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Document ID: NG TR(E) 451 2009

REVIEW OF DRAIN EARTH SHORTING SCHEMES (DrESS) APPLIED IN ACCORDANCE WITH NSI4

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PURPOSE AND SCOPE

National Safety Instruction four (NSI4) provides guidance to persons Senior Authorised under the National Grid safety rules with respect to minimum earthing requirements to help achieve safety from the system for specific work schemes on overhead line circuits. The application of drain earths is principally used to manage voltage induced by an adjacent energised circuit, usually the parallel circuit of a double circuit route. When drain earths are applied at two physically separate points on the same phase conductors and there is an adjacent power carrying parallel circuit an induced current will circulate in the loop formed by the phase and earth conductors and the drain earths.

The magnitude of the inducted current is dependant on the power flow in the parallel circuit the tower geometry and the tower earth resistances.

NSI4 defines two purposes of earthing: earthing to manage and control induced voltages at the point of work and earthing to manage and control induced currents on the circuit being worked on.

Currently, based upon the maximum possible circulating current, two drain earth applications or Drain Earth Shorting Schemes (DrESS) are employed: a single DrESS rated at 450 A and a double DrESS rated at 900 A. The double dress is employed where there are two or more sources of induction in parallel with the earthed circuit and therefore potential for a doubling of the induced current close to the point where the source of induction changes. Historically these circuits have been classed as complex.

The use of the double DrESS significantly increases the manual handling and working at height exposure of overhead linesmen with the application and removal of a double DrESS taking 7 man-days, increasing the length of the circuit outage and therefore the possibility of incurring additional system management costs.

The rating requirement for drain earths used to control induced currents was based upon what, at the time of study, was anticipated to be the highest power flow in the parallel circuit (see References). This was deemed to be the rating of twin 30.5 Ω .m redwood (850 mm²) conductor operated at 90°C i.e. 3190 MVA and gave a rating of 450 A. This requirement was then applied universally.

Due to the additional health and safety risks and the implications for outage length and system access a review of complex circuits was undertaken to identify those where there is a realisable risk that current doubling would result in a flow in excess of 450 A. This report details the findings of that review.

PART 1 – REPORT DETAILS

1 INTRODUCTION

The application of double DrESS earthing schemes only applies to complex circuits i.e. those with two or more separate sources of induction. The transmission network was reviewed to identify all circuits that meet the definition of complex. These circuits are detailed in Appendix A1 to A3.

For the circuits that were considered complex a review of the transmission network topology and of circuit ratings was carried out to assess the likelihood that the maximum induced current would in fact exceed the rating of a single DrESS.

The accepted continuous current rating of a single overhead line drain earth is 150 A. The original test documentation to provide evidence of the criteria used to support this rating is not available but it is thought that the tested continuous current capability was 170 A (a recent test conducted by P+B Weir Electrical (Engineering Report No. 120308) supports the assertion that overhead line drain earths can safely conduct 170 A continuously), this being reduced by approximately ten percent as a factor of safety. For a DrESS scheme a minimum of three drain earths are applied in parallel giving an arithmetic rating of 450 A. As a factor of safety has already been applied to each individual earth's rating it has been assumed that this will also cater for disproportionate sharing of current between the earths so the use of 450 A in this study is considered valid. This is in line with the practice applied to the combined rating of multiple substation portable primary earths where a ten percent down rating is used. In practice NSI 4 requires an equal number of earths to be applied to each sub-conductor of an overhead line bundle, therefore on twin and quad conductor bundles a minimum of four earths will be applied.

A model was constructed using the MUNA (Multi Unbalanced Network Analysis) software package that simulates a system with three transmission circuits such that when one circuit is taken on outage there are two independent sources of induction. The arrangement is shown schematically in Figure 1 below.

Figures 2 and 3 show examples of outage and power flow scenarios and the corresponding currents induced into applied drain earths. In each figure diagram a) shows the circuit configuration and which circuit is on outage. As can be seen from figures b) and c) the current induced and flowing through the mid-point drain earth is not just dependant on the power flow in the live circuits but is also dependant on the relative direction of the power flows. Therefore when considering the application of drain earths on circuits that have two independent sources of induction there are two key influences on the required rating of the drain earths; the power flowing in the live circuits and the relative direction of the power flows.

The latter influence is significant as even with power flows large enough to induce 450 A flowing in the live circuits they may not sum in the mid-point earth. Therefore the current passed by the mid-point earth could be significantly less than 450 A.

2 REVIEW OF COMPLEX CIRCUITS

Appendix A details the findings of a review by Asset Engineering to determine which circuits on the England and Wales electricity transmission network have more than one source of induction when switched out of service and earthed. For each circuit or group of circuits the possible outage scenarios were considered with circuit ratings and possible power flow combinations evaluated.

Studies using the MUNA model, Figure 1, were carried out to ascertain the minimum power flows in the live circuits that would result in a circulating induced current in excess of 450 A through the mid-point earth should the currents be additive. This power flow was found to be 2050 MVA in each circuit. In practice it is the sum of the power flows that is critical. This means provided that the sum of the power flows in the live circuits is no greater than

4100 MVA the induced circulating current in the mid-point earth will not exceed 450 A. It is important to note that this is based on an assumption that the tower earth resistances are good (i.e. around 10 Ω) and that each terminal tower has a bonding earth tape between it and the substation earth mat. A disconnection between the terminal tower and the earth mat could result in a ten percent increase in circulating current through the mid-point earth. At a combined power flow of 4100 MVA in the live circuits this would overload the drain earths. It is therefore important to ascertain the status of terminal tower connections prior to applying drain earths. Remediation of tower earth bond is covered by National Grid Technical Guidance Note TGN(E)215. The level of circulating current is relatively insensitive to tower footing resistance and this should not normally be an issue. However where it is known that ground composition and structure could result in extremely high footing resistances (e.g. in excess of 200 Ω) confirmation of earthing requirements should be sought.

For circuits operating at 275 kV the limiting sum of power flows in the live circuits is 3050 MVA.

From Figure 2 and Figure 3 it is apparent that the induced currents only sum in the mid-point earth when the power flows in the live circuits are in the same direction at the common point of connection, Substation A and Substation C respectively.

Using Figure 3 as an example the current in the mid-point earth will only be in excess of 450 A when:

- The power flows in the live circuits sum to greater than 4100 MVA
- The power flows in live circuits both flow into Substation C or both flow out of Substation C

Where Substation C is not part of the meshed transmission system, i.e. it only has two feeder circuits connecting it to the transmission network, National Grid's transmission licence obligation through the System Quality and Security of Supply standard limits the amount of generation or demand that can be supported at the site. Grid Supply substations with a demand significantly greater than 300 MW are likely to require three feeder circuits whereas the maximum generation export capacity with two feeder circuits is 1320 MW. For such connection arrangements only one circuit outage configuration makes it possible for the mid-point earths to carry more than 450 A, Figure 4 explains diagrammatically. For this outage scenario circulating currents in excess of 450 A in the mid-point earth will only flow when the power flow in the remaining live circuit exceeds 2780 MVA for 400 kV circuits and 1580 MVA for 275 kV circuits. However, depending on operational constraints at the time of outage Network Operations may limit the output of a generator to 1000 MW in order to limit the power loss for a single circuit event. This would mean an additional 320 MW could be allowed within the 450 A circulating current limit.

As part of the review of circuits listed in appendix A consideration was given to the possible use of short time circuit ratings. In particular Network Operations may make use of circuit twenty minute ratings to allow for post-fault ameliorating actions to be taken, which return the network to an acceptable operational state e.g. generator drops, quadrature booster taps. As the drain earth rating already has a sharing safety factor applied and limited test evidence to support a rating well in excess of 170 A [2] for the purpose of this report they have been deemed capable of supporting any additional induced current for the period of the short-term rating. This does not apply to circuits where the rating is limited by a section of cable which may have significantly higher extended short-term rating for a period of six hours or more.

The circuits listed in appendix A have been reviewed in line with the criteria detailed in the preceding paragraphs and have been assessed as to whether a single or double DrESS is required. It must be noted that in this report only the need for a single or double DrESS has been considered. For circuits that only require a single DrESS it is possible that the application of earths as stipulated for the control of induced voltages is sufficient to manage induced currents as well, although connection in this manner has not been tested to 450 A and therefore cannot be recommended in this report.

Finally for circuits that operate at a different voltage either side of the tower it has be assumed that the tower construction and cross-arm design are the same on both sides of the tower and therefore meet the clearance requirements for the higher of the two voltages. It is considered that with, respect to induced circulating, current the effect of having reduced length insulator strings on the lower voltage side will be negligible. Therefore the value for the limiting sum of power flows in the live circuits will be that of the higher voltage line construction.

3 CONCLUSIONS

For the current network configuration and circuit ratings where double circuits are operated at 275 kV only or 275 kV on one side of the towers it is not reasonable to expect induced circulating currents in excess of 450 A to flow through drain earths applied under NSI4 earthing schemes. For such routes therefore the use of a single DrESS will always be adequate in the management of induced circulating currents. It must be stressed that this is based on the information provided and listed in appendix A2 and A3. Any changes to network configuration or any increase in circuit rating due to, for example, installation of new conductor or 'hot wiring' could lead to need to apply a double DrESS under NSI4.

For the current network configuration and circuit ratings where double circuits are operated at 400 kV only, as identified in appendix A1, there are sixteen circuit combinations where induced circulating currents may exceed 450 A. This represents 45 % of the total number of 400 kV only routes that are considered to be complex circuits. As stated above any change in network configuration or increase in circuit rating could lead to a change in earthing requirement.

The earthing requirements as detailed in appendix A could be used to generate an earthing application list for use by overhead line senior authorised persons when applying drain earth shorting schemes in accordance with NSI4. Such a list will need to be controlled and reviewed to make sure that the impact of any change to circuit rating or network configuration on drain earth requirement is captured and implemented in a timely manner.

4 FORMS AND RECORDS

Not applicable.

PART 2 - DEFINITIONS AND DOCUMENT HISTORY

5 DEFINITIONS

Not applicable.

6 AMENDMENTS RECORD

Issue	Date	Summary of Changes / Reasons	Author(s)	Approved By (Inc. Job Title)
1	March 2009	First Issue	John Hyde Asset Policy	Zac Richardson Asset Engineering Manager

PART 3 - GUIDANCE NOTES AND APPENDICES

7 REFERENCES

TR(E) 259 - Overhead Line Induced Voltages and Currents Study for 400 kV Drain-Earth and Earth-Switch Specifications, K Basak

Engineering Report No. 120308 – Review of Temperature Rise Characteristics for 50sq.mm Aluflex Lead Assemblies Relative to Load Current, P+B Weir Electrical

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