Company Directive

STANDARD TECHNIQUE : SD6F/1

Dealing with Potentially Disturbing Electrical Loads/Equipment

This Standard Technique details how to identify potentially disturbing electrical equipment, assess its acceptability for connection, establish what control measures are required and communicate/record what is acceptable.

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Document Revision & Review Table		
Date	**Comments**	**Author**
8/11/2012	**Data Collection Forms have been updated and Tables 2 and 3 have been revised to reflect this.**	**S. Scarbro**

INTRODUCTION

1.1 POL:SD2/2, POL:SD3/2, POL:SD4/1 and POL:SD5/1 require that new connections shall be designed to ensure compliance with the following Engineering Recommendations, as amended:

a) P28
b) G5/4-1
c) P29.

1.2 This ST defines what to do to ensure compliance with the above requirement. It details how to identify potentially disturbing electrical equipment, assess its acceptability for connection, establish what control measures are required and communicate/record what is acceptable. For complex situations it will be necessary to refer to the base documents: P28, G5/4-1 and P29. However, where possible, guidance is given that shall be used to support and interpret these documents.

2.0 PROCESS

2.1 The basic procedure for dealing with potentially disturbing equipment is shown in Figure 1. This procedure comprises six distinct stages and these are explained below.

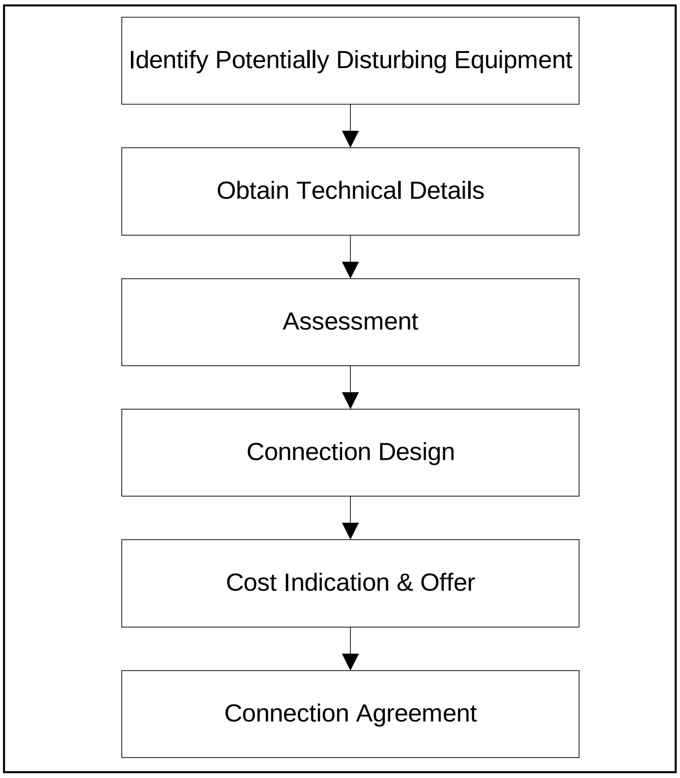

Figure 1 – Basic Procedure – Dealing With Potentially Disturbing Equipment

2.2 Note: Some equipment will be accepted by New Connections in accordance with ST:SD5O, as amended; this equipment is therefore not normally subject to this ST.

3.0 IDENTIFYING POTENTIALLY DISTURBING EQUIPMENT

3.1 Definition: Potentially Disturbing Equipment

3.1.1 Potentially disturbing equipment is electrical equipment of a type that may cause electrical disturbances (or 'interference') that could be unacceptable to other customers.

3.2 Potentially Disturbing Equipment

3.2.1 The ability of customer electrical equipment to disturb other customers depends on the characteristics of the equipment, how it is operated and the source impedance of the network it is to be connected to as seen from the 'point of common coupling' with other customers.

3.2.2 There are various forms of disturbance. However, the majority of those requiring assessment concern 'flicker'.

3.2.3 See Appendix A for definitions of the various types of disturbance.

3.2.4 Table 1 gives examples of potentially disturbing equipment. The most commonly encountered are motors and welders.

Potentially Disturbing Equipment
• Motors • Welders • Induction furnaces • Arc furnaces • Kilns • Motor drives (i.e. variable speed drives [VSDs] or variable frequency drives) • Uninterruptible power supplies and other battery charging systems • Industrial/commercial convertors (i.e. rectifiers, AC-DC convertors and AC-AC convertors) • Industrial/commercial AC regulators (agricultural lighting control or industrial heating control) • Train traction supplies • Multiple personal computer installations (e.g. large offices, data centres etc) • Electric boilers and other equipment compliant with British Standard BS EN 61000-3-11 or BS EN 61000-3-12 • Other high powered equipment preceding BS EN 61000-3-2, BS EN 61000-3-11, BS EN 61000-3-3 & BS EN 61000-3-11 • Generators • Switched capacitors

Table 1 – Examples of Potentially Disturbing Loads

3.3 Is Potentially Disturbing Equipment Involved?

3.3.1 Through dialogue with the customer the presence of potentially disturbing equipment may be identified. The process is formalised through the questionnaire included as part of the Cost Indication process; the customer confirms "yes" or "no" to whether they will be installing motor equipment, welder equipment or other equipment that may be potentially disturbing. If "yes" then the Planner shall request further details (section 4.0 below) before assessment (section 5.0 below) and before moving to the Connection Offer stage (section 7.0 below).

3.3.2 With the Simple Service Quotation (SSQ) pad, used for quoting on small connections or alterations, this formal process does not occur; given this, the Planner shall ask whether any potentially disturbing equipment is to be installed. If the answer is "no" then the following clause shown in Box 1 shall be entered on the form under "Conditions" in the absence of a specific clause in the terms and conditions (NB current situation at time of writing).

Our proposals and charge are based on the Customer not installing any equipment likely to cause disturbance to WPD's distribution system or other Customers

Box 1

3.4 What Type Of Disturbance(s) Can We Expect?

3.4.1 Appendix B shows possible/likely disturbances by type of equipment.

4.0 OBTAINING TECHNICAL DETAILS

4.1 Standard Data Collection Forms

4.1.1 Table 2 details Standard Data Collection Forms prepared for commonly encountered potentially disturbing loads. These are designed to allow sufficient data to be obtained from customers (or their representatives) to permit a disturbance assessment.

4.1.2 The complete set of forms are accessible through the following links. Note ST:SD6J relates to Formset J.

Form A	Motors – flicker
Form B	Welders/plasma cutters – flicker
Form C	Voltage distortion (harmonics) - generic
Form D	Flicker - generic
Form E	Arc furnace
Form F	Induction furnace
Form G	Office etc
Form H	Sub-harmonics & interharmonics
Form I	Rectifier commutation (notching)
Form J1 Form J2 Form J3 Flow Chart	Heat pump system
Form X	Equipment rated ≤75A per phase (excluding heat pumps)

Table 2 – Standard Data Collection Forms

4.1.3 Table 3 provides a ‘look-up’ table that can be used to decide which Forms to send out.

Potentially Disturbing Equipment	**Data Collection Form**										
	A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J1-J3**	**X**
Motors	✓		✓ VSD[1] or soft start only								
Heat pump										✓	
Electric boiler			✓ **#1**	✓ **#2**							✓ **#3**
Welders		✓	✓ **DC**								✓ **#4**
Induction furnaces	✓ Motor generator		✓			✓			✓		
Arc furnaces					✓			✓			
Kilns			✓ **#1**	✓ **#2**							✓ #3
Motor drives (i.e. variable speed drives)	✓		✓						✓		
Uninterruptible power supplies and other battery charging systems			✓ **#1**	✓ **#2**					✓		✓ #3
Industrial/commercial converters (i.e. rectifiers, AC-DC convertors and AC-AC convertors)			✓ **#1**	✓ **#2**				✓ AC-AC	✓		✓ **#3**
Industrial/commercial AC regulators (agricultural lighting control or industrial heating control)			✓ **#1**	✓ **#2**							✓ #3
Multiple personal computer installations (e.g. offices, data centres etc)							✓				
Other (e.g. high powered equipment not designed to take account of disturbance controlling standards or ‘industrial’ equipment used in low fault level situations)			✓ **#1**	✓ **#2**							✓ #3
Train traction supplies	None – refer direct to Engineering Recommendation P24										

#1: Rated >75A/phase or non-compliant with BS EN 61000-3-2 and 61000-3-12.
#2: Rated >75A/phase or non-compliant with BS EN 61000-3-3 and 61000-3-11.
#3: Rated ≤75A/phase.
#4: Rated ≤75A/phase and non-professional.

Table 3 – Look-up Table – Data Forms By Potentially Disturbing Equipment

4.1.4 Generators

4.1.4.1 No forms are provided for generators:

a) The policy for dealing with small scale (up to 16A) embedded generators is given in ST:NC1R, as amended.

[1] VSD = Variable speed drive.

Page revised 7 February 2013

b) For all other generators that will be connected in parallel with the WPD network two separate forms are provided. These are based on the Distribution Code and accessible through the following links:

Synchronous Generator Form
Asynchronous Generator Form.

4.1.4.2 In addition, data on flicker, voltage step change and harmonic emissions would be requested where relevant (e.g. wind turbines). For wind turbines this is typically published in a standard format dictated by British Standard BS EN 61400-21.

4.1.5 Capacitors

4.1.5.1 No forms are included for capacitors. Capacitors used by customers (e.g. power factor correction capacitors) can produce ‘oscillatory transient voltages’ during switching, can change ‘resonant frequencies’ for harmonic voltage distortion and do cause voltage step-change (e.g. voltage rise when in). However, given the size of capacitors involved and network arrangement, these disturbing effects are normally localised to the customer with the capacitors; consequently, a complaints driven approach is used – see ST:CS1B, as amended.

4.2 Obtaining Data

4.2.1 Customers shall be requested to complete and sign the relevant forms in order to establish exactly what is proposed to permit assessment. Initial information may be incomplete. Often, the nature of the business will provide a starting point for questioning the customer further. In some cases, where the technical knowledge of the customer is limited, the Planner may have to seek the information from the equipment manufacturer or supplier directly. In such cases, to avoid later disputes, it will be necessary to get confirmation from the customer that they agree the data supplied is accurate.

4.2.2 To avoid requesting data for equipment that is insignificant an appreciation of what can be a problem is required. Experience will help guide Planners in judging when details are required.

4.2.3 Equipment Intended To Be Subject To Conditional/Restricted Connection

4.2.3.1 Some equipment (e.g. high-powered domestic electric boilers) produces flicker disturbances at such a level that it must be subject to conditional connection. In the equipment’s Instruction Manual the user is instructed to consult with the ‘supply authority’ (i.e. WPD) to determine whether the network impedance is or can be made sufficiently low enough to be able to accept the equipment.

4.2.3.2 Similarly, some equipment produces harmonic current emissions at such a level that it must be subject to restricted connection. In the equipment’s

Instruction Manual there will either be a statement regarding minimum fault level or the need for acceptance by the 'supply authority'.

4.2.3.3 In such cases the following data must be obtained:

a) What make, model and rating is involved (e.g. Trianco Aztec 12kW)?
b) What statements, if any, are made in the Instruction Manual that relate to having to consult with the 'supply authority'? Example statements are given in Appendix D.

4.2.4 General Electrical Equipment With Rated Current ≤ 16A

4.2.4.1 The majority of electrical equipment has a rated current of no more than 16A and, if made recently will have been manufactured to two standards (or equivalent) that control the levels of flicker and harmonic current emissions produced; namely, BS EN 61000-3-3 (flicker) and BS EN 61000-3-2 (harmonics). This is a condition of it being able to be sold in the European Union. In general, it will not be necessary to consider obtaining data for such equipment. However, in installations with significant multiples of such equipment, individually compliant with these standards, the combined effect may be an issue if the equipment operates simultaneously (e.g. large office etc) – see section 4.1**.** Multiples of BS EN 61000-3-2 compliant equipment are only significant for harmonic assessment if the sum of the rated currents is more than 16A per phase.

4.2.4.2 Note: Prior to the introduction of the above standards, the flicker and harmonic disturbances from household appliances and similar electrical equipment were controlled by British Standard BS 5406. The same approach as described above shall be applied to equipment complying with this earlier standard.

5.0 ASSESSMENT

5.1 Two basic levels of assessment are possible:

a) Some equipment can be readily assessed and accepted without the need to resort to detailed analysis (e.g. 'small' motors).
b) Assessment of other equipment requires more detailed analysis.

5.2 Note: It is <u>not</u> necessary to obtain technical details for certain equipment as detailed in section 4.2.4; such equipment is <u>not</u> subject to assessment.

5.3 Acceptance Without Detailed Analysis

5.3.1 Where we have obtained technical details, the following equipment can be accepted, subject to certain conditions, <u>without</u> detailed analysis:

a) 'Small' motors
b) Certain equipment with rated current ≤ 16A.

5.3.2 **'Small' Motors**

5.3.2.1 The assessment process for acceptance of 'small' motors without detailed analysis is shown in Figure 2.

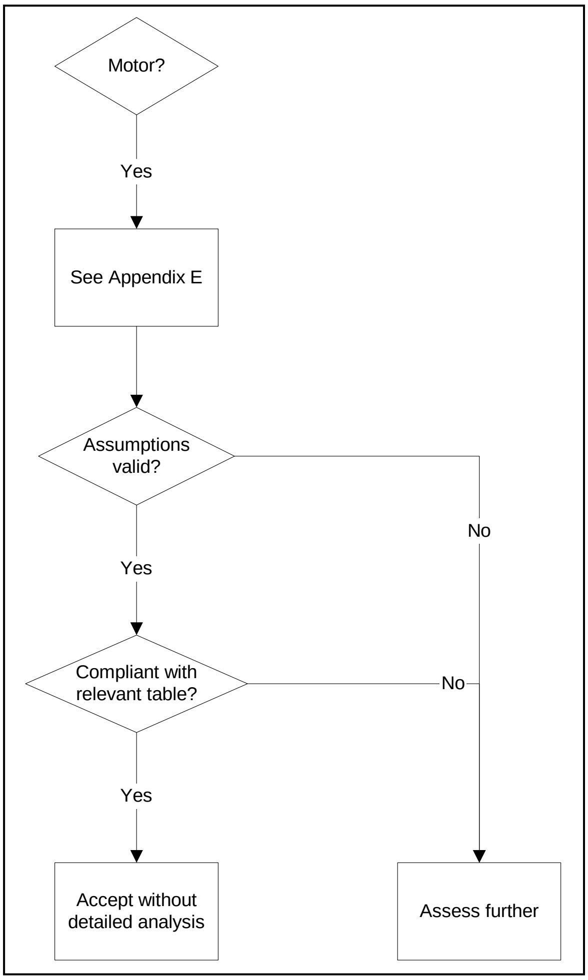

Figure 2 – 'Small' Motor Acceptance Procedure

5.3.3 **Certain Equipment With Rated Current ≤ 16A**

5.3.3.1 Convertors or AC regulators with rated current ≤ 16A can be connected without detailed assessment if used for industrial applications or overnight battery charging.

5.3.3.2 See also section 4.2.4**.**

5.4 Assessing Acceptability With Detailed Analysis

5.4.1 The type of detailed assessment required depends upon the nature of the disturbance expected. This was identified in outline form when deciding what technical details to obtain. Interpretation of the technical details received may further refine the decision as to which detailed assessment(s) is/are required. The range of possible assessments includes:

a) Flicker/voltage fluctuation
b) Harmonic voltage distortion
c) Voltage unbalance
d) Voltage notching
e) Sub-harmonic voltage
f) Inter-harmonic voltage.

5.4.2 The majority of assessments will be flicker assessments. Some will involve harmonics and a minority will include the other types of assessment listed above.

5.4.3 The following sections explain how to conduct the assessments.

Note: Sections 5.4.4.1.6 to 5.4.9 will, in general, only be relevant to 11kV Planners and Primary System Design.

5.4.4 Flicker Assessment

5.4.4.1 Motors and Welders

5.4.4.1.1 Appendix F provides background information on flicker, motors, motor starters and welders.

5.4.4.1.2 Section 5.3.2 details how ‘small’ motors may be accepted without detailed assessment. For other motors the assessment method depends upon the ‘point of common coupling’ (PCC) with other customers.

5.4.4.1.3 For an LV PCC the flicker assessment shall be done using WinDebut (see ST:SD5N), where appropriate, for:

a) Single LV motors
b) Single-operator hand-held welders

5.4.4.1.4 WinDebut flicker assessment has limitations; it is generally appropriate if the assumptions given in Section 2.0 of ST:SD5N apply.

5.4.4.1.5 For an HV PCC use the Motor_HV_VD_CALC spreadsheet or Welder_HV_VD_CALC spreadsheet as appropriate. Note: WinDebut can still be used to assess the impact at the customer supply terminals and also the maximum ‘P28 Voltage Disturbance Limit @ PCC’. The latter is compared with the predicted disturbance to determine acceptability.

5.4.4.1.6 'Complex' Situations

5.4.4.1.6.1 Some assessments cannot be conducted using the basic approach detailed above (e.g. multiple motors or welders, ramped voltage changes, multi-operator or seam welding machines etc). When this is the case it is necessary to refer to Engineering Recommendation P28. Guidance on its application is given in Appendix G; section G3.0 gives guidance on fault level to be used.

5.4.4.2 Equipment Intended To Be Subject To Conditional Connection - Electric Boilers And Similar Equipment

5.4.4.2.1 Section 4.2.3 explains what equipment is referred to in the title above.

5.4.4.2.2 ST:SD6J, as amended, defines how flicker and harmonic voltage distortion shall be controlled for relevant equipment. If the equipment complies with the relevant standard then flicker assessment has been conducted and the design process simply involves ensuring the network impedance is low enough at the supply terminals. Similarly, for harmonic emissions the design process involves ensuring the fault level is high enough but, in this case, it is the point of common coupling that matters.

5.4.4.3 Wind Turbines

5.4.4.3.1 Section 8 of BS EN 61400-21 provides guidance on flicker and voltage change assessment. Data reported in turbine test results is used to predict the flicker severity and voltage change for switching operations and also flicker severity for continuous operation. This approach shall be adopted as appropriate to predict flicker levels from wind turbines and the results incorporated into flicker assessment under P28 Stage 2 or 3 as appropriate. See Appendix H. Section G3.0 of Appendix G gives guidance on fault level to be used.

5.4.4.4 Other Flicker-producing Equipment

5.4.4.4.1 There is a range of less common equipment that can also produce flicker. This includes arc furnaces, induction furnaces and 'static frequency converters', 'cycloconverters' and 'subsynchronous converter cascades'. Refer to Engineering Recommendation P28 for assessment. Section G3.0 of Appendix G gives guidance on fault level to be used.

5.4.5 Harmonic Assessment

5.4.5.1 Generalised Harmonic Assessment

5.4.5.1.1 Situations not covered below shall be assessed using Engineering Recommendation G5/4-1. Guidance on its application is given in Appendix I.

Page revised 7 February 2013

5.4.5.2 Equipment Subject To Restricted Connection (BS EN 61000-3-12)

5.4.5.2.1 Section 4.2.3 explains what equipment is referred to in the title above.

5.4.5.2.2 For harmonic producing equipment claiming compliance with BS EN 61000-3-12 there are 3 possible messages that must be included in the equipment Instruction Manual/Literature[2]:

a) 'Equipment conforming to BS EN 61000-3-12, provided $R_{sce\ min}$ = 33'
b) 'Equipment conforming to BS EN 61000-3-12, provided $R_{sce\ min}$ = xx as verified by the supply authority'
c) 'This equipment requires supply authority acceptance for connection to the public supply network'.

5.4.5.2.3 All such cases shall be referred to Primary System Design for consideration.

5.4.5.3 Equipment With Rated Current ≤ 16A Not Compliant With Appropriate Standards

5.4.5.3.1 In the unlikely event that we are asked to approve connection of low-powered equipment (i.e. rated current under 16A) that does not comply with the relevant standard refer to Primary System Design; it may be that no connection is possible without mitigation.

5.4.6 Voltage Unbalance Assessment

5.4.6.1 If 'large' single-phase equipment has been identified then assessment is required. Examples include:

a) Phase-phase railway traction load
b) Phase-phase induction furnace
c) Phase-phase arc furnace.

5.4.6.2 Engineering Recommendation P29 shall be used for assessment of voltage unbalance, including estimation of voltage unbalance where necessary and to determine acceptability. For AC traction supplies to railways refer also to Engineering Recommendation P24. Appendix J provides background information on voltage unbalance.

5.4.7 Voltage Notching Assessment

5.4.7.1 Engineering Recommendation G5/4-1, section 9.3 'Notching' shall be used for assessment of voltage notching. G5/4-1 sets a limit for the 'notch depth' which is compared with that advised by the customer.

Note: Voltage notching arises with power electronic devices (e.g. three phase converter) when current is 'commutated' from one phase to another. This

[2] Note that $R_{sce\ min}$ is a term defined in BS EN 61000-3-12.

effectively creates a momentary short-circuit between two phases and creates a notch in the voltage waveform.

5.4.8 Sub-harmonic And Inter-harmonic Assessment

5.4.8.1 Engineering Recommendation G5/4-1, section 9.2 'Sub-harmonic and Inter-harmonic Distortion' shall be used for assessment of sub-harmonic and inter-harmonic emissions.

5.4.9 Assessment Of Other Types Of Disturbance

5.4.9.1 The list of types of assessment in section 5.0 is not exhaustive. In particular, some voltage waveform disturbances are not specifically covered (e.g. capacitor switching transients). Generally, this only comes to the attention of WPD if customers experience problems. However, should a customer ask specifically for agreement to connect such equipment (e.g. a 'large' capacitor) then refer to Primary System Design.

6.0 CONNECTION DESIGN

6.1 It may not be possible to connect disturbing loads to the distribution system with a connection simply chosen to meet the rating of proposed customer equipment. In such cases, either some form of mitigation on the customer-side or a change in the connection design (or a combination of the two) is required.

6.2 In general, it may be possible to accept a disturbing load by measures that reduce system source impedance to the point of common coupling (PCC) with other customers. These measures may include:

a) Increase transformer size
b) Increase conductor cross-sectional area
c) Connect the customer direct to the transformer with a dedicated feeder
d) Use a dedicated transformer to give the PCC at a higher voltage.

6.3 Alternatively or in addition, the customer may be able to change the characteristics of the proposed equipment or its operating regime to reduce the disturbance. This may prove more economic than a network solution.

6.4 Where the equipment produces harmonic current emissions, in addition to designing a connection to give compliance with Engineering Recommendation G5/4-1, it may be necessary to consider the additional heating effect that harmonic currents introduce. In particular, transformers, LV cabinets and LV cables may need to be 'oversized' to cater for this additional heating.

6.5 As a guide, Table 4 gives examples of transformer de-rating for different types of non-linear equipment (that produce harmonic current) and mixes of non-linear and linear equipment (NB linear equipment = no harmonic current). The examples assume no cancellation of harmonic current from different sources (i.e. the most onerous case). Primary System Design can assist with calculation of transformer de-rating/over-sizing if necessary.

Equipment Connected to Transformer	De-rate Transformer to X% of Nameplate, X%
100% switched mode power supply (SMPS) (e.g. personal computers)	77.5
100% 6-pulse Motor Drive	86.5
100% Electronically ballasted lighting (e.g. compact fluorescent lighting)	66.4
50% SMPS/50% Linear	89.0
30% SMPS/70% Linear	93.2
33% SMPS/33% Electronically Ballasted Lighting/33% Linear	85.7
50% 6-pulse Motor Drive/50% Linear	93.1

Table 4 – Examples of Transformer De-rating By Load Mix

6.6 For LV cables and LV cabinets use the "Cable and Cabinet Rating Assessor" spreadsheet to determine if over-sizing is required.

7.0 CONNECTION COST INDICATIONS, OFFERS AND AGREEMENTS

7.1.1 In providing connection cost indications or offers to customers where disturbing equipment is involved it is important to identify the assumptions/constraints that apply. This shall be done by inclusion of a statement of information used in the assessment (e.g. this is based upon x, y and z that you have told me and the following assumptions) or by defining restrictions such that the important characteristics and assumptions are sufficiently well defined. The offer process allows users to pick specific restriction clauses as appropriate.

7.1.2 Where judged necessary, planners shall incorporate additional clauses in connection agreements to ensure that the conditions of granting connection are recorded. Such cases may include situations that are marginal, where information is poor or assumptions broad and where the disturbing equipment is significant. This is necessary to allow enforcement should problems/complaints occur post-connection. Appendix K reproduces the standard clauses that will cover most cases.

8.0 ELECTRICITY SAFETY, QUALITY AND CONTINUITY REGULATIONS 2002

8.1.1 Regulation 26 of the Electricity Safety, Quality and Continuity Regulations 2002 specifies the procedure to use if we consider that an installation is causing or would cause disturbance and also the procedure to challenge our refusal to give or continue a supply. If a load is causing or would cause disturbance we can issue a notice in writing requiring remedial works within a reasonable period; if this remedial work is not carried out we may disconnect or refuse to connect and must issue a notice in writing setting out the reasons.

9.0 BACKGROUND

9.1.1 As a condition of our Electricity Distribution Licence we are required to comply with the Distribution Code. Notably, the Code requires compliance with the limits/levels set out in Engineering Recommendations P28, G5/4-1 and P29, covering flicker, voltage distortion and voltage unbalance.

APPENDIX A

DISTURBANCE DEFINITIONS

Disturbance	Definition[3]
Flicker	Impression of unsteadiness of visual sensation induced by a light stimulus whose luminance or spectral distribution fluctuates with time. NOTE Voltage fluctuations cause changes of the luminance of lamps which create the visual phenomenon called flicker. Above a certain threshold flicker becomes annoying. The annoyance grows very rapidly with the amplitude of the fluctuation. At certain repetition rates even very small amplitudes can be annoying.
Flicker severity	Intensity of flicker annoyance is defined by the UIE-IEC flicker measuring method and evaluated by the following quantities:- - short-term severity (P_{st}) measured over a period of ten minutes - long-term severity (P_{lt}) calculated from a sequence of twelve P_{st} values over a two hour interval
Voltage fluctuation	A series of voltage changes or a cyclic variation of the voltage envelope.
Voltage distortion & harmonics	Deviation from the ideal sinusoidal waveform. Harmonics are sinusoidal voltages or currents that are integer multiples of the fundamental frequency, 50Hz.
Voltage unbalance	In a three-phase system, a condition in which the RMS values of the phase voltages or the phase angles between consecutive phases are not equal.
Voltage notching	A severe voltage change, generally of very short duration, caused by the commutation action of a rectifier.
Inter-harmonic voltage & sub-harmonic voltage	A periodic voltage disturbance having a frequency which is a non-integer multiple, μ, of the fundamental 50Hz system frequency. If μ is less than 1, then the term sub-harmonic voltage disturbance is used.
Oscillatory transient voltage	A sudden, non-power frequency change in the steady-state condition of voltage that includes both positive- or negative-polarity value.
Transient overvoltage	A short duration oscillatory or non-oscillatory overvoltage usually highly damped and with a duration of a few milliseconds or less.

[3] Sources: BS EN 50160, Electrical Power Systems Quality, Dugan R.C. et al and G5/4.

APPENDIX B

POSSIBLE DISTURBANCE BY EQUIPMENT TYPE

Potentially Disturbing Equipment	Possible Disturbance					
	Flicker	**Voltage Distortion (harmonics)**	**Unbalance**	**Sub-harmonic & Interharmonic Voltage Distortion**	**Voltage Notching**	**Oscillatory Transients**
Motors	✓	✓ (VSD & soft start)			✓ (VSD & soft start)	
Welders	✓	✓ (DC welder)		✓		
Induction furnaces	✓	✓ (certain types)	✓ (certain types)	✓ (certain types)	✓ (certain types)	
Arc furnaces	✓			✓		
Kilns	✓					
Motor drives (i.e. variable speed drives)		✓			✓	
Uninterruptible power supplies and other battery charging systems		✓			✓	
Industrial/ commercial converters (i.e. rectifiers, AC-DC convertors and AC-AC convertors)		✓		✓ (certain types)	✓	
Industrial/ commercial AC regulators (agricultural lighting control or industrial heating control)		✓				
Train traction supplies		✓	✓			
Multiple personal computer installations (e.g. offices, data centres etc)		✓				
Other (e.g. high powered equipment not designed to take account of disturbance controlling standards)	✓	✓				
Generators	✓					
Switched capacitors						✓

APPENDIX C

STANDARD DATA COLLECTION FORMS

See 4.1.2 & Table 2.

EXAMPLE STATEMENTS IN INSTRUCTION MANUALS – EQUIPMENT SUBJECT TO CONDITIONAL/RESTRICTED CONNECTION

Equipment	**Statement**
Trianco Electric Boiler	"Important The electrical supply requirements:- The 2kW boilers and 6kW boilers meet the requirements of EN 61000-3-3. The 9kW and 11kW boiler must be installed in premises having a service supply of ≥ 100 A per phase and meet the requirements of IEC 60417-5855. The 12kW boiler must be installed in premises having a system impedance of not more than 0.1939 + 0.1939 ohm."

MOTORS THAT CAN BE CONNECTED WITHOUT DETAILED FLICKER ANALYSIS

E1 Small Rural Transformers 1-Phase 240V and 1-Phase 480V

Transformer	1-Phase 240V Motor		1-Phase 480V (split-phase) Motor	
	Frequent Start	Infrequent Start	Frequent Start	Infrequent Start
5kVA	N/A Ze>0.35Ω		N/A	
10kVA	0.28kW	0.62kW	N/A	
15kVA	0.30kW	0.66kW	N/A	
16kVA	0.30kW	0.66kW	N/A	
25kVA	0.32kW	0.71kW	N/A Ze>0.35Ω	
50kVA	0.35kW	0.78kW	0.97kW	2.14kW
100kVA	N/A		1.11kW	2.44kW

Table E1 – Maximum Motor Rating Without Flicker Analysis – See Assumptions Table E4

E2 3-phase Rural Distribution Transformers

Transformer	3-Phase 415V Motor		1-Phase 240V Motor	
	Frequent Start	Infrequent Start	Frequent Start	Infrequent Start
25kVA	0.79kW	1.73kW	0.26kW	0.58kW
50kVA	1.20kW	2.65kW	0.34kW	0.75kW
100kVA	1.67kW	3.68kW	0.41kW	0.91kW
200kVA	2.26kW	4.99kW	0.49kW	1.09kW

Table E2 – Maximum Motor Rating Without Flicker Analysis – See Assumptions Table E4

E3 Urban 11kV/415V

Transformer	3-Phase 415V Motor		1-Phase 240V Motor	
	Frequent Start	Infrequent Start	Frequent Start	Infrequent Start
≥300kVA	2.66kW	5.86kW	0.53kW	1.18kW

Table E3 – Maximum Motor Rating Without Flicker Analysis – See Assumptions Table E4

E4 Assumptions

	Table E1	Table E2	Table E3
Motor Starting	Direct-on-line		
Motor Starting Power Factor	0.3		
Frequent Start	No more than one start per minute		
Infrequent Start	No more than four starts per hour		
PME Earth Loop Impedance	0.35Ω		
HV Fault Level	10MVA	25MVA	75MVA
HV X/R Ratio	1.5	1.5	8

Table E4 – Assumptions Used in Producing Tables E1-E3

Note: 1 HP = 0.746kW and 1kW = 1.34HP

BACKGROUND INFORMATION – MOTORS, WELDERS AND FLICKER

F1.0 MOTORS

F1.1 Motors have the following characteristics:

a) Rating
   i) In kVA or horse power (HP)
   ii) NB 1 HP = 0.746kW; 1kW = 1.34 HP
   iii) Typical range: 0.5 HP – 4 HP 230V and 1 HP – 20 HP 400V
b) Motors draw several times running current on starting
c) Starting current depends on type and rating of motor and method of starting
d) Motor starting torque is proportional to the square of the applied voltage
   i) Motor will not start or may take a long time at reduced voltage and risk overheating
   ii) A motor needs a minimum of approximately 80% rated motor voltage.

F1.2 Example motor starting current is shown in Figure F1. Starting can take several seconds.

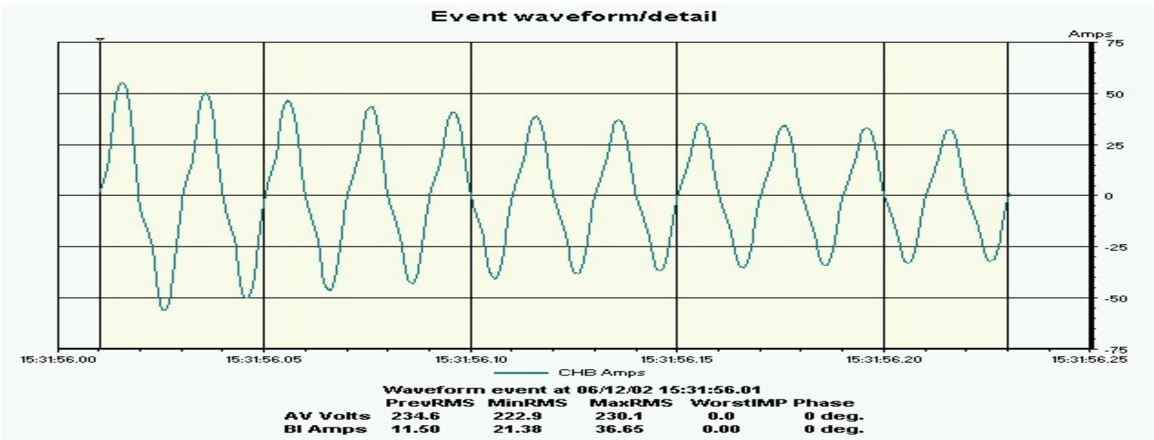

Figure F1 – Example Motor Starting Current

F1.3 Table F1 shows the ratio of starting current to running current. The highest ratio is with direct-on-line starting. This is the lowest cost option. Resistance starters initially insert a resistance in series with the motor; this is shorted out after a delay. Star-delta starters connect the windings in star initially and then reconnect in delta after a delay; this reduces the starting current.

Starter Type	Starting Multiplier
Direct-on-line	7
Star/delta	3.5
Auto-transformer	3.5
Electronic soft-start/variable speed drive	2.5
Slip-ring rotor resistance	1.5
Single-phase capacitor start	4.5
Single-phase series-parallel	2.5

Table F1 – Motor Starting:Running Current Ratios

F2.0 **WELDERS**

F2.1 There are two basic types of welder: arc welder and resistance welder. Further sub-divisions are possible as shown in Table F2.

Basic Type	Sub-type
Arc	Manual metal arc
	Tungsten inert-gas (TIG) (a.k.a GTAW)
	Metal inert-gas (MIG) (a.k.a. GMAW)
Resistance	Spot
	Projection
	Wire
	Seam

Table F2 – Welder Types

F2.2 Figure F2 shows an example of an arc welder. The welding transformer reduces the voltage but increase the current to produce a useable welding current. A voltage change occurs when an arc is struck and when broken.

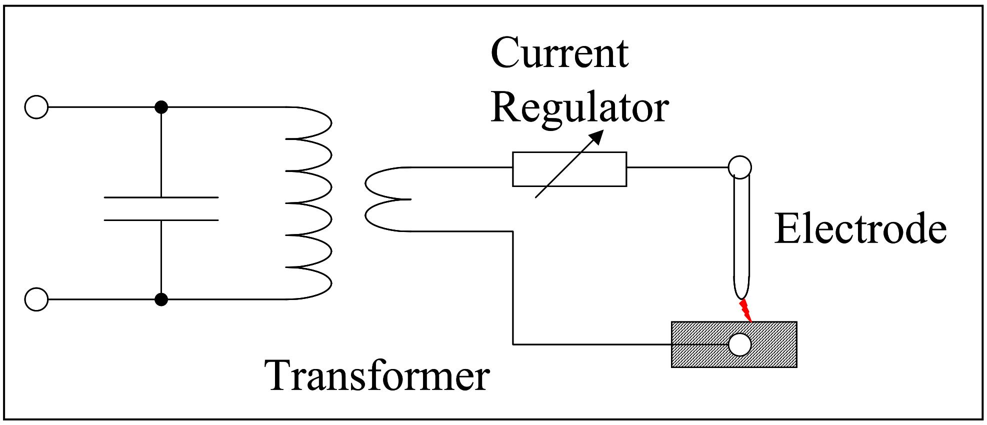

Figure F2 – Arc Welder

F2.3 Figure F3 shows an example rating plate for an arc welder. The format is standardised in BS EN 60974-1. The parts circled are significant for flicker assessment.

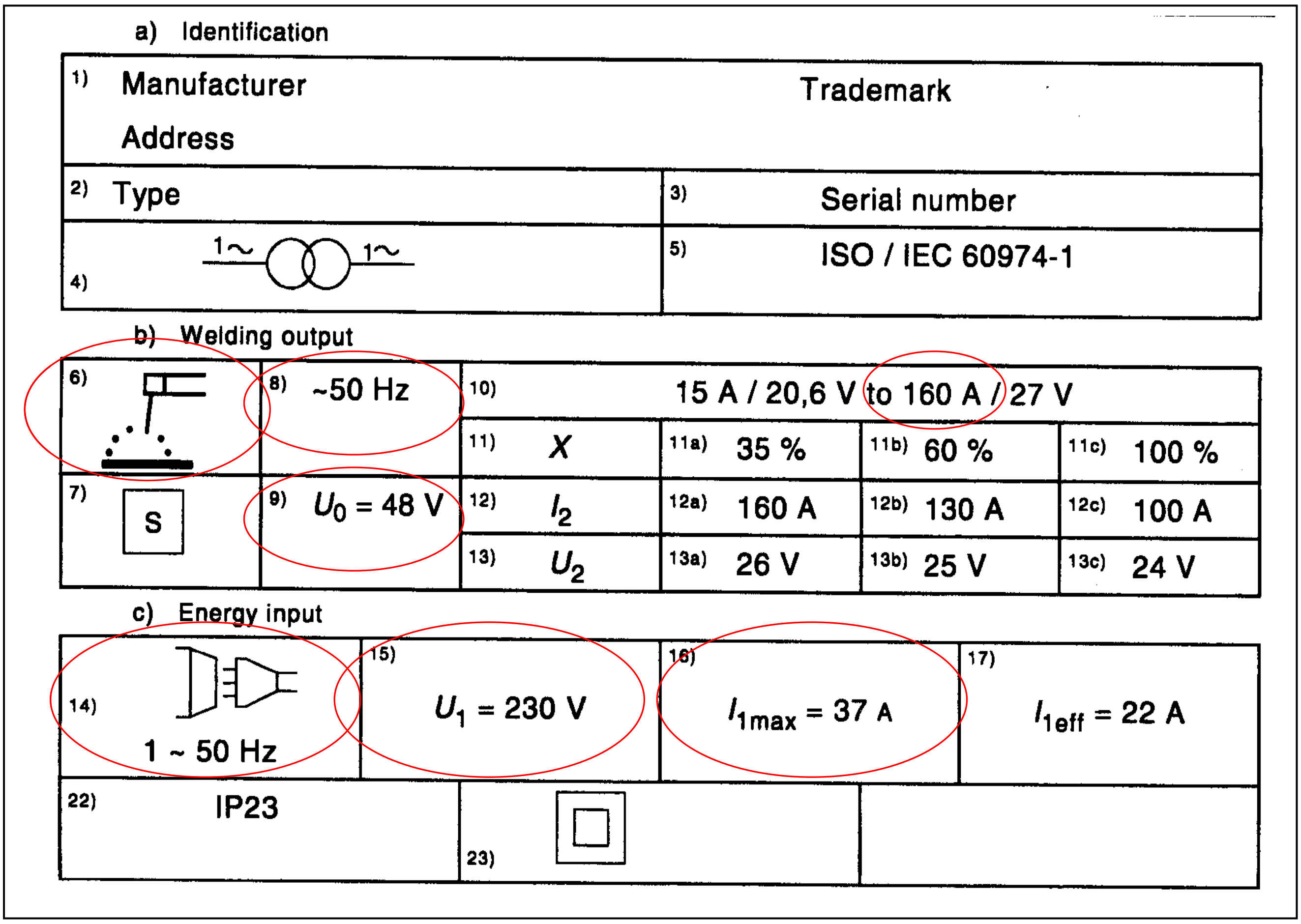

Figure F3 – Example Arc Welder Rating Plate

F2.4 The Rating Plate is interpreted as follows:

- Boxes 14 and 15 provide the input phases and voltage.
- Box 8 indicates whether the welder is an AC or DC welder.
- Boxes 15 and 16 give the information necessary to calculate the input kVA.
- Box 9 gives the open circuit welding voltage. Box 10 gives the maximum welding current.

F2.5 Figure F4 shows an example based on the data in Figure F3.

F2.6 In addition to the voltage change due to the current drawn when welding there is also voltage change due to magnetising inrush superimposed on the welding current. This magnetising inrush is worst if energised at the voltage 'zero-crossing'. Some welders are fitted with 'point-on-wave' control to eliminate the voltage drop due to inrush; this 'fires' at voltage peak..

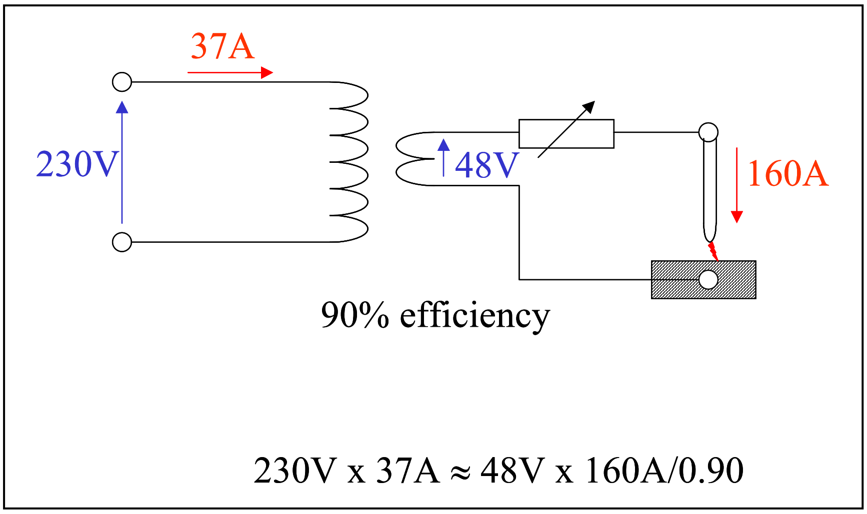

Figure F4 – Example Arc Welder Data

F3.0 FLICKER

See Appendix A of P29.

GUIDANCE ON APPLICATION OF ENGINEERING RECOMMENDATION P28 TO 'COMPLEX' SITUATIONS

G1.0 STAGE 2 ASSESSMENT

A Stage 2 flicker assessment involves verifying that at the PCC:

a) Short-term flicker severity, P_{st}, from the proposed load is not greater than 0.5 AND
b) Voltage change is not greater than 3% (NB 1% for welders from ACE Report No.7 which is referenced in P28).

The above assumes that, provided (b) is also met, any proposed load that produces a $P_{st} \leq 0.5$ can be connected. This is based on the fact that the combined effect of 8 such loads with small risk of coincident voltage changes is at the threshold of irritation (i.e. $P_{st} = 1$ from $P_{st} = \sqrt[3]{8(0.5)^3}$). Clearly, if the number of such other disturbing loads exceeds 7 or the risk of coincidence is not small and/or the existing equipment produces levels higher than $P_{st} = 0.5$ individually or 0.956 combined then the underlying assumption is invalid. Some care is therefore required.

For situations where WinDebut is inappropriate (e.g. ramped voltage changes, multi-operator or seam welding machines, multiple motors and other complex cases) the following methods of assessment are possible:

- Calculation
- Simulation
- Measurement and adjustment for fault level.

Engineering Recommendation P28 explains how to perform assessments for such 'complex' situations. Note: Calculation can be involved and it is normally better to use flicker simulation software, held by Primary System Design, to predict P_{st} for 'complex' cases.

G2.0 STAGE 3 ASSESSMENT

If equipment is not acceptable under Stage 2, then it proceeds to Stage 3 for assessment. Engineering Recommendation P28 explains how to perform such assessments. This involves measurement of existing flicker severity levels and then prediction of the expected levels were the equipment to be connected.

Note that equipment with an LV PCC cannot normally be assessed under Stage 3. This is because of the difficulties in controlling connection of domestic disturbing load which may increase the background levels.

The Stage 3 limits are reproduced in Table G1.

Nominal Voltage at PCC	Limit	
	P_{st}	P_{lt}
≤ 132kV	1.0	0.8
>132kV	0.8	0.6

Table G1 – Flicker severity limits from Engineering Recommendation P28

A P_{st} of 1.0 corresponds to marginal flicker visibility for 50% of test observers. Note that complaints can occur for values below these planning limits. Extreme caution is justified in accepting equipment under Stage 3 if the predicted flicker severity is close to the set limits; a conditional connection agreement is necessary as mitigation or disconnection may be necessary should complaints be received.

Note that if short-term flicker is sustained at the same level over 2 hours then the P_{st} value equals the P_{lt} value. This is because the long-term value, P_{lt}, where $P_{lt} = \sqrt[3]{\frac{1}{12}\sum_{j=1}^{12} \left(P_{st\,j}\right)^3}$, is calculated using a series of twelve P_{st} values and a P_{st} value is calculated for each 10 minute period.

G2.1 **Summation Factors**

To assess a proposal the expected flicker level from new flicker-producing load when combined with the existing background flicker level must be estimated. Appendix A2.2 of Engineering Recommendation P28 provides guidance on this.

To apply the given summation formula it is necessary to decide which summation factor, m, to use. For most situations a summation factor of m = 3 is a good approximation for loads where there are unlikely to be exactly co-incident voltage changes.

The value of m should be chosen based on the characteristics of the main source of fluctuation and using the descriptions in Appendix A2.2 as guidance

The summation factor of m = 2 should be reserved for independent operation of multiple arc furnaces with different cycle times. In this case there is a high probability of coincident melts.

It should be noted that the summated flicker severity derived is only an estimate often based on limited data; furthermore, the flicker severity itself is also only an indication of the likelihood of complaints. This highlights the importance of conditional connection agreements such that mitigation is required where justified if complaints arise.

Note that P_{lt} values can be summated in the same manner as P_{st} values; this is not explicitly stated in P28.

G2.2 **Flicker Simulator**

A flicker simulator programme and explanatory notes are accessible via the following links:

Flicker Simulator
Flicker Simulator Explanatory Notes.

The flicker simulator allows the short-term flicker severity, P_{st}, to be calculated by computer rather than hand-calculation (i.e. memory-time technique detailed in P28). It can be used to estimate P_{st} for single or multiple disturbing loads. This is done via multi-point entry of the voltage versus time; the data entry process is further simplified for welders.

G3.0 **FAULT LEVEL**

In Stage 2 and 3 flicker assessments it is necessary to decide on which network configuration(s) to consider. As this affects network impedance, which is a key factor in determining flicker via size of voltage step change, the choices made are critical to the assessment. The following guidance is provided:

P28 Stage	**Network Arrangement To Consider**	
	PCC	
	LV	HV/EHV
Stage 2	Normal running	Single outage/fault giving highest network impedance
Stage 3	N/A	Single outage/fault giving highest network impedance

Table G2 – Network arrangement for assessment versus PCC voltage

Some background information is provided below.

Engineering Recommendation P28 offers somewhat contradictory statements. P28, section 4.2:

"The impedance value to be used is that which gives a realistic maximum value of flicker severity which may occur at the times when lighting is in widespread use over the useful lifetime of the disturbing load. This is very much dictated by local conditions…"

but it also adds "Outages due to faults or maintenance should in general be disregarded as they will normally occur for short periods. Major maintenance can usually be undertaken during the summer months when the use of lighting is at a minimum."

P28, Section 7:

"Attention is given to Section 4.2 which gives advice on the system impedance to use in determining P_{st} and P_{lt} for compliance with able 1. In particular due consideration should be given to supply arrangements where the supply impedance can increase significantly for some outages. Such outage conditions may give rise to a significant risk of flicker complaints if the normal supply flicker levels are close to the Table 1 limits and in these cases extreme caution should be taken in accepting additional fluctuating loads."

Note that the ESQC Regulations take precedence over P28 and Regulation 3 state:

"Generators, distributors and meter operators shall ensure that their equipment is -

…
(b) so constructed, installed, protected (both electrically and mechanically), used and maintained as to prevent danger, interference with or interruption of supply, so far as is reasonably practicable".

PREDICTION OF FLICKER AND VOLTAGE STEP CHANGE FROM WIND TURBINE INSTALLATIONS

The standard BS EN 61400-21 covers the measurement and assessment of power quality characteristics of wind turbine generators. Section 8 of BS EN 61400-21 provides formulae for the calculation of flicker and voltage step change; these formulae are reproduced in Tables H1 and H2. The formulae use parameters detailed in a wind turbine test report. An example report can be accessed through the following link:

NEG NM900/52 Wind Turbine Test Report.

Operation	Parameter	Formula	
		Single Turbine	**Group of Turbines**
Continuous	$P_{st} = P_{lt}$	$c(\psi_k, \nu_a)\frac{S_n}{S_k}$	
	$P_{st\Sigma} = P_{lt\Sigma}$		$\frac{1}{S_k}\sqrt{\sum_{i=1}^{N_{wt}} \left(c_i(\psi_k, \nu_a)S_{n,i}\right)^2}$
Parameter	**Key**		
P_{st}	Short-term flicker emission from the wind turbine.		
P_{lt}	Long-term flicker emission from the wind turbine.		
$P_{st\Sigma}$	Short-term flicker emission from the group of wind turbines.		
$P_{lt\Sigma}$	Long-term flicker emission from the group of wind turbines.		
$c(\psi_k, \nu_a)$	Flicker coefficient of the wind turbine for the given network impedance phase angle ψ_k at the PCC, and for the given annual average wind speed, ν_a at a hub-height of the wind turbine at the site.		
S_n	Rated apparent power of the wind turbine.		
S_k	Short-circuit apparent power at the PCC.		
$c_i(\psi_k, \nu_a)$	Flicker coefficient of the individual wind turbine.		
$S_{n,i}$	Rated apparent power of the individual wind turbine.		
N_{wt}	Number of wind turbines connected to the PCC.		

Table H1 – Formulae – Continuous Operation – Flicker

Note: For continuous operation, the equation for $P_{st\Sigma}$ and $P_{lt\Sigma}$ in Table H1 may underestimate the flicker level on a weak network with induction wind turbines due to possible synchronisation of the turbines.

Operation	Parameter	Formula	
		Single Turbine	Group of Turbines
Switching	P_{st}	$18.N_{10}^{0.31}k_f(\psi_k)\frac{S_n}{S_k}$	
	P_{lt}	$8.N_{120}^{0.31}k_f(\psi_k)\frac{S_n}{S_k}$	
	$P_{st\Sigma}$		$\frac{18}{S_k}\left(\sum_{i=1}^{N_{wt}} N_{10,i}\left(k_{f,i}(\psi_k).S_{n,i}\right)^{3.2}\right)^{0.31}$
	$P_{lt\Sigma}$		$\frac{8}{S_k}\left(\sum_{i=1}^{N_{wt}} N_{120,i}\left(k_{f,i}(\psi_k).S_{n,i}\right)^{3.2}\right)^{0.31}$
	d	$100.k_u(\psi_k)\frac{S_n}{S_k}$	Not required.

Parameter	Key
P_{st}	Short-term flicker emission from the wind turbine.
P_{lt}	Long-term flicker emission from the wind turbine.
$P_{st\Sigma}$	Short-term flicker emission from the group of wind turbines.
$P_{lt\Sigma}$	Long-term flicker emission from the group of wind turbines.
d	Relative voltage change in % due to a switching operation of a wind turbine.
$k_f(\psi_k)$	Flicker step factor of the wind turbine for the given ψ_k at the PCC.
S_n	Rated apparent power of the wind turbine.
S_k	Short-circuit apparent power at the PCC.
N_{10}	Number of switching operations of the wind turbine within a 10 minute period.
N_{120}	Number of switching operations of the wind turbine within a 2 hour period.
$k_{f,i}(\psi_k)$	Flicker step factor of the individual wind turbine for the given ψ_k at the PCC.
$S_{n,i}$	Rated apparent power of the individual wind turbine.
$N_{10,i}$	Number of switching operations of the individual wind turbine within a 10 minute period.
$N_{120,i}$	Number of switching operations of the individual wind turbine within a 2 hour period.
N_{wt}	Number of wind turbines connected to the PCC.
$k_u(\psi_k)$	Voltage change factor of the wind turbine for the given ψ_k at the PCC.

Table H2 – Formulae – Switching Operation – Flicker and Voltage Step Change

APPENDIX I

GUIDANCE ON APPLICATION OF ENGINEERING RECOMMENDATION G5/4-1

See ETR 122.

APPENDIX J

BACKGROUND INFORMATION – VOLTAGE UNBALANCE

Background information on voltage unbalance is provided in P29 and ETR116.

CONNECTION AGREEMENT CLAUSES – DISTURBING LOADS

K1.0 INTRODUCTION

K1.1 Although there are a variety of disturbances that can be caused by customer equipment, the most common are voltage step-change (giving flicker) and harmonic current (giving voltage distortion). Given this, it is useful to have standard clauses for the connection of equipment that causes these disturbances.

K2.0 BACKGROUND TO FLICKER CLAUSES

K2.1 To comply with the Distribution Code, when a customer wishes to connect potentially flicker-producing equipment we must assess how/whether this can be done. The Code requires we use the assessment methods given in Engineering Recommendation P28.

K2.2 To accept the connection of disturbing equipment may require special network requirements over and above that to meet the customer load and/or restrictions on the use/size/type of customer equipment. For the majority of such equipment that we encounter, this can be done by limiting the step-change in voltage caused together with how often the step-change occurs.

K2.3 Given that we have the knowledge of system impedance, it is correct to simply limit the current drawn and the repetition rate in the connection agreement.

K2.4 Whilst from a P28-compliance perspective, we need only protect other customers from annoyance, it is in our interests and those of the disturbance-causing customer to also point out if the voltage change at the Exit Point would be above the planning limit if such limits were applied to the disturbing load Exit Point rather than the point of common coupling.

K2.5 To avoid having to assess all motor loads, Appendix E gives sizes that need no assessment. These can be connected without specific reference using the Schedules below.

K3.0 BACKGROUND TO HARMONIC CLAUSES

K3.1 In the case of harmonic-producing equipment, to comply with the Distribution Code we may have to constrain customer harmonic current emissions. To allow later enforcement it may be necessary to record limits of current emissions in the connection agreement. This facility is provided in the Schedules below.

K4.0 PROPOSED CONNECTION AGREEMENT CLAUSES

K4.1 The General Terms for Connection already provides some protection for the Company against a customer who operates equipment that adversely affects voltage regulation or the supply of electricity. However, the following clauses shall be added where the Company is aware that the customer is installing equipment that may cause disturbance:

> You shall not connect any electrical equipment that may adversely affect the supply of electricity to others without Our previous written consent, which will not unreasonably be delayed or withheld. Consent has been granted for the equipment (if any) specified in the attached Schedule 1 and is subject to any operating restrictions specified. Where appropriate, this consent is based upon estimating the disturbance caused by the proposed equipment (which cannot be precisely determined in advance) and taking a risk-based approach to likelihood of complaint. Given this, it may be that, after installation is complete, the disturbance levels are determined to be unacceptable, and/or complaints are received that are attributable to Your equipment. We therefore reserve the rights given in Schedule 2 – the General Terms for Connection. We will not be liable for any costs incurred to remedy the situation.
>
> Your installation shall comply with the requirements of Electricity Association Engineering Recommendations P28 "Planning limits for voltage fluctuations caused by industrial, commercial and domestic equipment in the United Kingdom", G5/4-1 "Planning levels for harmonic voltage distortion and the connection of non-linear equipment to transmission systems and distribution networks in the United Kingdom" and P29 "Planning limits for voltage unbalance in the United Kingdom".

Clause 1

K4.2 Further additional text is specified to warn of possible flicker problems at the Exit Point, when appropriate (i.e. equipment may be accepted where the flicker disturbance at the Exit Point of the customer wishing to connect the disturbing equipment would be annoying but would not be annoying for other customers):

> The calculated voltage change when operating Your equipment may cause flickering lights within Your installation. Sensitivity to flicker varies widely between different people so the threshold of flicker perception and irritation are significantly dependent on the observer. We will not be liable for any costs incurred should You subsequently request reduction to the voltage change to alleviate flicker.

Clause 2 – Exit Point Disturbance Warning

K5.0 Schedule of Disturbing Equipment Granted Consent For Connection Subject to Operating Restrictions

Operating Regime	**<DESCRIBE CONSTRAINTS>**
Motor 1	
Phases:	1 or 3
Nominal voltage:	230/240/400V/415/460/480V
Rating:	<VALUE: default to 0>kW/<VALUE: default to 0>HP
Starting power factor:	0.3/0.9
Maximum starting current:	<VALUE: default to 0>A RMS
Maximum starting current:	<VALUE: default to 0>A RMS
Minimum time between starts:	<VALUE> hours/minutes/seconds
Motor 1	
Phases:	1 or 3
Nominal voltage:	230/240/400V/415/460/480V
Rating:	<VALUE: default to 0>kW/<VALUE: default to 0>HP
Starting power factor:	0.3/0.9
Maximum starting current:	<VALUE: default to 0>A RMS
Maximum starting current:	<VALUE: default to 0>A RMS
Minimum time between starts:	<VALUE> hours/minutes/seconds
Motor 1	
Phases:	1 or 3
Nominal voltage:	230/240/400V/415/460/480V
Rating:	<VALUE: default to 0>kW/<VALUE: default to 0>HP
Starting power factor:	0.3/0.9
Maximum starting current:	<VALUE: default to 0>A RMS
Maximum starting current:	<VALUE: default to 0>A RMS
Minimum time between starts:	<VALUE> hours/minutes/seconds
Motor 1	
Phases:	1 or 3
Nominal voltage:	230/240/400V/415/460/480V
Rating:	<VALUE: default to 0>kW/<VALUE: default to 0>HP
Starting power factor:	0.3/0.9
Maximum starting current:	<VALUE: default to 0>A RMS
Maximum starting current:	<VALUE: default to 0>A RMS
Minimum time between starts:	<VALUE> hours/minutes/seconds
Motor 1	
Phases:	1 or 3
Nominal voltage:	230/240/400V/415/460/480V
Rating:	<VALUE: default to 0>kW/<VALUE: default to 0>HP
Starting power factor:	0.3/0.9
Maximum starting current:	<VALUE: default to 0>A RMS
Maximum starting current:	<VALUE: default to 0>A RMS
Minimum time between starts:	<VALUE> hours/minutes/seconds

Schedule A: Motor Schedule For Flicker Control

Operating Regime	**<DESCRIBE CONSTRAINTS>**
Welder 1	
Phases:	1 or 3
Nominal voltage:	230/240/400V/415/460/480V
Type:	AC or DC
Point-on-wave switching:	Fitted/Not Fitted
Maximum input kVA:	<VALUE: default 0> kVA
Maximum welding kVA:	<VALUE: default 0> kVA
Maximum number of welds:	<VALUE: default 0> per hour/minute/second
Welder 2	
Phases:	1 or 3
Nominal voltage:	230/240/400V/415/460/480V
Type:	AC or DC
Point-on-wave switching:	Fitted/Not Fitted
Maximum input kVA:	<VALUE: default 0> kVA
Maximum welding kVA:	<VALUE: default 0> kVA
Maximum number of welds:	<VALUE: default 0> per hour/minute/second
Welder 3	
Phases:	1 or 3
Nominal voltage:	230/240/400V/415/460/480V
Type:	AC or DC
Point-on-wave switching:	Fitted/Not Fitted
Maximum input kVA:	<VALUE: default 0> kVA
Maximum welding kVA:	<VALUE: default 0> kVA
Maximum number of welds:	<VALUE: default 0> per hour/minute/second
Welder 4	
Phases:	1 or 3
Nominal voltage:	230/240/400V/415/460/480V
Type:	AC or DC
Point-on-wave switching:	Fitted/Not Fitted
Maximum input kVA:	<VALUE: default 0> kVA
Maximum welding kVA:	<VALUE: default 0> kVA
Maximum number of welds:	<VALUE: default 0> per hour/minute/second
Welder 5	
Phases:	1 or 3
Nominal voltage:	230/240/400V/415/460/480V
Type:	AC or DC
Point-on-wave switching:	Fitted/Not Fitted
Maximum input kVA:	<VALUE: default 0> kVA
Maximum welding kVA:	<VALUE: default 0> kVA
Maximum number of welds:	<VALUE: default 0> per hour/minute/second

Schedule B: Welder Schedule For Flicker Control

Voltage (V)	Phases	Aggregate restriction		
		Convertor		AC Regulator
		6-pulse (kVA)	12-pulse (kVA)	6-pulse thyristor (kVA)
400/415	3	<VALUE: default to 0>	<VALUE: default to 0>	<VALUE: default to 0>

Schedule C1: Schedule For Restriction By Limitation of Convertor/Regulator Rating

Voltage (V)	Phases	Aggregate restriction	Permitted Use
		AC Regulator (kVA)	
230/240	1	5	Industrial applications or overnight battery charging

Schedule C2: Schedule For Restriction By Limitation of Small AC Regulator Rating - Industrial Applications or Overnight Battery Charging

Harmonic	Maximum Harmonic Current At Exit Point (A RMS)[1,2]
3	<VALUE: default to 0>
5	<VALUE: default to 0>
7	<VALUE: default to 0>
9	<VALUE: default to 0>
11	<VALUE: default to 0>
13	<VALUE: default to 0>
15	<VALUE: default to 0>
17	<VALUE: default to 0>
19	<VALUE: default to 0>
21	<VALUE: default to 0>
23	<VALUE: default to 0>
25	<VALUE: default to 0>
All other odds	<VALUE: default to 0>
All evens	<VALUE: default to 0>

1. Measured in accordance with IEC 61000-4-7.
2. You shall employ adequate control measures to achieve the above.

Schedule C3: Schedule For Harmonic Current Control – Specific Control of Current Emissions - Simplified

Harmonic	Maximum Harmonic Current At Exit Point (A RMS)[1,2]
2	<VALUE: default to 0>
3	<VALUE: default to 0>
4	<VALUE: default to 0>
5	<VALUE: default to 0>
6	<VALUE: default to 0>
7	<VALUE: default to 0>
8	<VALUE: default to 0>
9	<VALUE: default to 0>
10	<VALUE: default to 0>
11	<VALUE: default to 0>
12	<VALUE: default to 0>
13	<VALUE: default to 0>
14	<VALUE: default to 0>
15	<VALUE: default to 0>
16	<VALUE: default to 0>
17	<VALUE: default to 0>
18	<VALUE: default to 0>
19	<VALUE: default to 0>
20	<VALUE: default to 0>
21	<VALUE: default to 0>
22	<VALUE: default to 0>
23	<VALUE: default to 0>
24	<VALUE: default to 0>
25	<VALUE: default to 0>
26	<VALUE: default to 0>
27	<VALUE: default to 0>
28	<VALUE: default to 0>
29	<VALUE: default to 0>
30	<VALUE: default to 0>
31	<VALUE: default to 0>
32	<VALUE: default to 0>
33	<VALUE: default to 0>
34	<VALUE: default to 0>
35	<VALUE: default to 0>
36	<VALUE: default to 0>
37	<VALUE: default to 0>
38	<VALUE: default to 0>
39	<VALUE: default to 0>
40	<VALUE: default to 0>
41	<VALUE: default to 0>
42	<VALUE: default to 0>
43	<VALUE: default to 0>
44	<VALUE: default to 0>
45	<VALUE: default to 0>
46	<VALUE: default to 0>
47	<VALUE: default to 0>
48	<VALUE: default to 0>
49	<VALUE: default to 0>
50	<VALUE: default to 0>

1. Measured in accordance with IEC 61000-4-7.
2. You shall employ adequate control measures to achieve the above.

Schedule C4: Schedule For Harmonic Current Control – Specific Control of Current Emissions

APPENDIX L

SUPERSEDED DOCUMENTATION

This document supersedes ST:SD6F dated October 2006 which should now be withdrawn.

APPENDIX M

ASSOCIATED DOCUMENTATION

ST:CS1B/1	Power Quality Investigations
ST:NC1R/1	Applications for the Connection of Small-Scale Embedded Generators to WPD's Distribution System
POL:SD2/5	132kV System Design
POL:SD3/5	66kV and 33kV System Design
POL:SD4/4	11kV and 6.6kV System Design
POL:SD5/4	LV System Design
ST:SD5N	Use of WinDebut Software for Assessing Motor and Welder Voltage Disturbance (Flicker)
ST:SD5O/1	Load Approval at Domestic Properties Requiring No Detailed Investigation
ST:SD6J	Connection design - potentially disturbing electrical equipment rated ≤75A/phase subject to conditional connection
Engineering Recommendation G5\4-1	Planning Levels for Harmonic Voltage Distortion and the Connection of Non-linear Loads to Transmission Systems and Public Electricity Supply Systems in the United Kingdom
Engineering Recommendation P24	Traction Supplies
Engineering Recommendation P28	Planning Limits for Voltage Fluctuations Caused By Industrial, Commercial and Domestic Equipment in the United Kingdom
Engineering Recommendation P29	Planning Limits for Voltage Unbalance in the United Kingdom
Engineering Technical Report ETR 116	Voltage Unbalance due to British Rail AC Traction Supplies
Engineering Technical Report ETR 122	Guide to the application of Engineering Recommendation G5/4 – in the assessment of harmonic voltage distortion and connection of non-linear equipment to the electricity supply system in the UK
ACE Report No.7	Report on the Supply to Welding Plant
BS EN 60974-1	Arc Welding Equipment. Part 1: Welding Power Sources.
BS EN 61000-3-2	Electromagnetic compatibility (EMC). Limits. Limits for harmonic current emissions (equipment input current ≤ 16A per phase).

BS EN 61000-3-12	Electromagnetic compatibility (EMC). Part 3-12: Limits for harmonic currents produced by equipment connected to public low-voltage systems with input current < 75A per phase and subject to restricted connection.
BS EN 61000-3-3	Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems, for equipment with rated current ≤16A per phase and not subject to conditional connection.
BS EN 61000-3-11	Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems, for equipment with rated current ≤75A per phase and not subject to conditional connection.
BS EN 61400-21	Wind turbine generator systems – Part 21: Measurement and assessment of power quality characteristics of grid connected wind turbines.
BS 5406-3	Disturbances in supply systems caused by household appliances and similar electrical equipment. Specification of voltage fluctuations.

APPENDIX N

IMPACT ON COMPANY POLICY

This Standard Technique is relevant to staff involved in planning and agreeing to connection of customer equipment that may cause disturbances. It is also relevant to staff investigating associated complaints.

APPENDIX O

IMPLEMENTATION OF POLICY

Immediate.

APPENDIX P

KEYWORDS

Connection, connection agreement, cost indication, design, disturbing load, disturbance, flicker, G5/4, harmonic, motor, offer, P28, unbalance, voltage distortion, welder.