

**Engineering Recommendation No.10  
of the Electricity Distribution Code**

**Limits for Voltage Unbalance  
in the Electricity Supply System**

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**Prepared by:**

Abu Dhabi Distribution Company,  
Al Ain Distribution Company,  
Abu Dhabi Supply Company for Remote Areas (RASCO)

**Approved by:**

Regulation and Supervision Bureau  
for the Water and Electricity Sector of the Emirate of Abu Dhabi

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## 1 Preface

This document has been prepared in accordance with the Distribution Code and forms part of Annex 1 of the Code. It applies to all Users of the Electricity Distribution System and is based on the Engineering Recommendation P29 which has been used successfully in the UK since 1990.

## 2 Definition of voltage unbalance

In a three-phase system, the degree of voltage unbalance is expressed by the ratio (in per cent) between the rms values of the negative sequence component and the positive sequence component of the voltage.

This ratio may be approximated as:

$$\text{Voltage unbalance (\%)} = \frac{\text{Maximum deviation from the average of the three-phase voltages} \times 100\%}{\text{average of the three-phase voltages}}$$

## 3 Scope & definitions

This engineering recommendation has been prepared to provide limits for voltage unbalance in public distribution networks operating at 33kV and below, to be used in the technical evaluation of proposed new loads which may give rise to additional voltage unbalance. In assessing requirements for the connection of the load, account will be taken of significant sources of unbalance already known to be connected in order to maintain an acceptable quality of supply.

Unbalance due to faults is not covered by this engineering recommendation and the levels that occur are likely to exceed the specified limits. Equipment which may be damaged by such a situation should be protected by loss- of-phase, out-of-balance or negative phase sequence protection as appropriate.

Definitions of technical terms are given where they occur in this document. All other terms and definitions are as used in the Electricity Distribution Code.

## 4 Description of voltage unbalance

The voltage measured at the terminals of a generator, and provided to the distribution system, is almost perfectly sinusoidal in shape with the three

phases equal in magnitude and separated by 120°. If the impedances of the various system components were linear and identical for each phase, and if all loads were balanced and three-phase in nature, the voltages would remain balanced. However, many low voltage loads are single phase and at higher voltages some large single-phase loads may be connected (e.g. rotating machines, furnaces). The result is that the aggregate of these diverse and varied loads may give rise to a small unbalance in the 3 phase supply voltage (by drawing different currents on each phase, or at a phase angle slightly outside 120° between each phase). This unbalance in voltage will then affect other customers connected on the same supply network, from the point of common coupling (pcc) downwards.

Unbalanced voltages at the low voltage level are not transferred upwards to HV due to the relatively high impedance of power transformers (and low source impedance at higher system voltages). Voltage unbalance at higher voltages is, however, transferred to lower voltages.

## 5 Effects on Equipment

Experience in other countries has shown that provided the limits of unbalance specified in this document are observed, equipment will not generally be adversely affected by unbalance. These same limits have been adopted for the emirate of Abu Dhabi.

Some types of equipment are more sensitive to unbalance than others, in particular 3 phase rotating machines, where the main affect of voltage unbalance is overheating of stator and rotor windings. Also, rectifier and inverter equipment tend to generate more harmonics when subject to an unbalanced supply voltage.

## 6 Estimation of Unbalance

The voltage unbalance arising at the point of common coupling (pcc) due to a combination of unbalanced three-phase loads or phase to phase loads may be evaluated by the following expression:

$$\text{Voltage unbalance (\%)} = \frac{\sqrt{3} \times \text{negative phase sequence Component of the loads (A)} \times \text{line voltage} \times 100\%}{\text{Three-phase short circuit level at exit point (MVA)}}$$

The voltage unbalance caused by a load connected only between two phases may be calculated as:

$$\text{Voltage unbalance (\%)} = \frac{\text{single phase load (MVA)} \times 100\%}{\text{three phase short circuit level (MVA) at that point}}$$

## 7 Measurement of Unbalances

An approximate assessment of unbalance may be made as discussed in section 6 above. However, accurate measurement of unbalance requires the use of phase sequence recording equipment and analysis software (see ref. 2). This takes into account the phase angle as well as the magnitude of unbalances from different loads and provides a method to aggregate their affect.

## 8 Reduction of Unbalance

A number of technical options may be considered in order to reduce existing or potential unbalance in a supply system:

- connection of disturbing loads to a different supply point
- rearrangement of phase connections of one or more loads
- connection of disturbing load at a higher voltage level
- provision of phase balancing or filtering equipment

## 9 Planning Limits for Voltage unbalance

In the European Standard EN 50160 (1994) voltage unbalance is measured in relation to the negative phase sequence component of the supply voltage since this is considered the most relevant with respect to interference to equipment. This standard implies that if the magnitude of the negative phase sequence component is within 2% of the positive phase sequence component then the unbalance is acceptable.

This limit for voltage unbalance is common to a number of international standards and it is recommended for the Emirate of Abu Dhabi. This limit is to be taken for the combined affect of all new and existing loads at the point of common coupling.

In the supply system there may be a background level of unbalance (normally less than 0.5%) and therefore the affect of any new load must be considered in the light of existing levels of unbalance. The UK document Engineering Recommendation P29 states that unbalance caused by individual loads should be kept within 1.3%, although short term deviations (less than 1 minute) may be allowed up to 2%.

In summary, the adopted limits for unbalance are:

- (a) unbalance at individual loads / connections: **1.3%**
- (b) unbalance at pcc (aggregate affect of several loads): **2%**

## 10 References

1. **Engineering Recommendation P29**  
Planning Limits for Voltage Unbalance  
Energy Networks Association, 1990
2. **Engineering Technical Report 116**  
Report on Voltage Unbalance due to Traction Supplies  
Energy Networks Association, 1989
3. **IEC publication 146 - semi-conductor converters**  
(susceptibility to unbalanced supply voltage)  
International Electrotechnical Commission
4. **European Standard EN 50160 (1994)**  
International Electrotechnical Commission

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