

GB GENERATING PLANT RESILIENCE SURVEY

I. Introduction

1. During the blackout incident in Italy on 28 September 2003, major generation tripped unexpectedly under depressed voltage and frequency conditions. Following the incident, concern was expressed within National Grid Electricity Transmission (NGET) that generating plant in GB might trip under similar conditions when system frequency, although depressed remained above the level specified for continuous plant operation.
2. NGET also had extensive experience of unexpected loss of generation coincident with large power system disturbances. For these reasons, we initiated a survey to better understand plant performance under severe system disturbance conditions including conditions when both the system frequency and voltage are depressed.
3. The issue was discussed at the GCRP (Paper GCRP 05/12) and a Working Group formed in September 2005 agreed the objective and format of the survey. The survey was sent off to Generators (with plant rating above 100MW) on 4 November and most of the responses were received in December 2005/January 2006.
4. This paper gives a report on the survey progress and summarizes the major findings and recommends the ways forward. However, to maintain the confidentiality obligations with the Generators, the report here is on a generic basis.

II. Survey Response Process

5. Survey questionnaires were sent to cover nearly 80 stations with about 85% of responses received. The responses are generally constructive but some key information was missing or required further clarifications. The response from each station was assessed with the initial focus on identifying the critical issues. NGET will follow up with those stations where data have not been received or require clarifications.
6. The key issue for the investigation is to identify if there is any risk of premature tripping of generating plant under severe system disturbance conditions including conditions when the system frequency is depressed to a level which is just above the 47.5 Hz level. This criterion forms the basis for the assessment of the responses received.

III. Areas of concern

7. The initial review of the data has indicated major concerns in the following areas:
 - Limited frequency operating range
 - Variable speed drives unable to ride through fault disturbances
 - Over sensitive generator under-voltage protection settings
 - Uncertain auxiliary motor performance under depressed voltage and frequency conditions

Frequency Operating Range

8. Generating units are required by the Grid Code to remain connected to the system unless the system frequency is above 52.0Hz, below 47.0 Hz or between 47.0 to 47.5 Hz for over 20 sec. Information received indicated that some generating units will be disconnected by their high or low frequency relays when the system frequency remains within the above limits.
9. A major concern is the possible loss of a major station on falling system frequency to below 48 Hz. Given the urgency, NGET has taken immediate actions to clarify the position with the station and is in the process of seeking resolution.

10. A further observation is that the low frequency trip settings at several other stations (total 1.3 GW) are correctly set to 47.5 Hz but the time delays are shorter than 20 sec required by the Grid Code.
11. The submitted data also revealed an unexpected 3 GW could be lost during incidents when the system frequency remains at below 52 Hz but above 51 Hz. It is common that a large generation loss could be preceded by a high frequency event. The impact of this on the System security should not be under-estimated. NGET is uncertain if there are further stations in this category but not responded or reported.
12. NGET has taken actions to clarify the above issues with the affected stations and would like to share our concerns with the GCRP members.

Variable Speed Drive (VSD)

13. Variable speed drives are being installed in generator major auxiliary sub-systems. These drives are known to be susceptible to transient voltage dips resulting in their undesirable disconnections from the supplies. The failure mechanism for VSDs is well known from experience of equivalent technology used as the main generators in wind farms.
14. The survey identifies several GWs of generation for which critical VSDs are protected by instantaneous under-voltage protection with settings typically at 85-90% nominal voltage.
15. NGET is aware of programmes of progressive fitting of VSDs to critical drives at major stations. An unexpected loss of two generating units at a station in January 2005 was the result of tripping of all VSD driven PA fans during a common transmission disturbance (ie single-phase to earth fault). The immediate loss was 550MW of generation but this could be significantly more if the Generator had completed the PA fan drive replacement programme at the station.
16. NGET has worked closely with the Generator and a solution has been derived by the VSD supplier which is being implemented and tested to confirm the VSDs are no longer susceptible to system switching and fault disturbances. The solution will be implemented on new VSDs and retrofitted to earlier installed units at the station.
17. The survey also identifies a second application of VSD drives at the same station. These drives apply to coal feeders and are connected at LV (415V). As this is embedded further into the electrical power system within the station, the impact of transmission system fault on these drives is less severe. However, any trip of such motors would lead to a loss of all the main units within a minute on loss of fuel supply.
18. The survey data received provide little information about VSD applications at other stations. However, NGET believes there are other stations which have replaced or in the process of replacing their major drives with VSD technology including similar designs to those which are known to be susceptible to voltage disturbances described above.
19. Given the importance of this issue and the lessons learnt from the examined station, NGET believes it is important to raise the awareness of this issue within the industry to avoid unnecessary tripping of stations.

Generator Under Voltage Protection

20. Some generators are fitted with instantaneous under-voltage protection with setting at 80% of nominal voltage or higher. Our concern is that these stations could trip under a

transient voltage dip condition.

21. Further investigation is required to identify the extent of the problem and seek resolution with the relevant stations if required to avoid unnecessary tripping of stations in this category.

Auxiliary Motor Overload Protection

22. Motors are normally designed to operate at or near nominal voltage and frequency conditions. When the supply voltage and the frequency are depressed under severe system disturbance conditions, we are concerned that some of the critical generating plant auxiliary motors could be disconnected on overload leading to the premature tripping of the associated generation.
23. Many motors are specified to IEC 34-4 or BS EN60034-1 which stipulates that motors shall be capable of continuous operation between 0.98 to 1.02 pu of rated frequency and short-term operation between 0.95-0.98 and 1.02-1.03 pu rated frequency. The temperature rise may also be higher under these extended operating ranges. The current concern is in the lower range between 47.5 to 49 Hz.
24. The sustained low frequency when coupled with depressed voltage conditions could accelerate the overloading effect on the motors. Given the current / thermal overload settings reported could be as low as 105%, a depressed frequency to 47.5 Hz and voltage to 90% nominal could result in a motor overload condition leading to the tripping of these motors within a short time.
25. Given the complexity of the motor/load operating characteristics and the various overload protection relay types and settings adopted, more detailed investigation will be required to appreciate the risk associated with this problem. NGET would like to take this forward with GCRP to seek a view on appropriate short and long-term solutions.

IV. Recommendations

26. The GCRP is invited to:
 - a) note the four issues raised from the survey,
 - b) note NGET is in the process of resolving the frequency range and under voltage issues with the relevant stations,
 - c) support NGET to clarify the VSD applications with the stations and to support Generators and their VSD suppliers to avoid the unnecessary tripping of their critical drives and hence the immediate loss of the associated generating plant during system fault disturbances.
 - d) support NGET to take the motor overloading issue forward with the industry including, Generators, motor manufacturers and motor protection equipment companies.