INTEGRATION OF NEW ICTS FOR EPS IN THE SCOPE OF UTILITIES SERVICES

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INTRODUCTION

New era of information and communication technologies (ICT) is changing traditional works and solving challenges for human activities. Progress and advances in different fields are being carried out in order to improve the quality of operations and perform automations.

EPS (Electric Power Systems) are not an exception for these advances. Thus, information and communication technologies introduce new ways to develop EPS tasks. However, this is only possible if the EPS special requirements on ICT are met (notably in terms of reliability and timing constraints).

The paper proposes a definition for ICT, and then current practices and standards of EPS are briefly cited. The paper analyses the use of the new ICT components in a fault localization and isolation task. The required ICT components are described and a demonstrator is presented. This demonstrator was used in the laboratory experiences in order to evaluate the timing necessary to implement the fault localization ICT under TCP/IP communication protocol.

The works included in the article are integrated in the CRISP[1] project and in the EURODOC program (PhD mobility) of the French Rhone-Alpes Region.

ICT DEFINITION

Information and Communication Technology can be defined as follows:

The technology involved acquiring, storing, processing and distributing information by electronics means (including radio, television, telephone, and computers).

Three processes are involved inside the ICT definition:

information acquisition, communication of the information between different entities and information computerization (it includes information analysis, storing and visualization).
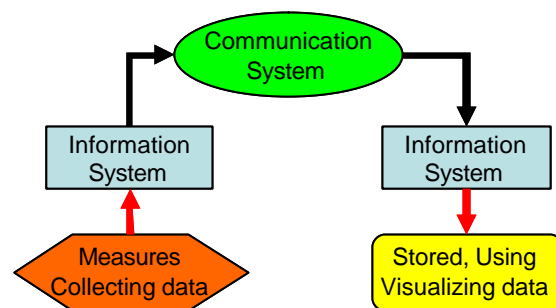

Figure. 1.-Information vs Communication vs Computerization

Communication is the fact of transmitting information between two or more points/agents of the system. The information and communication processes are related very closely. The information system is responsible of obtaining or measuring the parameters/variables that the systems need to control for a normal operation. So, at this step the information exists and can be transmitted from this point of measure to other points of the system for further utilization.

The communication system is responsible of this transmission and different communication media are used to transfer the information. The information transformed into different signals (analog or digital) is transmitted by the communication media to different centers where these signals are converted into other formats (data formats exploitable by the centers) and finally the communication process is finished when these data (information) are stored.

The computerization consists in the use of the information or data in order to analyze the system or to establish a help for taking conclusions and so elaborating decisions. The computerization can be carried out there where there is the information (with or without communication between two entities because a same entity can obtain the information and computerize it). This computerization system includes the coordination between different agents and actors and refers mainly to the different computer tools and operating systems that can be applied in a computer, PLC or Control unit.

Current practices in EPS. The use of communication media in SCADA (Supervisory Control and Data Acquisition) systems or EMS (Energy Management Systems) for EPS depends on different factors such as the nature of the media, possibility of interference or electromagnetic distortion, investment cost for installation or the requirement of special licenses.

Figure. 2.- Some Standards of Electric Power System Communication

The International Standard Associations like IEC or IEEE have been working to establish standards and recommended practice for the communication between different agents and for different tasks in EPS (market, substation automation, communications inside SCADA…) [1]. In figure 2, some standards of EPS communications are cited.

The main component of the EPS communication system is the SCADA system. Basically, it is the architecture to acquire, store and process the parameters needed to control the system. The SCADA of TSOs or utilities is normally composed of several types of communication systems such as [2]:

- Fixed networks including public switched telephone and data networks
- Wireless networks including cellular telephones and wireless ATM (Asynchronous Transfer Mode), radio systems, microwave (radio signals operating on the 150 MHz to 20 GHz frequency range)
- Power line carrier is the most commonly used communication media for protection function. However, this medium does not offer a reliable solution for wide area data transmission. Communication with remote sites can not be maintained during a disturbance.
- Computer networks including various dedicated LANs, WANs, and the Internet.
- The satellite network is another segment of the communications system that can provide important services which are difficult to carry out with normal communication techniques. These services include detailed earth imaging, remote monitoring of dispersed localizations and time synchronization using signal from GPS (Global Positioning System).

The delays or latencies and data rate of such communication media differ from a system to another. In table 1, a comparison is carried out in the case of wide area measurement networks [3]:

TABLE 1-Communication delays of some communication in wide area measurement networks

Communication link	Associated delay-one way (milliseconds)
Fiber-optic cables	100-150
Digital microwave links	100-150
Power line (PLC)	150-350
Telephone lines	200-300
Satellite link	500-700

The different data rate of the currently media used in the power system are compared in Table 2 [4], [5], [6]:

TABLE 2- Communication data rate for different communication media.

Communication link	Associated data rate
Fiber-optic cables	1 Gbits/s
Radio frequency	9.6 kbits/s
Power line (PLC)	2 Mbits/s

Future applications on ICT components to develop traditional and new functions in EPS can be carried out with Internet or with Virtual Private Networks (VPN). Internet presents the advantages in terms of availability through telephone lines; but, the security questions are not cleared and as EPS is a critical infrastructure for societies, the use of Internet for EPS should be limited for non-critical issues. Thus, the option of VPN seems to be more adequate.

This VPN could be physically established through IP networks. The utility IP network could be used to unify the different activities inside the SCADA (communication between SCADA components, measurements…). An example of this case is shown in figure 3.

Figure. 3.- IP network for an utility SCADA system.

One practical example of these VPN uses is used by REE (Red Eléctrica Española), Spanish Transmission System Operator, in order to establish a strategy to interrupt loads if needed in the control of the transmission system [7].
This article proposes the use of an TCP/IP network for a fault

localization speed-up with a new localization algorithm [8]. The applicability of such algorithm in real practice is closely related to the total timing processing (including the three ICT components: information acquisition, communication and computerization).

PROPOSED ICT DESCRIPTION: DEMOSTRATOR

As it was mentioned, the paper presents a practical implementation of a distributed intelligence. In this case, the distributed intelligence is a help tool to fault diagnostic (HTFD). This HTFD contains the fault localization algorithm and needs to evaluate different information (from EPS devices such as fault passage indicator (FPI), switch (SW) and fault recorder (FR)) to indicate to the operator the probable fault placement in the network. After these indications, the operator could isolate the faulted section in a reduced time delay and continue to supply so many customers as possible [9].
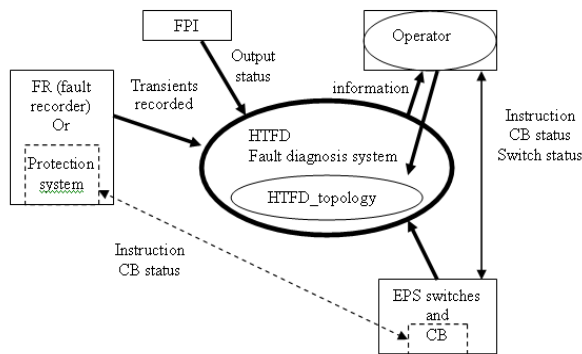
Figure. 4.- Context diagram for the Fault Diagnosis system

The tool proposed represents an additional function to the existing protection system. The main existing information systems are taken into account in the proposed tool, the required information exchanges as described in the figure 4. The Fault Diagnosis ICT System has four main sources of information:

- Fault Passage Indicator: The FPIs are distributed in general at key points of the distribution EPS, on the main feeder and derivations, being associated in general with the boundaries of elementary areas. The FPI sends state information to the Fault Diagnosis System through the FPI_ICT component.

- Fault Recorder or the protection system: The voltage and the current are measured in magnitude and in phase at a given point of the network in case of fault, the sending-end of a feeder in general. Then, FR sends electrical variable information to the Fault Diagnosis System. This information may involve a heavy file (transients), while the real information needed by the localization tool is small.

Indeed, a solution with a local analysis and data reduction is proposed. The FR_ICT_component is developed to treat the transient measurements and send only the essential data to the main tool.

- The EPS Switch: EPS Switches allow reconfiguration of the power network by opening or closing a flow point. They may or they may not be associated with an FPI, depending on the planning and exploitation choices of the operator. Each switch change in the network has to be taken into account properly in the topology description inside the Fault Diagnosis System: the reconfiguration has a great influence in the fault localization evaluation. The EPS Switch communicates its state to the Fault Diagnosis System and receives orders from the operator to modify its state. The EPS_ICT_component is developed as part of the system to carry out these functions.

- The Operator: The main role of the operator is to make decisions when different actions are needed and may endanger the EPS proper running. The HTFD tool communicates information and proposes decisions to the operator. Then, the operator sends orders to CB and EPS switches with existing control system.

The Fault Passage Indicator and the EPS Switch all are connected and distributed into the power grid. The Fault Recorder is linked to the protection system, collecting transients measured by the protection devices distributed at each sending-end feeder. Their localization is given by the operator in the network topology included in the HTFD tool.
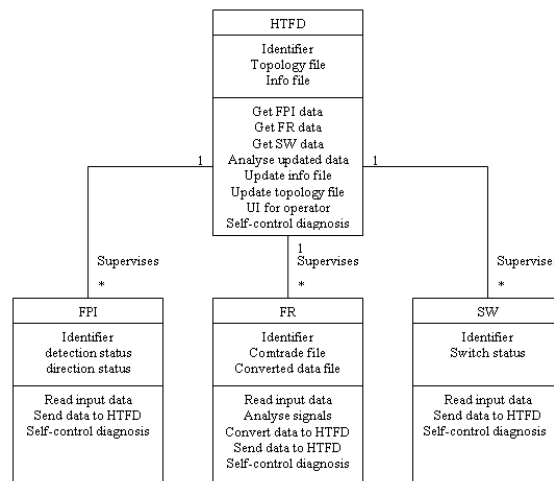

Figure 5.- Class diagram for the ICT main components in the Fault Diagnosis System

In figure 5, the network components (FPI, FR and SW) are represented by objects / classes within the Fault Diagnosis System. The network components will then have their ICT counterparts as distributed subsystems within the Fault Diagnosis System (figure 4). The network component objects will have their 'controlling' part, including intermediate calculations, deployed on the ICT component and an

information part on the HTFD subsystem.[*]

The operator role is not specified in the diagram, but is represented by the UI 'attribute' of the HTFD class. The UI (User Interface) takes care of representing the right information to the operator and receiving information from the operator. The operator sends the instructions to the EPS switches by an existing control system. The HTFD needs to know the state of the switches in order to update the network configuration. The network topology is important in this application and some data required are specific to the fault localization. But some other data are common with other possible applications to be developed in the future: local demand supply matching (local market may introduce temporary changes in the local power system configuration), power quality studies (voltage profile, harmonics).

The different ICT components were integrated in a demonstrator (see figure 6) in order to test their performances with TCP/IP network.
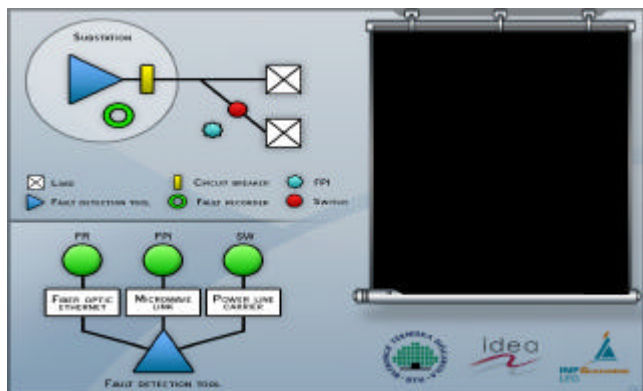
Figure 6.- Demonstrator interface for the test of the system under TCP/IP network

In a very simple case, the demonstrator consists of a number of PCs, some acting as nodes and other as communication links (communication links between the information points (FPI, FR and SW) and the main tool (HTFD)), all running the FreeBSD operating system. The different communication properties, such as throughput and latency, were simulated on the computers acting as links by using the dummynet [10] feature in FreeBSD in conjunction with bridging.

The visualization and control tool was implemented in the C programming language and executed on a node-type computer in the network. The user interface is shown in figure 6.

RESULTS

Two time frames were evaluated for the communication sequences: time for transmitting data files and time for communication streams. Actually the total communication time is larger than the time needed for file transmission: the transmitted files are usable before the last messages of acknowledgement between the PCs. If the same device has several messages to send in a short delay, the PCs remain

connected and the messages are sent successively when FP flag (end of last message) is passed.
A typical value is the stream rate in Kbit/s, given in our demonstrator a typical latency (TL) for a simple way. A simple file sent takes nearly 5*TL for the total communication sequences (from synchronization to disconnection), and the useful transmission of a short file takes nearly 3*TL.

TABLE 3 Measured latency for a simple way and various stream rate (specific bridge)

Data rate (Kbit/s)	TL (ms)
1000	8
565	11
140	10
40	18
12	50
10	57
9.6	66

In the demonstrator, if no bridge is used, the TL found is 0.2ms; Launching a call to establish the communication or printing a reference date in a file takes nearly 4ms each, this time being added as a first step of connection requirement.
The following figure gives the case of an order emitted from the tool (HTFD device) to a switch (SW device) with a direct link between them at 10Mbit/s
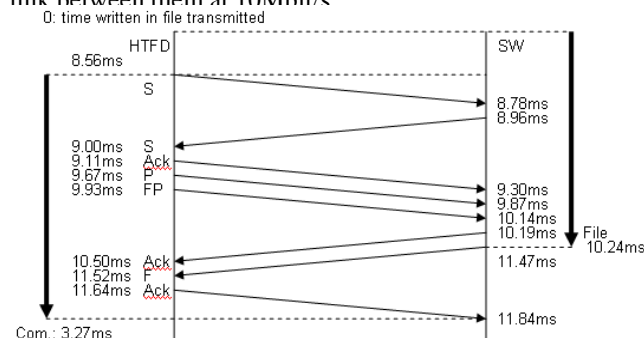

Figure 7.- Exchanges messages to send data from HTFD to the SW with 10 Mbit/s link

The following figure gives the same case with a bridge set to 9.6Kbit/s
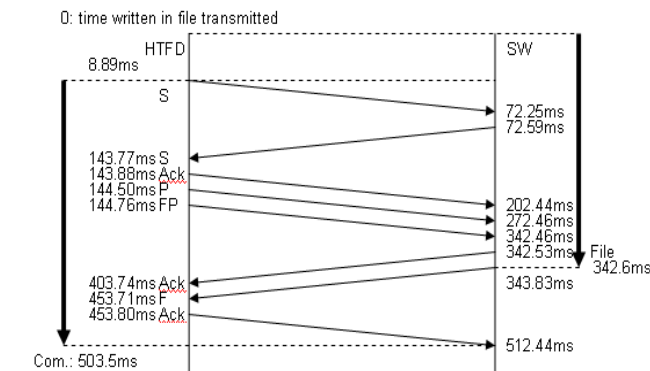

Figure.8.- Exchanges messages to send data from HTFD to the SW with 9.6 Kbit/s link

The purpose was to evaluate the total time required for the localization. As indicated the latency for real message transmission can be higher or lower depending on the stream rate capacity and CPU capacity. In the developed tests, the IP performances seem acceptable for its application in real practice.

CONCLUSION

The paper has presented a view of new ICT components to be introduced in the EPS operation. The applicability of new ICT depends both in the computerization timing of new algorithms and also in the communication and information system delay.

TCP/IP communication protocol is a wide-spread standard which could be valuable in order to implement the communication between different distributed intelligence in EPS. Here, the IP network was tested for a fault diagnostics use, but other uses could be thought for the future (e.g. Virtual power plants or islanding operation).

One critical parameter in EPS is the ICT systems security and quality of performance. At this point, IP networks depend on messages collision, loss of messages, congestion in the network and external intrusions. Special attention should be paid to these problems for correct operation and one can think about priorities associated to the information in a layered router strategy (different pre-defined IP routes for different information priority).

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