AUTOMATIC NETWORK RECONFIGURATION – SPLIT AIRPORT (CROATIA)

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ABSTRACT

Split Airport is an exceptionally important and sensitive consumer. SS 10/0,4 kV Airport 1 and 2 have the possibility of supply from two SS 35/10 kV. During usual operation they are supplied from SS 35/10 kV Divulje, and in case of fault or other reasons they are supplied from another source - SS 35/10 kV Kastela. Split Airport also has its own generators. The duration of switching from one to another source depends on time of manual switching of the dispatcher and availability of the operating staff, and is measured in minutes. In order to reduce the outage time to a minimum automation and remote control equipment (remote terminal unit - RTU with PLC functions) was installed to perform the automatic reconfiguration function. IEC 61850 communication standard is used for communication between the two RTUs each installed in one of the 10/0,4 kV SS. The main function of the automatic network reconfiguration system is power supply loss detection (by voltage or fault indicator, SCADA, or combination of these and switch status) which triggers the Automatic Network Reconfiguration (ANR) algorithm that performs all the necessary switching operations for supply restoration without the influence of dispatcher. The applied technical solution serves as a model for supplying exceptionally important and sensitive consumers such as hospitals, courts, jails or to just provide and offer more reliable power supply to all customers.

INTRODUCTION

SS 10(20)/0,4 Airport 1 i 2 supply the power to the electrical grid of the Split Airport, which has the possibility to get the power from two sides respectively, SS 35/10 kV Kastela i SS 35/10 kV Divulje. Besides double power supply possibilities the Split Airport owns backup diesel generators. In the normal working situation SS Airport 1 and 2 are supplied from the distribution grid from the SS Divulje, while in the case of power loss the supply is switched to SS Kastela. Due to the large short circuit currents, or large capacitive currents in case of earth fault a long term parallel power supply scenario is not possible. Power supply switching time is limited to manual switching procedure from the operators in the dispatch center in Trogir or Split and can be in the period of tens of minutes depending of their availability.
To fully shorten the power supply switching time for priority customer like Airport, Substation Automation System (SAS) was installed with the main function of automatic network reconfiguration. Both SS Airport 1 and 2 are equipped with SAS based on RTU that collects all the process data from the SS. The two RTUs communicate to each other using IEC 61850 communication standard and exchange the switching states of the two SS. Communication to the SCADA/DMS system in the DC Elektrodalmacija Split is also implemented using optical communication and IEC 60870-5-104 communication standard.

Main function of the installed system is to detect the fault on the incoming feeders from the 35/10 kV SS or on the connection feeder between the two SS (thru fault indicators) and perform automatic network reconfiguration thus ensuring power supply from the different available source. Algorithm also includes all necessary interlocking actions to ensure safe execution of the algorithm. Execution time of the ANR algorithm is within couple of seconds from the fault on the incoming feeders or connection feeder which are considered as triggers of the ANR.

This project (ANR) presents a solution that can be considered as Smartgrid and is to be considered to be a model how to solve reliability of power supply for the priority customers such as hospitals, courts, jails, airports. Such solution can be offered to all customers who would like to make their power supply more reliable.

AIRPORT POWER GIRD

SS Airport 1 was built back in 1979 as 10 kV SS consisting of two transformers (2 x 630 kVA), two measuring bays, two active feeders and one reserve feeder. On the incoming feeder a circuit breaker was installed as in transformer bay, while on the connection feeder to SS Airport 2 only an isolation switch was installed, figure 1.

SS Airport 2 was built in 1983 as 10 kV SS consisting of two transformers (2 x 630 kVA), one measuring bay, two active feeders and one reserve feeder. Circuit breakers are only in transformer bays while in all other just isolation switches, figure 1.

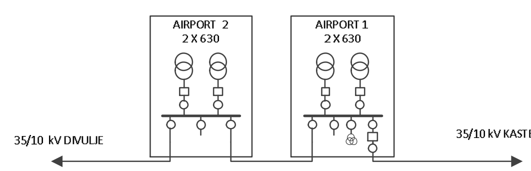

Figure 1. Single line diagram – Split Airport SS 1 and SS 2

Power supply possibilities

In normal operation both SS Airport 1 and Airport 2 are supplied from the SS 35/10 kV Divulje, see figure 2. While switching the power supply to the SS 35/10 kV Kastela by manually closing the breaker (Incoming feeder from Kastela) in SS Airport 1 a short parallel operation is performed (between SS 35/10 kV Divulje and SS 35/10 kV Kastela). Parallel operation is then cancelled by opening the isolator in the nearby SS Divulje 9 (Jadro). In the procedure the SS 9 is also switched to SS 35/10 kV Kastela because of the isolator being at the side of the SS 35/10 kV Divulje.

In the case of power supply failure from SS Divulje switching to SS 35/10 kV Kastela can also be performed by supplying all the loads all the way to SS 35/10 kV Divulje, except when the loads are extremely high. If the fault is on the incoming feeder from SS 35/10 kV Divulje then the isolation of the fault is done first (same as the power supply was from SS Kastela). If you would like to switch just SS Airport 1 and 2 to SS 35/10 kV (without SS Divulje 9) then it is necessary to prepare all the grid state in the power less state. All the operations were done by operation staff manually with coordination with the dispatching team in Trogir or Split.

Due to the SS switchgear and the grid configuration it was usually to power down the customers so to have the possibility to prepare the grid for reconfiguration and supplying the Airport and all was taking too long from the power supply reliability point of view.

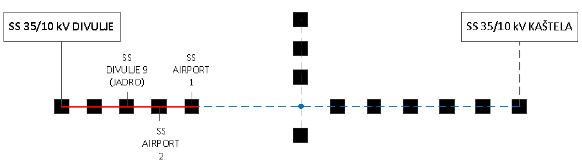

Figure 2. Normal operation state of the 10 kV distribution network

Airport backup power supply

In case of voltage loss on LV busbars in the SS Airport 1 and 2 the start of the diesel generators occurs. The first generator (640 kVA) starts within 7s from the loss and powers the SS Airport 1 and within 14s second generators (640 kVA) takes over and powers the rest of the Airport grid. In SS Airport 2 the power supply is taken over by a generator (1000 kVA) within 21s. Power supply switching is done by changeover breakers disabling the possibility to have parallel supply from the grid and from the generators.

If the power los occurs and comes back within the period of 7s, generators remain working and are turned off in the period of 60s.

However the Control tower doesn't feel the power outages as it is powered from the UPS of certain autonomy.

RELIABILITY OF SUPPLY

Reliability before ANR

DSO archives all the outages longer the 3 minutes so in the last 6 years (2006. – 2011.) there were 36 outages that were in average longer than 100 minutes, table 1.

Table 1. Outages in SS Airport 1 and 2

Outage type	Nr. Outages	min	Cause
Planned	1	8	Fault clearing
Planned	2	200	Maintenance
Planned	4	1248	Grid construction
Not planned	8	358	Gris congestions
Not planned	21	1854	Fault
TOTAL	36	3668	
Yearly average (6y)	6	611	

Planned outages were 7 with the average period of 208 min. Not planned was 29 (6/y) and lasted in average 76 min. Almost half have lasted almost 30 min. These values can be presented thru SAIFI and SAIDI system reliability indicators. Short outages (less the 3 minutes) are not archived and thus there is no information about number of them. Planned outages are usually due to maintenance or by grid constructions. All manual operations are conditioned by local operators from Trogir in coordination with the dispatching operators from Split.

Reliability after ANR

Reconstruction of SS Airport 1 and 2 included the installation of new primary equipment based on new distribution vacuum switchgear with remote controllable apparatus which are the prerequisites for the ANR.

After reconstruction planned outages are more easier to perform and in case of unplanned outages much higher is the availability of the power supply to the Airport due to the ANR and automatic switching to different power supply point. Only in case of outage of both incoming feeders (from SS Divulje and SS Kastela) and faults at both of the Airport SS the power outage will be permanent and can't be tackled by ANR algorithm.

Taking into account modern vacuum switchgear and having short cable between the two SS rather small is the possibility of a fault in one of the Airport SS. In case of other faults ANR algorithm shortens the power outage in the periods of just couple of seconds thus meaning that these outages are not recorded at all in the DISPO system (developed in accordance to the norms IEEE Std 1366-2003 and EN 50160).

It is expected to be out for half the duration of forced outages (interruption duration) kept under 3 minutes. Therefore, it is expected to improve (decrease) the reliability index SAIFI for forced outages of 50%. Also, there will be an appreciable improvement in SAIDI.

ANR SYSTEM ARCHITECTURE

SAS that performs the ANR functions is based on RTU which are installed in both SS Airport 1 and 2, figure 3. Both RTUs have possibility to run PLC functions according to IEC 61131-3 that perform the ANR algorithm. Process information is collected by RTUs and are used and processed in the ANR algorithm. Outputs of the ANR algorithm are commands that are then issued to certain switchgear to perform the network reconfiguration.

Communication between the two RTUs (two SS) is thru optical connection based on IEC 61850 communication standard. Thru this communication channel all information is exchanged between the two SS. Each RTU has the connection to the SCADA/DMS system in DC Elektrodalmacija in Split. This connection is done also by optical connection but based on IEC 60870-5-104 communication standard. Thru this connection the dispatcher has all the information from the Airport SS at glance and can also perform manually operations to the SS switchgears.

To enable the customer the possibility to have the overview of the switching state of the grid and the status of the ANR algorithm a special computer is installed with the main function to monitor both the SS. The communication to this computer is via optical RS232 interface based on IEC 60870-5-101 communication standard. Airport operating personnel do not have any rights and the possibility to control none of the switchgear.

The system also provides local graphical user interfaces thru touch screen graphical panels installed on the swing frame of the cabinet. Graphical user interface communicates to the RTUs over RS232 MODBUS RTU communication standard. The graphical user interface enables the operator single line diagram of the SS, list of alarms, table of ANR information, measurement table and local control of the ANR algorithm.

All installed equipment of the ANR system is powered from the UPS system with the autonomy of 30 minutes. Longer autonomy is not needed as in case of the long power outage the power supply is provided thru the backup generators.

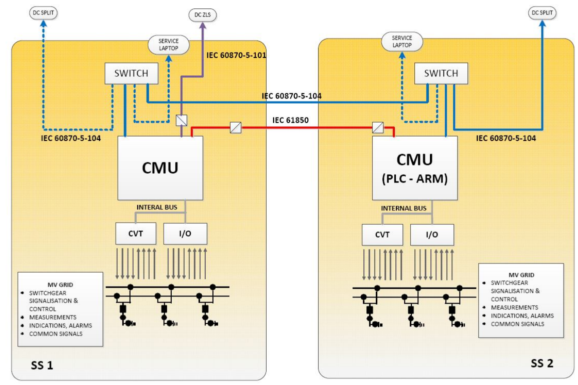

Figure 3. Architecture of the ANR system

ANR ALGORITHM

ANR Algorithm is performed in the PLC environment of the RTUs in SS Airport 1 and 2. The RTU in SS Airport 1 is the Master station and performs most of the ANR algorithm while RTU in SS Airport 2 is called the Slave station as just some part of the algorithm is performed there. Slave station function is to collect process information from the SS and send them to Master station which then performs the ANR algorithm. Afterwards the commands are sent to Slave station to open or close the switchgear on the SS.
ANR algorithm is consisting of the following blocks (structures):

- Grid start state calculation block,
- Start conditions calculation block,
- Safety interlocking calculation block,
- Reconfiguration sequence block.

ANR algorithm is processed cyclic in period of 200ms. Due to automatic reclose sequence in the transmission grid (0,4 – 0,8s) the start of the reconfiguration sequence is delayed for 2s. Having in mind the start times of the backup generators the expected time for ANR executing is 5-10s.

Grid start state calculation block

Main function of the block is to cyclically calculate the state of the switchgear of the Airport power grid. The inputs to this block are the states switchgear from the two incoming feeders (SS Divulje and SS Kastela) and the connection feeders. Depending of these switchgears there are 5 start grid states defined for the ANR algorithm. The grid start state calculation is necessary as the reconfiguration sequences is different depending of the start state of the grid and because the check if the grid is in the right predefined sate.

Start conditions calculation block

After the grid is in the right predefined switchgear state it is necessary that the start conditions are met. The start conditions are taking into account the following two cases:

- ANR equipment conditions,
- Grid conditions.

The first tackles the issues regarding the correct functioning of all the necessary ANR system devices, while the second takes care that there are no faults on the relevant feeders and that the voltage is present at the busbar of the two SS.

Safety interlocking calculation block

Safety interlocking enables the blocking (starting) of the reconfiguration of the grid if one of the events occurs.
If some of the apparatus are in earthed positions or if one of the Local/Remote switch is in Local position then the safety interlocking is turned on and the ANR algorithm is blocked.

Reconfiguration sequence block

After checking all the start conditions and safety interlocking and if the grid is in one of the predefined state the ANR algorithm is armed. If Armed means that the algorithm will perform automatic reconfiguration if one of the triggers occurs. The triggers for the ANR algorithm are:

- Voltage loss on one of the incoming feeders (from SS Divulje and SS Kasela),
- Fault indications in one of the incoming feeders (from SS Divulje and SS Kasela),
- Fault indications in one of the connection feeders (connection SS1 to SS2).

The faults are considered short circuit fault an earth fault.
If one of the triggers occurs then the algorithm calculates depending of the start grid state the right commands to the apparatus and performs automatic network reconfiguration.

If the reconfiguration was executed (successful or not) the information is generated and sent to the SCADA/DMS system along with the grid state number (1-5).

ANR ALGORITHM OPERATION

The complete ANR system can be operated in 2 regimes:

- Automatic operation,
- Manual operation.

Automatic regime meaning that the ANR algorithm is enabled and if armed will perform the automatic reconfiguration if the trigger occurs. In this case none of the remote commands are accepted from the SCADA/DMS system to the switchgear in the relevant feeders.
Manual operation considers that the ANR algorithm is disabled and that the switchgear can be normally operated remotely from the SCADA/DMS system.
For regime selection (Automatic/Manual) there are 2 switches, remote on the SCADA/DMS system and local on the graphical user interface in the SS Airport 1, all depending of the Local/Remote switches on both of the SS respectively.

CONCLUSION

This paper describes a solution that can serve as an example of solving the supply of important and vulnerable consumers such as airports, hospitals, courts, prisons, etc. or as a solution offering increased service reliability.

Until now, there was no experience in implementing ARM at Croatian DSO. This SmartGrids solution is modern technical solution that makes the appropriate primary equipment, remote station with PLC functions, fault indicators and voltage indicators, communication equipment (IEC 61850) and embedded logic.

The system does not depend on communication with local dispatch center already does automatic reconfiguration of the network. Chosen algorithm and the lock and communications solutions guarantee a safe and successful operation of the system.

The implemented system will bring benefits to insuring the necessary power supply to the Split Airport thus shorting down the system outages and lower the wear to the reserve generators of the Airport.

It is expected to be out for half the duration of forced outages (interruption duration) kept under 3 minutes. Therefore, it is expected to improve (decrease) the reliability indice SAIFI for forced outages of 50%. Also, there will be an appreciable improvement in SAIDI.

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