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To cite this article: J. R. Nuñez-Alvarez *et al* 2020 *IOP Conf. Ser.: Mater. Sci. Eng.* **844** 012016

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# Communications in Flexible Supervisor for Laboratory Research in Renewable Energy

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**Abstract.** In laboratories new systems are created where researchers hope to obtain improved functions at a reasonable cost. In them, specialists need efficient tools that offer better performance and flexible features. This paper designs and implements a SCADA system for GERA laboratory (Scientific Group for Applied Renewable Energy at the University of Oriente) adjusted to the inherent characteristics of flexibility and functionality required in research centers. All these features are supported in an efficient communication system with the implementation of various protocols and novel solutions for this type of systems for monitoring and control. It verifies and validates the system for formal methods.

## 1. Introduction

In today's highly competitive business environment, the industry is challenged by the demand for increased productivity, quality, safety and environmental protection, where the role of research centers in the development of new technologies is crucial in achieving these goals. The specialists who develop applications in these centers need efficient tools that offer better performance and flexible features [1]. On this issue is currently working on how to reuse existing software applications SCADA (Supervisory Control and Data Acquisition) [2, 3, 4]. This issue involves a major challenge for designers, since from the stages where software engineering is conceived it is necessary not only the use of diagrams and classical methodologies, but the use of formal mathematical tools is also imposed as Petri Nets (PN), which allow to model and simulate the behavior of systems prior to the relevant implementation [5, 6]. Although the use of formal methods a priori not guarantee a hundred percent correct result, you can however, greatly increase the understanding of the system revealing inconsistencies, ambiguities and inaccuracies that might otherwise go unnoticed [7, 8].

In the research [9], a test bench of a control and monitoring system for the discharge of drinking water in a well is designed and implemented. In the work, the graphical user interfaces (GUI) are designed to interact with the operator, as well as the human-machine interface (Human Machine Interface (HMI)) which was implemented in proprietary software and contemplates the rules for control and monitoring of system conditions. The HMI interface is connected to a programmable logic controller (PLC) where the process protection rules are implemented in ladder diagram (Ladder Diagram, LD).



The work of [10] develops a configurable SCADA system from a library of stationary, modular, parameterizable and reusable models. This tool is used in the energy diagnosis of sugar plants, taking process data and using a stationary process model, and using data reconciliation algorithms based on optimization techniques. It is also able to provide information about unmeasured variables, detect deviations from the measured variables and calculate indices related to energy efficiency. Since the application is going to be customized for different factories, tools have been developed that allow rapid reconfiguration and code reuse.

This paper designs and implements a SCADA system for GERA laboratory (Scientific Group for Applied Renewable Energy at the University of Oriente) adjusted to the inherent characteristics of flexibility and functionality required in research centers. All these features are supported in an efficient communication system with the implementation of various protocols and innovative solutions for such monitoring and control systems [11, 12].

In the next section II, the structure of SCADA is described, where the communication system (three fieldbuses) has the primary function. In III formal design details are explained in GHENeSys hierarchical extended PN [13] each of the three main software components. In IV implementation in Labwindows is explained [14] that allows its professional use in the GERA laboratory.

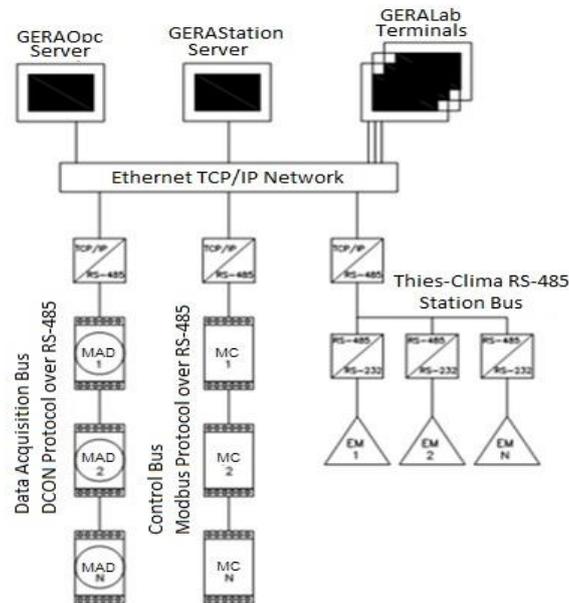
## 2. Methodology

### 2.1. General System Architecture

The GERA at University of Oriente has as main objective the development, study, evaluation and analysis of the different practical applications of renewable energy [15]. The beginning of the evaluating process of a system in the laboratory of the research center includes installation or assembly of technology in the polygon or center areas. The researcher together with center specialists in instrumentation and control will be responsible for installing sensors and actuators to be attached to experiment. Autonomously the server should detect the newly installed device and manager generate a software key where permissions and access to the physical I/O system is assigned; This will be delivered to the person responsible to develop the experiment. Finally, the researcher has a client software that will link with the server by a TCP-IP data network and have access to take measurements and/or implement control actions [16].

The flexible SCADA required differs from the standards that the concept of users is replaced by software keys that assign permissions to different copies of the client software running on the network. Permissions can be changed by the system administrator at runtime. Communication drivers allow link memory addresses located on remote equipment's with OPC servers that make up the application [17, 18]. The management of these are done automatically and completely transparent to users. The Synoptics of each experiment are created by different users at runtime, not by developers, where the desired graphical indicators are shown on the screen to analyze the information they really need in each experiment. By storing information associated with each process or experiment that is supervised or controlled in standardized relational databases facilitates systems of report generation to obtain the required information without investing great efforts in formatting and data preparation.

According with these requirements, the designed flexible SCADA system consists of distributed hardware support of three data buses and decentralized software support of three independent applications that interact through an Ethernet Data Network. The Figure 1 shows the three data buses of hardware block.



**Figure 1.** Schematic mono-linear SCADA Communications of GERA Laboratory.

### 2.2. System Components

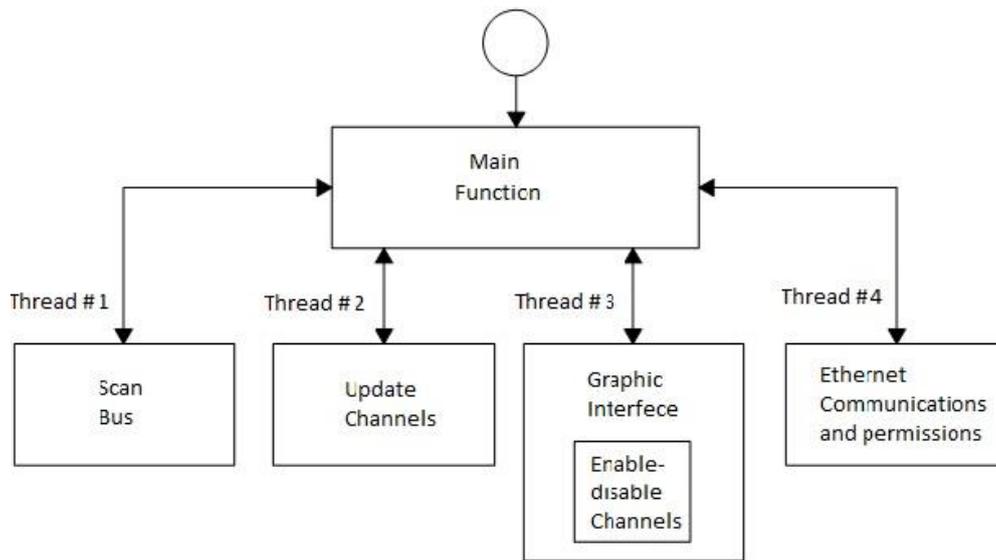
The data acquisition Bus is based on the DCON protocol on the physical standard RS-485 [19]. Where multiple data acquisition boards that support this protocol are linked. The control Bus is supported on physical standard RS-485 where proprietary cards are installed with Modbus communication [20] and digital and/or analog outputs with standard current and voltage levels for controlling multiple actuators. The Bus of meteorological stations is based on the communication protocol of Thies-clima weather stations [19] on the physical standard RS-485. Through this bus can be linked to the system until ten of this type weathers stations.

On top of Figure 1 shows the three software applications that make up the system, two of which will ensure access to communication buses (GERAOpc and GERASTation) and the third application (GERALab) is the central SCADA software and communicates with the above two applications using the OPC standard on the TCP-IP protocol [2, 21]. The distribution of the communications system in three buses ensure efficient control of them from the first two applications and a safety information flow throughout the SCADA. The complexity of the interaction of all system components requires formal design method explained in the next section.

### 2.3. System Formalization using GHENeSys Hierarchical Extended Petri Nets

Following the design methodology on GHENeSys given by [13], the first thing to consider in first step is the study of process to control and its functional requirements, which corresponds to the informal specifications phase. Equally steps 2 to 5 of the methodology are closely related, and are associated with the phase of formalization of the applications, thereby ensuring obtaining the right model. Following these principles, each application that forms the system was decomposed into modular structures shown as the example in Figure 2, that permit a PN modeling. Figure 3 is the GHENeSys extended hierarchical Petri net model developed on Visual Object Net 2.7 [22, 23, 24] by means of Figure 2.

Attention to data acquisition and control bus (GERAOpc) are separated from the attention to station bus (GERASTation) because the sampling time and peculiarities of the data are different in each. Also, the functions of the data and control bus are different. Differentiated attention of the three buses allows the simplicity and efficiency of communication.

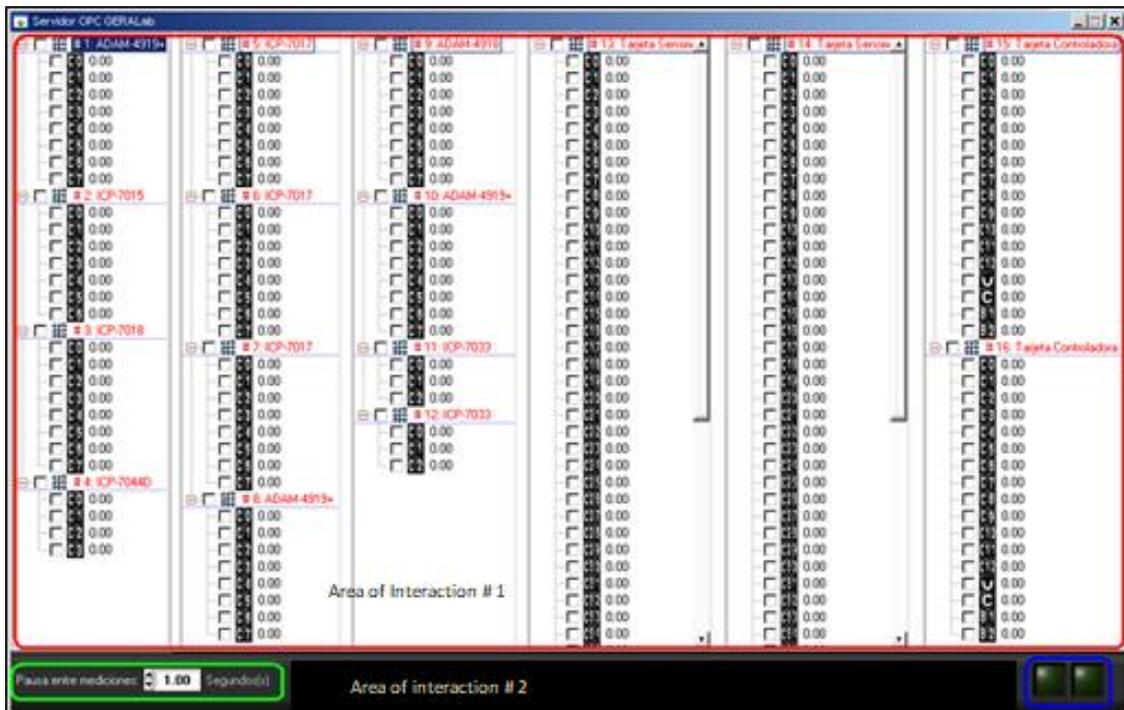


**Figure 2.** Hierarchical modular structure GERAOpC software.

The GERAOpC software (Figure 2) consists of two hierarchical levels and four concurrent threads to execute the program. At the top level is the functional unit, responsible for creating the four threads and manage access to global variables that will be used by the other functional blocks. At the second level the functions entrusted to scan and update channels in the Data Bus, to make communication in Ethernet network and to attend the graphical interface (GUI).

In the model on GHENeSys of this software (Figure 3) the P0 and P1 places correspond to the resource "Initial State" and "Main Function" respectively. By the T2 transition the provided four threads of concurrent execution are created. P2 and P6 places represent the "GUI" resource, P3 and P7 represent the "Communication Ethernet", P4 and P8 represent the "Scanning BUS" resource, P5 and P9 represent the "Update I/O" resource and P10 represents the "Final State" resource or close the application.





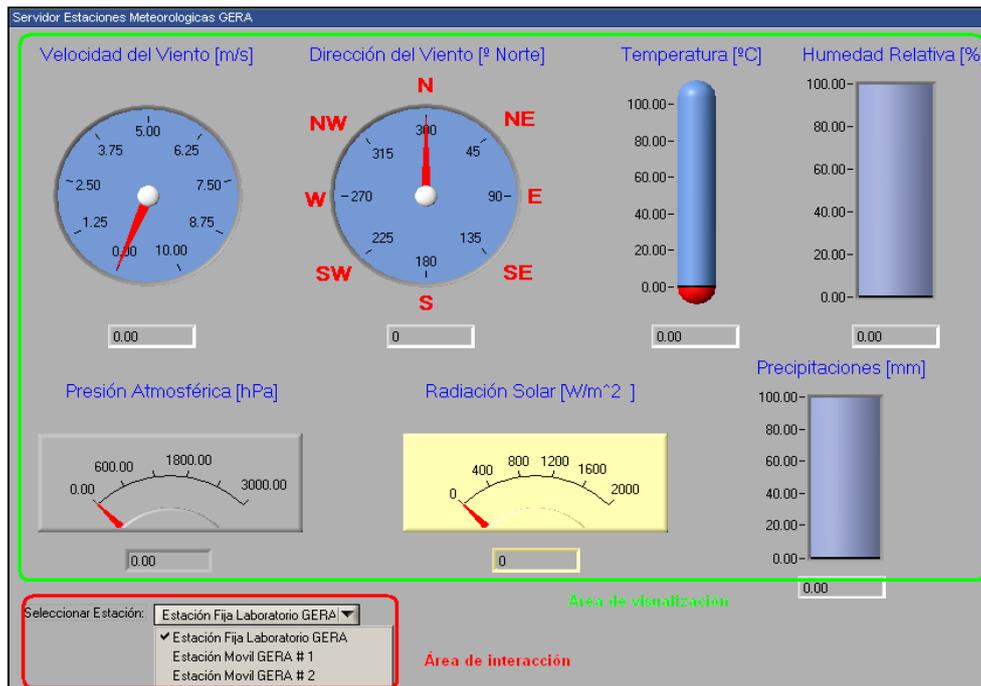
**Figure 4.** Window of GERAOpC software implementation.

Likewise, was created GERASTation (Figure 5) with files: Station.uir, Station.h and Station.c. The GERALab (Figure 6) includes GERALab.uir file where all the information relating to the design of the GUI is stored, asynctmr.h which is the library that includes the functions of asynchronous timers, inifile.h that enables automated reading of .ini file and movectrl.h that makes creating and editing of components at runtime.

The interface designed to GERAOpC includes a minimalist look with the aim of facilitating the characteristics of flexibility, but powerful auto-detection algorithms channels and visualization of data obtained using fieldbuses and control are included, providing the user only two areas of interaction and an information area (Figure 4). In the area of interaction # 1 (Figure 4, marked in red) all acquisition and control modules detected in the data buses are presented, and attached to each channel the user has a "Check Box" and a label displayed. By the first you can enable or disable the use of the channel in question and by the second can be displayed in real time the instantaneous values of each channel.

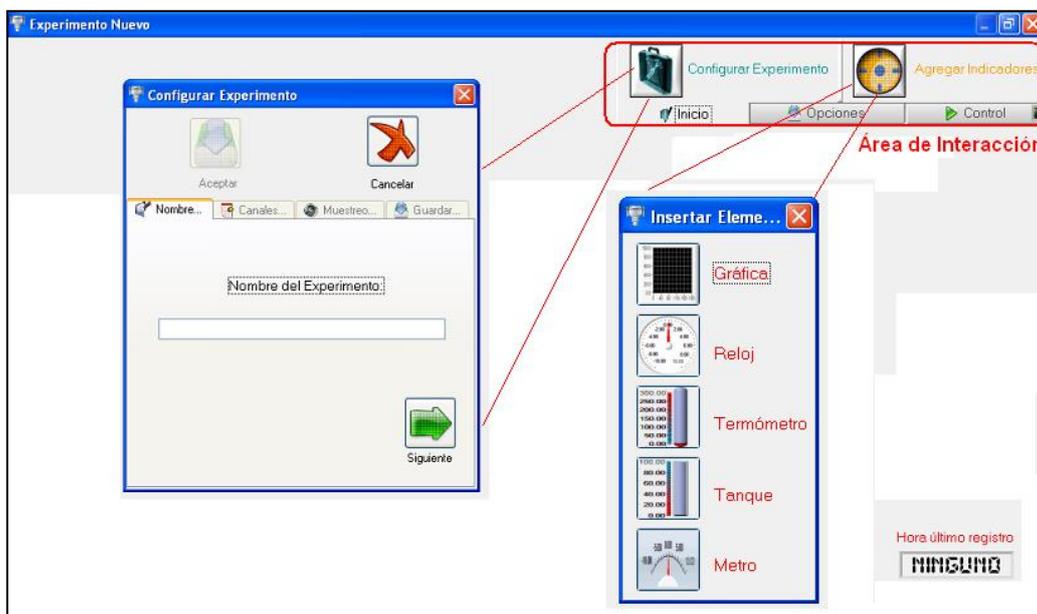
Through the interaction area # 2 (Figure 4, marked in green) can introduce a delay between each measurement cycle or channels scans, this in order not to overload excess resources available on the server that supports this software. And the display area (marked in blue) will be composed of two simple lighting indicators, one that flashes red to indicate when it is accessing data buses and other flash blue indicator to indicate when running storage routines in the database of real-time.

In the area of interaction (marked in red) GERASTation (Figure 5) all the weather stations linked to the network are displayed. By viewing area (marked in green) the program administrator can quickly check whether the values are logical.



**Figure 5.** Window of GERASTation software implementation.

The designed interface to create synoptic (Figure 6) has a simple look with the objective of facilitating the characteristics of flexibility, but complex routines communication with OPC servers, data visualization, data storage and calculations of controllers are included, providing the user only initial interaction area at the top right of the application window (Figure 6). Through these options the user can start a wizard which will tell the system all the details of the experiment in question. Then the user can configure mimic the experiment, with the possibility of inserting five different types of components on-screen display. For each of the inserted components the user will edit options available to obtain a fast and safety interface for the required experiments (Figure 7).



**Figure 6.** Configuration of a new experiment in GERALab software.

This Flexible SCADA system is being used in the GERA as the central tool for the development of experiments and data collection and national and international research projects, throwing good results.

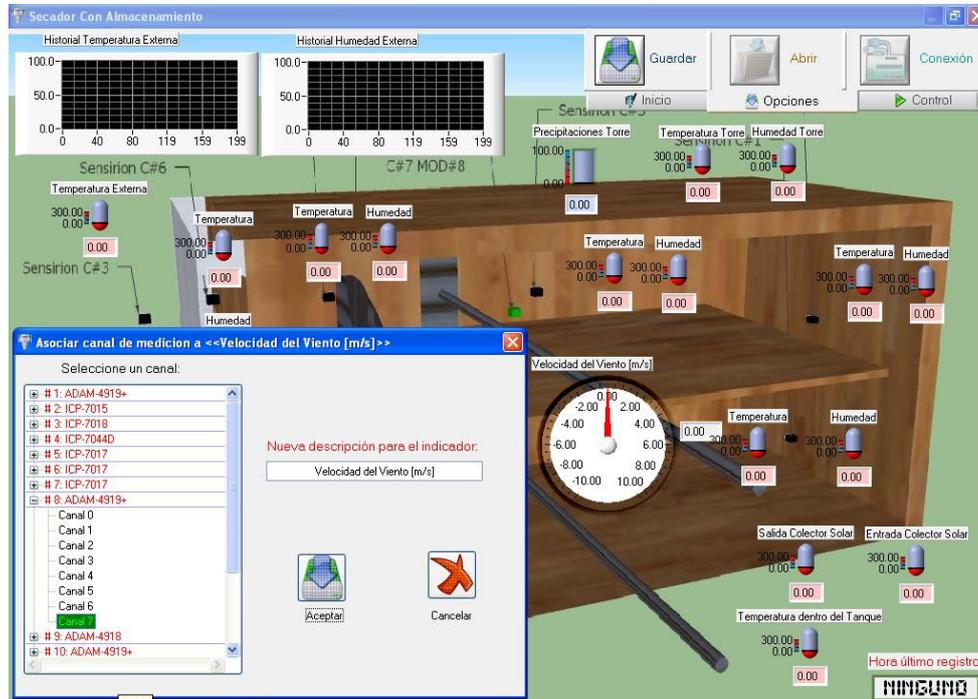


Figure 7. Example Window of GERALab software implementation.

## Conclusions

The software implementation was developed under the LabWindows / CVI 10.0 environment. By means of the model in GHENeSys it was possible to evaluate the sequence of operation and the conditionals that generated changes of state.

The designed interface includes a simple aspect in order to facilitate the flexibility features, but it includes complex communication routines with the OPC servers, visualization of the data obtained, data storage and controller calculations, facilitating the user an area of interaction. The functional behavior of each implemented module was proven by demonstrating compliance with the requirements demanded by its physical interpretation.

The main contribution of the GERALab software is that it executes in a synchronized way the control and data collection functions with which a database is obtained that allows researchers to analyze the behavior of the studied object based on the same unit of time to represent the measured parameters and the control actions executed.

This Flexible SCADA system is being used in the GERA as the central tool for the development of experiments and data collection and national and international research projects, throwing good results.

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