Upgrade and refurbishment methodologies apply to Gibraltar Electric Authority's power distribution system project

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ABSTRACT

This paper describes the choice in the project methodologies and taken to integrate the refurbishment and upgrades of the Gibraltar Electricity Authority HV grid and substations with clear limitations in the possible impacts.

GEA has decide to strongly invest on refurbishment, replacement and upgrade of the actual Distribution grid to improve it efficiency and reliability.
As introduction a brief description of the original GEA grid and the main project's constraints and how this has influence the grid architecture design and the project management choices.

In the second part, the authors present how the optimized replacement plan for the various substations and the implementation strategy has been finalized using grid simulation tools and evaluating each choice impact on the global project and future stages. The integration of the refurbished and new parts is detailed and how these new architectures (loop management, substation design, adaptive automation schemes, ...) and features (protection functions and settings, , partial Generation management, ...) and architectures have impacted the existing parts is also detailed with the respect of the continuity of service and the minimization of the environmental impact.

The third part presents the methodologies of Tests in the factories and on Site and explain the capabilities given to GEA to define the priority of evolutions based on GEA grid constraints and requirements.

As conclusion, some GEA project key features and lessons are briefly explored and described with some potential impact on the future GEA grid.

1° INTRODUCTION

Gibraltar Electricity Authority (GEA) is the Gibraltar organisation managing the HV/LV electrical grid (11 kV/6.6 kV/415 V). Gibraltar territory is of 6.8 km^2 with approximately 20,600 customers as at December 2017 (85% residential and 15% industrial/commercial), and the electricity is generated by local Diesel generator sources as GEA grid is islanded from the European grid. Over the next 10 years, projections show a 50% growth of the consumption linked to the new needs from harbour connection, data centers, airport extension, land reclamation projects and healthcare building increases.

In 2010, the GEA grid was an aging underground HV/LV network with many supply and power failures, increasing over recent years (in 2013 more than 52 unplanned outages were experienced, with a duration longer than 90 minutes.). Most power outages were due to generation faults whilst a smaller percentage were due to HV network faults. Each generator fault takes approximately 10 minutes to resolve with HV cable faults significantly more resulting in imbalances in the power pool leading to black outs.

2° GEA HV GRID & RETROFIT AND UPGRADE PROJECT CONSTRAINTS

In 2015, GEA initiate a plan to refurbish, expand and prepare the future of the GEA grid with respect to the continuity of customer services, integration of new technologies (smart and flexible grid, renewable generation, …) and a clear target to strongly reduce the System Average Interruption Frequency Index (SAIFI) and the System Average Interruption Duration Index (SAIDI). GEA specifications clearly indicate the need to have the most flexible architecture for a step by step migration based on customer quality level and GEA Grid management expectations.

Before upgrading and replacing the GEA HV/LV grid and substations, the selected supplier has simulated working scenarios to ensure that at each step the power delivery will be maintained and future GEA grid architecture evolutions will be simplified. This has imposed some specific choices for the project management and the planning definition to allow in the coming years a maximum flexibility for future new generation sources and energy management.

2.1° GEA existing HV Grid

Gibraltar Electricity Authority's HV grid (11 kV & 6.6 kV) is based on an historical architecture with a mix between mesh structure and open rings with mostly aged equipments. The HV Circuit Breakers are mostly not-

motorized or remotely controlled and near all IEDs (Protection, Measurement and Control devices) are analogue. 2 Power Diesel generation plants delivering energy to GEA grid are over 35 years old and face environmental constraints of the dry and salted atmospheric conditions around the “Rock”.
The structure of the various HV/LV substations grids has evolved over the years and turn from the simple multi-ring structure to a complex mesh design with near no redundancy and security management.

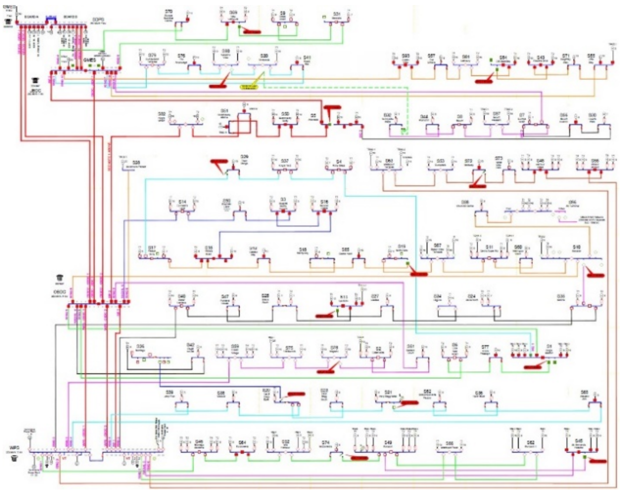

Figure 1: Gibraltar Electric HV grid (2016)

The aims of the GEA grid refurbishment and upgrade project are:

- Upgrade or replace the equipments connected on the GEA grid (CBs, Transformers, protections, measurement units) with the recent technology adapted to the future needs.
- Restructure of the existing HV grid to simplify and optimise the power delivery to final customer with a strong reduction of the SAIDI/SAIFI
- Avoid all local actions and replace them by remote capabilities with an efficient SCADA system and the associated communication network
- Prepare future consumption growth and introduction of renewable sources

All these must be achieved without major black-out and the lowest impact on the customers.

3° GEA HV GRID RETROFIT AND UPGRADE PROJECT

The strategy applied to the upgrade and refurbishment of the GEA grid is based on a step by step approach, with three main directions:

- The HV Distribution Center substations (5)
- The HV/LV rings (14). Decision was taken to consider each ring as a single project.
- The GEA HV & LV Dispatching center.

Note: GEA HV generator project has been managed separately. Interfaces of the GEA HV power plant data is part of the GEA HV Grid retrofit & upgrade project.

3.1 GE HV project solution approach and methods

Each refurbishment/retrofit HV Distribution Center Substation or HV/LV ring is based on the same methodology:

1. Expertise on site of the existing devices (primary, secondary, power supply, telecommunication, etc..) to evaluate the work plan
2. Based on the site work plan, use of simulation tools to evaluate the impacts of each phase and define the path with the lowest impact regarding customers and with the highest security
3. Upgrade/replacement of primary devices, protection, RTU, communication LAN & WAN, etc. and associated engineering.
4. Factory acceptance tests and validation
5. Implementation on site and test in-situ

GEA HV grid project consider the following supplies:

- Retrofit/replacement of the primary devices (Circuit Breaker, Switch, Auxiliary power supply, cabling, …),
- Communication Fibre Optic Ethernet based networks connecting the various equipment, protection devices, Gateways and RTU/PLCs with redundant capabilities,
- a SCADA system connected on IEC 61850 to allow the operator to visualise and control the connected equipment. It gives capabilities to adjust on-line the various protection & automation scheme settings.
- New automation schemes (distributed and global) to reduce impact of any grid failure, power supply constraint or unplanned even on the customers and automatically restructure GEA grid.

Compared to many projects, GEA HV grid upgrade and refurbishment project’s greatest difficulties are linked to the high density of the GEA grid, the inherent constraints of the power supply continuity and to the limited on-site working slots. These have imposed the greatest anticipation level on this type of project, simulation to identify any future incompatible architectures and maximum cooperation between the suppliers of all project elements, the site teams and GEA.

3.2 Architecture of the HV grid solution

The strategy applied in collaboration between GEA and the various suppliers has been to determine the best electrical topologies in regard to the existing grid and the constraints of power supply in Gibraltar; Cost and future evolutions are also elements of the equation.

The result of the work, the analyse of the existing elements and the various simulations has been a HV grid based on a group of five (5) primary HV Distribution Centers linked by seven (7) parallel 11 kV cables to the new Power Generation station (NMPS), which will be the only power generating plant in Gibraltar. From the HV Distribution Centers, a series of HV open rings power the LV customers through HV/LV substations (figure 2).

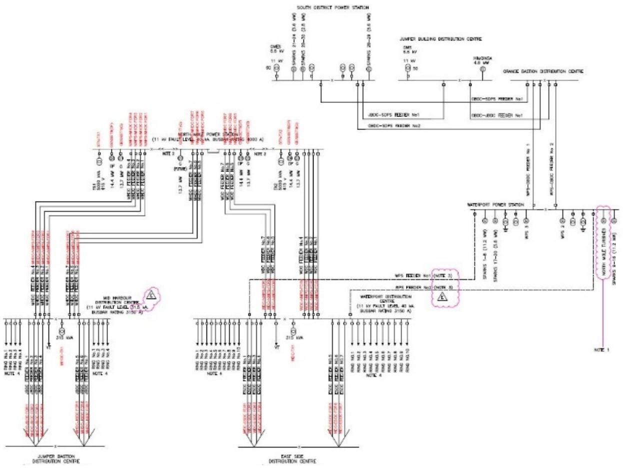

Figure 2: GEA final HV grid & Distribution Center substations

3.3 HV Distribution Center substations

As part of the GEA HV grid, the Distribution Center substations (DC) have been fully expertise and their equipments have been when possible upgrade or replaced depending of the age of them, their future use and their potential performances.

In each Distribution Center substation, three main programs have been applied:

- Circuit Breaker and switching devices
- Protection, Measurement and Control equipments
- Auxiliary services and communication elements

3.3.1 HV DC substation Circuit Breaker

For applications and performance needs, these CB have to be all motorized and their switching time lower than 150ms. Based on these requirements and the known obsolescence, near half of them in Distribution Center substation have been replaced by a later generation model and for the other specific additional modules to motorised them have been added to the manual switching block.

The upgrade and retrofit of the existing CB have been done directly in Gibraltar with pre-industrialised modules to reduce the unavailability time and limit the costs.

Figure 3: GEA Mid-Harbour HV substation

3.3.2 HV DC substation IEDs & ancillary elements

In the same way, the existing Protection, Control or Measurements units have be replaced by IEC 61850 Digital IEDs and the CB LV cabinets have been rewired to integrate:

- Digital protection relays (HV multi-function feeder Sepam and Differential Cable protection MiCOM) on the HV interconnector incomers,
- Digital OC protection relays (Sepam) and Automatic Self Reconfiguration PLC (MiCOM C264) for the outgoing HV ring feeders.
- Various equipment mainly Fast Load Shedding PLC (MiCOM C264), IEC 61850 switches, Gateway/SCADA server, Time synchronisation GPS based, Internal Arc Fault protection (VAMP 120) etc.

All Distribution Center substation equipments are connected over an IEC 61850 optical fibre redundant ring giving the highest safety level for data communication and distributed automation and a Gateway/SCADA server connects Distribution Center substation to GEA SCADA/Dispatching Center

In addition, a specific IEC 61850 redundant optical LAN is used to interconnect all HV Distribution Center substation dedicated RTU/PLC for the intelligent Fast Load shedding and Load Restore Automation schemes (iFLS)

The Distribution Center substation auxiliary power supply and ancillary services have upgraded to the new implemented technology and additional security and safety modules.

3.4 HV/LV substations & ring architecture

As part of the GEA HV grid, the various HV/LV substation and associated grid architectures have been fully expertise and the grid simulation tools have help to define in conjunction with the associated Distribution Center substation:

- the optimum HV ring architecture, and which cable to be used or isolated
- HV/LV substation protection & automation plan & schemes in line with the expected performances for the HV ring management.
- Global GEA Fast Load Shedding & Load Restore automation plan.

3.4.1 The HV/LV cables and ring architectures

The main action conducted during the GEA HV project has been to determine the characteristics of each cable interconnecting the various substations and define which ones are be kept active, need to be replaced achieving customer requested performances and the last one maintain on site but lock on open (possible use for maintenance purpose)

The final result is a pure series of HV open rings instead of the previous meshed architecture (figure 4).

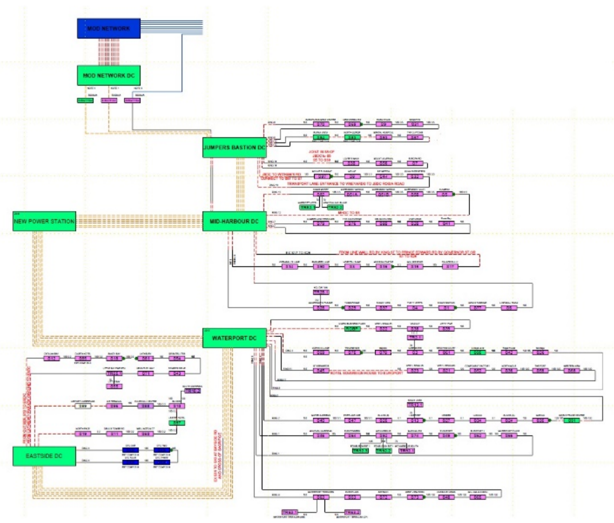

Figure 4: GEA HV final grid architecture

3.4.2 The HV protection plan

As the HV distribution grid interconnecting HV/LV substation will be restructured to create clear un-interconnected open rings instead of the existing meshed structure, the HV ring protection plan was evaluated. The original one was based on a mixed between Over-Current relays (50, 51, 50N, 51N), some OC fault detectors and HV fuses. The existing selectivity criteria were inadequate to provide the required protection selectivity and generate large black-outs and grid instability. Protection studies have been done using simulations tools DigSILENT and Schneider Electric RTDS simulator. These has help to choose the appropriate devices and fixe the protection settings in a global approach.

3.4.3 The HV/LV substations

In conjunction with the Distribution Center substations, actions done at HV/LV substations as they strongly and directly impact the final GEA customer have been focused on

- Retrofit/upgrade/replacement of the existing switchgear when possible (motorised CB or IS),
- HV feeder protection (Sepam relays) when consistent and coherent with the primary devices, the CT sensors. Some Fault Passage Indicators are still in place and will be replaced by IEC 61850 compliant protection devices in line with CBs upgrading,
- HV/LV transformer OC protection (Sepam relays). Some HV fuses have been kept and will be replaced as secondary substation switchgear is upgraded.
- Addition of RTU/PLC (MiCOM C264) in HV/LV substation to perform the Automatic Self-Reconfiguration scheme and data collection.

Figure 5: GEA HVLV distribution substation (Cumberland)

All HV/LV substation RTU/PLC from a HV/LV open ring are connected on the same redundant optical LAN with the HV Distribution Center feeders. In complement, in each HV/LV substation and at HV feeders, LV loads and equipment topologies are collected by PLC and shared on a IEC 61850 redundant optical LAN.

4° GEA HV project test methodologies

The GEA project acceptance tests are split in two steps:

- The Factory Acceptance Tests (FAT) run mainly in Schneider Electric premises (UK & France) for each module;
- The Site Acceptance Tests (SAT) done on site (Gibraltar) with all available equipments.

GEA representatives have agreed and reviewed the test plans (FAT & SAT) and participated to all FAT & SAT tests.

4.1 GEA Project Factory Acceptance Tests

Factory Acceptance Tests (FATs) are major project milestones done in the various factories where the products and/or solutions design, quality and performances can be demonstrated in accordance to the reference agreed documentations.

To facilitate the FATs, as most of the equipments were on site (refurbishment of existing ones), simulation devices were used to create missing information (injection box, contact case,) and to achieve automation schemes and checks their performances, the use of IEC 61850 messages allows ensure perfect simulation and inter-operability of the various schemes along all GEA HV substations & grids.

4.2 GEA Project Site Acceptance Tests

The Site Acceptance Tests (SAT) are run at equipment levels (new or refurbished) and systems levels. Following the GEA project document, SAT include the following tests:

- Visual check & tests including conformance documents and all necessary support documents (user & Maintenance manuals, compliance certificates, data sheets, wiring & cabinets schemes ...)
- Wiring tests (product & cubicles) and Communication tests (Substation LAN, Grid LAN & SCADA LAN)
- Single Functionality and setting checks and tests
- Global Functionality and setting checks and tests
- IHM displays for Control & Maintenance

The Site tests are run in two strategies:

- Nominal use of the different elements and global installation
- Tests under constraints to check the conformance with the customer requirements

As for the FAT, as some elements may miss or being not available, simulation equipments based on physical devices such as injection box or virtual IEDs using the IEC61850 capabilities.

All Site Acceptance Tests are agreed by GEA representatives with associated signed FAT reports.

5° LESSON LEARNED AND CONCLUSION

Today the GEA HV grid refurbishment is on-going with 5 Distribution Center (DC) substations and 3 HV/LV rings delivered and commissioned. Whatever is the time, some key features and lessons have been already identified and could be decline for any other similar utility grid retrofit projects.

- At protection level, the benefit or having a preliminary study before deciding which protection features will be implemented has been a strong advantage especially for the cubicle design, the sensors adaptation, the cabling and more important for the Site test plan (SAT).
- Use of simulation tools, analyse of the existing and dedicated engineering tools have been corner stone of the GEA project success and will make it real and successful.
- IEC 61850 communication represents a key evolution for the future of HV grid and open many new opportunities and potentials to make a better and more efficient use of GEA grid and has help to reduce some phases of the project leading and delivering time.

Renovation and upgrading of an existing HV grid is a challenge that the use of normalised products and solutions make possible at reasonable cost. These standardised procedures and methodologies make possible and simple the evolution over the entire duration of such project (5 to 7 years) with efficient and secured final results.

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