in order to increase the overall ride-through of the entire system. Embedded solutions are attractive, since in theory they do not require add on power conditioning equipment, but instead involve using more robust or improved components in the tool design [5].

## III. AGENT TECHNOLOGY

An *agent* is a software entity that is situated in some environment and can sense and react to changes in that environment. Agents are capable of operating autonomously and in a goal directed manner in order to meet its design objectives. In a multi-agent system, tasks are carried out by interacting agents that can cooperate with each other [6].

Multi-Agent systems are a relatively new sub-field of computer science – they have only been studied since about 1980, and the field has only gained widespread recognition since about the mid - 1990's. Since then, international interest in the field has grown enormously. This rapid growth has been spurred at least in part by the belief that agents are an appropriate software paradigm through which to exploit the possibilities presented by massive open distributed systems [6].

The emergence of the new field in computer science: *multi-agent systems*, is a very simple idea. An *agent* is a computer system that is capable of independent action on behalf of its user or owner. In other words, an agent can figure out for itself what it needs to do in order to satisfy its design objectives, rather than having been told explicitly what to do at any given moment. A *multi-agent* system is one that consists of a number of agents, which *interact* with one another, typically by exchanging messages through some computer network infrastructure. In the most general case, the agents in a multi-agent system will be representing or acting on behalf of users or owners with different goals and motivations. In order to successfully interact, these agents will thus require the ability to *cooperate*, *coordinate* and *negotiate* with each other, in much the same way that we cooperate, coordinate and negotiate with other people in our everyday lives [6].

### *III.A Agents and Objects*

Objects written with object-oriented languages such as Java, C++, etc. are similar to agents. While there are obvious similarities, there are also significant differences between agents and objects. The *first* is in the degree to which agents and objects are autonomous. The locus of control with respect to the decision about whether to execute an action is different in agent and object systems. In the object-oriented case, the decision lies with the object that invokes the method. In the agent case, the decision lies with the agent that receives the request.

The *second* important distinction between object and agent systems is with respect to the notion of flexible autonomous behaviour. The standard object model has nothing to say about how to build systems that integrate these types of behaviour.

The *third* important distinction between the standard object model and agent systems is that agents are each considered to have their own thread of control. In the standard object model there is a single thread of control in the system [6, 7]. Although multi-threaded objects are possible, but it is very difficult to achieve proper synchronization of the whole system, especially when the whole object model system has to behave in a flexible autonomous fashion

### *III.B Applications of Agent Technology*

Agents have found applications in many domains. Some examples are [6,7]:

- Agents for Workflow and Business Process Management. The ADEPT system is a current example of an agent-based business process management system.
- Agents for Distributed Sensing. The Distributed Vehicle Monitoring Test-bed (DVMT) provided the proving ground for many of today's multi-agent system development techniques.
- Agents for Information Retrieval and Management, data mining for example using the World Wide Web.
- Agents for Electronic Commerce. The simplest type of agent for e-commerce is the comparison-shopping agent.
- Agents for Human-Computer Interfaces
- Agents for Virtual Environments
- Agents for Social Simulation
- Agents for industrial systems management
- Agents for Spacecraft Control
- Agents for Air-Traffic Control, etc. [6,7].

## VI. AGENTS IN POWER SYSTEMS

Most current power system and control systems are based on the supervisory control and data acquisition (SCADA) model. The master control centre gathers information from a number of remote terminal units (RTU's) located in substations and power plants. The SCADA model provides acceptable performance and reliability, but has a number of drawbacks, especially in the areas of flexibility and open access to information.

Already, several manufacturers have introduced Intelligent Electronic Devices (IED's) that perform various functions such as protection, control and monitoring. Intelligent Electronic Devices (IED's) are devices that provide internal control and communication through various electrical interfaces. IED's can be digital fault & data loggers/recorders, power quality analyzers, intelligent switches, breakers, regulators, auto-restoration devices, remote terminal units, substation controllers / gateways, etc. Also, we have seen the introduction of Ethernet Local Area Networks (LAN's) in the mine plant. These are used to connect various IED's and control systems and allow access to data from other systems, such as databases and from outside locations. However, the problem is to provide a suitable framework for managing the large quantity of available information. Many vendors have developed systems based on client-server and Web technology. These systems are sometimes inflexible and often centralize much of the system monitoring functionality, which can lead to a requirement for high network bandwidth. Many are also one-vendor solutions, which prevent the integration of equipment from multiple sources.

Agent technology, as mentioned before, is one of the recent developments in the field of Distributed Artificial Intelligence (DAI), which can be used in order to solve these problems. Agents are loosely coupled and can communicate via messaging rather than by procedure calls (remote or local). New functions can easily be added to an agent-based system by creating a new agent, which will then make its capabilities available to others. The distributed power system architecture is suited ideally to a multiagent system, which provides greater autonomy than a traditional system [7].

*IV.A Multi Agent System Architecture*

Different types of agents can be used in power system architecture. The Belief-Desire-Intention (BDI) agents [6] are flexible and make them suitable for performing a wide range of tasks, such as real-time control, online monitoring and alarm/event management. Belief-Desire-Intention (BDI) agents are based on the concept of three mental states (beliefs, desires and intentions).

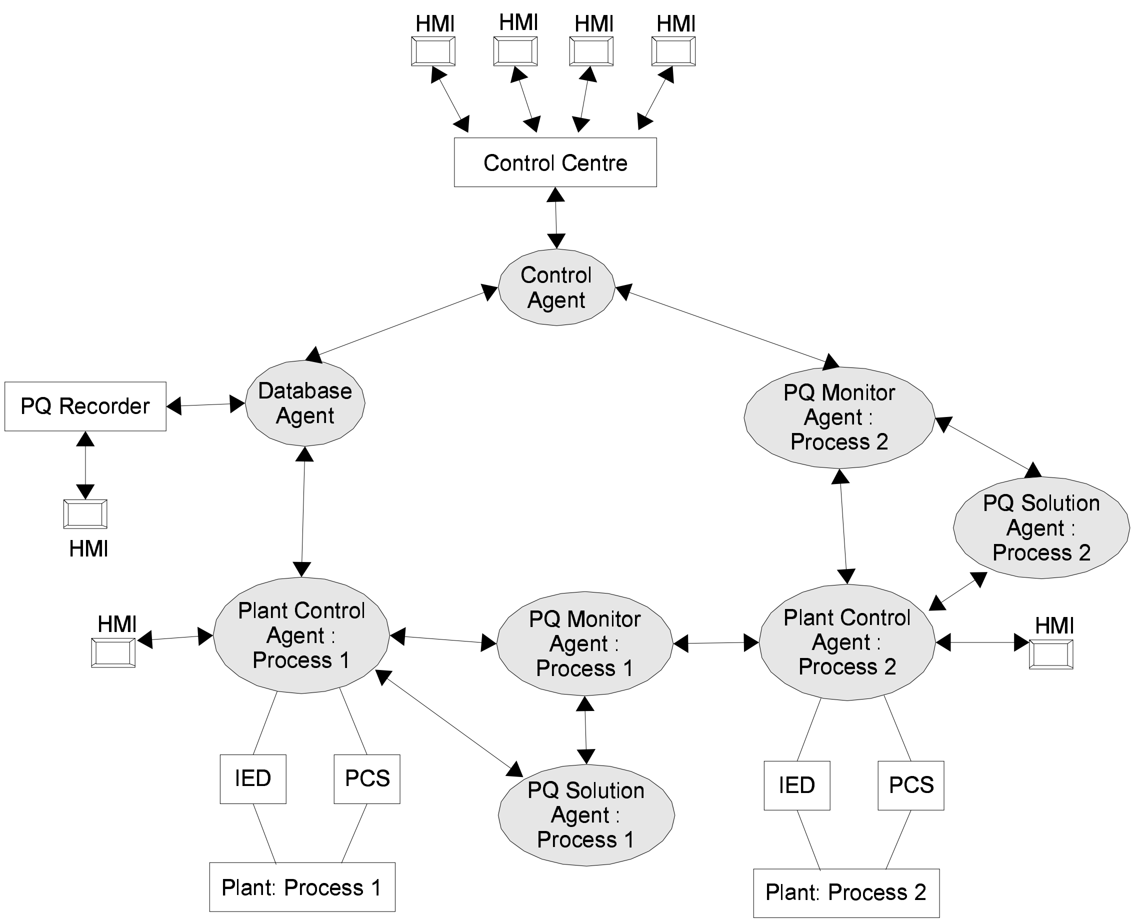


Fig. 4: Multi-agent System Architecture

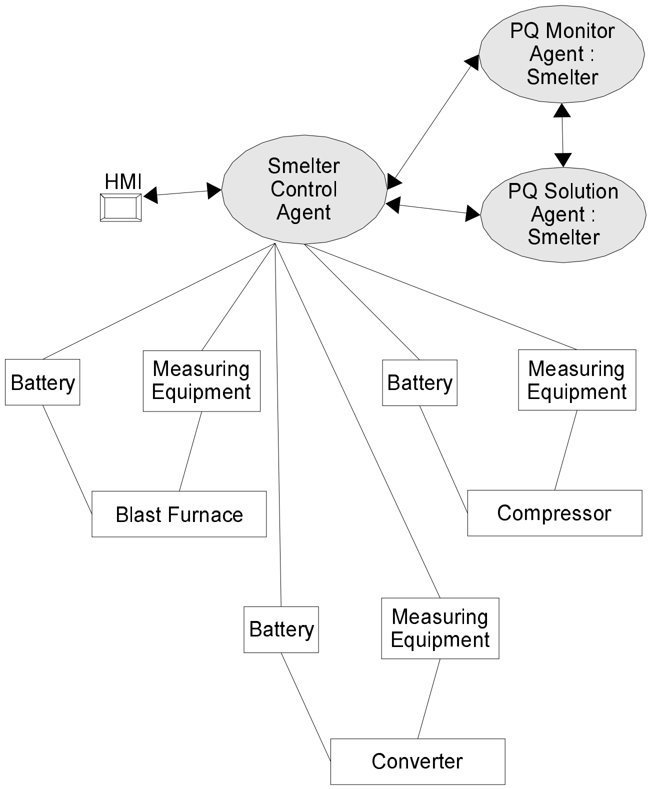


Fig. 5: Smelter Agent System

Power system architecture consists of a number of data sources, data storage and transportation mechanisms and data consumers. The primary source for monitoring information at the mining plant is through Intelligent Electronic Devices (IED's), such as protection relays that interact with the substation plant. Control/monitoring agents can then gather the information from the IED's over an Ethernet network. If no network interface is available, the information can be gathered from the plant Control System (PCS) over a network or serial link.

The protective relays / IED's provide a continuous 3-phase waveform for instantaneous voltages and currents. The IED's can also be synchronised at the plant by a Global Positioning System (GPS) or with IED's at other substations. From the instantaneous voltages and currents it is possible to calculate required analogue values using a plant control agent. This agent can then calculate active and reactive power flows through a transformer at a plant, active and reactive power flows for substation between different process, real-time MVA values, etc. All the data can be send to a database agent as described in next paragraph. The power quality (PQ) monitor agent can then use the calculated values from the plant control agent to monitor the power quality, and when there is a problem, it can inform the PQ solution agent to implement a scheme to solve the power quality problem. Since there can be different processes in the plant, each process can have its own control, monitor and solution agent (see Figure 4).

For the smelter (Figure 5) we then have a control agent that is controlling the batteries (or any other voltage dip solution equipment), measuring equipment, etc. The power quality monitor and solution agents will then detect power quality problems and aid the control agent in implementing corrective action.

Logging and storage of historical data and information at the plant can be stored in a database. A plant database agent can be used to store the collected information in a database. It can then give access to other agents to collect information from the plant database. These agents can send data to other process in the mine as well as to the Central Control Centre, depending on the type of request.

User agents can be used to make it possible for users to access the data of the power quality. The user agent can acts as the user's interface with the rest of the system. This agent can be standalone, integrated into a software package such as a Human-Machine Interface (HMI) situated at the substation of the plant to access the substation data or different process in the plant. A master user agent can be located at the Plant Control Centre to access data of all the plant in the power quality.

An agent can be dedicated to perform a specific task or several tasks combined. It can range from document and database retrieval, decision support, online intervention, data analysis and data processing. Each task has its own varying timing, network and computing resource requirements depending on the function it must perform. Different types of agents may be appropriate to different tasks. All of the agents are capable of communicating with other agents using an Agent Communication Language (ACL) [6].

Because multi-agent systems process data locally and only transfer results to an integration centre, computation time is largely reduced, and the network bandwidth is very much reduced compared to that of a central control. When new resources, loads or interconnections are added to the system, multi-agent systems allows for scalability as well as extensibility when performing new tasks or communicating a new set of data that becomes available [8].

Within a power quality, a large amount of information is generated and stored. For example, large quantities of numerical data, such as fault and event records, gathered from control and protection systems, status of the plant, alarms received from the field for overloaded lines, line trips or any fault condition. This is normally stored in databases. The control agent (see Figure 4) can perform this task and will communicate with other agents in order to send the correct data for the user agent to display it on the HMI.

## V. CONCLUSION

For the use of improving the power quality in different processes in the mine sector, a multi-agent system is introduced. Multi-agent system architecture is used and explained how to implement it in a power quality context. An efficient data acquisition system in the mine plant and power system environment is proposed using multi-agent technology, more flexible and robust than the conventional system. Also the multi-agent system can operate autonomously, requiring less human supervision and operation.

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