AUTOMATIC GRID RECOVERY (AGR/ARA), THE VIRTUAL OPERATOR

Juan MARTI
Iberdrola Distribución – Spain
juan.marti@iberdrola.es

Christa RICHTER
Siemens – Austria
christa.richter@siemens.com

Eugenio de GABRIEL
Iberdrola Distribución – Spain
e.degabriel@iberdrola.es

ABSTRACT

This paper presents an automatic tool integrated in the control system to isolate faults and to restore the network in a close loop. The lack of references of similar tools in operation and the promising results makes it highly innovative. The current implementation is giving solutions to network faults in less than three minutes (statutory limit), improving the QoS significantly, but has other beneficial impacts on the utility as well with huge potential. The number of telecontrol elements and fault detectors has an impact in the area/KVA isolated and in the speed of isolation (higher penetration of telecontrol reduces the isolated KVA and allows finding the fault faster).
Two R&D initiatives: "Grid4EU" European project cofounded by European Union under the 7th Framework Programme and "BIDELEK Sareak" co-founded by the Basque Country Government has sponsored this solution designed by IBERDROLA and implemented by SIEMENS.

INTRODUCTION

The operation of the Distribution network is complex, deals with lot of information and requires fast reaction to coming events. With the state of the art technology Distribution Dispatchers work with large complex networks and a myriad of real time alarms. With that information they have to decide fast and safe how to solve coming problems and how to restore power using their available options via telecontrol, or contacting local crews to do the needed operations in the field. The job becomes more difficult under pressure conditions as in storms or bad weather. The **Automatic Grid Recovery** (AGR/ARA) is designed to help the Dispatcher work under these conditions as a "virtual operator" with safety guaranteed. AGR/ARA will help the control rooms to isolate and restore power without any human intervention, while they are doing other tasks (Operators decide which substations, secondary substations and/or switch bays are handled by AGR/ARA).

This paper explains briefly the main characteristics of the tool installed in the control systems of Iberdrola Distribucion in Spain (Siemens-Spectrum Sinaut Power 4.7) and its basis, but it also describes the practical experience of deploying AGR/ARA in a real network, lessons learnt and the main outcomes of the first years of operation in a large grid.

Iberdrola Distribution supplies nearly 12M customers in Spain (around 40% of the country) controlled from 6 EMS/DMS/OMS systems where AGR/ARA has been installed to work with the entire MV distribution network.

The tool has been designed and developed by IBD-Siemens to help dispatchers in the Control room with these main characteristics:

- Designed thinking on security.
- It works on real time isolating faults in the network and restoring as much power as possible in the fastest period of time.
- All the task are done automatically by the Spectrum 4.7 system
- Integrated/developed to handle only the MV level (Ring-Radial network) with safety guaranteed.
- It uses the telecontrol information received from Substation, secondary Substation and Switches on Pole, and send commands to them.
- It sets operator's tags in the system after isolating the faulty segment.
- It is much more effective with higher telecontrol penetration.
- But it is also it is changing some of the practices used in the utility in engineering and protections network design.

AGR/ARA OVERVIEW

The Automatic Grid Recovery is a real-time close-loop system that allows isolating faults reconfiguring the network after verifying the more reasonable alternatives to restore the service, without human intervention. The affected area is reduced as much as possible in the shortest time showing a measurable increase in the electrical system resiliency.
The scope of this Use-Case is to recover automatically as much market as possible in a short time after a "Final trip" received from the protection relay in the MV Grid. AGR/ARA gets SCADA information from the message processing and uses the real time topology to evaluate the network. Once evaluated makes decisions using this information to send the command (network control) to field RTUs. The message processing supplies the triggers, time stamp, sequence of events,...etc, and the topology evaluation supplies the connectivity, topological searches (look for feeder-head, etc.) and generates lists of affected equipment and possible switching elements. Information from human operators available in the system just like the tags ("control inhibit", "Generators",

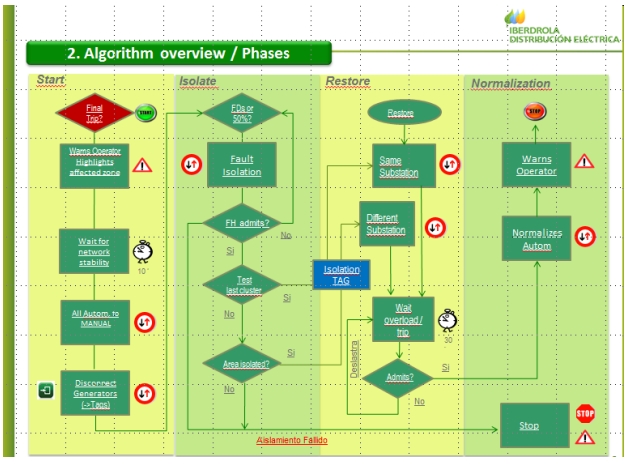
etc.) are also considered. All network controls follow the security layer for commands and evaluate switching operations as for any other command performed by a human operator.

AGR/ARA starts working just after:

- The security conditions are matched (tag to allow/reject, protection relays...).
- Circuit breaker is open / protection relay cycle is finished and inform using signal final trip.

One ARA sequence has always 4 phases:
Phase **1) Start** // Warns the operators a sequence is starting, at this moment, AGR/ARA as a virtual operator starts to handle the incident on the network.
Phase **2) Isolation** // command to isolate the area with fault
Phase **3) Restoration** // commands to restore deenergized network
Phase **4) Normalization** // restore the initial status as much as possible

This diagram describes the algorithm followed during the different phases.



A fault causing the trip of the feeder head circuit breaker or a breaker in line (recloser) to open; as a result the system detects de-energized network downstream the opened breaker (SCADA information) -> AGR/ARA analyzes the trip and triggers a sequence for isolation/restoration. If the right conditions are not matched to handle the trip (tags, security constrains,..etc) AGR/ARA discards the trip and writes the cause into a log file warning the dispatchers.

If the right conditions are matched after the final trip AGR/ARA will trigger a sequence assigning a sequence number. The first phase consists in highlighting the domain of the fault by setting it to blink in the distribution one line diagram, warn the dispatchers that the algorithm is taking control of this area, disable all local automatisms, and trip all distributed generation connected to this domain.

Then it tries to locate the fault (Phase 2) using the fault detector indicators information received in SCADA (the area pointing by fault detector will be split 50% using the breakers/switch with remote control). AGR/ARA energizes at least one time the fault area to confirm the fault.

The next step is to find one or some breakers downstream the fault, which allows restoring the power supply (Phase 3) from other feeders (AGR/ARA must be able to operate remotely the breaker and the other side of the breaker is energized). If there are more than one possible sources to resupply, AGR/ARA selects the one with more available capacity by comparing the actual current value (SCADA information) with the value the protection relay trip is configured. This is checked to avoid overloads during the restoration phase.

Finally AGR/ARA normalizes the network and brings back to original status all the elements not affect by the fault and used during the sequence (enable local automatisms, give permission to connect again generators, etc...). At this moment AGR/ARA (The "virtual operator") stops all actions on the network and informs the Dispatchers the end of the sequence.

AGR/ARA SECURITY CONCEPT

AGR/ARA was born with security and safety in mind. This has been a constant and a concern during the design of the algorithm due to the fact that it was the first time that Iberdrola was allowing the systems to send commands to the field in an automatic way and that no available references in other utilities where found in this regard.

Here are some of the basic rules considered in the design:

- All safety rules applying for human operators must apply for AGR/ARA.
- Human operators are always higher priority than AGR/ARA. (They can enable/disable and stop it at any time, and if any human action in the domain is detected AGR/ARA will stop the sequence immediately, passes control to the Operator and report.)
- AGR/ARA never energizes areas previously isolated.
- AGR/ARA will never couple networks
- AGR/ARA only works on the area enabled for it (MV radial)
- Training-course to Operators and local crews is a mandatory requirement for go

live.

Human operators have always the possibility to allow/reject AGR/ARA to run sequences and also have the possibility to stop all the sequence running by the algorithm, it means the possibility to stop one/all the virtual operators working on the network. One Virtual operator can be stopped by a manual entry or a command on the domain of the sequence. The operator is aware at any time of any AGR/ARA activity and can follow the activity of any particular sequence in detail as all actions done by the program are tagged in the general summary with the sequence number and can be filtered.

The information from operators (tags, Control inhibit,...) is very relevant to the security, and for this reason it is used by AGR/ARA to decide about the steps possibilities during the sequences.

A new sequence will not be started in a previously solved area until a predefined period of time has passed to prevent constant operations from the same breaker.

Although a final trip could have been received from a protection relay to start / handle the trips no new sequence will be started if there is missing information or it is inconsistent (some security checks are run regarding the quality bits / timestamp sent by the RTU at the protocol layer etc…)

AGR/ARA is able to detect situations (due to security rules) and decide to stop the sequence by itself warning the dispatcher, situations such as:

- Incorrect information from the protection relay cycle // final trip
- More than one sequence working on the same area
- Due to inconsistence trips
- Inconsistent topology (e.g. sometimes substation information arrives faster than pole mounted elements)
- Due to command failure after the retries (some modifications on the last release)
- Safe Circuit Breaker; > 3 trips against the same Circuit breaker

... assuring that the steps done with the available information were solid and in the right direction.

DISTRIBUTED GENERATION – AGR/ARA

Iberdrola has got a big penetration of distributed generation on some areas of MV. There is a big amount of power installed in Distribution: photovoltaic, CHP, wind turbines,… which are handled in the control system with an special tag. The big ones can be teletripped so AGR/ARA will use this capacity to disconnect the generators during the isolation phase to avoid island situations. For this kind of network, the fault detectors has being designed to inform about the direction the fault is seen and the algorithm has been adapted consequently to make use of this information which has been proven very valuable to identify the faulty segment faster. We can say AGR/ARA is prepared to work on distributed generation areas.

EXPERIENCE ON IBERDROLA CONTROL ROOMS

The system has been implemented on all Control Centers at IBERDROLA Distribution Spain - organized in 6 Systems - covering from the VHV to LV in each area, this is, around 1000 substations (100% telecontrolled), 100.000 secondary substations (13% telecontrolled), 3500 of pole mounted RTUs to supply nearly 12 million customers. Different releases of the tool have been produced and tested along several years before arriving to the current version which is operating in the whole MV distribution grid since 2013.

The first release of AGR/ARA was integrated in the control system of Toledo in July 2011 to work with a small area while the last implementation was done in November 2013, following a very conservative deployment, with strong testing sessions, and solving many problems associated with legacy substations engineering (lack of standardization). Since then it has been working as a virtual operator in all Iberdrola Control Centres in Spain for more than one year handling the entire distribution MV network.

The first results were showing only 59% of the incidents handled by AGR/ARA successfully finished inside the statuary limit (3 minutes) with the faulty segment isolated correctly and all possible network restored. In the rest of the incidents 41% no wrong action were ever recorded but sequences were not ending successfully complete due to commands failures, inconsistent information received and several other reasons that were thoroughly analyzed as shown in the next chart.

Picture - Numbers per control room until June 2012

Until June 2012	Total	Correct	Command	Signaling	System	Operation	Total	% correct	%Command	% Signaling	% System	%Operation
Centro	114	53	28	13	9	11	114	46%	46%	21%	15%	18%
Madrid	257	159	25	34	17	9	244	62%	26%	35%	17%	9%
Este Norte	73	43	21	1	6	2	73	59%	70%	3%	20%	7%
Este Sur	293	182	67	6	18	16	289	62%	60%	5%	16%	14%
Oeste	80	44	5	24	1	2	76	55%	14%	67%	3%	6%
Norte (*)	0	0	0	0	0	0	0					
	817	481	146	78	51	40	796	59%	43%	23%	15%	12%

The 41% of sequence stopped was divided in:

- 43% command errors
- 23% Protection Relay Final Trip incorrectly
- 12% Control room operators actions interfering or stopping

- 15% ARA/AGR decided to stop

As a result of this analysis some adjustments were done to the algorithm trying to improve its performance. Some of these corrections are described below:

- On the first release, command failures were stopping the sequence. To mitigate it new strategies were developed, finding another telecontrol point or retrying if none.

- The status of RTU was included to avoid considering points in telemeter error as part of the isolation / restoration strategy.

- Fault Detectors (FD) signalling has been effectively considered in the logic to find out /isolate faster the area with the fault (minimizes the number of trips during the isolation phase and the circuit breaker has to work less reducing their stress).

- Permanent /non-permanent Fault are integrated in the algorithm. AGR/ARA includes the possibility of restoring the complete circuit if it happens not to be a permanent fault.

- Logs generated by AGR/ARA at system level are translated and sent to a Web page for analysis. It gives a sequence summary and the steps done by the virtual operator. It describes the network at the moment of the trip, it describes the Area Isolate, the analysis done with the result of the FD signals, and traces the behaviour of the FD that might be working incorrectly (FD feedback)

- Include the direction of the fault in the information from the FD to facilitate the location of the fault, more relevant considering the big penetration of the distributed generation in MV.

The numbers today are very different and present 85% of the incidents handled by AGR/ARA finished successfully in less than 3 minutes.

Having this system in operation has changed the paradigm used to operate the distribution grid. Traditionally it was based in human operators supervising and controlling the network from a classical SCADA/DMS systems processing a big amount of alarms when a fault occurred and even worse in storm conditions. AGR/ARA brings a “virtual operator” to interpret fast the topology & alarms and to solve the network after a fault automatically. With the integration of OMS and mobility inside the DMS even sends the crew automatically to solve the problem in the field.

IBERDROLA BENEFITS FROM AGR/ARA

In the controversy of local versus centralized intelligence in Distribution Networks, Iberdrola has opted for the centralized intelligence on the control system.

This means Iberdrola has extended to all Distribution network in Spain without the need for an intensive investment at substation level (local approach), so the virtual operator has been introduce without a big changes at field level (Technical Benefit).

From other side, AGR/ARA helps to handle the network when one /several outages appear. It’s expected AGR/ARA to make life of the dispatchers easier, reduce their stress, and let them concentrate in managing crews to solve the outages on the fault area.

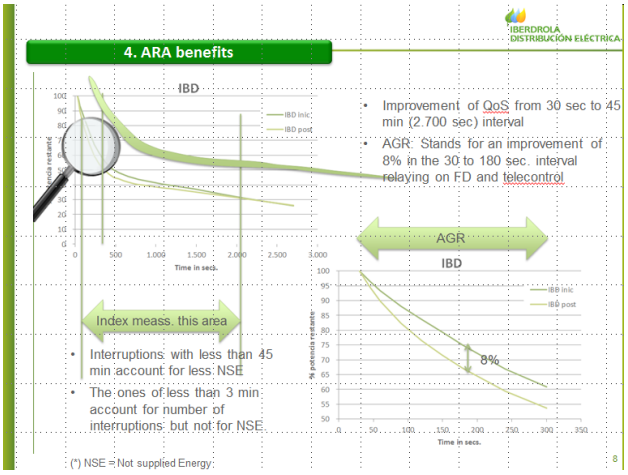
It’s wrong to consider AGR/ARA vs Dispatchers. It has proved to be a powerful tool for rapid and safe restoration, a very helpful tool for dispatchers, and it holds great potential to apply further smart grid concepts. (Human benefit)

Finally, the current solution defined by the Iberdrola Distribution network Spain integrating the AGR/ARA with the new secondary substation automation has already produced significant improvements in the QoS with the consequent increase of bonus. In addition, it provides very valuable feedback for protection system reliability and fault detectors. (Cash Benefit)

The difference in response time between Dispatchers and AGR/ARA can be significant in complex distribution networks, particularly when dealing with several disturbances at one time. (Customer Benefits)

Regarding to QoS Iberdrola had improvement from 30 sec to 45 min (2.700 sec) interval. AGR/ARA stands for an improvement of 8% in the 30 to 180 sec. interval relaying on FD and telecontrol. The percentage is calculated using the not supplied energy. It is compared one year in the past when AGR/ARA was not integrated and the values from year 2013 with AGR/ARA working in the distribution network.

Next chart shows the improvements of QoS graphically and how the curve has move inside the 3 minute solving time period.



The benefit of this "virtual operator" is important and gives benefit for several areas (technical, human, cash). All of them are enough reason for a lot of companies.

COMING SOON – AGR/ARA FUTURE

All the actions (commands) done by AGR/ARA are recorded on the OMS together with the Fault Detectors information. This gives the dispatchers the possibility to analyse the outages solved by the algorithm in an easy way where the performance of the Fault detectors can be evaluated and corrected by the protection maintenance team. It will also provide valuable information to the local maintenance as in gives detailed information of problematic areas or even for non-permanent fault the problematic points.

A new release to consider the corporate information about the Circuit Breaker age has been develop, so in the future AGR/ARA will know about the breaker limit restriction due to the age of the elements installed on field, so the number of commands and the time between them will be considered if those elements are old or new.

Having AGR/ARA in operation, and has arrived to stay in the utility, is making reconsider the protection and automation strategy. E.g why retrying locally while the program can start faster solving the network, or reconsider seccionalizing.

AGR/ARA has changed the concept. Allowing automatic commands to field elements from an algorithm in close loop has opened a new door for the future. E.g. allowing the system to keep intelligent network configuration based on loses or other security rules, implementing smart commands such as reducing the load of a transformer and many others.

As AGR/ARA is centralized intelligence can be upgraded with new requirements easily, but never forgetting security. For this reason a Test-book with strong testing is also available together with a detailed training manual.

REFERENCES

[1] Juan MARTI, 2011, "ARA – Automatic Isolation and restoration", *EPCC-11 conference*

[2] Eugenio De GABRIEL, 2014, "Control room: Automatic Isolation and restoration", *Spectrum Power User Group conference*