

NETWORK ISLANDING – A REAL EVENT

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ABSTRACT

One of the main nightmare scenarios regarding Distributed Generation is islanding. In that event, the electrical Utility ceases to have control over the frequency and voltage levels in the island. However, it is still responsible for the quality of service rendered to its clients. To prevent the occurrence of islanding a protection function is used. In the Portuguese case only frequency protection is directly used for this purpose. Despite having anti-islanding protection in all DG an islanding situation still occurred in Portugal during the year of 2011. Due to a fault a substation was disconnected from the network, however, the DG connected to that substation did not trip forming an island in which voltage was maintained at a low level (90%Vn) and frequency at normal levels. The DG feeding the substation was comprised of two thermal generation plants. These DG are connected to a factory and are able to form an island with the factory's loads, however, the islanding "mode" should only be activated in the case of a disconnection of the DG from the network.

In this paper the events leading to the network disconnection of the substation are presented with the aid of disturbance records. The transient evolution of voltage and frequency immediately after the fault is shown. The estimated behaviour of the DG during the islanding situation, and its elimination is also presented.

Finally, several comments regarding data acquisition necessary for "post-mortem" analysis of DG related islanding situations are made. EDP has managed to persuade the government and most DG to accept changes to law regarding the necessity of information gathering at the DG facility.

INTRODUCTION

This paper's objective is to present an actual island formation event that occurred in Portugal. The network's topology and state prior to the islanding event is addressed in the first chapter. Afterwards, the events leading to the island formation are presented. The operation of the networks is addressed in the next chapter before explaining the network restoration process. Finally the actions taken after the incident are presented and several comments on the necessity of reliable data are made.

NETWORK BEFORE ISLANDING

The network, where the islanding incident occurred, is constituted by substation 1 (SS1) which is connected to the

remaining network by a 60kV line to SS2. There are two thermal units connected by a 60kV line to SS1.

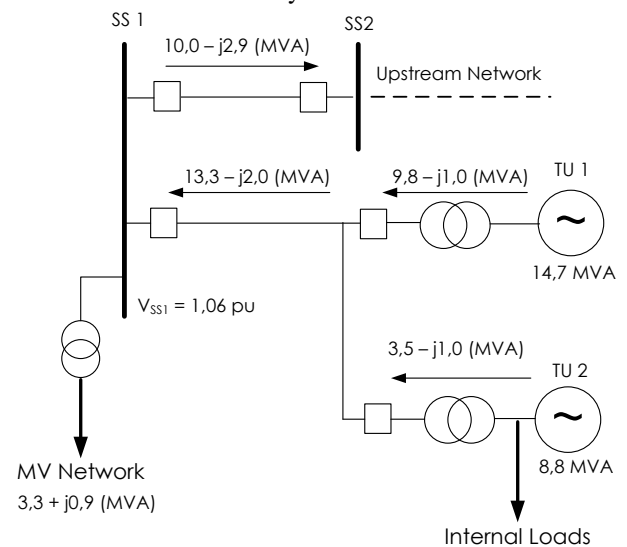


Figure 1. Network before islanding

Thermal Unit One (TU1) is a pure generation plant while TU2 has significant internal loads. Both units are prepared to work in island if the circuit breaker that connects them to the grid opens and only in that circumstance, according to the plants operators. This is meant to ensure that the thermal process is not, significantly, affected by network faults and that the plant is able to reconnect to the network as soon as the voltage returns to standard values.

The neutral arrangement for the 60kV network in Portugal is solidly grounded. However, the neutral is grounded solely at the EHV/60kV substations. The transformers of both thermal units are not connected to ground in the 60kV side.

In the moments prior to the islanding the power flow through the network was the one shown in Fig. 1.

ISLAND FORMATION

On a spring day in the year of 2011 a phase-to-ground fault occurred in phase A of the line between SS1 and SS2. The line distance protection on SS2 detected the fault in zone 1 and tripped the breaker in 0,14s. The under-voltage protection at TU1 and TU2 did not trip because the phase-to-phase voltage decreased to 82% V_N, at this voltage the protection would take 1s to trip.

The transformers of SS1, TU1 and TU2 have isolated 60kV neutrals so there was not enough zero sequence current to trip the line protection in SS1.

After the breaker in SS2 opened the fault remained in an isolated neutral system with an almost zero fault current, which led the fault to self-extinguish ([1]). After this

moment an island had been formed. The phase-phase voltage reached 100% V_N after the breaker trip at SS2 (figure 3).

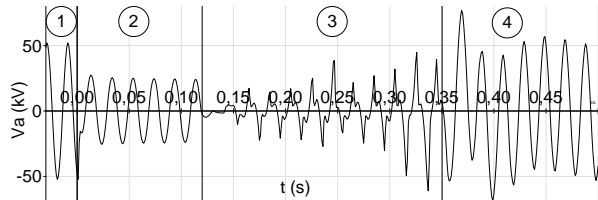


Figure 2. Phase A voltage seen in the 60kV busbar of SS1

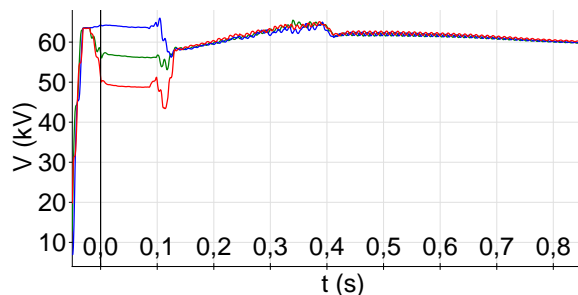


Figure 3. Phase-to-phase voltages seen in the 60kV busbar of SS1

Figure 2, which depicts the voltage in phase A of SS1, helps to clarify the sequence of events:

- Zone 1 – pre-fault
- Zone 2 – phase-to-ground fault fed by SS1 and SS2
- Zone 3 – phase-to-ground fault fed by SS1 in isolated neutral
- Zone 4 – post-fault after the fault self-extinguished

In the end SS1 was separated from the network by the line breaker opened in SS2.

After the formation of the island the frequency started to rise because this part of the network was exporting about 10MW to the upstream network ([2]). The frequency variation for the first second of the island formation is shown in figure 4.

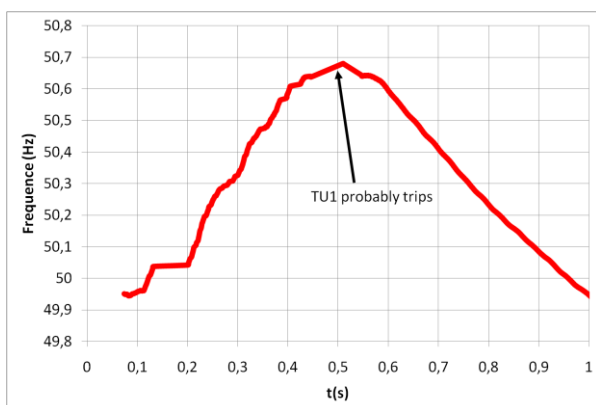


Figure 4. Island frequency in the initial stages

There was an automatic reclosure attempt by the line protection in SS2 0,3s after the trip. However, the order was cancelled by the synchro-check because there was already a large phase difference between line and busbar voltage.

The frequency continued to rise up to 50,7Hz and at this point it began to decrease. This was probably due to the trip of TU1 by the over-frequency relay at the connection point to the grid, which was set at 50,3Hz (in accordance with older regulations). The trip may have taken 0,2s (the frequency 50,3Hz occurs 0,2s before the trip) to be concluded due to the protection's internal frequency measurement algorithm and the circuit breaker opening time.

Several days after this incident, the operator of TU1 and TU2 supplied its events records. It was shown that there had been a trip by over-frequency protection in TU1 at that day. However, the records were not time synchronized which prevented the direct comparison between the TU1 records and the SS1 records. Unfortunately, the disturbance records had been replaced by newer ones due to the lack of storage capacity of the protection unit.

TU1 trip allowed the client's facility to continue to operate and to reconnect to the network at a later time, when the island situation had been undone.

The over-frequency relay of TU2 did not trip because it was set at 51,5Hz in accordance with newer regulations. After the TU1 trip the frequency starts to decrease reaching 49,95Hz at the end of the disturbance record. This sudden decrease maybe due to a lower inertia of TU2, however, due to the lack of data from the facility it was not possible to confirm this hypothesis.

SS1 doesn't have a continuous frequency register with enough time definition to allow the detection of these phenomena. So, it is not possible to present the frequency after the initial fault (the data of figure 4 was calculated from the disturbance record of the initial fault – figure 2).

OPERATION DURING ISLAND CONDITIONS

After the island formation there is a lack of information because the disturbance records are limited in time. However, from the disturbance record taken at the instant of the island break-up it is possible to determine the steady state situation of the island by using the pre-event data. The power flow is shown in figure 5.

In the estimated steady state condition SS1 MV loads were being fed by TU2. However, TU2 was not supplying reactive power and therefore the voltage at busbar 1 was about 83% of the nominal value. In the MV level the voltage was about 90% V_N .

During the operation in island condition the voltage supplied to the costumers was below the levels of EN50160. This meant that quality of the supply was not being assured although it is solely the responsibility of the DSO. If there had been complaints EDP would probably

have had to take responsibility although it did not contribute in any way to the island event.

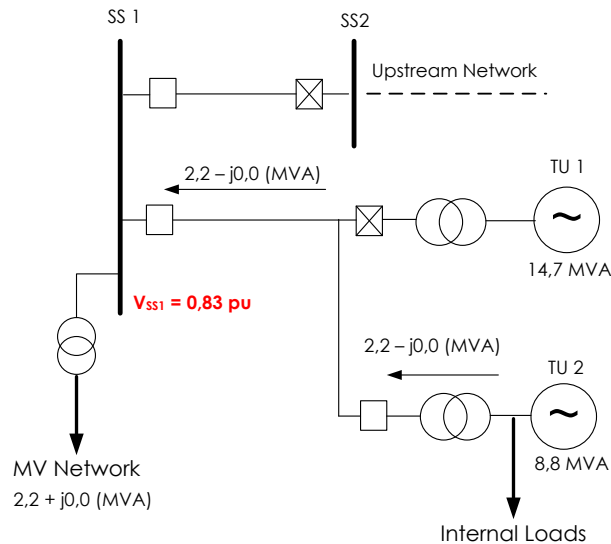


Figure 5. Steady state power flow after islanding

The frequency was inside the standard value range (49,9Hz) just before the island was reconnected to the network.

The island endured for 1m53s before the Dispatch centre close the line breaker at SS2.

NETWORK RESTORATION

After realizing that there was a part of the network in island the Dispatch centre ordered the line breaker at SS2 to close. Unfortunately there was a malfunction in the synchro-check which allowed the circuit breaker closure to occur with a large angle between the voltages in the SS2 busbar and the line. This malfunction, which manifested itself only for manual commands, was later repaired.

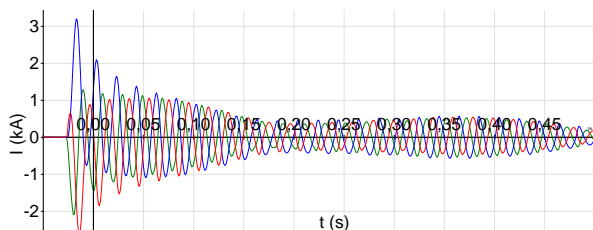


Figure 6. Current after network restoration (includes inrush current from SS1 transformer)

The current after the restoration instant was large (3kA peak) because of the inrush current in the transformers (mainly the one at SS1) in the first few cycles and then due to the generator's need to align itself with the network's angle in the following second.

However, there was a voltage drop at the TU2 site as an undesired effect of the synchro-check malfunction. This led to a trip of the under-voltage protection in the

connection point to the network of TU2.

TU2's trip was confirmed by the events records that were supplied by the TU2 operator. But, due to the lack of time synchronization in the interconnection protection unit it was not possible to cross-reference these records with SS1 records (these are time synchronized through a GPS system). The disturbance records had already been erased by newer records at TU2 when the information was gathered. Unfortunately, this protection unit has a limited capacity to record disturbance records.

AFTERMATH

In the aftermath of the islanding occurrence the following conclusions were reached:

- 1) TU2 controlled the island frequency during 1m53s when it was not supposed to do so;
- 2) The frequency protection of TU2 did not trip because the frequency was being controlled;
- 3) The phase undervoltage protection at TU2 did not trip because the phase-to-phase voltage never reached the trip values;
- 4) The zero sequence overvoltage protection of TU2 never tripped because the fault self-extinguished in a short amount of time (~0,5s). There was a time delay of 1s in the zero sequence overvoltage protection to prevent unwanted trips.

The protection used in Portugal to prevent islanding is the frequency protection. This did not trip because there was an active frequency control which kept it in the allowed range of operation. The power supplied by TU2 decreased from 3,5MW (pre-island) to 2,2MW (island).

One of the premises for connecting to the grid is not to control frequency, only active and reactive power. However, both TU1 and TU2 are allowed to operate in island mode if the grid connection circuit-breaker trips. This minimizes production losses and reconnection time to the grid.

After the islanding incident the operator of TU2 was inquired to supply data from its prime mover controller. The operator did not possess that information because the generator was about 20 years old and that information had not been requested to the manufacturer at the time of installation. Attempts were made to contact the generator's supplier which remains irresponsive to the TU2 operator's request for information.

Meanwhile, the protection unit's at TU1 and TU2 were tested and their behaviour was found to be correct.

CONCLUSIONS

This paper presents a situation of an actual islanding event in the network where the frequency protection of the DG was unable to detect the island. There was an active frequency control by the DG which prevented the frequency to reach the trip values. Voltage levels in the island were very low which raises the question of

responsibility of the DSO in case of damages to clients arising from operation in island conditions.

The spread of DG in the HV and MV levels increases the probability of islanding. To prevent this DSO must have data about the DG voltage and prime mover controllers. It is not usual to ask for that information thus far, at least in Portugal, but it is extremely important to perform “post-mortem” analysis on network island formation. EDP is in contact with the government agency responsible for the electrical network to make it obligatory for the new DG to supply the information about its controllers.

EDP had already drawn the legislator’s attention to the necessity of having more data, especially disturbance data, at the DG points. This work paid off when the Distribution Grid code, approved in 2010, stated that the DG needs to have disturbance recording, for an installed power above 6MVA, and that the DSO has the right to request information up to 60 days. This implies that the DG operator must maintain the information during at least 60 days. EDP has also issued a document with the specifications for disturbance recording to be applied in DG. This is meant to help the DG operators to safeguard the essential data.

REFERENCES

- [1] DIN VDE 0228 – Part 2.
- [2] P. Kundur, 1994, *Power System Stability and Control*, McGraw-Hill, New York, USA, 827-954.