DESIGNING SOFTWARE-BASED TOOLS FOR MONITORING, CONTROL AND TRAINING MICROGRID IMPLEMENTATIONS FOR ELECTRIC POWER NETWORKS

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Abstract: The current paper is the result of research program dedicated to designing new tools and instruments in designing and optimizing electric power networks management, and training for creating interaction between energy utilities providers and user behavior. We implemented a SCADA system for energy management and control, then we integrated a micro grid system with user interaction specific tools. On the current implementation we measured the training skills delivery results according with Scottish Credit and Qualifications Framework for creating the frame of acceptance and interaction for an efficient energy management.

Key words: Smart grid development, micro-grid, Quality of energy, training, user-interaction, smart living.

1. ELECTRICAL ENERGY MANAGEMENT IS PART OF OUR LIFE-HOW TO APPROACH IT?

The electrical energy is mostly the central part of our life, not only because it is supporting the other domestic utilities, but is strongly influencing the social life of everyone. So, in order to make steps forward into the progress tendencies in terms of modernization, it has to be accepted and favorized during implementation and updates of its added management techniques and methods. The positive point is that fact that

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“basic layer “in most of implementations starts from known, and stable implementations. For instance, the communication setup is implemented using RS485 with MODBUS protocol, then for communicating with software (through RS485), the devices are interconnected with serial cable with male-female connectors. The software is usually designed to allow and to support the students and professors in most of the training activities: control, and measurement interfaces, installation support, devices, and instruments individual control, debugging tools (devices supervision, Modbus control, reset). As an object-oriented representation technique [1], the global representation of electric power systems (for control and training) is shown in next figure.

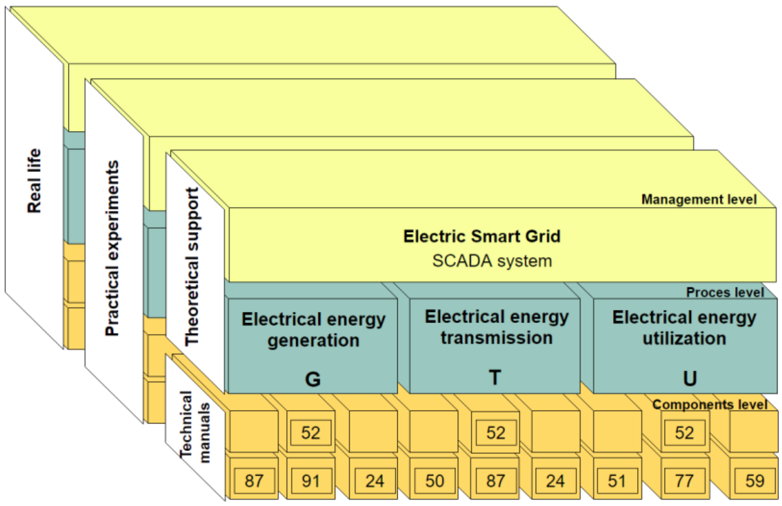


Fig.1. The multi-layer and object- oriented representation of the Smart Grid system that coordinates the involved electrical energy production processes

1.1 Service- oriented approach for training context- process levels trainers in system architecture design

Under the same branch name- GTU- there is a significant number of trainers dedicated to the energy production (Generation- G), transportation/ distribution (Transportation-T), and utilization (Utilization-U). The designed objectives of these trainer are intended to cover the most of the training topics from an electric power distribution network. In the next figure, there is represented a screen hoot that is taken from an electrical distribution software simulator, figuring generators, busbars, transmission lines with different load ratio, and demands from consumers, accompanied by some cost’s considerations [1-3]. In a simplified representation, we can identify components like in next figure.

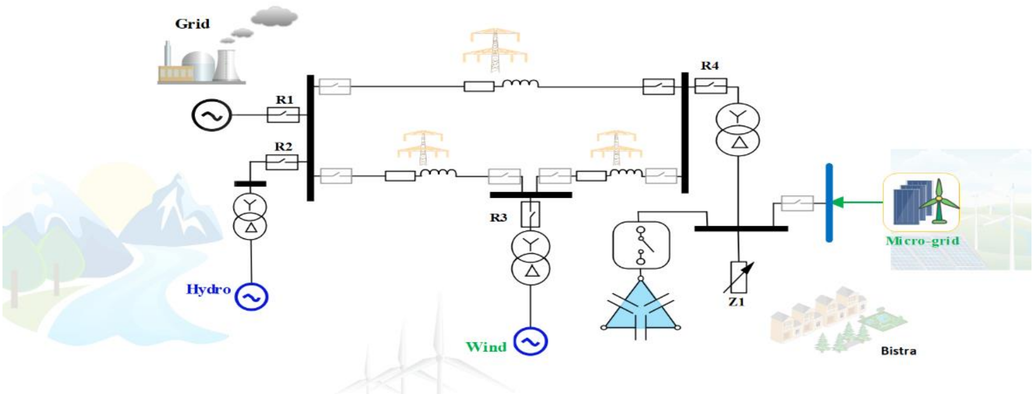


Fig.2. The one wire representation of the power grid entities involved in the energy management, according with [1], [3]

One wire representation of an electric power network composed by two generators, a loop transmission line, different power supplies, and a complex and big load, monitored and controlled by adequate protection devices and power switches.

1.2 The monitoring and control structure "planes" analysis approach

The associated documentation with the equipment and controlling software is grouped by three layers. It is organized from bottom-to-top, from simple-to-complex notions in progressive training approach, according with IEC TC 57.

1. Naturally, we must understand the role of the power network components, including measuring and protective devices. The main "language" of the study is using one wire representation with ANSI Standard Device Numbers (ANSI /IEEE Standard C37.2).

2. Then, because the trainer is approaching topics from electric power networks, the training continues with processes approach (generation of electrical energy, transportation and distribution of electrical energy, and use of it). At level process, we are studying and making experiments with devices through them application, not from the fundamental study point of view. All GTU groups of experiments are situated at this level.

3. In the actual context of the ICT and automation, the top level is the management level, with highly integrated intelligence. Smart-Grid trainer is our most representative trainer in this 3D representation.

1.3 The documentation "planes" approach analysis

On the different "planes" of the representation we have organized the analyzed documentation in the same similar progressive way.

I. First, we are using technical manuals support because the trainers are composed mostly by industrial devices used in electric power systems. Protection devices have own technical documentation and control software- they are invoked and used in our trainers.

II. Using reach and with high level of variety of theoretical sources, we added a comprised theoretical support (in many cases, organized like a state-of-arts of the used topics). The intention was to select theoretical literature cross- culture, and standard restrictions- free symbolizations.

III. The experiments are comprised in a specific chapter and they are organized in the way that they can be selected, and eventually printed as bundles. Optimally, they should be color printed in high resolution, but diagrams/ graphs are designed in the way that they allow also black and white printing.

IV. We have added also the forth section which suggests that all documentation is strongly linked with real life- we are inviting you in most of the cases to expand experiments, and scenarios according with available time and local specificities.

2. DESIGNING APPROACH FOR INTEGRATING LOCAL ALTERNATIVE ENERGY RESOURCES IN THE CONTEXT DESCRIBED REPRESENTATION

2.1 Service- oriented approach for integrating solar systems as ON-GRID implementation

In a simplified representation [1], [4], the approach intends to create suggestive representation of the place of solar system- as micro grid implementation- and the role of the user- as a beneficiary, like in next figure.

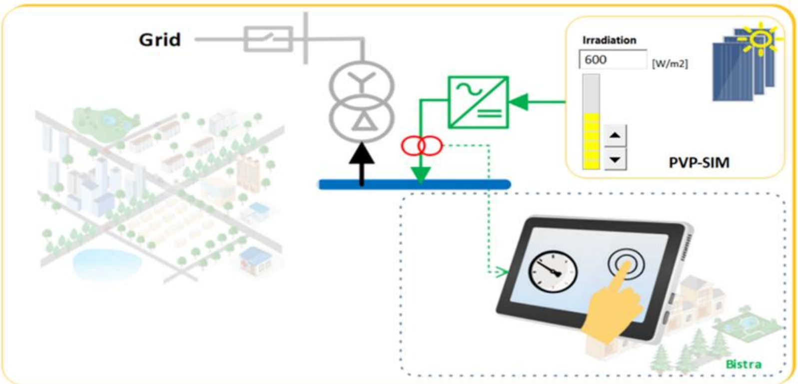


Fig.3. The integration of user/ grid entities in dedicated SCADA system

We have created a simulator of the solar panel (PVP-SIM) that replicates the entire behavior of the solar module, independent by the environment conditions, in a way that provide knowledge for the energy management at local level. The tablet symbol is representing the interactivity of the user.

2.2 Expanding the design analysis for integrating hybrid generators

For the study purpose, the hybrid inverter is integrated like in next figure (taken from inverter's user manual).

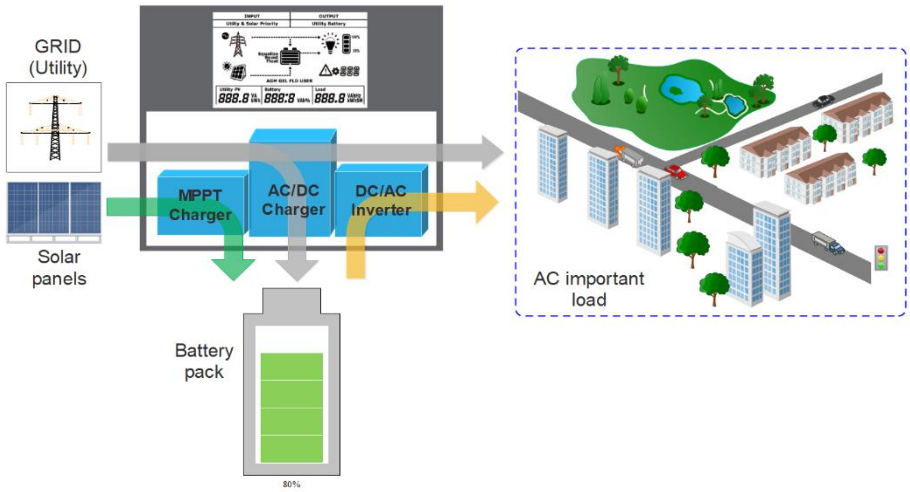


Fig.4. The symbolistic representation of the hybrid inverter integration in its management

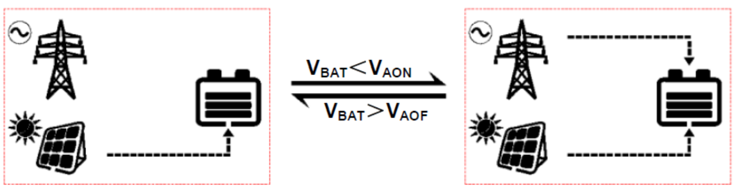
The main indicated flows show the inverter's components with them role: MPPT charger store regulated energy from the solar system into the battery pack; the charger add additional energy from the grid (utility) to the battery pack; then, the DC/AC inverter convert the DC stored energy into AC energy to be used by the important load.

The analysis of inverter's integration must be done from two point of views:

- Inputs point of view
  - o PV priority
  - o Grid priority
  - o PV & Grid
  - o PV
- Output point of view
  - o Grid
  - o Battery

2.3. Defining working mode for solar priority

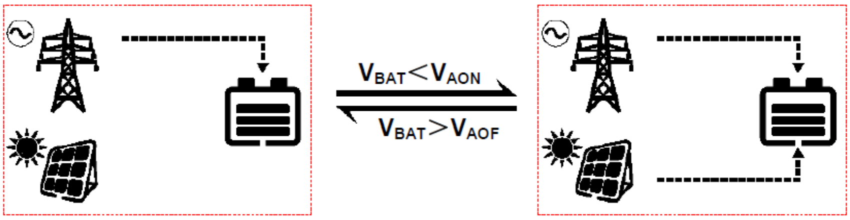
For the study, the representation model is shown next.



The software for monitoring allows setting up like in next procedure: the battery is charged in solar priority mode and when the battery voltage is lower than "Auxiliary Module ON Voltage (VAON)", the utility starts charging. When the battery voltage reaches to "Auxiliary Module OFF Voltage (VAOF)", the utility stops charging.

2.4 Defining working mode for utility priority

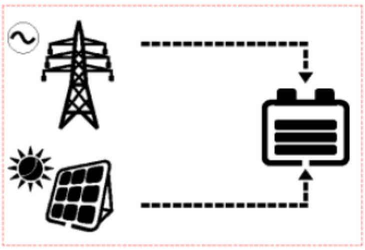
For the study, the representation model is shown next.



The battery is charged in utility priority mode and when the battery voltage is lower than “Auxiliary Module ON Voltage (VAON)”, the solar starts charging. When the battery voltage reaches to “Auxiliary Module OFF Voltage (VAOF)”, the solar stops charging.

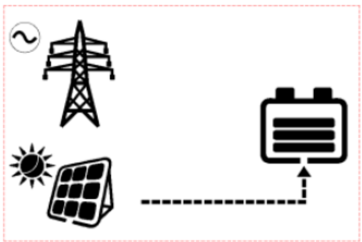
2.5 Defining working mode for utility and solar

In this representation, both, utility and solar are charging the battery.



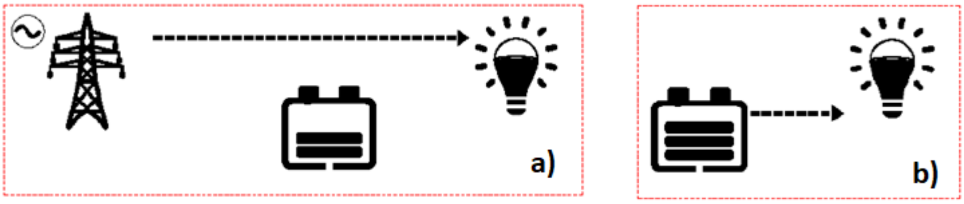
2.6 Defining working mode for solar input

In this representation we have next figure.



2.6 Defining working mode for the output priorities

When utility priority is configured/ desired, the representation is next (a). When battery priority is configured/ desired, the representation is next (b).



In any case of working mode, at control/ monitoring or training level, the role of the hybrid system must be understood with its main role.

3. TESTS ON THE INTERRACTION OF THE HYBRID SYSTEM INTO THE CONTEXT OF THE MICRO GRID INTEGRATION

For the testing purpose, but as a basic approach in training and understanding the role of the system, we have tested two major configurations [1], [5].

3.1 Working mode: Input- Grid (Utility) priority; Output: Grid (Utility)

The response of the SCADA environment shows intuitive icons and interfaces:

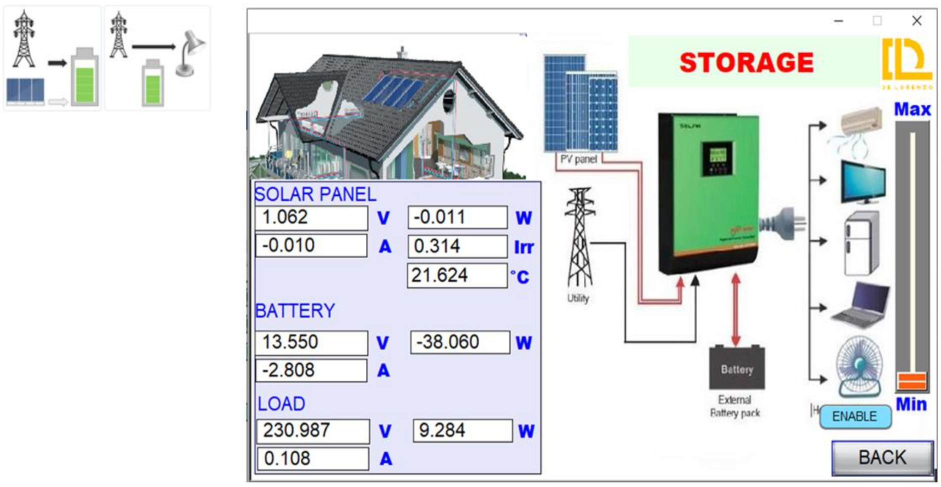


Fig.5. The "user" emulator interface showing the accessible data in one scenario of working

From the above figure, we understand the displayed data: 38.060 W used to charge the battery, 9.284 W consumed internally. No solar power available. Then, 38.909 W are consumed to charge the battery, and 37.302W is composed by the internal consumption 9.284 W and load consumption (37.302-9.284).

3.2 Working mode: Input- Solar and Grid (Utility); Output: Grid (Utility)

The response of the SCADA environment shows intuitive icons and a similar interface:

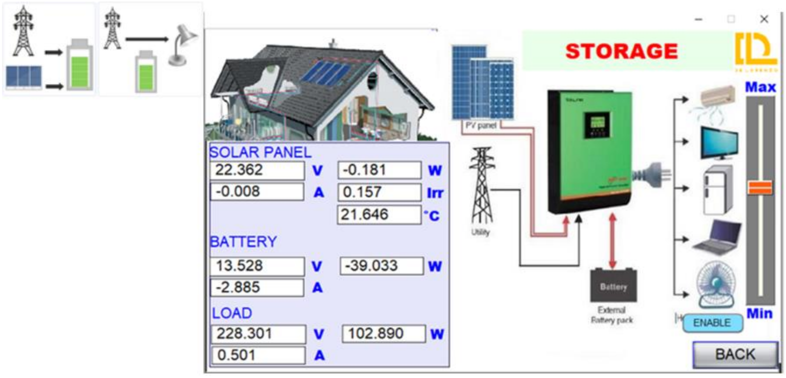


Fig.6. The "user" emulator interface showing the accessible data in another scenario of working

Where the read the data on the HMI application: at the moment of taking the screenshot, produced power from sun: 1.382 W; injected power into the battery 21.638 W, consumed power (internal loses and load) 103.251W. The total demanded power (21.638 W+103.251 W = 124.889 W) is covered by 1.382 W from sun and the rest from the grid (123.507 W. Then if we decrease the value of the load, the data should be changed in the corresponding text fields.

4. DESIGNING THE MODEL-BASED INTEGRATION OF THE MICRO-GRID SECTION INTO THE MAIN POWER GRID

A typical grid configuration could be represented like in next figure.

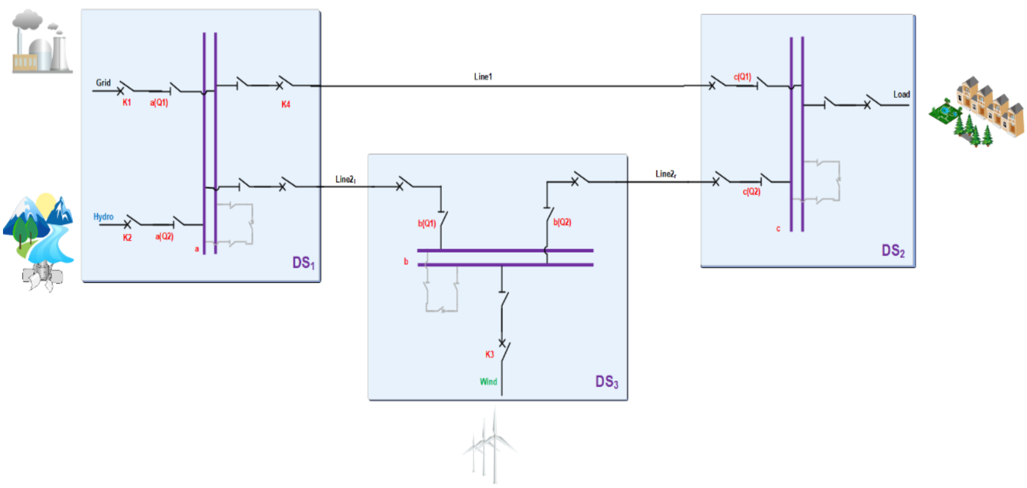


Fig.7. The "user" emulator interface in located and integrated in an electric power system scene, according with [1], [5], [6]

This mesh configuration allows supplying the load from the grid, with the possibility to add other power supplies, through the three distribution stations (DS1, DS2, DS3, also marked by letters a, b, c). Each distribution station is managed by insulation switches (labeled by Q) and power breakers (labeled with K); for instance, aQ1 is the first section of the insulation switch from the DS1; cQ2 is second section of the insulation switch from the DS2. The parallel line adds outcomes in terms of safety and reliability. At DS3 level the microgrid is intended to be integrated. The experiment is designed by separating the electrical energy production and the grid system, by the user, or human operator. The sense of this approach is to underline the two independent layers, with two different governing laws (energy management layer and user's behavior layer). The users/human operators are seeing the electrical energy production by the sun, and operate on some load according with own needs. So, the SCADA and the equipment are working according with designing principles of them (in grid), and the users have own way of approaching the trainer (in micro grid). The user actor in this experiment is represented by an HMI device (Human Machine Interface entity) that is connected to the SCADA for information exchanging with user's behavior, via a TCP/IP interface. The HMI has implemented an application that allows interaction between user and some trainer's component- specific to a user, without interfering into the grid SCADA management- see next figure (where PV-SIM is photovoltaic array simulator).

There is implemented a SCADA software for managing the grid operations (in current experiment we simulate the sun energy radiation for energy production), and on the HMI, there is implemented a software that manages the microgrid system. Where, as a user in the lab/dispatching system, in next figure we show you how to interact with the system (having in the mind that always, the user will act for simulating SCADA operations, and in the same time will be an energy consumer- as typical user).

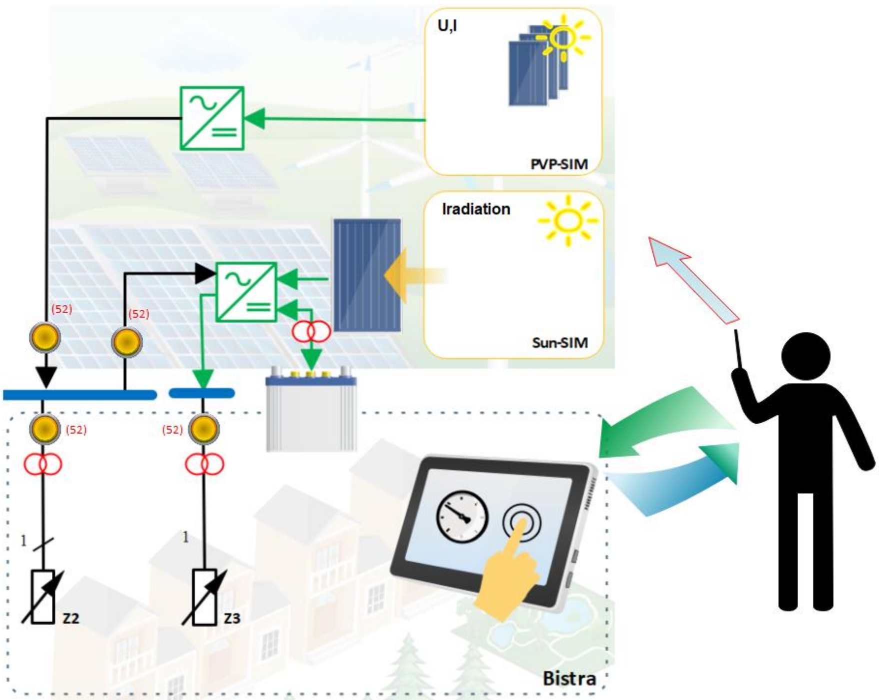


Fig.8. The "user" emulator interaction with the management level implementation

5. CONCLSIONS. METRICS FOR EVALUATING THE IMPLEMENTED SYSTEM

A proposed system is fully developed and it is working without no interruption for 4 months. The interface is developed and independent platform, providing data in local area network, and through a virtual private network in any web- accessible location. Next, the conclusions are provided as a tabular representation.

5.1 Descriptor: General architectures. Concepts

C1- Knowledge and understanding	C2- Practice; applied skills	C3- Generic cognitive skills	C4- Comm., ICT skills	C5- Autonomy and working in teams
critical understanding of the principal theories, concepts and principles of functions-based management in smart grid; extensive knowledge in cost-based management in smart grid	Apply knowledge, skills and understanding in smart grid architecture design; in planning and executing an extensive project of smart grid; designing particular project according with local particularities.	Critically identify, define, conceptualize and analyses complex/professional problems and issues in designing smart grid architectures. Offer professional insights, interpretations and solutions to problems and issues in smart grid applications.	Communicate, using appropriate methods, to a range of audiences with different levels of knowledge/ expertise.	Take responsibility for own work and/or significant responsibility for the work of others. Take significant responsibility for a range of resources.

5.2 Descriptor: Communication support for Smart grid. Reliability issues

C1- Knowledge and understanding	C2- Practice; applied skills	C3- Generic cognitive skills	C4- Comm., ICT skills	C5- Autonomy and working in teams
critical understanding of the principal theories, concepts and principles of communication systems for SCADA	Apply knowledge, skills and understanding in running specialized skills for reliability tests in smart grid communication	Deal with complex issues and make informed judgements in situations in the absence of complete or consistent data/information.	Communicate with peers, senior colleagues and specialists on a professional level.	Manage complex ethical and professional issues and make informed judgements on issues not addressed by current professional and/or ethical codes or practices.

5.3 Descriptor: SCADA support for smart grid. Software installation and configuration issues

C1- Knowledge and understanding	**C2- Practice; applied skills**	**C3- Generic cognitive skills**	**C4- Comm., ICT skills**	**C5- Autonomy and working in teams**
Knowledge and understanding of the ways in which the SCADA system is developed. Knowledge of programming environments for SCADA. Extensive knowledge in software engineering for SCADA	Apply knowledge, skills and understanding in executing a defined project of research, development or investigation and in identifying and implementing relevant outcomes for every particular case of software configuration and security.	Critically identify, define, conceptualize and analyses complex/professional problems and issues in SCADA systems as support for Smart Grid.	Communicate with peers, senior colleagues and specialists on a professional level.	Exercise autonomy and initiative in professional/equivalent activities. Practice in ways that show awareness of own and others' roles and responsibilities. Recognize the limits of these codes and seek guidance where appropriate.

5.4 Descriptor: Demonstration experiments

C1- Knowledge and understanding	**C2- Practice; applied skills**	**C3- Generic cognitive skills**	**C4- Comm., ICT skills**	**C5- Autonomy and working in teams**
critical understanding of a range of specialized theories, concepts and principles for smart grid major topic.	Apply knowledge, skills and understanding in demonstrating originality and/or creativity, including in practices when running processes experiments in Smart Grid.	Develop original and creative responses to problems and issues. Make judgements where data/information is limited or comes from a range of sources.	Communicate at an appropriate level to a range of audiences and adapt communication to the context and purpose.	Take significant responsibility for a range of resources. Work in a peer relationship with specialist practitioners.

5.5 Future development

After identifying the metrics parameters, and proving then consistency in the current development, next proposed research is to create quantitative weights of these parameters, according with SCOF [7]. The major reason of creating quantitative map of them is to create definite tools for controlling the skills delivery in the field.

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