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Real-time communication between MATLAB and IEDs in electrical distribution systems using OPC Technology

L. Le- Thanh, *Member IEEE*, R. Caire, *Member IEEE*, D. Thermoz-Liaudy

Abstract— Electrical Distribution Systems (EDS) are facing ever-increasing complexity due to fast growing demand and large amount of distributed energy resources integration. The conventional operation modes need to adapt the significant changes. The behavior of EDS needs monitoring and executing in a high speed and a reliable manner. With advanced Information and Communication Technology (ICT) infrastructure using more and more Intelligent Electronic Devices (IEDs) and sophisticated new functionalities for energy management, “Smart Grid” is becoming the most forward-looking solution to address these facing challenges. Having initiated a conceptual model, architecture, and implementation plan for the system in previous European research projects [1],[2], an integrated ICT - platform based distributed control and local management solution to demonstrate the feasibility of the new concept is under design. In this framework of the project, the author realized the real-time communication between a fault passage indicator Flair200C (Schneider Electric) and a MATLAB based local agent by using MATLAB OPC toolbox. The real-time communication will be used to realize an advanced fault location functionality which is developing in order to improve the reliability and quality of electrical distribution system.

Index Terms- OPC technology, ICT systems and Local Agent , Distribution Network, IEDs, Maltab OPC Toolbox, Distributed Generators, Protection devices, DCOM.

I. INTRODUCTION

A new kind of networks named autonomous network is foreseen as a possible evolution of the current passive electrical distribution networks. It may be technically and economically the best way to initially facilitate DG in a deregulated market. The active networks have been specifically conjectured as facilitators for increased penetration of DG and are based on recognition that new ICT technology and strategies can be used to actively manage the network. These changes are expected at several levels and scales from the generation and commercialization businesses to the distribution grid operation. As such Electrical Distribution Systems will require new planning strategies and tools, new design methodologies, redefining operation and control of electrical networks for instance.

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As described in various articles in literature e.g. [3][4][5][6][7][8]there are many implications for the grid when making a transition from centralize to decentralize control with merely some central coordination. When compared to hierarchically operated electricity grids with power centrally generated at high voltage levels on a large scale delivering electricity to consumers on lower Voltage levels in the network, Smart Grids [9] offer a number of challenges for technological research. Indeed, the EU long-term vision on future grids, European Smartgrids Technology Platform waterfall grid models will be more and more replaced by grids with electricity produced via installations or clusters of installations 'bubbling' upwards. ICT is considered to be an essential enabler for this new development. Grids with components connected by modern communication technology, Smart Grids equipped with facilities for more intelligent coordination, are expected to play an ever more pronounced role in such a transition.

On the same ambitious research direction, the INTEGRAL project (Integrated ICT- platform based Distributed Control (IIDC) in electricity grids with large share of Distributed Energy Resources and Renewable Energy Sources), will push the investigations further. Within this project’s framework, a field demonstrator which deals with emergency operation conditions of electrical distribution systems is implementing. The purpose of this demonstrator is to realize an appropriate fault location and fast reconfiguration of EDS after the fault in order to intelligently restore the power supply for customers. The demonstrator relies on an ICT platform in which the IEDs i.e automation devices being able to communicate, programmable logic controller (PLC) and distributed control system can be integrated. In the distributed control platform, a local agent is built in which a fault location algorithm is developed. When a fault occurs in a real distribution network, the fault passage indicator can detect and then communicate with the agent. By using pre-fault and post-fault data, the agent is able to determine the distance of fault from the substation and the exact faulty line. Afterward, the order to eliminate the fault will be sent to supervision (SCADA software PCVue) that is responsible for service restoration [10][11].

This paper aims to present partial test of the demonstrator which is real-time communication between the IEDs implemented in electrical distribution systems and a local agent developed under MATLAB by using OPC technology. In fact, OPC specifications has become de facto standard for the automation industry due to the widely acknowledge

benefits it offers. The test results can be used afterward to realize data process and advanced control in the demonstrator.

II. MATLAB OPC TOOLBOX AND COMMUNICATION PRINCIPLE

OPC is acronym of Open Process Control, also known as OLE for Process Control, is a series of several specifications defined by the OPC Foundation [12] for supporting open connectivity in industrial automation. OPC foundation which is responsible for defining OPC Specification is an independent, non-profit, industry trade association. There are several specifications such as Data Access, (OPC DA), Alarms and Events (OPC AE), Historical Data Access (OPC HAD), Batch, Security, XML, Complex Data and OPC Data eXchange (OPC DX) etc. They use Microsoft DCOM technology to provide a communication link between OPC servers and OPC clients which support the software application procedure communication in different platform. In power systems, these software applications include protocol drivers, databases and programmable logic, as well as distributed and centralized monitoring, control and SCADA systems. The data sources to support these applications are often IEDs, such as meters, relays, programmable logic controllers (PLCs), Remote Terminal Units (RTUs), etc.

MATLAB, which is promoted by MathWorks Corporation, is often regarded as an efficient tool among both academic researchers and control engineers. Many control algorithms can be simulated and/or developed and programmed with MATLAB easily and efficiently. Furthermore, with OPC toolbox, we can realize the real-time data exchange and remote communication between MATLAB and process devices.

MATLAB - OPC toolbox is an OPC Data Access client application, capable of connecting to any OPC Data Access compliant server. OPC DA standard provides the common mechanism for the server and client to interact with each other [13].

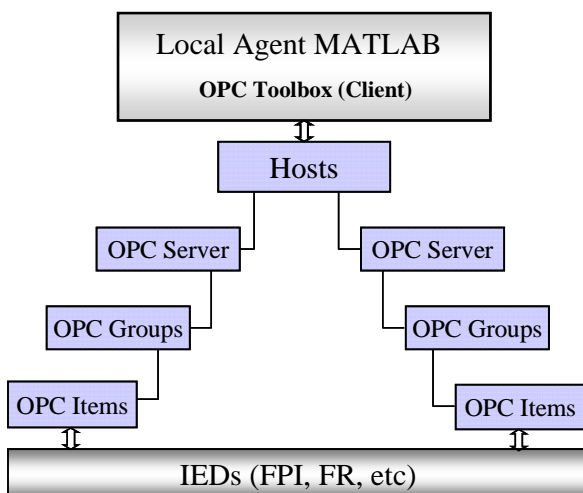


Figure 1. OPC Toolbox Object Hierarchy

Data access relationship between Local agent MATLAB

based on OPC Toolbox and IEDs is presented in Fig.1. Local agent that consists of several functionalities such as fault location algorithms programming with MATLAB, communicates to IEDs through OPC interfaces. It exchanges data with OPC server object. The OPC server object is defined by using the Host (computer on which the server is installed) and Server ID properties. In the OPC server object, OPC group objects can be created to manage OPC item objects. Each OPC server object can contains many OPC group objects. The direct data exchange with process data source is realized with OPC item objects. An OPC item object has a Value, a Quality, and a Timestamp, representing the information collected by the server from a process devices or a data point in SCADA system.

There are three methods for data exchange between OPC client and OPC server: synchronous, asynchronous and subscription. A synchronous operation means that MATLAB will wait for the server to return data from a previous request before continuing processing. With an asynchronous operation, OPC client sends a request to the server. Once the request has been accepted, MATLAB continues processing the next instruction without waiting to receive any values from the server. MATLAB handle the read/write event as soon as it is able to perform that task. As far as subscription way is concerned, the OPC server will notice the OPC client automatically when the data changes. We can set up the update-rate and dead-band to deal with each OPC group.

III. DESCRIPTION OF TEST SYSTEM

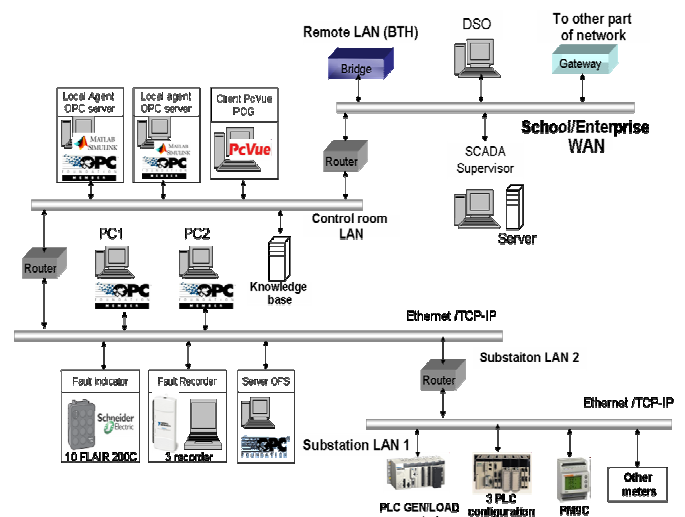


Figure 2. ICT architecture of demonstration

The ICT architecture for self-healing demonstrator is shown in Fig2. As the fault location algorithm has been developed within MATLAB the local agent were built within MATLAB and MATLAB OPC toolbox. OPC Data Access standard via Ethernet provides the common protocol for communication between OPC server associated with communicant RTU

(Modbus/TCP) or with SCADA center and OPC client (MATLAB OPC Toolbox) playing a role as local agent.

Communicating remote terminal unit (RTU) such as fault recorder emulator developed within LABVIEW, fault indicator (Flair 200C) is connected within several LAN. They communicate with some layer PC and local agent via OPC server/client. Finally, the advanced control and batch execution to accomplish self-healing functionalities could be carried out directly from local agent or indirectly from DSO (with the local agent advices) [14]

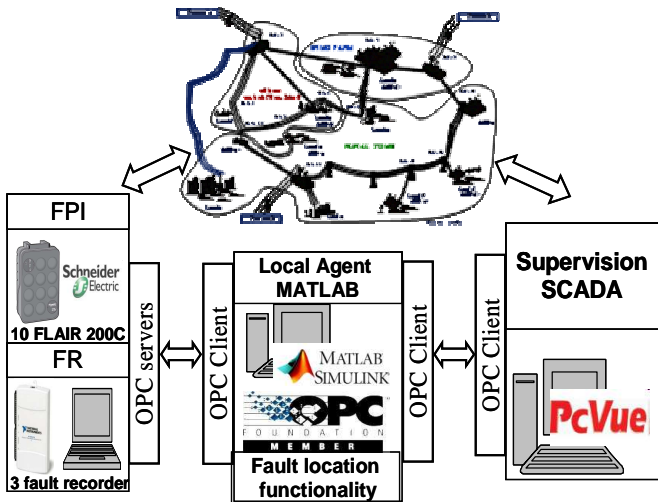


Figure 3. Composition of real-time OPC technology based communication system

The composition of OPC real-time communication system for the demonstrator is shown as Fig 3. The principal intelligent of this system is the MATLAB local agent in which a fault location algorithm and the OPC Client toolbox are implemented [15]. There are many current and voltage sensors implemented in the demonstrator. Dynamic behavior data of distribution network are exchanged continuously with the IEDs which are in that case the Flair 200C and the Fault recorder programming in Labview. Flair 200C is a fault passage indicator furnished by Schneider Electric Telemecanique. It is dedicated to the remote monitoring of MV/LV substation. When a passage of a fault is detected, the current and voltage data are recorded in real time and transmitted to Agent MATLAB through OPC server. A Schneider Electric OPC server product called OFS (OPC Factory Server) is used. The data exchange will be then performed between OFS and MATAALB OPC Client toolbox. Afterward, the exact faulty segment will be determined thank to fault location algorithm programming in MATLAB [9]. The selected solution actions such as what circuit breaks or switches will be opened or closed to restore as much as and as quick as possible load after the fault can be identified.. Since MATLAB do not have the direct link with the protection and automation devices in distribution network, Agent will have to send these solution actions to Supevisory software which is PcVue in that case.

The interfaces use the TCP/IP communication protocol to link with each others. The local agent can access to IEDs after configuring the OPC server object, the group objects and the items objects by using configuration tools. The OPC communication between Flair 200C and Agent through OPC Servers/Client are selected to present in detail in the following section.

IV. REALIZATION OF PARTIAL TEST WITH OPC COMMUNICATION

A. Hardware setting up and configuration

For the communication test purpose, a partial test of the demonstrator is performed. This means that a controllable load is connected to Flair. Then the voltage and current behaviors in real time will be observed in Agent due to OPC communication. Flair 200C is linked to a PC (Personal computer) operating under Windows XP and having at least one Web browser. The connection can be realized either by USB or Ethernet port. Ethernet TCP/IP connection has been chosen in this test. The default IP address can be changed. The Flair 200C product includes an embedded Web server which is initialized automatically as soon as connection is established. With the embedded server, the fault detector parameters are configured. The parameters to be configured for each variable could be variable name, type of access, assignment class, logical, remoter and internal addresses, etc. The address of variables needed to exchange is set up in order to provide input for the OPC server/Client communication. Two variables setting up for the test are phase current and voltage. The characteristic of these variables is shown in Tab.1

TABLE I. VARIABLE CHARACTERISTIC

Name	Address	Data type
Current	65	REAL
Voltage	81	REAL

B. Variables configuration on OPC server

The server OFS is an OPC data access server that may be used to read or write data on devices. It is able to interface between Schneider PLCs (in general but not exclusively) and one or more client applications. To do this, the server must have the necessary information for each device about the network to use, the address of the device on the network and the symbols table file if the variables are accessed using symbols. Moreover, the server supports a group of configuration parameters in order to best adapt the communication with the devices. OFS product provides also a configuration tool which allows the user to configure the OFS server to connect it to networks and devices. To use the server, one must first create an alias for each device that will be accessed. An alias is a shortcut being used when a network address for the device is necessary. In our test, an alias with the name being "Flair200C" is created. Since we use the TCP/IP protocol, the address of alias is IP address obtained in Flair 200C setting up step (MBT:192.168.102.36;10/NQ).

C. OPC Server/Client Configuration

There are two communication modes for the OPC Server/Client: local access and remote access by DCOM. Local access mode means that the MATLAB client toolbox and the OFS server are on the same PC (local host) whereas they are on separate PC, connected via the Microsoft TCP-IP network. Distributed COM (DCOM) must be configured correctly before launching remote operation. The remote execution mode requires an additional adjustment using the DCOMCnfg.exe tool provided with the DCOM package in Microsoft Windows XP. DCOM environment must be configured appropriately both in the server and the client PC.

For the OFS server PC, the properties of “Schneider-Aut OPC Factory Server” must be configured. One needs to modify the “Launch and Activation Permissions” and “Access Permissions” so that the “anonymous” or “everyone” users can be authorized for remote execution.

In the MATLAB client PC, the appropriate MATLAB application in “DCOM Configuration” directory must be modified in the same manner to allow the server to send back notification to the client PC.

D. Communication program

After finishing the preparation steps above, the communication can be performed. The connection of OPC toolbox can be done by either programming or GUI (Graphic User Interface). First, an OPC data access client object is created with the hostname of the server computer and the server ID. Two communication modes are test here in which the hostname in case of local access and remote access is “localhost” and “Server_OPC” with IP address “127.0.0.1” and “192.168.102.128” respectively.

Then, one creates the OPC data access group Object named “Predis_Integral”. In this group object, two item objects corresponding current and voltage are added. The items ID should be declared carefully.

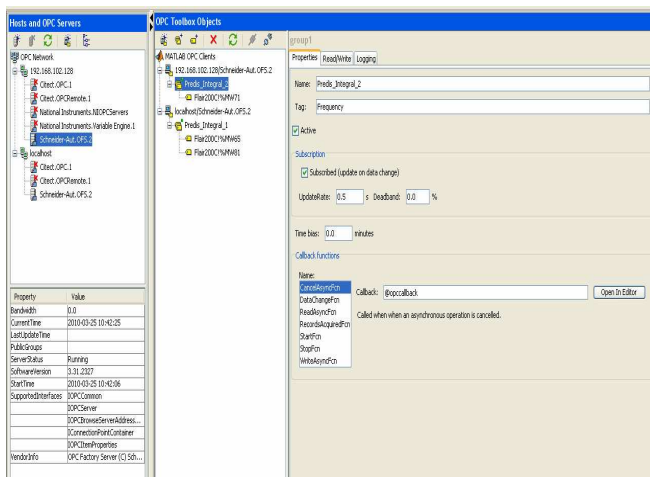


Figure 4. MATLAB OPC Client Toolbox

The connection using OPC Toolbox GUI is presented in the Fig 4. Since the client toolbox can connect to many servers simultaneously, an OPC Client object for local access and

another for remote access are created. The subscription is selected for client to get information on server item values. This mechanism allows the OFS server to notify a client when a server item’s value or quality has updated. The update rate is set to 0.2 s and dead-band is 0% in order to get every data changing.

The command line for this mechanism which will be able to integrate into fault location algorithm is also programmed. An example program to get and display real-time communication between MATLAB and Flair200C is shown as following.

```
%%%
clear
clc
da = opcda('localhost', 'Schneider-Aut.OFS.2');% Call local
host and OFS server
(da = opcda('localhost', 'Schneider-Aut.OFS.2');% Call a
distant host and OFS server)
connect(da);
grp = addgroup(da,'Predis_Integral');
itm1= additem(grp,'Flair200C!%MW65');
itm2= additem(grp,'Flair200C!%MW81');
set(grp,'UpdateRate',0.2);
set(grp,'RecordsToAcquire',60);
set(grp,'RecordsAcquiredFcnCount',5);
set(grp,'RecordsAcquiredFcn',@display_opcdata);
start(grp)
wait(grp)
...
disconnect(da)
delete(da)
clear da grp itm1 itm2
%%%
```

```
function display_opcdata(obj,event)
numRecords = min(obj.RecordsAvailable,60);
lastRecords = peekdata(obj,numRecords);
[i,v,q,t,et]= opcstruct2array(lastRecords);
plot(t,v/100);
isBad = strcmp('Goo',q,3);
isRep = strcmp('Repeat',q,6);
hold on
for k=1:length(i)
    h = plot(t(isBad(:,k),k),v(isBad(:,k),k)/100,'o');
    set(h,'MarkerEdgeColor','k','MarkerFaceColor','r')
    h = plot(t(isRep(:,k),k),v(isRep(:,k),k)/100,'*');
    set(h,'MarkerEdgeColor',[0.75,0.75,0]);
end
axis tight;
set(gca,'YLim',[0,100]);
datetick('x','keplimits');
eventTime = event.Data.LocalEventTime;
title(sprintf('Event occurred at %s', datestr(eventTime,13)));
drawnow;
hold off;
%%%
```

E. Communication results

In fault condition in distribution network, the current increases and the voltage decreases. The purpose of test is to monitor the real-time behaviors of current and voltage in order to assure the good communication when the whole demonstrator lunch. Therefore, the current behavior is realized by modifying the value of load whereas the behavior of voltage is done with auto-transformer.

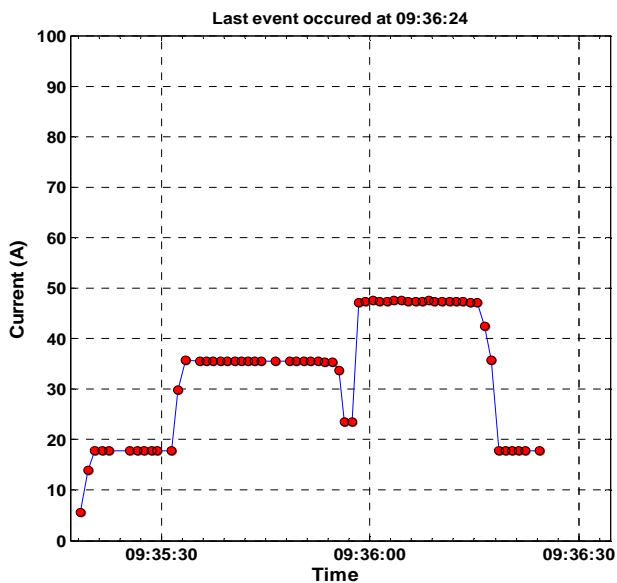


Figure 5. Real-time behaviors of phase current

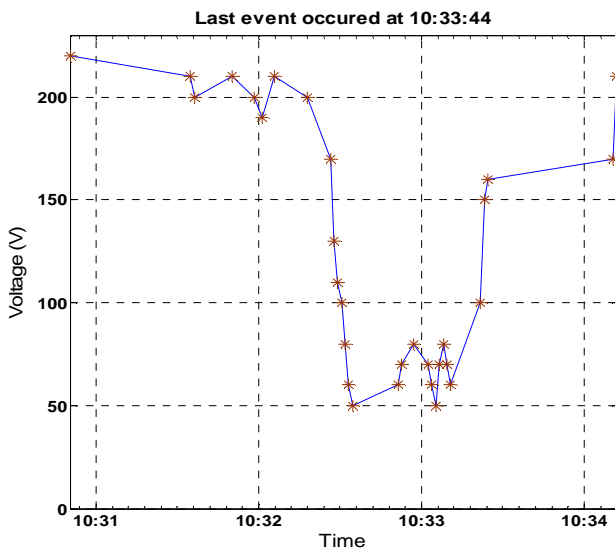


Figure 6. Real-time behaviors of voltage

The Fig 5 and Fig 6 show the real-time behavior of current and voltage when the MATLAB program is running. Once the data values change, the client toolbox obtains the changed value and logs them for the posteriors treatment.

V. CONCLUSIONS

The application of OPC technology to communicate

between the MATLAB and IEDs ensures the efficiency and high speed of data transmission. The control process and results verify that the data exchange is reliable. In fact, this communication which does not depend on the hardware driven program provided by the manufactures enables user to have the flexibility in devices selection in a whole data management platform. Moreover, MATLAB offers a very strong and open resource for the advanced control algorithms programming. As a result, this research presents vitality in the area of real-time monitoring and fault location in electrical distribution network.

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VII. BIOGRAPHIES

Luong LE-THANH (M'08) received his Diplôme d'Etudes Approfondies (DEA) and Doctorat de l'INPG degrees from the Institut National Polytechnique de Grenoble (INPG) in 2004 and 2008, respectively. He is now working as a fellow researcher in the GIE-IDEA (FRANCE). His research interests are the power systems equivalent, power system stability, fault detection and location, and distributed generators' impacts in electrical distribution system.

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Damien THERMOZ-LIAUDY received his diploma in electrical engineering from UTBM (Université de Technologie de Belfort-Montbéliard), France, in 2009. He is presently engineer at the G2Elab (Grenoble Electrical Engineering laboratory), and he working on fault recorder and fault passage indicator for INTEGRAL project, especially communication aspects between elements (OPC Technologies).