NORTHERN IRELAND ELECTRICITY plc
AMENDMENT SHEET - ISSUE 2 - 7 AUGUST 1992
TRANSIENT STABILITY CRITERIA DOCUMENT (PLM-ST-4 SEPT 1975)

1. Document PLM-ST-4 is a guide to the planning of developments to the NIE System, each scheme for reinforcement or modification being individually assessed by NIE in the light of economic and technical factors obtaining.

2. Particular Modifications in Respect of Fault Outages and Type

   Studies shall be conducted to ensure that only the following criterion is met.

   The system shall remain stable following the occurrence of a three phase fault to any circuit, at all levels of system demand, and with a reasonable number of other circuits out for maintenance.

   This is a reduction to the standard given in PLM-ST-4 in respect of not being required to test for transient stability for faults to busbars or faults simultaneously to both circuits of a double circuit line and is due to technical and economic considerations.

Planning Department

PLANNING MEMORANDUM PLM - ST- 4

CEGB CRITERIA FOR SYSTEM TRANSIENT - STABILITY STUDIES (SUPERGRID SYSTEM)

Issue 1 September 1975

ISSUE 1 SEPTEMBER 1975

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Issuing Branch: System Technical

Approved by: [signature]

Director of Planning

CEGB CRITERIA FOR SYSTEM TRANSIENT-STABILITY STUDIES (SUPERGRID SYSTEM)

FOREWORD

The standards of security for electricity supplies to Area Board customers in England and Wales are agreed for the Supply Industry as a whole through the Electricity Council and are set out in Engineering Recommendation P.2/4, 'Security of Supply'. These standards, which are related to size of demand at risk, take into account the risk of failure of plant and equipment on the system with the object of ensuring a satisfactory compromise between a secure and economic supply of electricity. The Generating Board's planning standards are independent of those in Engineering Recommendation P.2/4 although closely reflecting the standards defined therein, and are designed to ensure that the statutory quality of supplies to Area Boards is achieved with a high degree of security under all credible fault conditions on the Generating Board's system. Consideration is also given to maintaining the appropriate conditions of agreements for bulk supplies to direct customers and of energy exchange agreements with other supply authorities.

The CEGB Standards (refer PLM–SP–1 and PLM–SP–2) are in particular designed to ensure adequate security of generation production. This requires consideration of the dynamic-stability performance of the generating plant in view of the potentially serious losses of generation and major system disturbance which could result from loss of synchronism by generating plant. Should loss of synchronism occur, the subsequent pole-slipping of generators would be likely to cause unacceptable quality of voltage and frequency of the supply to Area Boards and even result in the disconnection of customer load by undervoltage or underfrequency protection. These considerations apply also to instability between sections of the system. The system and plant must therefore be designed with the intention that instability between individual generators and the system or between sections of system is prevented. Since in practice, loss of synchronism cannot be prevented for all possible system incidents and operating conditions even with unacceptable expenditure, design criteria which ensure that synchronism is maintained under all credible fault conditions are established.

1. SCOPE

This Memorandum reviews the reasons for seeking to ensure that transient stability is maintained and defines fault type, fault clearance times, fault locations and plant outages which should be used when assessing the transient-stability performance of generating plant or of the system, for system planning and design purposes.

2. TRANSIENT STABILITY

The transient stability of a generator or group of generators is judged on the maintenance or otherwise of synchronism during or after a fault on the system. Loss of synchronism of generating plant can result in one or more of the following consequences:

(i) The associated large fluctuations in voltage and frequency which occur at the generator terminals are likely to affect station-auxiliary power supplies and lead to loss of boiler firing and failure of station auxiliary motors followed by shutdown of the generating plant.

(ii) The associated fluctuations in voltage and to a lesser extent, frequency, may also result in tripping or other disturbances to consumer loads.
(iii) The associated rapid fluctuations in generator output power are reflected in the steam demand from the boiler and may result in loss of control of boiler leading to damage of plant and/or its shutdown.
(iv) Prolonged pole-slipping of generators can cause internal damage due to overheating and other effects and is not covered by present specifications, prices or works or commissioning tests.
(v) The flow of synchronizing power to and from the pole-slipping generators may result in indiscriminate operation of certain transmission protection leading possibly to cascade tripping of circuits and further instability or disconnection of supplies.

In addition, rapid resynchronization of turbo-generator plant from a pole-slipping situation is not assured.

The above factors are considered sufficient to justify the continuation of the present policy of designing the system using criteria which seek to prevent the loss of synchronism of generating plant under all credible system fault conditions, and of rapidly disconnecting from the system any generator which loses synchronism.

3. TRANSIENT-STABILITY CRITERIA

3.1 Fault Outages

The 400 and 275 kV supergrid system and supergrid-switched generating plant will normally be designed to remain stable for the following credible transmission plant fault outages with all CEGB transmission circuitry in service, without limiting the MW output of the generating plant.

(i) Any one double-circuit overhead line independent of length.
(ii) Any one single circuit overhead line, transformer feeder or cable circuit independent of length.
(iii) Any one transformer, reactor or booster.
(iv) Any single section of busbar. (The reserve busbar where provided being normally uncommitted.)
(v) Fault outages (ii) and (iii) with any second circuit out of service.

The combination of circuit outages considered should be that causing the most onerous conditions for stability, taking account of the slowest combination of main-protection/circuit-breaker operating times and strength of the connections to the system remaining after the faulty circuit(s) has been disconnected.

The maintenance of stability of generating plant and system will not be designed for in the following cases:

(vi) Faults on bus-section or bus-coupler switches which result in the tripping of two busbars.
(vii) Delayed fault clearance due either to failure, maloperation or slow operation of any protection or circuit-breakers.
(viii) Simultaneous system faults or protection malfunctions which cause multiple circuit trippings.

Whether instability occurs or not for the types of incident (vi), (vii) and (viii) will depend on the severity of the fault in terms of its duration and number of phases affected, on its location and on the circuits which are subsequently disconnected in removing the fault from the system. The occurrence of such faults is, however, considered sufficiently rare to justify acceptance of the risks involved. The disturbance to the system ensuing from these abnormally severe fault conditions is minimized through the installation and appropriate setting of system back-up protection, breaker-fail protection, pole-slipping protection, intertripping schemes and by resorting where necessary to system or busbar sectionalization. The system will be studied at the planning stage in order to quantify the severity of disturbances caused by faults of abnormal severity, and to establish the extent of requirements for other additional safeguards.

3.2 Fault Type

The severity of a fault as it affects transient stability is a function of the resultant voltage depression at the terminals of the generating plant. A three-phase short circuit close to the terminals of a generator will result in zero voltage at the point of fault and therefore no power transfer beyond the fault point. Other types of fault, phase-phase-earth, phase-phase, phase-earth will result in voltage changes and power transfers of various magnitudes. The voltage changes, irrespective of fault type, will also be dependent on the position of the fault in relation to generating plant terminals and the impedance of the fault path.

The system is subjected in practice to a wide range of faults and in general, the location and fault type cannot be predicted. The stability of generators should therefore be assessed for the most severe fault type to which they can be subjected. Three-phase faults will be considered causing circuit outages as defined in 3.1 above unless special circumstances such as phase-isolated connections exist.

3.3 Fault Duration and Location

Maintenance of synchronism between generators and system is dependent on the timely clearance of the fault condition: the operating times of the equipments which have to detect and remove the fault from the system are critical to the assessment of stability. Worst case situations for credible fault conditions will be studied, the fault locations selected for examination being dependent upon protection fault-clearance times. Stability will normally be assessed on the basis of the slowest combination of main protection and signalling equipment and circuit-breaker operating times. The fault clearance times employed will be inclusive of protection relays, signalling, trip relays and circuit-breaker operating times. Where equipment performance in specific cases has not yet been specified, nominal operating times should be used as defined in PLM–ST–1.

Where circuits are protected by distance protection, Zone-1 operating times will normally be assumed for local clearance of faults which are electrically close to a generating station. The performance of some distance protection for close up three-phase faults can give rise to delayed fault clearance and it is essential that protection times are checked. For faults located on the remote 20 per cent of feeders, clearance at the generating station will be slower due to the time delay incurred by the conditional Zone-2 acceleration trip signal, or in the case of over-reach distance protection, the time delay which is introduced to ensure receipt of the remote blocking signal. On certain short feeders, faults at the remote ends could therefore be more onerous for stability than faults close to generators and may need to be studied.

Main-protection equipment employed on transformers busbars etc. will normally have one nominal operating time which will be used for stability assessment. In the case of faults on teed-transformers or mesh corners, clearance will be dependent on intertripping to the associated remote circuit ends. In such cases, additional time delays will be incurred over the nominal protection operating time which must be taken into account.

Faults which occur between air blast circuit-breakers and associated line-side current transformers at double-busbar and other non-meshed substations will be detected by the local busbar protection but not by the circuit main-protection. Clearance at the remote circuit-end will normally be achieved by forward tripping from the busbar protection or by a selective-intertripping scheme. In the latter case, extended fault clearance times will be incurred which will need to be assessed for stability. Design modifications required to ensure stability for this type of fault should be requested where necessary.

4. BASIS FOR SYSTEM STUDIES FOR TRANSIENT-STABILITY ASSESSMENT

The transient stability of individual generators or groups of generators or stations is influenced by their power output and operating power-factor and also by the disposition and operating conditions of other generation on the system and upon system demand level. It is essential therefore that a representative number of system stability studies are carried out over the system demand spectrum from peak to minimum demand conditions.

The operating power-factor of a generating station has an important bearing on stability of that station because it affects the initial operating angles of the generators. From this consideration alone, the operating angles will be greatest and the plant stability margin least at times of minimum system load when the generators may be absorbing surplus reactive power generated by the shunt-susceptance of the transmission network. Power-factor of operation is therefore an important factor but it is not the only one.

The total output of the generating plant (i.e. system load) is important insofar as it influences the change in the frequency of the total system as a result of a system fault. This movement of the total system can considerably reduce the angular separation between the system and the generating station under study and thus enhance the stability margins. There are two general rules which can be used in consideration of the problem:

(i) For a given fault (type, location and duration) the movement of the total system increases as the total system MW load decreases.

(ii) For a given fault the movement of the total system increases as the power factor of the total load on the generation changes from lag to lead, i.e. as the system load decreases.

Both tend to enhance the stability of a power station at low system loads and thus counter the detrimental effect of underexcited operation of the power station at such times. An alternative consequence is that for a remote power station (where one's choice of operating power-factor may be constrained by the transmission system) stability margins may be least under high system load conditions. No firm guidelines can be stated at present and it is recommended that stability of power stations should be studied with the stations delivering rated MW output over a range of system load conditions.

Plant manufacturers' estimated design parameters or actual parameters of similar existing plant should be used. Account should also be taken of generator excitation control and turbine governing systems and any other control schemes which may be provided for improving generating plant and system dynamic performance.

5. REFERENCES

This Memorandum makes reference to the following documents:

Electricity Council Engineering Recommendation P.2/4, 'Security of Supply'.
Planning Memorandum PLM–SP–1, 'Planning Standard of Security for the Connection of Generating Stations to the System'.
Planning Memorandum PLM–SP–2, 'Planning Standard of Security for the Transmission Network'. (In course of preparation.)
Planning Memorandum PLM–ST–1, 'Fault Clearance Times for System Studies'. (In course of preparation.)

Comments by users on the contents of this Memorandum would be appreciated by the System Technical Engineer, Planning Department, CEGB HQ.

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