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DESIGNING VIRTUAL LEARNING ENVIRONMENT FOR ELECTRIC POWER DISTRIBUTION NETWORKS

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Abstract: The current paper is the result of research program dedicated to designing new tools and instruments in industrial processes control, optimization and fast learning. The process is replaced by a virtual environment that reacts to the controlled process by using Real Time Unit (RTU) from Supervisory Control and Data Acquisition (SCADA) systems, and answer similar with real process. The software application is designed using specific SCADA developing software, and it is implemented through specific SCADA structure. The designed results will create and understand typical operational restrictions in distribution stations, offer the database status parameters for integrated controls used in the specific SCADA. We have teste the software for both interruptible and non-interruptible regime of load supplying.

Keywords: Process simulation, Electric power networks, SCADA, Control optimization, Learning environment.

1. ENGINEERING EDUCATION- ELECTRIC POWER DISTRIBUTION STUDY CASE

An important research group [1, 2, 3] provided an excellent review report on most frequently used virtual learning methods. In current research paper we are focusing on electric power distribution learning approach.

The documentations follow some study cases scenarios. In the current configurations of electric power networks, we might be "linked" at one moment, by the agreement, to entities like in figure 1.

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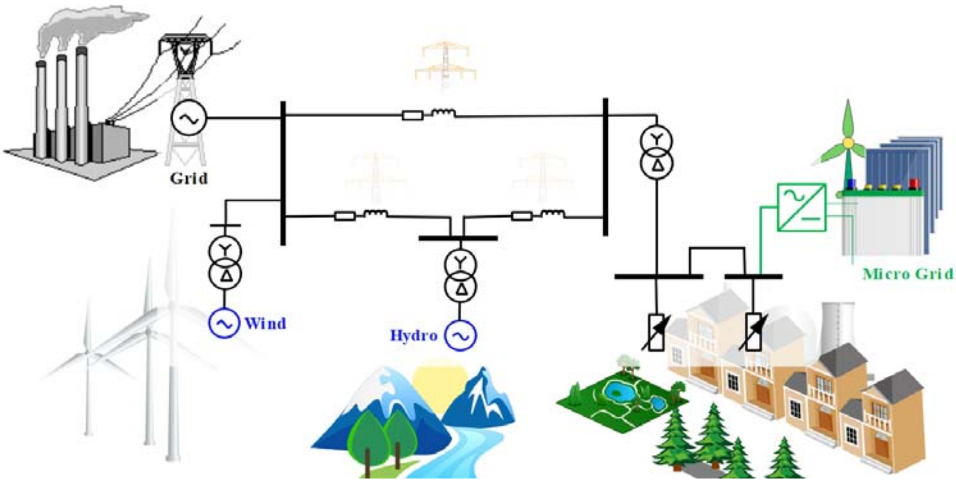


Fig.1. The electric power network model used in current implementation [4]

We say "at one moment" because, depending by the agreement, the configuration might be changed considering that the constrains could be time-variable: security constrained, or cost constrained, or reliability constrained. The consumer "Bistra" is connected through the distribution station to the grid via two main transmission lines paths. From a "faraway" place, Bistra can buy electricity from a hydro plant generator, according with a scheduled program not only to maintain the voltage value at busbar level above .99 pu (see next figure) but also to ensure a high-quality energy. Our electricity invoice will contain a green certificate component of the wind farm connected to the grid, when it is not delivering energy to the grid [10], [12].

In the same time, the consumer "Bistra" is using a local, alternative energy source- a compound of solar, wind, and battery storage systems. The, so- called, micro-grid system is following the grid rules when it works as an on-grid system. Generally speaking we might imagine that micro-grid is also managed to work as off-grid system.

The intention of this approach is to guide users (students/trainers/professors/ researchers) to always imagine their network as an electrical distribution network over which to apply operating rules, market rules, optimization rules [13].

1.1. Busbars general consideration

The industry needs PLC

In this context, one weak part of the power network is the connection point between power line- called also electric power distribution point. High-voltage substations are points in the power system where power can be pooled from generating sources, distributed and transformed, and delivered to the load points. Next figure shows typical power structure focused on distribution stations; where a) Single busbar; Double-busbar (BB – busbar, M-BB – Main busbar, A-BB – Auxiliary busbar, G – Generator, K – circuit breaker, Q – Disconnector, CT – current transformer, VT – voltage transformer, SE – Earthing switch).

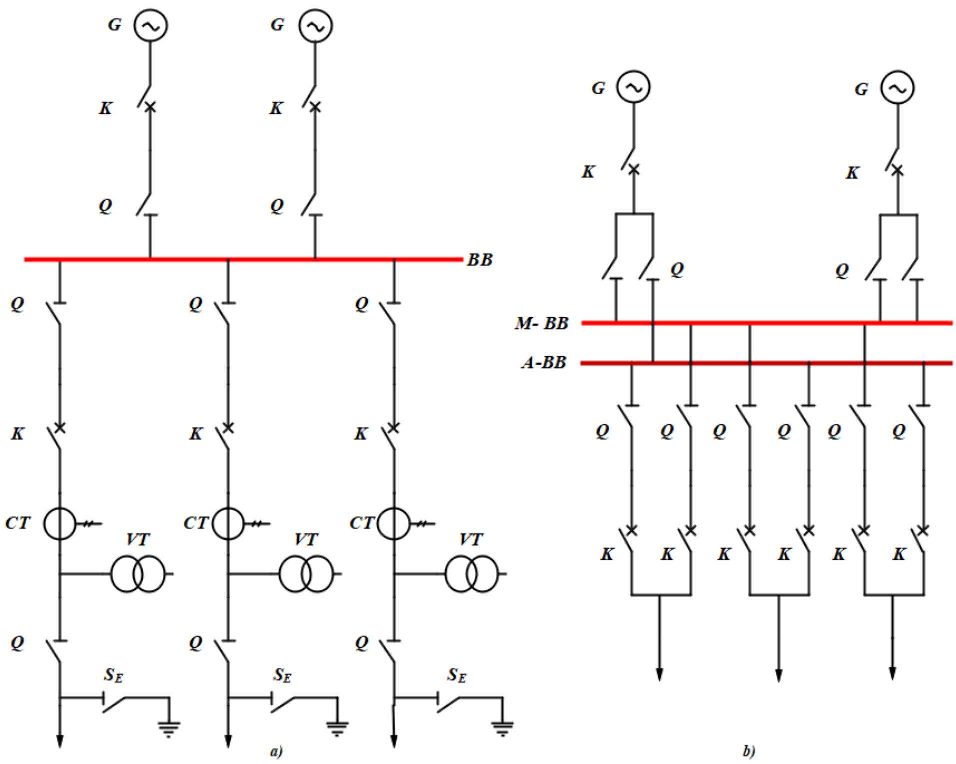


Fig.2. The electric power network model used in current implementation [4, 5, 6]

Above figure (a) shown the single busbar and because it has only one busbar and the minimum amount of equipment, this scheme is a low-cost solution that provides only limited availability. Substations are interconnected with each other, so that the power system becomes a meshed network. Because it has only one busbar and the minimum amount of equipment, this scheme is a low-cost solution that provides only limited availability. In the event of a busbar failure and during maintenance periods, there will be an outage of the complete substation. To increase the reliability, a second busbar has to be added. In double busbar systems, shown in above figure (b), two identical busbars are used in such a way that any outgoing or incoming feeder can be taken from any of the bus. Actually, every feeder is connected to both buses in parallel through an individual isolator. The double busbar arrangement increases the flexibility of the system.

The more complex scheme of a double-busbar system gives much more flexibility and reliability during operation of the substation. For this reason, this scheme is used for distribution and transformer substations at the nodes of the power supply system. It is possible to control the power flow by using the busbars independently, and by switching a feeder from one busbar to the other. Because the busbar disconnectors are not able to break the rated current of the feeder, there will be a short disruption in power flow. To have a load change without disruption, a second circuit breaker per feeder has to be used. The key points of the virtual environment studies related to the busbar operation are:

- Busbar general operation
- Power transfer in a double busbar system with supplying interruption
- Power transfer in a double busbar system with continuous supplying
- Supplying a double busbar system with a backup power line.

2. MODELS IN VIRTUAL LEARNING ENVIRONMENTS

According with technical literature [6, 7] we propose models in progressive approach from the difficulty point of view. Next figure shows the circuit diagram of double busbar basic system. The subject of this experiment is to underline the operation of pairs Q1-K1, and Q2-K2 for supplying/disconnecting the busbars BB1 and BB2 from the distribution station SD.

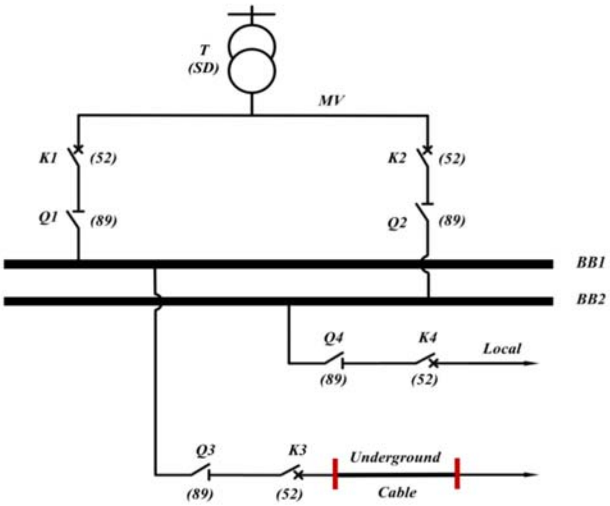


Fig.3. Simplified model for basic operation studies

Then, we are studying the operation of the pair Q3-K3 for supplying/disconnecting the underground cable, and the pair Q4-K4 for supplying/disconnecting the local consumers. Before starting the experiments, we recommend you understand the role of the hardware components of the trainer and how they are arranged and handled. This double busbar basic system is the simplest configuration: one power supply (SD) which in our laboratory configuration is represented by the three-phase power supply, is connected together with a three-phase model of an underground transmission line. Each connection point uses breakers (52) - connected to a double busbar. Special care must be taken to ensure that the individual phases are connected correctly in order to avoid later short-circuits.

High-voltage substations are points in the power system where power can be pooled from generating sources, distributed and transformed, and delivered to the load points. In the main and transfer bus arrangement we have two buses one is the main bus and the other is transfer bus. With the help of isolator switches, it is connected to the transfer bus which is called by pass isolators and with the help of circuit breakers and isolator switches it is connected to the main bus. There is also bus coupler as shown in the following figure.

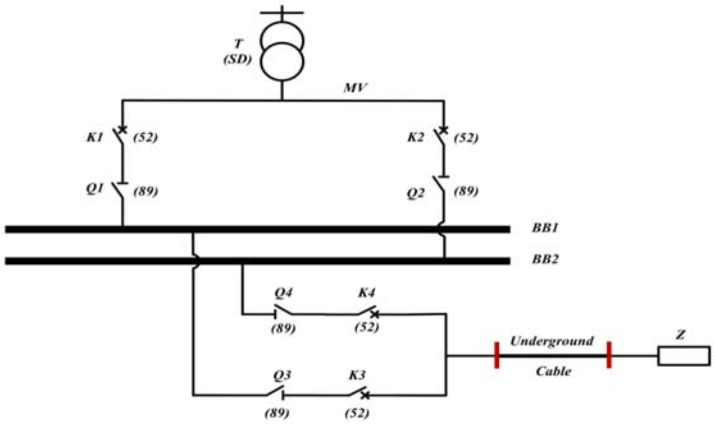


Fig.4. Simplified model for load supplying with interruption

Where, BB1 is main busbar, BB2 is transfer busbar (or reserve busbar). Both according with a procedure will transfer power to the load (Z). As you can see, each busbar can be fully insulated from the electrical powering point of view (see the position of the insulator switches). The subject of this experiment is to underline the operation of pairs Q1-K1, and Q2-K2 for supplying/disconnecting the busbars BB1 and BB2 from the distribution station SD. Then, we are studying the operation of the pair Q3-K3 for supplying/disconnecting the underground cable from one busbar, and the pair Q4-K4 for supplying/disconnecting the underground cable from second busbar. This experiment differs from the previous one because it proposes an improvement in load power supplying:

- Adding at busbar level a busbar coupling system caller busbar coupler
- Completing operational procedure in order to allow continuous power supplying and maintain the security at the busbar's levels.

Technical literature [7, 8, 9] presents two different situations of using busbar couplers. The coupler is used to equalize the voltage potential of the two busbars- preliminary operation for allowing switching between one power path (BB1) and reserve power path (BB2). Second situation of using busbar coupler is also known a busbar sectionalizing system- see next figure.

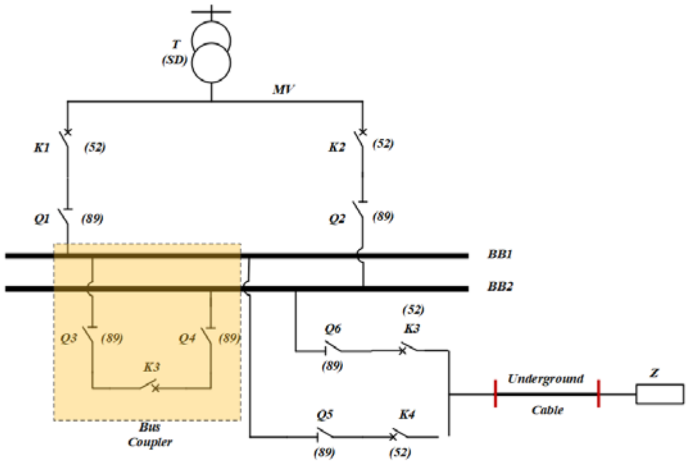


Fig.5. Simplified model for load supplying without interruption- equalizing voltage in first stage

The coupler is used to equalize the voltage potential of the two busbars- preliminary operation for allowing switching between one power path (BB1) and reserve power path (BB2). Second situation of using busbar coupler is also known a busbar sectionalizing system- see next figure. Both couplers have similar structures, but the operational procedure is different- following different purposes. The current experiment will be focused on first situation- as an alternative of previous experiment procedure- to supply continuously a load, when switching from main busbar to the transfer busbar.

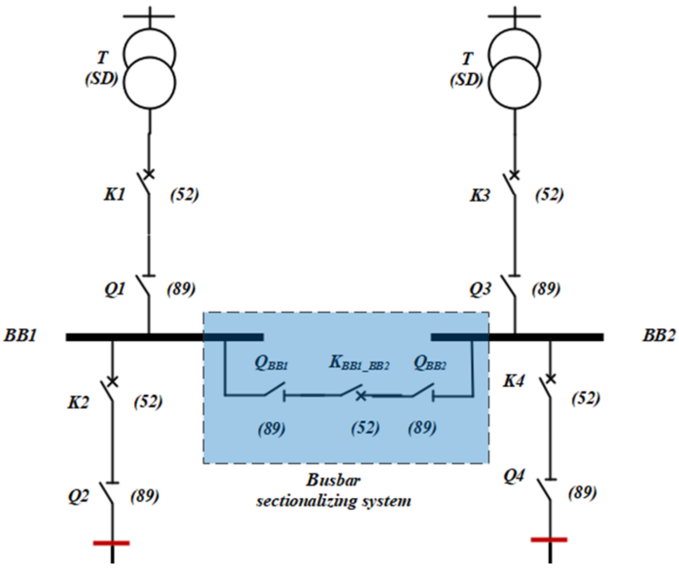


Fig.6. Simplified model for load supplying without interruption- equalizing voltage in first stage- reserve procedure

The subject of this experiment is to underline the operation of pairs Q1-K1, and Q2-K2 for supplying/disconnecting the busbars BB1 and BB2 from the distribution station SD.

Then, we are studying the operation of the pair Q5-K5 for supplying/disconnecting the underground cable from one busbar, and the pair Q6-K6 for supplying/disconnecting the underground cable from second busbar (transfer busbar). To keep continuously the power at the load a coupler is required Q3-K3-Q4.

3. SOFTWARE RESOURCES USED IN MODELS IMPLEMENTATION

3.1 Events triggering considerations

The implementation starts with some control considerations that are used in software model implementation- events triggering. Before creating any program, any flow diagram we must understand:

- What is asked from the automata system?
- What we need to provide to the system in order to “produce” what is asked?

These questions are well symbolized by next figure (systemic representation):

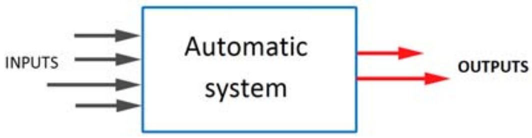
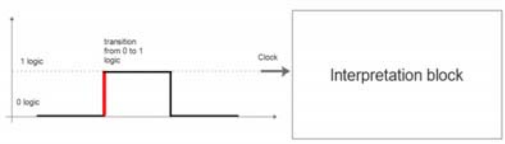
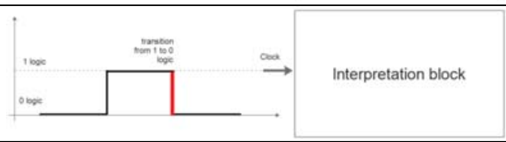
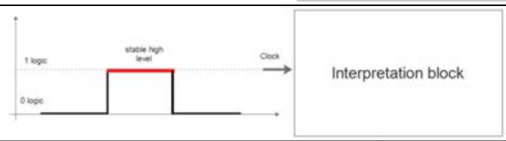
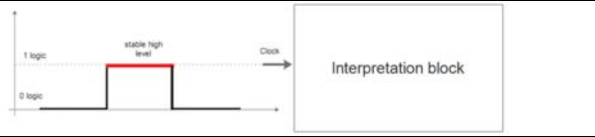
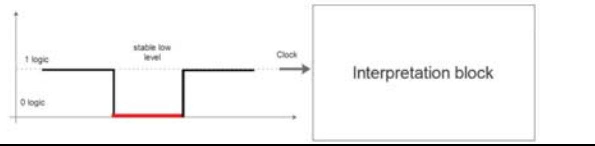


Fig.7. Simplified model of the controlled process; any big practical problem is divided in many simple problems, in many simple systemic representations, with many local working algorithms

Triggering option is referring to the moment of starting understanding the input action. Usually, in automation, there are few options shown in next table.

Triggering on transition from 0 to 1 logic- positive edge triggering	
Triggering on transition from 1 to 0 logic- negative edge triggering	
Triggering on stable high level	

Triggering on stable low level	
Triggering on middle point of the pulse (Manchester code)- the control clock period is double of master clock.	

3.2 Developing software model using SCADA specialized software development

The SCADA project is developed in WinLog programming environment. It is open source technology are based on the provided SCADA software for current trainer, you are able to expand your functions using WinLog.

If you want to re-install/ install SCADA on the new PC, to run SCADA applications two steps are required on the PC:

- Install WinLog
- Import SCADA project in WinLog

If you leave Run Winlog Evo 4.0.15 checked, it will start and project explorer will appear like in figure 8.

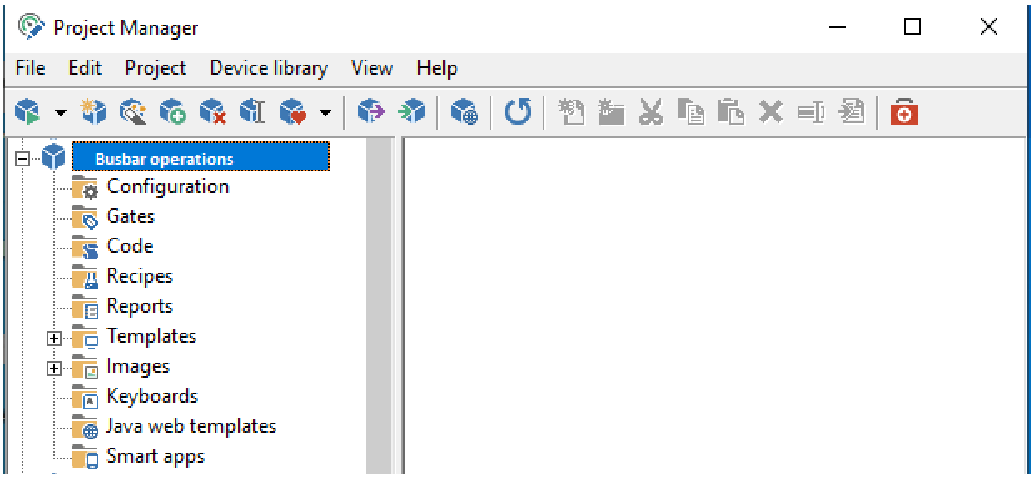


Fig.8. The main window of project explorer in Winlog

4. TESTS AND RESULTS OF VIRTUAL SUPPORT IMPLEMENTATION

When we are running the project, the runtime generates typical SCADA interfaces.

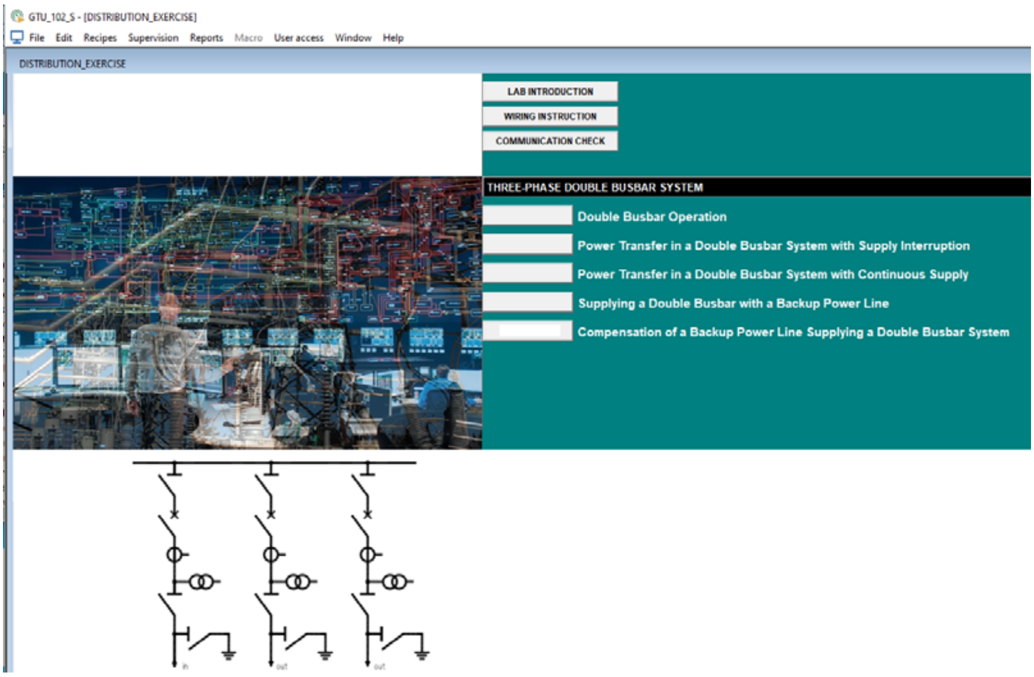


Fig.9. SCADA experiments main window developed in Winlog

4.1 Busbar standard operation implementation

Next figure shows the main SCADA window.

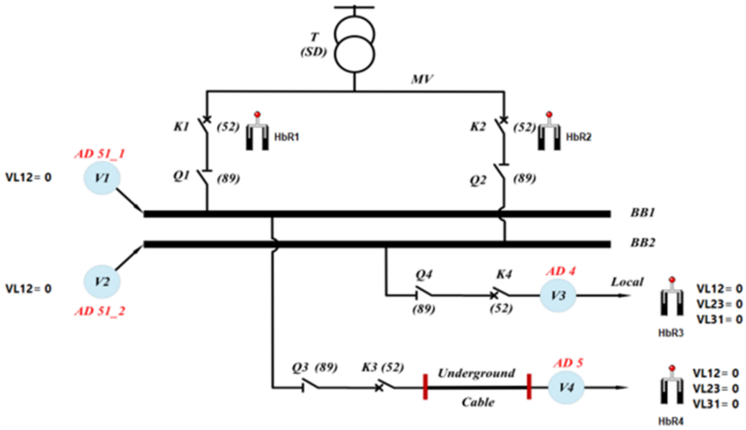


Fig.10. SCADA experiments for basic operations

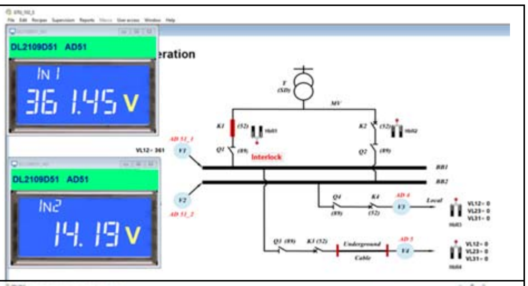
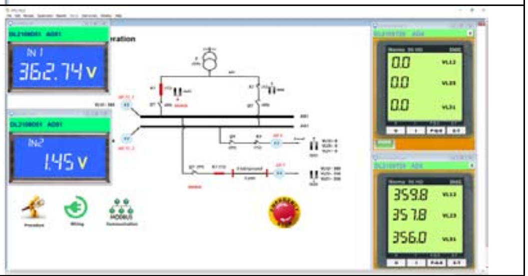
According with the objectives we will supply/ disconnect the power to the underground cable and to the local consumers, independently each other, focusing on the order how to operate devices (insulation breakers (89)- Q1- Q4, power breakers (52)- K1- K4).

A connection point is always composed by one device 89 and one device 52. They are interconnected (according with the law procedures) for correct operation order.

The operation order in one connection point is:

- Closing operation: close 89 than close 52
- Opening operation: open 52 than open 89.

The results are show in next table (by following software implemented procedure).

Closing K1 is on the software	
Close Q3, after that close K3	

In the similar way, the operation of second busbar is controlled by the software. Next figure shows the interface for load supplying in above mentioned conditions.

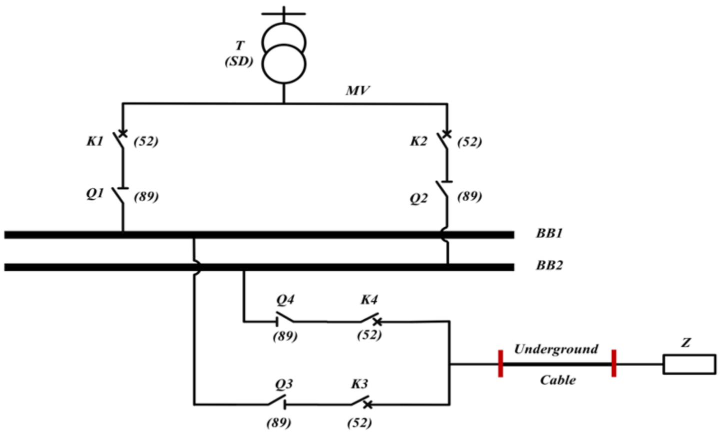


Fig.11. SCADA experiments for basic operations for load supplying

4.1. Busbar operation implementation for non-interruptible power supply and reserve ensuring

Next figure shows typical interface.

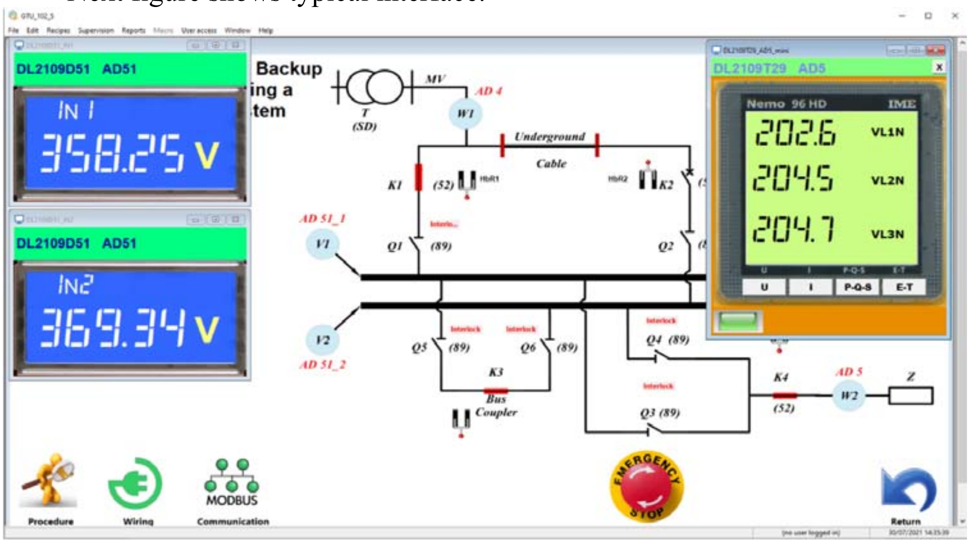


Fig.12. SCADA experiments for non-interruptible supplying

5. CONCLSIONS

The designed SCADA follows the typical power system regulations.

The double system is used to bring to the busbar system power from one/more power supplies through two different power circuits.

The busbar system (simple or double) is a system that defines the voltage lines circuits. It is used to connect/disconnect lines from the voltage presence point of view. A double system creates double line circuits.

The exercise in repeating operations from the previous experiments and continues with power transfer from main busbar to the transfer busbar. The first conclusion is that the order of operating breakers (52 and 89) at busbar level must be always followed.

This operational procedure is transferring the power from main busbar to the transfer busbar by interrupting the power at the load level- this procedure can be used only for the consumers that allow this situation. It is never recommended to be used to supply the consumers where interruption of the power will produce significant losses or victims (hospitals, metallurgical, or transportation industry).

This operational procedure is transferring the power from main busbar to the transfer busbar with continuous the power at the load level- this procedure can be used only for the consumers that allow this situation- being very expensive. It is recommended to be used to supply the consumers where interruption of the power will produce significant losses or victims (hospitals, metallurgical, or transportation industry).

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