A Monitoring System Based on a Multi-Agent Platform

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***Index Terms* – Electric variables measurement, CAMAC, fault diagnosis, distributed computing.**

I. Introduction

Monitoring of distributed systems puts significant challenges in the management and computation of data. In particular, the data should be locally collected according to global user needs keeping under control reliability and accuracy.

Furthermore, in literature many solutions involving computational intensive approaches are proposed,. In particular, it is now common practice to adopt advanced soft-computing solutions for the processing.

In previous papers, the authors analyzed a possible architecture and algorithm for an advanced diagnostic and monitoring system to be applied in industrial plants mostly where electrical drives are involved.

In order to obtain a flexible and easily reconfigurable architecture, in [1] the authors proposed a multiprocessing structure where an agency is implemented to optimize the computational load. In this application a monitoring platform for electrical drive system was introduced.

In this paper the authors analyze the impact of the agent-technology on the measurement and control sections. The operations in the measurement section (data post-processing for monitoring and diagnostic purpose) are coordinated within an agency-agent frame; the operations in the control section are coordinate by a special virtual agent implemented by Virtual Test Bed environment (VTB). In particular a custom fuzzy agent is devoted to the computation of risk coefficients in order to determine working condition of the motor.

II. The Concept of "Agency"

The agency is a network of agents. The role of the agency is to bring together a variety of sensorial information and to perform inference activity. The agency captures the complexity of the entire system and it is capable of holding different complementary partial models of the phenomena. The diagnostic agency here considered is constituted by a network of sensing agents. The agents are capable of autonomous activity such as dynamically adapting and self-reconfiguring, exchanging information with other agents and taking decisions. Each agent has a partial knowledge of the entire system but the ability to share information and allocate tasks leads to the complex capabilities of the agency.

A classification of agents-agency environment properties was proposed by Russel and Norvig [3]:

- *Accessible o non accessible environment*: within an accessible environment the agent can get a complete picture of the system through updated and accurate data. The availability of significant information concerning the status of the system makes the task of the agent easier to be performed. When such status information can not be obtained or it is not accurate or up-to-date, then the system is called non-accessible.
- *Deterministic o non deterministic environment*: environment in which any given action results in a

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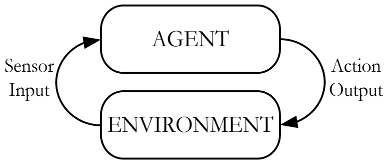

Fig. 1 An agent and its environment.

corresponding determined effect. On the other hand, non deterministic environments call for a different and more complex approach to agent;

- *Event or non-event*: In an event environment, the performance of an agent depends on a number of discrete events
- *Static o dynamic*: A static environment status changes only based on the actions of the agent.. A dynamic environment status changes depending on processes other the the action of the agent. The agent therefore is not in control,
- *Discrete o continuous environment*: Within a discrete environment the possible actions are countable, finite and fixed and so are the percepts. These properties do not hold in a continuous environment

In this perspective, any control and measurement system could be viewed as an agency. This point of view led the authors to apply the agent-agency approach to distributed measurement problems.

Backing to our application, it is well known that processing and correlating sensor data in order to achieve a richer and more defined knowledge of the diagnostic of a complex electrical system is in general an issue.

Two kinds of approach are possible:

- *Central intelligence approach*: this is the traditional approach in distributed monitoring and diagnostic systems. It is based on hierarchical networks composed of many sensors, independent among them and distributed over the system. This kind of approach is not further discussed in the present extended abstract. More detail will be reported in the final paper.
- *Intelligent agents*: a radical change in the concept of sensor network for complex system monitoring is represented by the possibility of giving autonomous and intelligent capabilities of interpretation of reality to the networks (or even to the single measurement devices or "agents"), by means of Artificial Intelligence (AI) techniques [4], [5].

It is important to note that an intelligent agent is one that is capable of flexible autonomous action in order to meet its design objectives, where flexibility means:

- *Reactivity*: intelligent agents are able to perceive their environment, and respond in a timely fashion to changes that occur in it in order to satisfy their design objectives;
- *Pro-activeness*: intelligent agents are able to exhibit goal-directed behavior by taking the initiative in order to satisfy their design objectives; single agents can dynamically adapt their measurement capabilities when system conditions vary, and thus configure themselves in an autonomous way.
- *Social ability*: intelligent agents are capable of interactive with other agents in order to satisfy both their design objectives, for rationalization and increment information recollection and for validation by comparison of both data and fault models.

In such a way, agents of a *diagnostic agency* able to support in the best way the system monitoring and the fault detection and location are the single measurement devices. From this standpoint, *agencies* provide the best tool for the design of the architecture of a distributed measuring system. The system is oriented to a single perception task, in accordance to the conception of the diagnostic agency as a unitary machine[6].

The aims of the intelligent technologies and of the resulting architectures are defined as follows[2]-[7].

- *Reactivity*: the architecture must take into account system evolutions in the inference cycle and must be able to adapt autonomously to the agents' behavior.
- *Efficiency*: during each well known phase of action, the supervisor agent, embedded in the architecture of the agency, must be able to efficiently schedule well defined action plans involving one or more agents.
- *Re-usability*: the supervisor agent must take into account existing processes and also existing communicating tasks, proper of the support provided by the architecture.
- *Reasoning explanation*: the agents act in order to understand the behavior of the system and to improve its knowledge.

Two fundamental elements are important in a diagnostic agency:

- the *communication capabilities*, that allow an effective and unitary cooperation process between agents; the communication network has to support and permit all the procedures devoted to give the physical links for the co-operation between the different agents, control the measurement process in a multi-agent system and collect measurement data obtained from a large number of agents. Very sophisticated devices are nowadays available for communication tasks for Internet Protocol (IP).
- the *artificial intelligence techniques* that support the reasoning activity on the acquired knowledge. This activity can be implemented, for example, in a simple and economical way by means of a single *fuzzy logic* chip .

III. An Experimental Example

Fig. 2~~Fig. 2~~ shows the experimental setup used for our application. The diagnostic of an electrical drive system is performed through a network of agents. The system, thanks to the inference capabilities, is able not only to monitor the drive operations but also to coordinate the control structure given requirements from the power distribution system. In particular we want to consider situations where control reconfiguration capabilities are critical for the global stability of the system. This is mostly useful for applications such as power systems on board of a ship where the power available is limited.

The network of Fig. 2~~Fig. 2~~ realizes the agency structure. Each component is an intelligent element and it is “represented” by an agent, performing diagnostic and/or controlling actions and exchanging data through the Internet.

The introduced agents are:

1. *Data Acquisition and Monitoring* (DAM);
2. *Drive Control* (DC);
3. *Fuzzy Unit* (FU);
4. *Simulation Agent* (SU) [7];
5. *System Manager* (SM).

The final paper will include a complete discussion concerning the architecture and algorithm of any single agent.

The communication is performed through TCP/IP protocol, even if an extension to industrial field-bus such as CAN-Bus is under consideration.

The proposed agency structure presents all the previous mentioned advantages of agent technology. In particular, the case study adopted here highlights the peculiarities of such a system. The agent performing sophisticated computations can be conveniently dislocated. There’s no need to move the software or the hardware around. This characteristic is very appealing, not only from the practical standpoint, but also if security issues or proprietary issues are involved, as is the case for military or private industry applications.

As stated before, the simulation agent running in parallel to the real system, can use real data as input of the simulation. Such an arrangement allows the detection of discrepancies between the model of the system and the system itself. This information can be used for model validation or, once the model is dependable, for the detection of abnormal operating conditions.

The distributed computation resulting from the proposed structure allows the distribution of the computation burden and the differentiation between the machines. For example, less powerful, rugged devices can be located in challenging environments, while powerful machines performing sophisticated computations can be located far away in a safe environment.

Three agents are involved in the first limited experimental setup:

- the DAM makes measured data available to the other agents through the Internet,
- the FU agents collects data from the DAM, computes a diagnostic index and makes it available through the Internet,
- the SM agent collects data from the DAM and from the FU agents and provides visualization of all

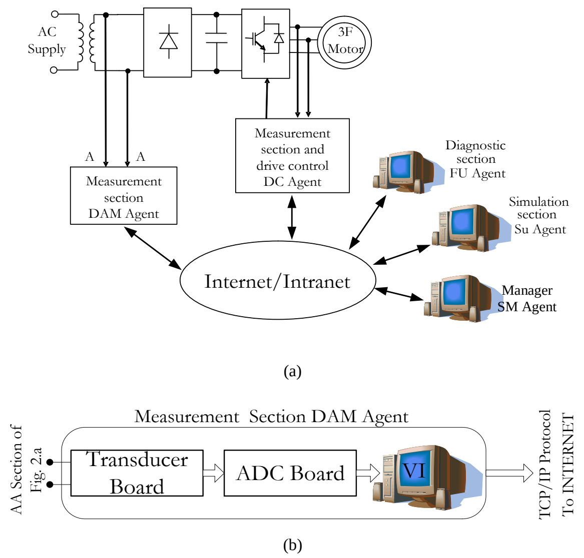

Fig. 2 – a) Proposed agency structure for the monitoring and control system; b) Measurement Section of DAM Agent (Section AA of Fig. 2.a): the monitored and controlled electrical drive, signals in and out the system are characterized with origin or destination.

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available data.

These agents are implemented in a *LabView* environment as VI. Each of them is hosted by a dedicated PC and has a local interface for IP address and port setting, data visualization in numerical and graphical form, connection error detection, plus some ancillary indicators.

In particular, the DAM agent includes also the measurement section. Voltage and current transducers have been specially realized in order to ensure both a high accuracy level over a wide band and a proper insulation level between channels and between the supply and measuring devices.

The structure of the realized and tested transduction and acquisition systems will be discussed in the final paper.

The Fu agent work by an algorithm previous developed by the authors and presented in[9]-[12]. The FU unit is based on a preprocessing of acquired data by wavelet transform[13]-[20]. For the present application a more sophisticated release of the aforementioned algorithm is developed and it will be reported in the final paper.

The SM agent collects data from the DAM and from the FU agents and provides visualization of measured data and fault index. In this work, where the general feasibility of the system is investigated, the SM agent plays the role of collecting and visualizing all data made available by the other agents. In the planned development of this system, that will appear in near future works, the SM agent will make the inference of information and will send control signals to the acquisition section.

As far as the performed experimental tests as concerned, two cases are introduced here : normal load operating condition at 50Hz, Fig. 2, and faulty, open rotor phase, no-load condition at 25Hz (Fig. 4~~Fig. 4~~).

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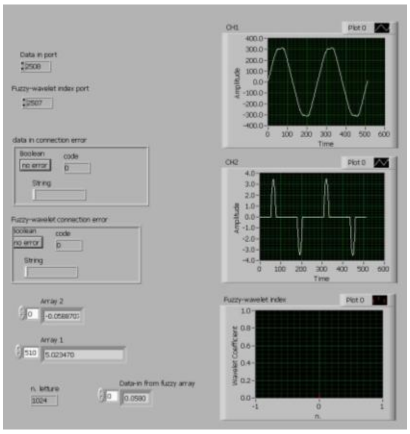

Fig. 3 - Non-fault condition, for the drive operating in load condition at 50Hz. Screenshot from the SM agent interface. The top graphs report voltage and current of the motor, the bottom graph report the fault index.

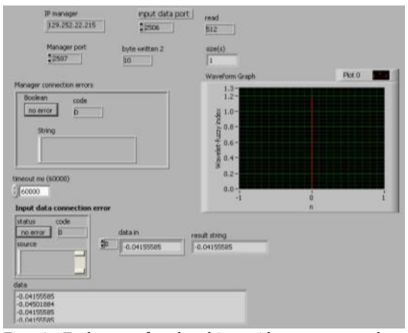

Fig. 4- Fault case for the drive with open rotor phase operating at 25Hz. Screenshot from the FU agent interface. The top graphs report voltage and current of the motor, the bottom graph report the fault index.

The value of the index appears as 0.1 (red line), indicating that the current operating condition of the drive is well away from fault. On the VI interface the graph reports the value of the fault index, in this case 1.2 (red line), indicating that the current operating condition is faulty. The index identifies the presence of an open rotor phase.

In the top-left of the interface the following controls are available to the user: the IP address and port of the machine hosting the SM, to which the computed index is sent and the local port where measured data are collected, as sent from the DAM.

IV. Conclusions

In the full paper, a new monitoring and diagnostic platform based on agent approach will be described. In particular, how the use of this technology allows the realization of a system where simulation and measurement are employed together for monitoring, fault diagnosis and control will be discussed. In effect, the agency approach, thanks to multiprocessor structure, allows advanced signal processing and use of complicate modeling tools. A discussion about the application for the reconfiguration in industrial applications will complete the presentation.

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