Remote Disconnection System for Distributed Generation Units

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Abstract. This paper presents a Remote Disconnection System for Distributed Generation Units. It is destinated to supervise dispersed power generation centers and network status at the interconnection line. The main function of the developed system is the automatically opening of the autoproducer´s connection breaker, when defined circumstances happen. Remote automatic disconnection observes always basical requirements about security, obedience, reliability and speed.

Furthermore, this system allows properly authorized staff of the electrical utility to check and manage certain control actions from the Remote Operation Control Position, into some elements belongs to autoproducer instalation.

Key words

Distributed Generation, Power Quality, Co-generation and Special Regulations, Automation, Remote Control.

1. Introduction

The growing interest in environmental aspects has cause, an important activity in creation of normative and laws around the new concept of *sustainable development*. This tendency is going to mark the future evolution in many activities and ranges, including industrial and electrical sectors. [1]

This concern about how to satisface the actual needs whitout jeopardizing the capability of futures generations to satisface their owns necessities, joined to the energy external dependence, has promoted inside European Union to make a real bet on an energy politicy. In this politicy, renewable energies and energy efficiency have a preferable place. So, it is promoted the more rational use of energy to reduce its consumption and get a bigger efficiency.

At the same time it has stimulated the development of renewable energies as a clean and inexhaustible source of supply. In this way, European Commission has stabilised as an objective that 22.1% of produced energy should be generated from renewable energy sources by 2010.

In another way, the proliferation of small electric energy producers introduces new conditionants in the management and operation of the power system. This forces to redefine quality parameters of electrical supply and imposes a new concept of electrical network. [2]-[4]

To this effect, their satisfactory control by the system operator becomes essential to insure the correct work of the network. Both because of aspects which make reference to insure the quality, and those about security standards. Anyway, due to the owns particularities inherent to those small and dispersed generation centers, many times, it is not workable nor economical make effective this control according to a classical conception. [5]-[7]

In this communication, continuing in the same line of other previous works [8][9], the authors present a Remote Disconnection System (RDS) for Distributed Generation Units. It is destined to integrate those small plants into the Distribution Control System, which has the mission of manage the system resources. For this purpose, it is used a flexible and low cost system, sufficiently effective to provide the required operation and safety funcionalities.

The developed system has been designed as a modular system, so it can be applied to different autoproducer's connection configurations (simple or double circuit, final or middle line position) by means of the adjustment and specification of its particular characteristic parameters. If necessary, it also allows to include more advanced remote supervision and control functions.

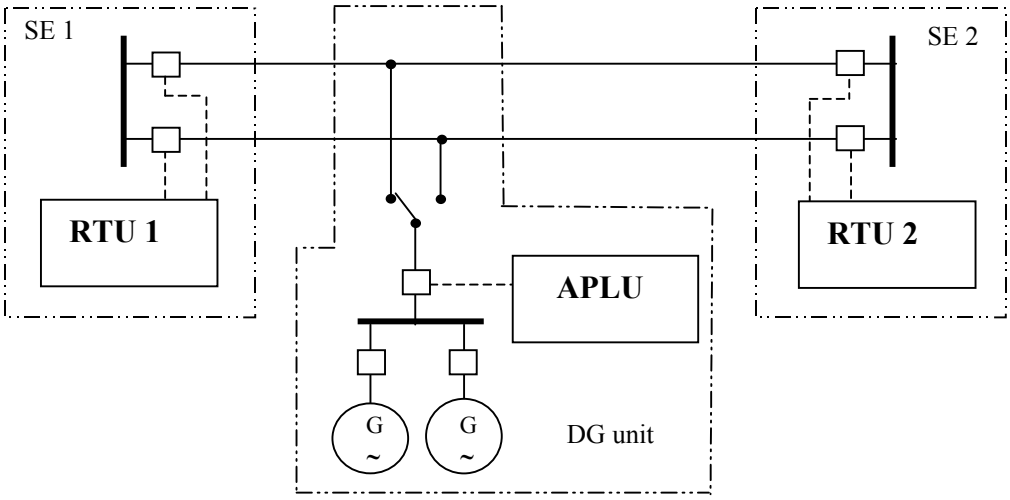

Fig. 1. Remote Disconnection System Configuration

2. System configuration

The Remote Disconnection System for Distributed Generation Units presented in this paper has two clearly distinguished parts (Fig. 1):

- Autoproducer Local Unit (APLU).
- Remote Terminal Unit (RTU).

These subsystems are interconnected via radio with an RS-232 series connection. Used communication is full-duplex. (Fig. 2)

Regarding connection configuration of the autoproducer, developed system allows to consider different posibilities. So, with a simple change in values of some configuration parameters, it is possible to manage different Distributed Generation units (DG units) supplies by:

- Simple circuit radial line.
- Double circuit radial line.
- Simple circuit two terminal line.
- Double circuit two terminal line.

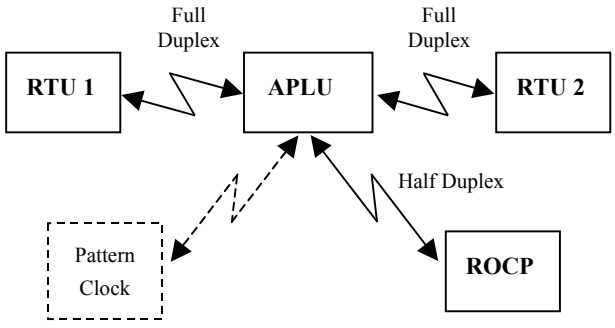

Fig. 2. Communications

A. Autoproducer Local Unit

The APLU is situated inside the instalation of the autoproducer. Its main mission consist on watch over operation conditions which must cause the automatical disconnection of the generation unit and, if neccesary, carry out the opening operation of its connection breaker

In orther to get the faster answer as possible, the APLU has not more function than those relatives to remote disconnection of de DG unit. In this way, to ensure the functionality and operation of the automatism, only those generic functions are included:

- Supervision of comunications
- Watch over APLU's availability

Supervision of the Remote Disconnection System can be realized in a remote way from the Remote Operation Control Position (RCOP) of the electrical utility which have the mission to manage the system where DG unit is connected.

To this aim, there is a second serial comunication channel. In this case, the used comunication is half-duplex and, depending autoproducers qualities, it will be used a connection by telephonic modem or a radio channel.

Additionally, the APLU developes a registration where the most important alarms and events relatives to the Remote Disconnection System are sequentially and chronologically storaged. Each registration shows the date, hour, minute, second and second hundredth when the incidents happened, the signal description and its status to make easier its ulterior analysis.

To reach this objective, an internal clock is used. This clock runs inside the processor unit and it can be adjusted locally or remotely using comunications. When a higger accurance and coherence is required between the times of incidences in differents elements of Distribution Control

System, it is possible make a continous clock adjust, using an external synchronization signal, via radio, from a pattern clock or any similar system

B Remote Terminal Unit

RTU is situated in the Electric Substation (SE) from departs the line where the considerated DG unit is connected to. There will be a RTU from each substation involved. So, depending on the system configuration, each APLU will comunicate with one or two RTU.

In the first case they will be generations units connected to radial lines that depart from an only SE.

In the other hand, when the autoproducer is fed by a two terminal line, the local unit must communicate with two different remotes located in end line Substations.

Otherwise, in the Substation there is an independent RTU for each DG unit. For security reasons, even though the same information is managed by many APLUs, it shouldn't be use the same equipment to comunicate with different instalations. To this effect, it is considered that all the generation units interconnected by the same circuit breaker make up a single instalation, despite the size and number of them.

RTU's function is to pick up all necessary information to decide the automatic opening of DG unit connection breaker. This information will be send continuously to involved DG units. The own remote terminal has to ensure that this information is sure an reliable enough.

Additionally, RTU unit supplies locally extra indications about the situation of the own automatism. These data will be used in maintenance works.

It is not contemplated direct comunication between operation center and RTU.

3. Hardware

The Remote Disconnection System presented in this communication has been designed using an appropriate combination of integrated hardware of control, process regulation devices and modern systems of operation, supervision, diagnosis and communication. The developed system is essentially based on Sisteam A programmable logic control (PLC) witch allows the required open and shapeable architecture.

Sisteam A is a low-medium range programmable modular control system. This modular system and can be used in direct process controls, remote control utilities or automation in general. [10][11]

It is a low cost compact system wich has a high calculus power and a huge tecnologic funtions library. Because all this, it becomes a good option for applications in which a safe and reliable system is required, without need a big number of signals to manage (inputs/ outputs).

Into the general caracteristics of used equipment, these are the most important:

- Main processor module is based on an Intel 80386EX microcontroler of 32 bits at 32 MHz.
- It has also an auxiliar Siemens C161 microprocessor of 16 bits at 16 Mhz. It makes the comunications control.
- The processor module has incorporated two serial ports RS232.
- 2500 V_{ac} galvanic isolated input and output cards.

Sisteam A can be programmed using four differents programmation languages, based on international standard IEC 1131-3:

- SFC: Sequential Function Chart. State-transition diagrams editor for logic state blocks (derived from Graphcet).
- FBD: Diagram Function Blocks. Graphic programmation language, based in logic and functional blocks.
- LD: Ladder Diagram. Contacts diagram based on traditional wiring logic.
- ST: Structured Text.

Although hardware configuration in both units can be different depend on the size and type of autoproducer's connection, a basic structure can be established. According to necessities in each particular case, it could be extended in order to get the required aditional functionalities.

A Hardware configuration of the APLU

The Autoproducer´s Local Unit is composed basically of:

- 1 CPU (BH2104).
- 2 digital input cards at 24 V_{dc} (BH2311). Both of them with capacity for 16 inputs.
- 2 digital output cards at 24 V_{dc} (BH2311) externaly fed. Both of them with capacity for 16 outputs.
- 1 analogic input card (BH2351). It allows to connect 8 input in a commond way. They are voltage inputs at ±10 V and works whit 11 bits resolution and sign.

In those cases in which the APLU must be connected to two RTU, it will be necessary to add an extra serie comunication card (BH2501), since processor unit only has two serial ports. Both used to comunicate the unit with Remote Operation Control Position of the electrical utility and with one of the substations remote unit.

This extra comunication card will be needed too, in those cases in which the cronologic alarms and events registration is done with synchronization by external clock.

B Hardware configuration of the RTU

The basic hardware configuration in each Remote Terminal Unit is:

- 1 CPU (BH2104).
- 1 digital input card at 24 V_{dc} (BH2311) with capacity for 16 inputs.
- 1 digital output card at 24 V_{dc} (BH2311), externaly fed , with capacity for 16 outputs.

The comunication with APLU is done through one of the serial ports availables in the processor card.

4. Functional characteristics

In this section, the main functional characteristics of the Remote Disconnection System are described. Those which make reference to following aspects:

- Data capture and treatment.
- Operation conditions.
- System supervision

A. Data

Both, APLU and RTU units have the ability to manage one input/output cicle each 10 ms. In the same way, after pick up the information, data are submitted to a check and validation process to ensure their validity and reliability. When validated, the data are transmited to the required direction. The lapse of time between data pick up and its transmision starts is, in any case, less than 30 ms.

Although depending on each instalation characteristics data volume can vary, the main signals managed by the Remote Disconnection System are the following:

1) APLU:

a. Digital inputs:
   - Connection breaker status.
   - Status of disconnecting switches
   - Status of circuit breakers of the groups.
   - Alarms associated to the connection breaker.
   - Triping of protection relays of connection breaker.
   - Local commands relatives to RDS and to control capability
   - Energy counters.

b. Digital outputs:
   - Connection breaker opening.
   - Close locking of connection breaker.
   - Indication of the feeder breaker status.
   - Indication of selected line.
   - Indication of automatism status.
   - Indication of alarms and failures relatives to RDS.

c. Analogic inputs.
   - Active and reactive power, both measured in the interconnection busbar.
   - Active and reactive power in each generation group.
   - Voltage in busbars.
   - Voltage in interconnection lines.

2) RTU:

a. Digital inputs:
   - Feeder breaker status.
   - RDS activate / desactivate command.
   - Autoproducer´s connection breaker opening command.

b. Digital outputs:
   - Indication of autoproducer's connection breaker status.
   - Indication of close locking status of autoproducer´s connection breaker.
   - Indication of automatism status.
   - Indication of alarms and failures relatives to RDS.

In order to get a higger security in the system operation, circuit breaker possitions will be fixed by the value of two independent signals (open and close). Before validate a circuit breaker status, system will check the non exitence of discordant information between those two signals.

In the same way, in order to remove rebound posibilities in signals captation, before give effect to the change in the circuit breaker possition, it is checked that its state permanence during almost two consecutive input/output cicles.

B. Operation

Remote Disconnection System is destinated to disconnect a DG unit when some certain circumstances happen in the lines, where they are connected to. If so, it proceedes to do the automatic opening of autoproducer's connection breaker.

The automatism that must check opening conditions of this circuit breaker and, when necessary, must execute the triping command is situated in the APLU. In this unit there is available all the information necessary for this operation. Both, those data relative to local signals which are picked up through its owns inputs, as those data relatives to substations from where the DG unit is fed. Which are picked up and trasmited by the corresponding RTU .

Circuit breaker opening command is connected directly to its triping device. This information is included inside an "or" logical function that gets orders from differents control positions and actives automatisms (with capability to execute that operation).

The automatism will proceed to start a DG unit disconnection when three following conditions happen at the same time:

- The feeder breakers of substations corresponding to the used line are opened
- Automatism are connected.
- System is available.

In case of having two terminal line, the feeder breakers of both substations must be opened. In other case, the automatism don´t execute the automatic disconnection.

The automatic opening of the connection breaker, made by the RDS, is indicated locally, thus autoproducer will be informed, and also will be notified by comunications to ROCP and to involved Substations.

Otherwise, system allows to execute a remote disconnection of the DG unit from the ROCP of electrical utility, if it has transfered the control capability. In this situation the connection breaker will remain locked. To restore the connection, autoproducer will first unlock it locally. This operation needs the corresponding permission of electrical utility.

In order to ensure their action security both APLU and RTU have non volatile memories, where critics variables of operation are saved. So when disconnection of any part of the system happen, the information remains on those memories and when the element is reseted the previous conditions can be restablished.

C. Supervision

The correct operation of all elements that compose proposed Remote Disconnection System are checked locally and in a remote way.

In this sense, it must be emphasized that there are hard and soft autotest incorporated on the system devices. Using them, it is possible to detect the main part of possible functional failures.

Automatism status is checked into two different levels:

- Hardware.
- Communications.

Therefore, the availability of the system is determinated by the correct operation of both levels. To establish the availability of the system, both context are continuosly checked. So the automatism will be disconnected if any of the following circunstances is detected.

- System has remained in non avaliable situation more than a certain time. This time period can be adjusted to different values.
- During a certain period of time, system has suffer some non-avilability situations and has acumulate a non available time period higger than a prearranged time. Both time parametres can be modified.

Besides, in order to ensure a suitable security level in operation of the network, RDS allows properly authorized staff of the electrical utility check and manage certain control actions, into some elements belongs to autoproducer instalation.

By this means, if its control capability is not locally restrained, it is possible to realice these operations from ROCP:

- Activate / desactive RDS.
- Opening autoproducer connection breaker.
- Locking autoproducer connection breaker.
- Adjust clock inside processor.

5. Conclusion

The developed system supervises DG unit and network status, and its main function is the automatically opening of the autoproducer´s connection breaker, when defined circumstances happen. Remote automatic disconnection observes always basical requirements about security, obedience, reliability and speed.

Besides, the system offers the own functionalities of a remote control system, that can be summarised as follow:

- Capture, filtering, treatment and registration of information relative to operation status of DG unit.
- Connection and data transference between DG unit and substation´s control equipment.
- Direct communication with the network control center.
- Remote control of connection elements and the automatism itself.
- Local and remote supervision of the automatism.
- Status, event and alarm displaying.

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Abbreviations

RDS	Remote Disconnection System
DG	Distributed Generation.
APLU	Autoproducer´s Local Unit.
RTU	Remote Terminal Unit.
SE	Electric Substation
ROCP	Remote Operation Control Position

References

[1] Real Decreto 2818/1998, de 23 de diciembre, sobre producción de energía eléctrica por instalaciones abastecidas por recursos o fuentes de energía renovables, residuos y cogeneración.

[2] S. Diolettas and J. Lloveras, "Las Ventajas de la Generación Eléctrica Distribuida", in *Proc*. *XVII Congreso Nacional de Ingeniería de Proyectos,* Murcia 2001.

[3] L. Fernández, "Generación distribuida: ¿la generación del futuro?", Energía. Ingeniería Energética y Medioambiental, nº 172, pp144-148, Sep/Oct 2001.

[4] A. Quijano and L. Pérez, "Control distribuido. Nuevo concepto de las redes eléctricas", Energía. Ingeniería Energética y Medioambiental, nº 172, Jul/Ago 2003.

[5] J.H. Choi, J.C. Kim and S.I. Moon, "Integration Operation of Dispersed Generations to Automated Distribution Networks for Network Reconfiguration", in *Proc*. *2003 IEEE Bologna Power Tech*.

[6] M. Begovic, A. Pregelj, A. Rohatgi, J. Greatbanks, D. Popovic and T. Green, "GA for Optimization of Realibilityy of Distributed Generation-Enhanced Feeders", in *Proc*. *ISAP 2003*.

[7] A. Borghetti, R.Caldon, S. Guerrieri and F. Rossetto, "Dispersed Generators Interfaced with Distribution Systems: Dynamic Response to Faults and Perturbations", in *Proc*. *2003 IEEE Bologna Power Tech*.

[8] K. J. Sagastabeitia, A. J. Mazón, I. Zamora, Z. Aginako and J. R. Saenz, "Remote Control System for Small Hydro Energy Power Stations", in *Proc*. *ICREPQ´2003*.

[9] K. J. Sagastabeitia, A. J. Mazón, I. Zamora, M. D. Gutiérrez and J. R. Saenz, "Distributed Control System for Electric Substations", in *Proc*. *2nd International Conference on Automatic Control,* Santiago de Cuba 2002.

[10] TEAM, Manual de uso. SISTEAM A. Hardware. Sistemas integrados de Control y Regulación de Procesos, Información Técnica ITSA, Bilbao.

[11] TEAM, Manual de uso. SISTEAM A. Software. Sistemas integrados de Control y Regulación de Procesos, Información Técnica ITSA, Bilbao.