

Motor starters and controllers

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Foreword

This standard makes reference to the following British Standards:

BS 88, *Electric fuses for circuits of voltage-ratings up to 660 volts.*

BS 91, *Electric cable soldering sockets.*

BS 115, *Metallic resistance material for electrical purposes.*

BS 140, *Liquid starters and controllers.*

BS 148, *Insulating oil (low viscosity) for transformers and switchgear.*

BS 229, *Flameproof enclosure of electrical apparatus.*

BS 280, *Field rheostats and rheostats for other purposes.*

BS 775, *Contactors.*

BS 4941, *Motor starters for voltages up to and including 1 000 V a.c. and 1 200 V d.c. — Part 1: Direct-on-line (full voltage) a.c. starters — Part 2: Reduced voltage a.c. starters, star-delta starters — Part 3: Rheostatic starters — Part 4: Reduced voltage a.c. starters, two-step auto-transformer starters.*

BS 2725, *Memorandum on the measurement of cooling medium temperatures.*

BS 2757, *Classification of insulating materials for electrical machinery and apparatus, on the basis of thermal stability in service.*

BS 2817, *Types of enclosure for electrical apparatus.*

BS 5856, *Motor starters for voltages above 1 kV a.c. and 1.2 kV d.c. — Part 1: Direct-on-line (full voltage) a.c. starters.*

This British Standard, prepared under the authority of the Electrical Industry Standards Committee, has been revised in view of the developments in practice and materials since the previous edition was issued in 1940.

The starting times for various classes of motors have been reviewed, and the performance clauses have been amplified and extended. The clauses covering ratings of resistances have been formed into a separate section and Appendix D has been added, based on resistor ratings standardized in the U.S.A. and Canada.

The classification of insulating materials has been revised to line up with BS 2757.¹⁾ Appendix B has been included in its present form pending the issue of recommendations on clearances and creepage distances by the International Electrotechnical Commission.

Appendix E and Appendix F have been added to illustrate graphically starting times and resistor ratings.

The information to be supplied to the manufacturer with enquiry or order has been revised, and is now contained in Appendix C.

For convenience, Appendix G enumerates those clauses in the specification which apply to a.c. hand and automatic switching starters in the range 1 to 25 h.p. and up to 550 volts. It does not, however, apply to starters employing resistors or auto-transformers, nor to starters for traction motors.

The requirements for direct-on-line starters for voltages up to and including 1 000 V a.c. are now covered by Part 1 “*Direct-on-line (full voltage) a.c. starters*” of BS 4941, “*Motor starters for voltages up to and including 1 000 V a.c. and 1 200 V d.c.*”

The requirements for reduced voltage a.c. starters, star-delta starters, and rheostatic rotor starters for voltages up to and including 1 000 V a.c. are now covered by Part 2 “*Reduced voltage a.c. starters, star-delta starters*” and Part 3 “*Rheostatic rotor starters*” of BS 4941.

¹⁾ BS 2757 “*Classification of insulating materials for electrical machinery and apparatus, on the basis of thermal stability in service.*”

The requirements for reduced voltage a.c. starters, two-step auto-transformer starters for voltages up to and including 1 000 V are now covered by Part 4 “*Reduced voltage a.c. starters, two-step auto-transformer starters*” of BS 4941.

The requirements for direct-on-line a.c. starters for voltages above 1 kV are now covered by Part 1 “*Direct-on-line (full voltage) a.c. starters*” of BS 5856.

Declaration of obsolescence. This standard should not be used for new equipment specifications. It is retained only to provide for the continuing servicing of existing equipment that is expected to remain in use over a long working life.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 33 and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

1 Scope

This British Standard covers the various types of hand operated and automatic apparatus for the starting and/or control of a.c. or d.c. electric motors for voltages up to 11 kV alternating current and up to 650 V direct current. It also covers resistors and auto-transformers which are part of starters or controllers, and those forming self-contained units for use with starters or controllers.

The specification does not apply to the following:—

- Liquid starters and controllers
- Field rheostats
- Control gear for electrical traction
- Control gear for aircraft.
- Direct-on-line starters for voltages up to and including 1 000 V a.c.

Reduced voltage a.c. starters, star-delta starters, for voltages up to and including 1 000 V a.c.

Rheostatic rotor starters for voltages up to and including 1 000 V a.c.

Reduced voltage a.c. starters, two-step auto-transformer starters for voltages up to and including 1 000 V.

Direct-on-line a.c. starters for voltages above 1 kV.

When a field rheostat complying with BS 280 is mounted and connected inside a starter or controller complying with this British Standard, the whole may be deemed to be covered by this specification.

Attention is drawn to the following relevant British Standards:—

- BS 88, *Electric fuses for circuits of voltage ratings up to 660 volts.*
- BS 91, *Electric cable soldering sockets.*
- BS 115, *Metallic resistance material for electrical purposes.*
- BS 140, *Liquid starters and controllers.*
- BS 148, *Insulating oil (low viscosity) for transformers and switchgear.*
- BS 229, *Flameproof enclosure of electrical apparatus.*
- BS 280, *Field rheostats and rheostats for other purposes.*
- BS 775, *Contactors.*
- BS 822, *Recommendations for terminal markings for electrical machinery and apparatus.*
- BS 2757, *Classification of insulating materials for electrical machinery and apparatus, on the basis of thermal stability in service.*
- BS 2817, *Types of enclosure for electrical apparatus.*

BS 4941, *Motor starters for voltages up to and including 1 000 V a.c. and 1 200 V d.c. — Part 1: Direct-on-line (full voltage) a.c. starters — Part 2: Reduced voltage a.c. starters, star-delta starters — Part 3: Rheostatic rotor starters — Part 4: Reduced voltage a.c. starters, two-step auto-transformer starters.*

BS 5856, *Motor starters for voltages above 1 kV a.c. and 1.2 kV d.c. — Part 1: Direct-on-line (full voltage) a.c. starters.*

2 Definitions

The following definitions have been adopted for the purposes of this British Standard:—

NOTE The word “model” is used as a general term to cover the various classes of apparatus dealt with. In specified instances it may cover a starter, controller, resistor, auto-transformer or appropriate combinations of them.

2.1

motor starter

a device arranged for starting and accelerating a motor to normal speed, and having no “running” position other than the FULL-ON position

the term “motor starter” includes:—

- a) Direct-on starters.
- b) Pole-changing starters.
- c) Star-delta starters.
- d) Series-parallel starters.
- e) Auto-transformer starters.
- f) Rheostatic starters.
- g) Capacitor starters.

2.2

motor controller

a device for controlling the speed of a motor or motors. It may or may not be intended for starting purposes. A controller does not necessarily include the resistors or other means of control employed therewith, neither does it include shunt field rheostats

2.3

hand (manual) starter

a starter in which the operation of starting is carried out by hand operation throughout the entire starting sequence

2.4

automatic starter

a starter which automatically carries out the operation of starting when an initial impulse has been given by external means, e.g. by a push button, pilot switch or the like

2.5
contactor starter or controller

a starter or controller in which the contacts for the main circuit are made by contactors

2.6
solenoid starter

an automatic starter in which a single operating electro-magnet is employed for cutting out a resistor in a series of steps

2.7
single-step starter

a direct-on starter, i.e. a starter in which there is no accelerating position between the OFF and the FULL ON positions

2.8
2-step starter

a starter in which there is one accelerating position between the OFF and FULL ON positions

2.9
n-step starter

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

Examples: A 5-step rheostatic starter has four resistance sections, and a star-delta starter is a 2-step model

2.10
rheostatic starter

a starter comprising a resistor and means for readily reducing the amount of resistance in circuit

2.11
rheostatic controller

a controller by means of which more or less resistance can be introduced into a circuit

2.12
liquid starter or controller

a rheostatic model in which the resistor is a liquid

2.13
faceplate starter or controller

a starter or controller in which the switch contact parts are arranged upon a plane surface

2.14
faceplate breaker-starter or controller

a starter or controller in which circuit breaking is removed from the starting contacts by the provision of a line contactor or switch operated by a single control

2.15
drum starter or controller

a starter or controller in which the moving contact parts are arranged upon a cylindrical surface

2.16
drum breaker-starter or controller

a starter or controller in which circuit breaking is removed from the starting contacts by the provision of a line contactor or switch operated by a single control

2.17
cam controller

a controller in which the moving contacts are operated by a camshaft

2.18
multiple-switch starter or controller

a starter or controller in which separate hand-operated switches are provided for each step

2.19
switching starter

a starter which is arranged to start a motor without the use of any current limiting devices such as auto-transformers, resistors, etc., and may be either hand-operated, or automatic

2.20
direct-on-line starter

a switching starter which connects a line voltage across the motor terminals in one step

2.21
star-delta starter

a switching starter for a three-phase induction motor arranged in such a way that in the starting position the stator windings are connected in star, and in the running position they are connected in delta

2.22
series-parallel starter

a switching starter for a two-phase induction motor arranged in such a way that in the starting position all the windings of each phase are in series, and in the running position the windings of each phase are in two parallel circuits

2.23
series-parallel controller

a controller by means of which the windings of two or more motors can be connected in series or parallel at will

2.24
change-pole switch

a switch designed to connect the windings of a change-pole motor on any of its various speeds but not designed to make and break the supply

2.25**change-pole controller**

a controller designed to start a change-pole motor on any of its various speeds and to change speed without interrupting the supply elsewhere

2.26**stator/rotor starter or controller**

a rheostatic starter or controller which comprises a switching device for connecting the primary winding of an a.c. motor to the supply and means for varying the amount of resistance in the secondary circuit. The switching device for the primary winding may be supplied separately

2.27**auto-transformer starter**

a starter which includes an auto-transformer and is so arranged that, with the switching device in the intermediate or starting position, a reduced voltage is applied to the motor terminals

2.28**primary resistor starter**

an a.c. starter in which the starting current is reduced by connecting resistance in series with the primary winding during the starting period

2.29**primary reactor starter**

an a.c. starter in which the starting current is reduced by connecting a reactor in series with the primary winding during the starting period

2.30**single-phase split-phase starter**

a starter for a single-phase induction motor which has, in the starting position(s) on the stator side, a phase splitter consisting of a resistor and/or reactor for starting purposes

2.31**single-phase capacitor starter**

a starter, for a single-phase induction motor, which controls both stator windings and capacitor(s). The stator windings and capacitor(s) may be arranged differently in the running position and the starting position(s)

2.32**series controller**

a rheostatic controller having a resistance in series with the motor armature for controlling the speed of the motor

2.33**armature diverter controller**

a controller in which, in addition to a series speed-regulating resistance, a resistor is connected across the motor armature terminals for the purpose of obtaining low speeds

2.34**field diverter controller**

a controller in which increased speeds may be obtained by connecting a resistance across the series field

2.35**rheostatic-braking starter or controller**

a starter or controller in which the armature is disconnected from the lines in one or more steps and reconnected in a closed circuit for braking purposes

2.36**potentiometer-braking controller**

a controller in which, in the overhauling direction, the series field and resistor are connected to the line, and the armature is connected across the field and varying parts of the resistor for braking purpose. In the opposite direction, the controller is usually arranged for either series, or armature diverter and series, regulation. Such controllers are commonly used with d.c. hoisting motors on cranes

2.37 Dynamic braking

A generic term applying to various methods of electrical braking where the speed of the motor is reduced without the use of friction devices.

2.37.1**regenerative braking**

a form of dynamic braking in which the motor returns power to the supply system

2.37.2**D.C. injection braking**

a form of braking applying to a.c. motors in which the motor is disconnected from the a.c. supply and direct current is injected into one main winding (usually the primary), the other main winding (usually the secondary) being closed, through resistors if necessary

2.37.3**reverse-current braking (plugging)**

the retardation of a motor by changing the supply connections so that reversed torque is obtained

2.38**inching (jogging)**

the momentary closure of the circuit to start a motor from rest for the purpose of accomplishing small movement(s) of the driven machine

2.39
field rheostat

a rheostat designed for connection in the circuit of a field winding of an electrical machine

2.40
contactor

a device suitable for repeatedly opening and closing the circuits of electrical apparatus. It may be operated electro-magnetically or electro-pneumatically; the speed of make and of break is independent of the operator

2.41
isolator

a mechanical device capable of opening or closing a circuit under conditions of no-load or negligible current

2.42
isolating switch

a switch which isolates a circuit and is capable of breaking not less than its rated current at rated voltage

2.43
master or pilot controller

a multi-way switch for controlling the operation of a set of contactors

2.44
master switch

a switch for connecting and disconnecting a contactor coil or a set of such devices

2.45
master stop-switch

a switch which, when operated, will cause a circuit to be opened and which will prevent reclosing until it is deliberately reset

2.46
tappet switch

a switch so arranged as to be mechanically operated by the motion of the driven machine. It controls the operation of the machine or some allied circuit or apparatus

2.47
limit switch

a switch preventing over-travel and arranged so as to be mechanically operated by the motion of the driven machine

these switches may be either of the shunt or series type, depending on whether they are connected in the control circuit or the main circuit

2.48
auxiliary switch

a switch working in conjunction with, and actuated by, another switch, circuit breaker, contactor or the like and serving to control the operation of auxiliary devices such as trip coils, closing coils, alarm bells, or for providing electrical interlocking

2.49
interlock

an electrical or mechanical device for making the operation of a piece of apparatus dependent upon the fulfilment of certain predetermined conditions

2.50
magnetic blow-out

a device in which the parts are arranged to produce a magnetic field in the neighbourhood of an arc to assist in breaking a circuit

2.51
overload device

a device, the operation of which causes the interruption of current at a predetermined excess value, but not necessarily under short-circuit conditions. Such a device most frequently includes some form of time delay

2.52
overcurrent device

a device designed to cause interruption of the circuit with both operational excess currents and short circuits

NOTE This is not a standard feature on motor control gear (see Clause 7.18).

2.53
under-voltage (low-voltage) protection

the circuit is opened if the voltage falls to an abnormally low value, *but cannot be reclosed* on restoration of adequate voltage, until subsequent manual operation, or its equivalent

2.54
under-voltage (low-voltage) release

the circuit is opened if the voltage falls to an abnormally low value *but may be reclosed automatically* with or without time delay on restoration of adequate voltage

2.55
open-type model

a model having exposed live parts

2.56
oil-immersed model (Not considered standard for d.c.)

a model which is immersed in oil (with the possible exception of terminals and the operating mechanism)

3 Types of enclosure

Type I. General purpose. An enclosure designed primarily to prevent accidental contact with live parts. It is suitable for general purpose applications indoors where atmospheric conditions are normal. It does not prevent the ingress of damp and dust, and may be ventilated.

Type IA. Dust and damp protecting. An enclosure similar to Type I with the joints and openings in the enclosure so packed or fitted as to prevent the ready ingress of dust and water.

Type II. Drip-proof. An enclosure similar to Type I with the addition of drip shields or their equivalent.

Type III. Weatherproof (weather resistant). An enclosure providing protection against specified weather conditions. It is suitable for outdoor application without further protection.

Type IV. Hoseproof. An enclosure designed to exclude water when washed down by a hose through a $\frac{3}{8}$ in. (9.5 mm) nozzle with a maximum pressure of 30 lb/sq. in. (2.1 kg/sq. cm) for a period not exceeding 30 seconds from a minimum distance of 6 ft (1.8 m).

Type V. Dust-proof. An enclosure so constructed that dust of specified fineness and nature cannot enter in an amount sufficient to interfere with the successful operation of the apparatus enclosed. Such enclosures are suitable for application in steel mills, cement mills, boiler houses, and other locations where excessive dust is prevalent.

Type VI. Watertight. An enclosure in which the live parts are enclosed by a cover, or covers, so constructed as to exclude water when the whole is immersed under a 3 ft (0.9 m) head of water for 15 minutes.

Type VII. Flameproof. An enclosure designed to comply with the provisions of BS 229, "Flameproof enclosure of electrical apparatus".

Type VIII. Vermin-proof. An enclosure so constructed as to prevent specified vermin from causing damage to the apparatus enclosed. (The maximum size of any opening is to be specified by the purchaser.)

4 Service conditions

Motor starters and controllers complying with this specification are suitable within the limits of their ratings for installations where the service conditions are not more severe than those stated below.

4.1 Ambient temperature. A peak ambient temperature not exceeding 40 °C with an average value not exceeding 35 °C over 24-hour periods.

NOTE Under normal conditions of service the available cooling air is subjected to natural atmospheric variations of temperature and hence the peak temperature occurs only occasionally during the hot season, and on those days when it does occur it does not persist for lengthy periods. Meteorological records indicate that temperatures at least 10 Centigrade degrees below the peak temperature will occur within the same 24-hour period and that the average temperature taken over any 24-hour period that includes the peak temperature will be at least 5 Centigrade degrees below the peak value.

When the normal conditions of service differ from those stated above, and are such that the cooling air remains at a practically steady temperature, the ratings assigned to the apparatus only apply to an average ambient temperature not exceeding 35 °C.

4.2 Altitude. An altitude not exceeding 3 300 ft (1 000 m) above sea level.

When a model intended for service at high altitudes is tested near sea level the limits of temperature rise as given in Clause 8 shall be reduced one per cent for each complete 1 000 ft (300 m) above sea level at which the model is intended to work in service. The correction shall not be applied for altitudes below 3 300 ft (1 000 m).

4.3 Atmosphere. An atmosphere not subject to excessive pollution by smoke, chemical fumes, salt-laden spray, etc. Such pollution occurs in some industrial areas and in some coastal districts, and an important feature in this connection is the degree of certainty with which rainfall can be relied upon — as regards sufficiency and frequency — to act as a washing agent.

5 Ratings, sizes and markings

5.1 Standard supply voltages. The following supply voltages are regarded as standard for the purpose of this British Standard:—

d.c.: 50, 110, 240, 480, 500, 600 volts.

a.c.: 115, 220, 240, 380, 415, 440, 550, 660, 3 300, 6 600, 11 000 volts.

Nevertheless this specification covers models suitable for other voltages up to and including 650 V d.c. and 11 kV a.c. provided they comply in all other respects with its requirements.

Standard models shall be suitable for voltages not more than 10 per cent below, or 6 per cent above, the declared voltage of the supply for which they are designed, except where a voltage range is specified.

Standard d.c. faceplate starters and controllers are not intended for use on systems of 500 volts and upwards with one line earthed.

5.2 Standard a.c. supply frequency. Standard a.c. models shall be suitable for a frequency of 50 c/s. Nevertheless this specification covers apparatus suitable for other frequencies within the range 25 – 60 c/s if they comply in all other respects with the requirements of this British Standard.

5.3 Classes of mechanical duty for starters.

Four classes of mechanical duty (i.e. maximum number of operation per hour) are recognized as follows:—

- a) Infrequent duty (for oil-immersed rheostatic models); 1 operation per 2 hours.
- b) Ordinary duty; 2 operations per hour.
- c) Intermittent duty; 15 operations per hour.
- d) Frequent duty; 40 operations per hour.

Models having ratings superior to those laid down for their respective duties are nevertheless standard models if they comply in all other respects with the requirements of this specification. Such models are usually combinations of contactors (see BS 775).

The ratings apply at the standard reference ambient temperature (see Clause 4.1).

If models are to be used for “inching” or “plugging”, the manufacturer’s advice on rating should be sought. For intermittent or frequent duty starting or plugging, purchasers should satisfy themselves that the motors and cables are capable of such duty.

5.4 Duty rating of switching starter models.

Switching starter models rated for ordinary duty, intermittent duty or frequent duty shall be suitable for use in a service which does not ordinarily involve starting more than 2, 15 or 40 times per hour respectively.

The design of standard a.c. switching starter models is based on the ability of the motor and drive to accelerate freely when the starter is in the starting position with an appropriate starting period not exceeding that given in Table 1. The ratings are based on the assumption that the full-voltage motor starting current at standstill does not exceed 8 times the full load current for motors up to and including 100 h.p., and 6 times the full load current for motors over 100 h.p. (see Clause 7.19).

Table 1 — Maximum motor starting times with standard switching starter models

Type of starter	Maximum motor starting times (see also Appendix E)
Direct-on models up to 600 h.p.	3 + h.p./10 seconds, with a maximum of 15 sec
Star-delta models up to 175 h.p.	9 + h.p./3 seconds, with a maximum of 45 sec
Series-parallel models up to 100 h.p.	9 + h.p./2 seconds, with a maximum of 60 sec

NOTE 1 If conditions necessitate longer starting periods than these the purchaser should consult the manufacturer, otherwise difficulty may arise in connection with overload protection (see Clause 7.17 *et seq.*).

NOTE 2 The initial starting torque with star-delta starting will not be greater than $\frac{1}{3}$, and that with series-parallel starting will not be greater than $\frac{1}{4}$ of that with direct starting.

5.5 Duty rating of auto-transformer starter models. The ratings are based on the assumption that the full-voltage motor starting current at standstill does not exceed 8 times the full load current for motors up to and including 100 h.p. and 6 times the full load current for motors over 100 h.p.

5.5.1 Permitted period for acceleration of motor. For models rated for ordinary duty, the period required to accelerate the motor shall be assumed not to exceed the following values (see also Appendix E — Graph):

On 75 per cent or higher: 6 + h.p./5 seconds, with a maximum of 30 seconds.

On 60 per cent tap or lower: 9 + h.p./3 seconds, with a maximum of 45 seconds.

For models rated for intermittent and frequent duty the total starting period shall be assumed not to exceed:

Intermittent duty — 1 minute in each 15 minutes.

Frequent duty — 2 minutes in each 15 minutes.

5.5.2 Permitted number of starts in a given period. The permissible number of starts shall be assumed to be not more than those given in Table 2.