EXPERT SYSTEM FOR THE INTEGRATED MANAGEMENT OF A POWER UTILITY'S COMMUNICATION SYSTEM

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Abstract: In this paper we present a rule-based expert system applied to the fault diagnosis in the communication system of a power utility. The expert system is part of the system devoted to the management of a power utility's communication system, that we called NOMOS. Actually, NOMOS is managing the communication systems of Sevillana de Electricidad and Unión Eléctrica Fenosa (two major Spanish power utilities).

Keywords: Expert systems, Communications system fault diagnosis, Management, Communication equipment, SCADA system, Communication system operations and management, Protocols, Communication standards.

I. INTRODUCTION

Traditionally, power utilities over the world have owned private communication systems, utilized mainly for activities directly related with their productive process. During last years, different factors [1] have made necessary to employ Telecommunication Management Network Systems (TMN). In a short relation we considered the following factors:

- -Change from an analog environment to a digital one.
- -Increasing integration of the communication systems.
- -Rising complexity of the communication systems, from both point of view, the size and the management.
- -Increasing strategic value of the communications.
- -Priority of decreasing the operation and maintenance costs.

It is also necessary to consider the presence of a great variety of solutions offered by vendors supporting management for their own equipments only. Other problems are the high cost of equipments, the fragmentary management of the communication system and the need of qualified personnel working full-time in management. These problems make difficult to develop effective TMN systems.

To face these problems arose the concept of integrated TMN systems [2], supporting in an unique platform all the management solutions implemented by differents vendors. The use of expert system technology is an alternative in order to improve the quality of service and to mitigate some of the existing communication system management difficulties [3][4]. Is in this context that must be located the Project NOMOS, accomplished by two Spanish power utilities: Sevillana de Electricidad (CSE) and Union Eléctrica Fenosa (UEF), in collaboration with the Department of Electronic Technology of the University of Seville.

In this paper, we present the main characteristics of the NOMOS system. Also, we will describe the NOMOS expert system applied to the network fault diagnosis of one of the CSE communication systems, the microwave network. Finally we will expose some of the results obtained during the expert system operation.

II. THE NOMOS SYSTEM

NOMOS is an integrated expert system applied to the management of a power utility communication system [5]. The NOMOS system has to integrate the management information generated from these communication systems (Fig. 1). NOMOS uses an expert system which helps the operator locating and resolving network failures.

The main NOMOS system features are:

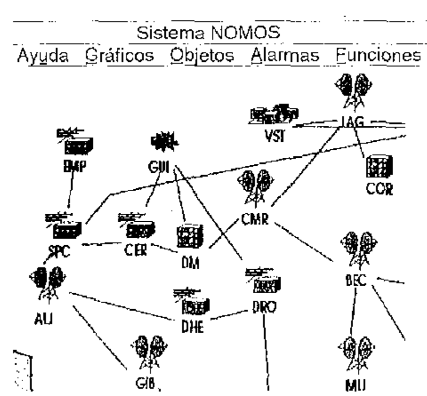

Fig. 1. Example of NOMOS system screen

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-Automated conversion between communication protocols.
-Description of network elements employing international standards (ISO and ITU-T), mainly GDMO (Guidelines for Definition of Managed Objects).
-An easy definition of the rules to achieve the expert fault diagnosis.

NOMOS is today implemented for the integration of six differents private communication systems, belonging to two different power utilities: The microwave network, the Cross-Connect Digital network of TITAN and the PABXs network ALCATEL 4000, all them belonging to CSE. The network of transmission equipment of both NOKIA and ALCATEL, and, the modem network of TELDAT, all belonging to UEF.

III. PROTOCOLS

A first key issue of the integrated management of a communication sytem is the integration of the different present and future protocols used by the different devices present in the network.

To get this target we have taken advantage of the use of ESTELLE [6], which is based on the Formal Description Techniques (FDT), and is standardized by ISO.

The integration of the protocols is obtained by the definition of every protocol using ESTELLE, which provides automatically the corresponding executable code.

Every particular protocol uses CMIS [7] services to set the communication with the NOMOS system. CMIS services have been standardized by ISO for its network open managing architecture. This way of implementation does not mean that the several managed subnetworks must be operated using the CMIP standardized by ISO as the managing protocol. Instead, it implies that every particular protocol is adapted to the CMIS services. In this way, on every single protocol, a service adapter layer is added offering to the TMN system a common API (Application Program Interface). In this common API it can be plugged so many new protocols as required, since all of them are seen in the same way by NOMOS, achieving a full integration.

IV. OBJECTS

Other key issue of the integrated management of a communications system is the integration of the different equipments (objects) [8] in a single TMN system. One of the main problems to get this integration is the very different classes of objects used in the communication systems. Every one has its own features and behaviors, and no common definition can be used for most of them. ISO has set several standards to define, in a compatible way, any object in the communication systems.

The standard GDMO [9] is used to define the managed objects in the NOMOS system. In these standards, a double hierarchical structure is defined: the type structure and the object structure. The object classes are hierarchically structured in such a way that the lower object classes inherit the features from upper object classes (object oriented technology). On the other side the objects are structured in a functional reliance tree. Both structures do not overlap usually.

Unfortunately, the GDMO do not have syntax oriented to its automatic reading. In the NOMOS system an automatic processing of the object types is required. For this reason, based on GDMO, a modified syntax to define the object types has been proposed, in such a way that it allows its automatic processing.

Fig. 2 shows an example of a dialog box where the System Object Classes of a network are defined in NOMOS. There is an Object Class called "MDM 34/8: Third Order MUX". If the "Modify" button is pressed, then the definition of an Object Class dialog box (Fig. 3) will be shown. That dialog box allows describing different characteristics of the object class, such as attributes, actions, and so on.

V. EXPERT FAULT MANAGEMENT

As an example of the expert features included into the NOMOS system we describe the case of the microwave communication system fault diagnosis.

A. The Microwave Communication System

The CSE microwave communication system is composed of digital transmission/reception equipment via radio in the UHF and SHF bands, digital multiplexors and auxiliary equipment, which employ the Pulse Code Modulation technique, and a number of auxiliary equipment, installed into 39 stations covering an area of 100.000 km^2.

The management of the microwave system was made, before

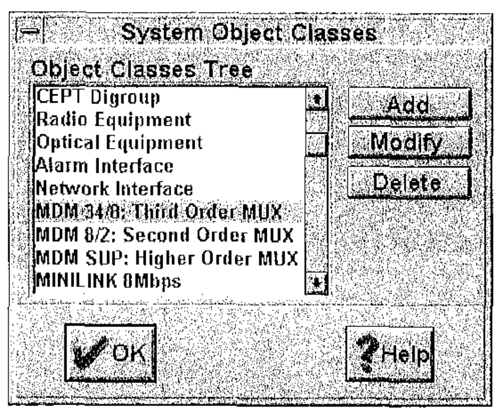

Fig. 2: System Object Classes Dialog Box

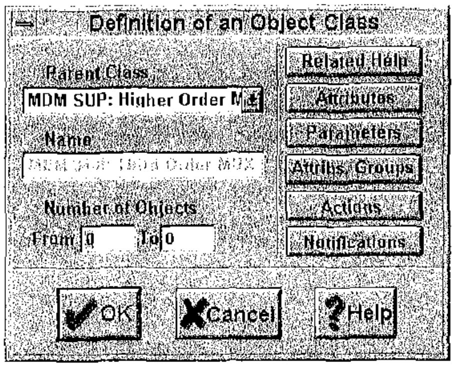

Fig. 3: Object Definition Dialog Box

NOMOS operation, using a supervision system called SSC (Communication Supervisory System). This system can monitor, in real time, the network's main parameters, making use of the information supplied by a SCADA system, formed by a Control Center (placed on the main CSE building), and RTUs installed into different stations. The use of a SCADA system is due to the management limitations of the microwave communication equipment.

The SSC allows the operator to acquire information (alarms or digital and analog parameters of measure) registered on each RTU. Starting from the supplied information, the operator is able to undertake actions through the SSC in order to solve the failures that could appear or to send a technician to repair the stations equipment.

Usually the operator does not supervise the SSC constantly. Under normal system conditions, the operator controls periodically the list of active alarms looking for the presence of possible failures, unless the operator recives a warning about relevant failures in the communications, which need to be resolved at once. In the SSC operation, two main problems arise:

1) The SSC shows to the operators a great amount of redundant information in the case of a relevant communication equipment failure. So operators usually are not able to resolve specific faulty situations.

2) The need of high-qualified operators, because the SSC does not provide explicit information about the failures that can be the origin of each alarm or group of alarms.

B. NOMOS expert fault diagnosis

In order to solve these problems, NOMOS expert system acts collecting the SSC information and applying rules that contains the operators' knowledge. These rules carry out the following tasks:

* Redundant alarms are filtered in order to avoid the saturation of the capacity of the operator. This filtering is not accomplished indiscriminately. Those alarms that show a service degradation or that can mask certain failures are not eliminated.

* Sytem failures are detected using the information collected by the alarms.

* A severity index is created to give priority to the alarms.

* Some recommendations are shown to the network operators in order to resolve failures or to improve the system operation.

To reach the established objectives we have used a Rapid Prototyping method [10]. We have used the Structured Interview as knowledge acquisition method [11], representing the declaratory knowledge in the form of facts (alarms collecting by the SSC) and the procedural knowledge in the form of If-Then rules (information supplied by the expert about alarms processing). To implement the expert system included into NOMOS, the shell ART-IM of Inference Corporation was selected. It has been employed a workstation SUN SparcStation 10 to program the expert system. In the case of the microwave network, the resultant expert system has about 200 rules.

The expert rules are specific for each management environment but they have some common characteristics:

* The rules are valid for each alarm or group of alarms regardless the place where alarms occur.

* The relationship among rules is based on temporal simultaneity criteria. Therefore, several alarms are not related if they take place within a temporal interval greater than a certain fixed value.

* The rules are structured in a modular way to make easy to add new expert knowledge.

In the case of the expert system for the microwave network, we can show some types of rules:

1) Supression rules. These rules were designed to filter those alarms that appear and disappear in a reiterative way in short time intervals. The mentioned filtering is essential if we wished the system operating in real time. It has the mission of increasing the process speed, reducing the set of fact on which are applied the rules of the expert system. The filter also permits to reduce the quantity of redundant information that is displayed to the operator. An example of supression rules is showed in the Tab. 1.

The filtering only affects to the expert system, because the NOMOS operator has available a Log of Alarms where all the

TABLE I
NOMOS SUPRESSION RULE EXAMPLE

```
(defrule SSRFIL1
(declare(salience 2))
?A<-(?date ?h1 ?rtu ?alarm ?station ALARM)
?B<-(?date ?h2 ?rtu ?alarm ?station ALARM_DISAPPEAR & :
(<(ABS(- ?h1 ?h2)) 1.00))
(TEST(NOT(equal ?alarm CMF-38_PREBER_1)))
(TEST(NOT(equal ?alarm CMF-38_PREBER_2)))
(TEST(NOT(equal ?alarm SPU_1_PREBER_1)))
(TEST(NOT(equal ?alarm SPU_1_PREBER_2)))
=>
(retract ?A)
(retract ?B))
```

indications from the SSC are collected. Bear in mind that expert system acts as a help system integrated in an integrated management environment. The operator is the one who decides about the convenience of following the expert system advices.

2) Rules dealing with alarms excluded from the filtering process. There is a set of rules that act on the alarms that specifically have been excluded from the filtering, due to the fact that the appearance and disappearance of such alarms gives information about possible failures in the microwave communication system. These rules usually evaluate the repeated appearance and disappearance of an alarm, throughout a given time interval.

3) Rules dealing with failures in the auxilliary equipment. The alarms associated to such failures usually appear related to alarms on the transmission/reception equipment because a failure in some of the physical devices (sources, wave-guides, etc) will cause problems in transmission or reception.

4) Rules to check the presence of an alarm during extended time intervals. In certain cases, it is necessary to evaluate the presence of a specific alarm during a given period of time in order to identify a failure. An example of these rules is SSR59 (Tab. 2). In this rule the voltage in a general distribution panel (TENSION CUADRO DIS GEN) must be lower than an previously specified limit during at least 30 minutes to determine the existence of a failure in the power supply unit.

C. NOMOS expert system results

In this subsection we summarise some results of the operation during the last year of a NOMOS expert system applied to microwave communication system fault diagnosis. We divide this analysis in different sections:

1) Filtering Effectiveness. For the last year, system filters on average, a total of 93.7% of the alarms coming from the SSC every day. In the worst case, this figure is greater than 89%. Each failure produces, on average, 13 significant alarms and 200 filtered alarms.

TABLE II
RULE TO CHECK AN ALARM DURING CERTAIN INTERVAL

```
(defrule SSR59
(declare(salience -1))
?A<-(?date ?h1 ?rtu TENSION_CUADRO_DIS_GEN
MEDIDA_PASA_A_ALARMA_POR_LIMITE_INFERIOR ?num)
?B<-(?date ?h2 ?rtu TENSION_CUADRO_DIS_GEN
MEDIDA_PASA_A_ALARMA_POR_LIMITE_INFERIOR ?num & :
(>(ABS(- ?h1 ?h2)) 30))
(NOT(?date ?h3 ?rtu TENSION_CUADRO_DIS_GEN
MEDIDA_EN_ALARMA_LIM.INF_PASA_A_NORMAL & : (<(ABS(-
?h1 ?h3)) 30)))
(NOT(?date ?h4 ?rtu TENSION_CUADRO_DIS_GEN
DESAPARECE_ALARMA & : (<(ABS(- ?h2 ?h4)) 30)))
=>
(retract ?A)
(retract ?B)
(printout t "Severity Index: 3" t)
(printout t "Failure: FAULT IN POWER SUPPLY UNIT, STATION " ?rtu
t)
(printout t "Recommendation:CHECK POWER SUPPLY UNIT." t))
```

2) Location Precision. The obtained results show that, in the 50% of the cases, the expert system offers only one location, (understood as communication equipment, or communication equipment element, and the station where it is installed), for a determined failure. In a 39.1% of the cases it indicates a double location, and only in 10.9% of the cases, it offers a triple location. Never it is proposed more than three possible locations for a failure. So we have, on average a total of 1.6 indications of location for each failure.

In order to evaluate the certainty regarding the location, we define a *Location precision (LP)* parameter (1):

$$LP = \frac{N^{\#} of\, Alarm - N^{\#} of\, Indications}{N^{\#} of\, Alarm - N^{\#} of\, Failures} \qquad (1)$$

In such way, if the Number of Failures is equal to the Number of Indications, the precision will be 100%, while if the Number of Alarms is equal to the Number of Indications offered by the expert system, the precision will be 0%.

During last year system operation, we obtained, on average, 13 alarms for each failure. As the average number of indications resulted of being 1.6, then the location precision is 95.2%.

3) Location Success. In addition to the number of locations with failure that is represented by a determined group of alarms, the exact place where the fault has been produced is always defined by one of the locations offered by the expert system. In consecuence the *location success* is 100%.

4) *Processing Time.* One of the targets to start the development stage of the expert system, was the possibility of real time operation. A year of system operation allows us to

confirm that the time for processing groups of up to 600 alarms is below to 5 seconds (Fig. 4). If we take into account that the biggest number observed during NOMOS current operation is 260 alarms per minute, then the requirements for real time operation are fulfilled.

VI. CONCLUSION

NOMOS offers a solution to the growing demand of an integrated management systems for power utilities communication systems. To sum up, within the developed system, it is relevant the expert system technology for fault diagnosis which has been employed. System operation during last year shows NOMOS performances in order to improve the management of CSE and UEF communication systems.

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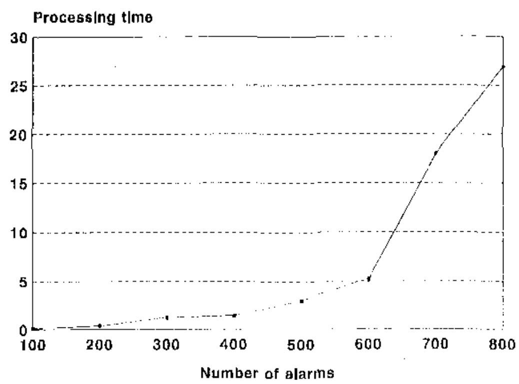

Fig. 4. Processing time

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VIII. BIOGRAPHIES

Carlos León received his Physical Electronics degree in 1991 and his Doctorate in Computer Science in 1995, both from the University of Seville (Spain). He has been a Professor of Electronic Engineering at the University of Seville since 1991. His areas of investigation being expert systems, neural networks and fuzzy logic focus on Communications System Management. Dr. León is a Member of the IEEE.

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Fernando Gonzalo Received his Ingeniero Superior de telecomunicacion degree in 1971 from the University of Madrid and the Ph. D. degree in 1983 from the University of Seville. Since 1971 he has been working in planning, design, installation and maintenance on both Communications and energy control applications (SCADA and EMS) for CSE. Presently is head of the Communication Unit and is the Spanish member of CIGRE SC35 Study Committe. Dr. Gonzalo is a Member of IEEE.