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Specification for
Motor starters for voltages up to
and including 1000 V a.c. and 1200 V d.c.

Part 3. Rheostatic rotor starters

Spécification des démarreurs de moteur pour les tensions inférieures
et égales à 1000 V en courant alternatif et 1200 V en courant continu
Partie 3. Démarreurs rotoriques à résistances

Spezifikation für Motorstarter für Spannungen bis und einschließlich
1000 V Wechselstrom und 1200 V Gleichstrom
Teil 3. Widerstandsanlasser für Schleifringläufermotoren

Foreword

This British Standard has been prepared under the authority of the Power Electrical Engineering Standards Committee. It is identical with Publication 292 'Low-voltage motor starters' Part 3 'Rheostatic rotor starters' published by the International Electrotechnical Commission (IEC). It supersedes those requirements of BS 587 : 1957 'Motor starters and controllers' that relate to rheostatic rotor starters for voltages up to and including 1000 V a.c.

Because the text of an IEC Publication has been copied it includes some minor material not appropriate to a British Standard.

For the purposes of this British Standard the text of IEC 292-3 given in this publication should be modified as follows.

Terminology. The words 'British Standard' should replace 'Recommendation' wherever it appears.

Cross-references. The references to other IEC Publications should be replaced by references to British Standards as follows.

Reference to IEC Publication

IEC Publication 144 'Degrees of protection of enclosures for low-voltage switchgear and controlgear'

IEC Publication 157 'Low-voltage switchgear and controlgear'

Part 1 'Circuit-breakers'

IEC Publication 158 'Low-voltage controlgear'

Part 1 'Contactors'

IEC Publication 292 'Low-voltage motor starters'

Part 1 'Direct-on-line (full voltage) a.c. starters'

IEC Publication 292-1A 'First supplement to Publication 292-1 (1969)'

IEC Publication 337 'Control switches (low-voltage switching devices for control and auxiliary circuits, including contactor relays)'

Part 1 'General requirements'

Appropriate British Standard

BS 5420 'Degrees of protection of enclosures of switchgear and controlgear for voltages up to and including 1000 V a.c. and 1200 V d.c.'*

BS 4752 'Switchgear and controlgear for voltages up to and including 1000 V a.c. and 1200 V d.c.'

Part 1 'Circuit-breakers'*

BS 5424 'Controlgear for voltages up to and including 1000 V a.c. and 1200 V d.c.'

Part 1 'Direct-on-line (full voltage) a.c. starters'*

BS 4941 'Motor starters for voltages up to and including 1000 V a.c. and 1200 V d.c.'

Part 1 'Direct-on-line (full voltage) a.c. starters'

Appendix C 'Co-ordination with short-circuit protective devices'

BS 4794 'Control switches (switching devices, including contactor relays, for control and auxiliary circuits up to and including 1000 V a.c. and 1200 V d.c.)'

Part 1 'General requirements'

*In course of preparation.

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LOW-VOLTAGE MOTOR STARTERS

Part 3 : Rheostatic rotor starters

1. General

1.1 Scope

This Recommendation applies to starters for industrial use, designed for starting an a.c. induction motor having a wound rotor, by cutting out resistors previously inserted in the rotor circuit, and to provide means for the protection of the motor against operating overloads, and to cause intentionally the motor to stop.

It applies only to starters, the main contacts of which are intended to be connected to supply circuits the rated voltage of which does not exceed 1 000 V a.c. In the case of asynchronous slip-ring motors (wound-rotors), the highest voltage between slip-rings shall be not greater than twice the rated insulation voltage of the switching devices inserted in the rotor circuit (see Clause 4.4.1.4).

Note. — This easement is based on the fact that the electric stresses are less severe in the rotor than in the stator and are of short duration.

This Recommendation applies also to starters for two directions of rotation when reversal of connections is made with the motor stopped (see Clause 4.4.6). Operations including inching and plugging will necessitate additional requirements and shall be subject to agreement between manufacturer and user.

This Recommendation applies to resistors which are part of the starter or constitute a unit specially designed to be associated with the starter.

The starters dealt with in this Recommendation are not designed to interrupt short-circuit currents. Therefore, suitable short-circuit protection (see IEC Publication 292-1A: First supplement to Publication 292-1) shall form part of the installation, but not necessarily in the starter.

The clauses of this Recommendation relating to overload protection may not apply in the case of controlgear associated with built-in over-temperature protective devices.

Note. — The expression "built-in" means "built into the motor".

This Recommendation does not apply to:

- unbalanced starters, viz. where the resistances do not have the same value in all phases;
- equipments designed not only for starting, but also for adjustment of speed;
- liquid starters and those of the « liquid-vapour » type;
- static starters using semi-conductor elements.

1.2 *Object*

The object of this Recommendation is to state:

1. the characteristics of rheostatic rotor starters;
2. the conditions with which starters must comply with reference to:
 - a) their operation and behaviour;
 - b) their dielectric properties;
3. the tests intended for confirming that these conditions have been met, and the methods to be adopted for these tests;
4. the data to be marked on the apparatus.

2. **Definitions**

For the purpose of this Recommendation, the following definitions shall apply.

2.1 *Starter*

See IEC Publication 292-1.*

2.2 *Rheostatic starter*

A starter utilizing one or several resistors for obtaining, during starting, stated motor torque characteristics and/or for limiting the current. It comprises the mechanical switching devices necessary for cutting out the resistors.

Note. — A rheostatic starter generally consists of three basic parts which may be supplied either as a composite unit or as separate units to be connected at the place of utilization:

- the mechanical switching devices for supplying the stator (generally associated with an overload protective device);
- the resistors inserted in the stator or rotor circuit;
- the mechanical switching devices for cutting out the resistors successively.

2.2.1 *Rheostatic rotor starter*

A rheostatic starter for an asynchronous wound-rotor motor which, during the starting period, cuts out successively one or several resistors previously provided in the rotor circuit.

2.3 (Vacant)

2.4 *Manual starter*

See IEC Publication 292-1.

2.5 *Electromagnetic starter*

See IEC Publication 292-1.

2.6 *Motor-operated starter*

See IEC Publication 292-1.

2.7 *Pneumatic starter*

See IEC Publication 292-1.

* Whenever reference is made to IEC Publication 292-1, the clause with the same clause number applies, in some instances modified by the text which follows.

2.8 *Electro-pneumatic starter*

See I E C Publication 292-1.

2.9 *Over-current*

See I E C Publication 292-1.

2.10 *Overload*

See I E C Publication 292-1.

2.11 *Short-circuit current*

See I E C Publication 292-1.

2.12 *Overload relay or release*

See I E C Publication 292-1.

2.13 *Thermal overload relay or release*

See I E C Publication 292-1.

2.13 a *Magnetic overload relay or release*

An overload relay or release depending for its operation on the force exerted by a current flowing in the coil of an electromagnet.

Note. — Such a relay or release usually has an inverse time-delay/current characteristic.

2.14 *Current setting of an overload relay or release*

See I E C Publication 292-1.

2.15 *Current setting range of an overload relay or release*

See I E C Publication 292-1.

2.16 *Undercurrent relay*

A measuring relay which operates when the current through it is reduced below the operating value.

2.17 *Single-step starter*

A starter in which there is no intermediate accelerating position between the OFF and FULL ON positions.

Note. — This is a direct-on-line starter.

2.18 *n-step starter (see Figure 1)*

A starter in which there are $n - 1$ intermediate accelerating positions between the OFF and FULL ON positions.

Example: A three-step rheostatic rotor starter has two sections of resistors used for starting.

2.19 *Starting time t_s*

The length of time while the starting resistors or parts of them carry current.

3. **Classification**

3.1 (See IEC Publication 292-1.)

3.2 (See IEC Publication 292-1.)

3.3 (See IEC Publication 292-1.)

3.4 According to the degree of protection provided by the enclosure, distinction is made in accordance with IEC Publication 144.

3.5 According to the method of changing starting steps, starters are designated as:

- automatic change-over (i.e. independent of the operator), e.g.: controlled by a timer or an undercurrent relay;
- non-automatic change-over (i.e. dependent on the operator), e.g.: controlled by hand or by push-buttons;
- semi-automatic change-over, i.e. for which the successive orders of the operator during starting are executed only after having been checked by an automatic device.

3.6 According to the means of cooling of resistors, starters are designed as:

- having resistors cooled by convection;
- having resistors cooled by forced air;
- having resistors cooled by immersion in oil.

4. **Characteristics of rheostatic rotor starters**

Note. — If, for special applications, the intermediate steps are not considered as transitional positions for starting, but on the contrary as normal operating connections, an agreement as to the special characteristics required shall be reached between manufacturer and user.

4.1 *Summary of characteristics*

The characteristics of a rheostatic rotor starter shall be stated in the following terms, where such terms are applicable:

- characteristics of starting (see Clause 4.4.6);
- types of switching devices (see Clause 4.2);
- types and characteristics of automatic acceleration control devices (see Clause 4.8);
- types and characteristics of relays and releases (see Clause 4.3) and number of these devices;
- degrees of protection provided by enclosures (see IEC Publication 144: Degrees of protection of enclosures for low-voltage switchgear and controlgear);

- rated quantities (see Clause 4.4);
- control circuits and air-supply systems (see Clause 4.5);
- auxiliary circuits (see Clause 4.6);
- types and characteristics of starting resistors (see Clause 4.9);
- co-ordination with short-circuit protective devices (see IEC Publication 292-1A: First supplement to Publication 292-1).

4.2 *Types of switching devices*

The following shall be stated:

- 4.2.1 Number of poles, according to their function: for supplying the stator or for short-circuiting resistors.
- 4.2.2 *Interrupting medium (air, oil, etc.)*
- 4.2.3 *Method of operation* for example: dependent manual operation, dependent power operation (e.g.: contactor), stored energy operation, etc.

In the case of manual starters, the type of operating device shall be stated: handle, lever, push-buttons, etc.

4.3 *Types and characteristics of relays and releases*

Note. — In the remainder of the Recommendation, the words "overload relay" shall be taken to apply equally to an overload relay or an overload release as appropriate.

4.3.1 *Types*

1. Release with shunt coil (shunt trip).
2. Under-voltage opening relay or release.
3. Overload time-delay relay, the time-lag of which is:
 - a) substantially independent of previous load (e.g.: time-delay magnetic overload relay);
 - b) dependent on previous load (e.g.: thermal overload relay).
4. Instantaneous over-current relay or release (when applicable).
5. Other relays or releases (e.g.: phase unbalance relay, control switch associated with devices for the thermal protection of the starter).

Note. — Types referred to in Items 4 and 5 require consultation between manufacturer and user according to the particular application.

4.3.2 *Characteristics*

1. Release with shunt coil and under-voltage opening relay or release:
 - rated voltage;
 - rated frequency.
2. Overload relay:
 - either the associated motor full-load current, or the ultimate trip current (see Clause 7.5.3.2);

- rated frequency (when necessary);
- current setting (or range of settings);
- time-current characteristics (or range of characteristics), when necessary;
- number of poles;
- nature of the relay: thermal or magnetic.

Notes 1. — Depending on the nature of the relay, the opening conditions are given in Clause 7.5.3.2 or in Clause 7.5.3.3.

2. — The overload relay is commonly inserted in the stator circuit. As a result, in the case of a rheostatic rotor starter, it cannot efficiently protect the rotor circuit and more particularly the resistors (generally more easily damageable than the rotor itself or the switching devices in case of a faulty starting); protection of the rotor circuit shall be the subject of a specific agreement between manufacturer and user (see inter alia Clause 7.1.1).

4.3.3 *Designation and current settings of overload relays*

See IEC Publication 292-1.

4.3.4 *Time-current characteristics of overload relays*

See IEC Publication 292-1.

4.3.5 *Influence of ambient air temperature*

See IEC Publication 292-1.

4.4 *Rated quantities*

The rated quantities established for a rheostatic rotor starter shall be stated in accordance with Clauses 4.4.1 to 4.4.8, but it is not necessary to establish all the rated quantities listed.

4.4.1 *Rated voltages*

A rheostatic rotor starter is defined by the following rated voltages:

Note. — For rated voltages of control circuits, see Clause 4.5.1.

4.4.1.1 *Rated stator operational voltages*

A rated stator operational voltage (U_{es}) of a rheostatic rotor starter is a value of voltage which, combined with a rated stator operational current, determines the application of the stator circuit including its mechanical switching devices and to which are referred the making and breaking capacities, the type of duty and the starting characteristics.

Note. — It is expressed as the voltage between phases.

4.4.1.2 *Rated rotor operational voltages*

A rated rotor operational voltage (U_{er}) of a rheostatic rotor starter is a value of voltage which, combined with a rated rotor operational current, determines the application of the rotor circuit including its mechanical switching devices and to which are referred the making and breaking capacities, the type of duty and the starting characteristics.

It is taken as equal to the voltage measured between slip-rings, with the motor stopped and the rotor open-circuited, when the stator is supplied at its rated voltage.

4.4.1.3 *Rated stator insulation voltage*

The rated stator insulation voltage (U_{is}) of a rheostatic rotor starter is the value of voltage which designates the devices inserted in the stator supply as well as the unit they are part of, and to which dielectric tests, clearances and creepage distances are referred.

Unless otherwise stated, the rated stator insulation voltage is the value of the maximum rated stator operational voltage of the starter. In no case shall the maximum rated operational voltage exceed the corresponding rated insulation voltage.

4.4.1.4 *Rated rotor insulation voltage*

The rated rotor insulation voltage (U_{ir}) of a rheostatic rotor starter is the value of voltage which designates the devices inserted in the rotor circuit as well as the unit they are part of (connecting links, resistors, enclosure), and to which dielectric tests, clearances and creepage distances are referred.

It shall be noted that the voltage corresponding to the rated rotor insulation voltage is only applied for a short duration during the starting period. For this reason, it is permissible that the rated rotor operational voltage exceed the rated rotor insulation voltage by 100%.

Further, it shall be noted that the maximum voltage between the different live parts (e.g.: the switching devices, the resistors, the connecting parts, etc.) of the rotor circuit of the starter will vary and account may be taken of this fact in choosing the equipment and its disposition.

4.4.2 *Rated currents*

A rheostatic rotor starter is defined by the following rated currents, related to the FULL ON position, viz. after cutting out resistors with the motor running at its normal speed.

4.4.2.1 *Rated stator thermal current*

The rated stator thermal current (I_{ths}) of a rheostatic rotor starter equipped with suitable overload relays is the maximum current it can carry on eight-hour duty (see Clause 4.4.4.1) without the temperature rise of its several parts exceeding the limits specified in Clause 7.3 (Tables V and VI) when tested in accordance with Clause 8.2.2.

4.4.2.2 *Rated rotor thermal current*

The rated rotor thermal current (I_{thr}) of a rheostatic rotor starter is the maximum current that those parts of the starter through which the rotor current flows in the FULL ON position, viz. after cutting out resistors, can carry on eight-hour duty (see Clause 4.4.4.1) without their temperature rises exceeding the limits specified in Clause 7.3 (Tables V and VI) when tested in accordance with Clause 8.2.2.

Notes 1. — For those elements (switching devices, connecting links, resistors) through which a current of practically no value flows in the FULL ON position, it shall be verified that, for the rated duties (see Clause 4.4.4) stated by the manufacturer, the value of the integral $\int_0^{t_s} i^2 dt$ does not lead to temperature rises higher than those appearing in Clause 7.3.

2. — When resistors are built-in into the starter, certain additional conditions may be necessary in order to take into account the mutual influences.

4.4.2.3 *Rated stator operational currents or rated stator operational powers*

A rated stator operational current (I_{es}) of a rheostatic rotor starter is stated by the manufacturer and takes into account the rated current of the overload relay installed in this starter, the rated stator operational voltage (see Clause 4.4.1.1), the rated frequency (see Clause 4.4.3), the rated duty (see Clause 4.4.4), the starting characteristics (see Clause 4.4.6) and the type of protective enclosure.

The indication of a rated stator operational current may be replaced by the indication of the maximum rated power output, at the rated stator operational voltage considered, of the motor for which the stator elements of the starter are intended. The manufacturer shall be prepared to state the relationship assumed between the motor power and the rotor current.

4.4.2.4 *Rated rotor operational currents*

A rated rotor operational current (I_{er}) of a rheostatic rotor starter is stated by the manufacturer and takes into account the rated rotor operational voltage (see Clause 4.4.1.2), the rated frequency (see Clause 4.4.3), the rated duty (see Clause 4.4.4), the starting characteristics (see Clause 4.4.6) and the type of protective enclosure.

It is taken as equal to the current flowing in the connections to the rotor when the latter is short-circuited and the motor is running at rated full load and the stator is supplied at its rated voltage and rated frequency.

When the rotor part of a rheostatic rotor starter is rated separately, the indication of a rated rotor operational current may be supplemented by the indication of the maximum rated power output, for motors having the rated rotor operational voltage considered, of the motor for which that part of the starter (switching devices, connecting links, relays, resistors) is intended. This power varies in particular with the breakaway torque foreseen and consequently takes into account the starting characteristics (see Clause 4.4.6).

4.4.3 *Rated frequency*

The supply frequency for which a starter is designed and to which the other characteristic values correspond.

4.4.4 *Rated duty*

Whatever the duty envisaged, the starter shall be capable of permitting two successive operating cycles, starting from the cold state, the time interval between two starts being equal to twice the starting time t_s .

The rated duties considered as normal are as follows:

4.4.4.1 *Eight-hour duty*

The duty in which the starter is in the FULL ON position and the main contacts of the switching devices which constitute it, which are closed in this position, remain closed whilst each of them carries a steady current long enough for the starter to reach thermal equilibrium, but not for more than 8 hours without interruption.

Notes 1. — This is the basic duty on which the rated thermal currents of the starter are determined.

2. — “Interruption” means breaking of the current by operation of the starter up to the OFF position.