LEARNING MODULE

IN

EET 317 - MOTOR CONTROL

Prepared by:

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Associate Professor I

FINAL 2nd semester 2021-2022

MODULE 3

TITLE : **Reduced- voltage Starters**

TOPIC : **1. Introduction to Reduced-voltage Starters**

2. Types of Reduced- voltage Starters, Construction, and Operation

3. Wiring diagram of Reduced-voltage Starters

TIME FRAME : **30 HOURS**

INTRODUCTION: Reduced- voltage starters are devices that start motors by reducing the power supplied at start-up. Reducing the power in turn reduces potentially damaging electrical and mechanical shocks on the system. Reduced- voltage Starters (RVS) are used in applications with large horsepower motors. They are used to reduce the inrush current and limit the torque output and mechanical stress on the load.

The Reduced- voltage starters prevents inrush by allowing the motor to get up to speed in small steps by drawing smaller increments of current. This starter is not a speed controller. It reduces the shock only upon start-up.rters

OBJECTIVES : *In this lesson, student will be able to:*

1. Described Reduced- voltage Starters
2. Explain the construction, operation and application of different types of Reduced-voltage Starters
3. Interpret wiring diagram of Reduced- voltage Starters
4. Install Reduced-voltage Starters

LEARNING ACTIVITIES:

1. Read and study module 3, Page 48- 74

2. Answer the pretest, self- evaluation and posttest of module 3

3. Project (diagram of reduced voltage starter)

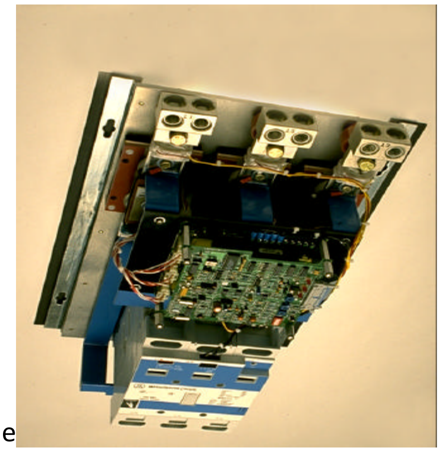
ule 

FIGURE 1. REDUCED VOLTAGE STARTER

As the name implies, starters "start" motors. They can also stop them, reverse them, accelerate them, and protect them. Whether it's a small fan, or a gigantic piece of mining equipment, electric motors are often the driving force behind them. In fact, electric motors consume 60% to 70% of all the energy used in the United States.

Starters are made from two building blocks, controllers and overload protection.

FIGURE 2. A STARTER IS MADE UP OF A CONTROLLER AND OVERLOAD PROTECTION

- Controllers turn on and off the electric current to the motor. A contactor is a type of controller that is controlled by an electromagnet.
- Overload Protection protects a motor from drawing too much current and literally "burning out" from overheating. The overload relay is the device used in starters for motor overload protection. It limits the time the overload current is drawn to protect the motor from overheating.

A starter lets you turn an electric motor (or motor-controlled electrical equipment) on or off, while providing overload protection. It is a power control device that also limits the amount of current drawn to protect the motor from burnout.

There are three main ways to start a motor. These are:

1. Across the line starter – This method simply places the motor directly on the

incoming utility line, and the motor draws current as it needs it.

2. Adjustable Frequency Drive – This method places a device called a drive between the motor and the incoming utility line. We will look at drives in detail in Module 20, Adjustable Frequency Drives, and will not consider them here.

3. Reduced Voltage Starters – This method places a device called a reduced voltage starter between the motor and the incoming utility line to regulate the amount of current fed to the motor. This is the focus of this training module.

Reduced voltage starting of an AC induction motor allows you to bring the motor up to speed in smaller steps, resulting in less current drawn than with a traditional starter. Due to the decreased voltage, torque is also reduced, resulting in a soft, or easy, start.

Reduced voltage starters are used on all types of DC and AC motors. However, they are used most commonly with the AC squirrel cage induction motor because of its simplicity, ruggedness and reliability.

This module will focus mainly on applying reduced voltage starters to the AC squirrel cage induction motor.

IN THE WORKPLACE

This professional foodservice blender uses a **starter on the motor** to allow it to get up to speed without tripping the internal circuit breaker.

If the blender were to be overloaded with food, and the motor was not able to turn at its synchronous speed, it would attempt to draw more current in order to do so.

The resulting **overload would trip the breaker, causing the blender to stop** until the overload condition was removed.

Reduced voltage starting is needed for two reasons:

1. To avoid overloading the power distribution system.
2. To avoid unnecessary wear and tear on equipment by reducing starting torque.

Let's take a moment to look at each reason in more detail.

A typical NEMA design B motor can draw six to eight times its full load operating current when it is first started up. That inrush of current can be enormous when the customer's operation has large numbers of big electric motors.

What is a Reduced Voltage Starter?

Reduced Voltage Starter is a device that starts motors with reduced power supplied at start-up. Reducing the power reduces potentially damaging electrical and mechanical shocks on the system.

As the name implies, starters "start" motors. They can also stop, reverse, accelerate and protect them. Whether it's a small fan, or piece of mining equipment, electric motor are often the driving force behind them. Electric motors consume 60% to 70% of all energy used in the United States.

Reduced Voltage Starters are a combination of a controller and overload protection.

CONTROLLERS - turns electric current to the motor on and off. A contactor is a controller that is controlled by an electromagnet.

OVERLOAD PROTECTION - protects a motor from drawing too much current and "burning out" from overheating. The overload relay is the motor overload protection used in reduced voltage starters. It limits the time the overload current is drawn and protects the motor from overheating.

Reduced Voltage Starters place a device called a soft starter, between the motor and the incoming utility line to regulate the amount of current fed to the motor.

Reduced Voltage Starters enable the AC induction motor to speed up in smaller, resulting in less current drawn than with a traditional motor starter. Due to decreased voltage, torque is also reduced resulting in a soft, or easy start. Reduced Voltage Starters are used on all types of AC and DC motors. They are most commonly used with the AC squirrel cage induction motor because of its simplicity, ruggedness and reliability.

Why Reduced Voltage Starters are needed

1. To avoid overloading the power distribution system

2. To avoid unnecessary wear and tear on equipment by reducing starting torque

A typical NEMA design B motor can draw six to eight times its full load operating current when it's first started. If the utility's power distribution network is loaded to capacity, the current inrush from starting up large motors can result in anything from flickering lights to brownouts. It can also result in nuisance tripping of circuit breakers and protective devices on the system. Many utilities impose limits on the amount of power customers can draw at any one time, enabling a balance in their distribution system. Reducing voltage to motor terminals at startup reduces the current surge.

Types of Reduced Voltage Starters

There are five main varieties of Reduced Voltage Starters:

- Primary Resistor
- Auto Transformer
- Part Winding
- Wye Delta
- Solid State

PRIMARY RESISTOR

Developed in the early 1900's, this simple unit is one of the first reduced voltage starters placed into operation. Fig. 4 shows that there is a resistor for each of the three phases of current. Resistors resist the flow of current. When the motor is started, the resistors resist the current flow resulting in a voltage drop. Approximately 70% of the line voltage is sent to the motor terminals at startup. A timer closes a set of contacts after the motor has accelerated to a pre-determined point. This removes the resistors from the circuit and lets full power through to the motor.

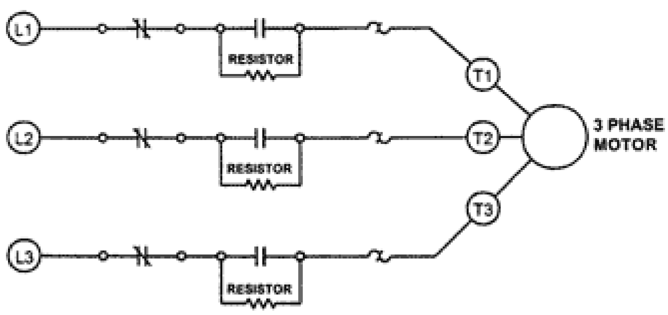


FIGURE 4. TYPICAL ELECTRICAL DIAGRAM FOR A PRIMARY RESISTOR REDUCED VOLTAGE STARTER

Primary resistors starters are known for their smooth starts. They offer two-point acceleration, or one step of resistance. For extra-smooth starting, add additional stages of resistors and contactors.

AUTO TRANSFORMER

Auto transformer starting is one of the most effective methods of reduced voltage starting. It is preferred over primary resistor starting when the starting current is drawn from the line must be held to a minimum, yet the maximum starting torque per line amp is required. Instead of using resistors, this starter uses taps on transformer windings to control the power input to the motor. Taps are usually set up to provide 80%, 65% and 50% of the line voltage, respectively.

These taps provide built-in flexibility. Activating any one of three taps on the windings allows different amounts of current to the motor. In Fig. 6, the motor is receiving voltage through the second of the three taps. This type of starter can supply more current to the motor than other reduced voltage starters, while keeping voltage low. The transformer steps up the current making it greater than the line current input during startup.

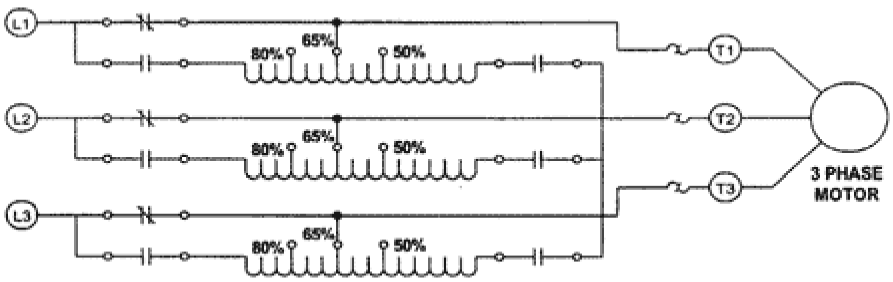


FIGURE 6. TYPICAL ELECTRICAL DIAGRAM FOR AN AUTOTRANSFORMER REDUCED VOLTAGE STARTER

PART WINDING

The part winding method requires dividing the motor windings into two, or more, separate sets. These identical winding sets are intended for parallel operation. At startup, power is applied to only one set of windings. As the motor comes up to speed, power is applied to the other winding set for normal running. When windings are energized in this manner, they produce reduced starting current and reduced starting torque. Most dual voltage (230V/460V) motors are compatible with the part winding starter at 230 volts.

WYE DELTA

Wye Delta starting requires the motor have connection points to each of the three coil windings. These are specially wound with six leads for Delta and Wye connections. Fig. 8 illustrates the winding configurations as they are connected at startup.

It is called the Wye Configuration because it is shaped like the letter "Y". This connection results in line voltage applied to an electrically larger winding, reducing the line current. It provides 33% of the normal starting torque and 58% of the normal starting voltage.

After a pre-determined time, the starter electrically switches the windings over to a Delta Configuration. This configuration resembles the Greek letter "delta". The windings are connected in their normal run configuration with every winding receiving full voltage.

An important consideration with this starter is at the transition point, where the starter switches from Wye to Delta, the motor MUST disconnect and reconnect. This type of Wye Delta starter is known as Open Transition and can have a momentary hitch in operation, allowing a momentary current inrush.

Closed Transition is another type of Wye Delta starter. It uses an extra contactor and set of resistors to keep the motor on-line during the transition. It eliminates the inrush concern and the cost is slightly higher than the open transition version.

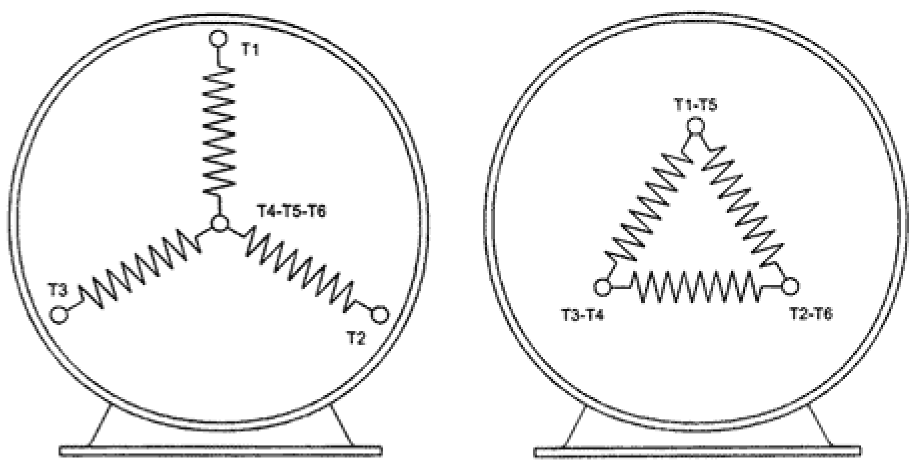


FIGURE 8. WYE CONFIGURATION AT START-UP

FIGURE 9. DELTA CONFIGURATION AS MOTOR NEARS FULL SPEED

SOLID STATE

The newest reduced voltage starter method is the solid state type. It replaces mechanical components with electrical components. The key is the Silicon Control Rectifier or SCR. During motor acceleration, this device controls motor voltage, current and torque. Fig. 11 shows how the solid state reduced voltage starter controls the current draw and the starting torque. The SCR has the ability to rapidly switch heavy currents. This allows the reduced voltage starter to provide smooth stepless acceleration - the smoothest of any of the reduced voltage starter methods.

The solid state reduced voltage starter is the newest method of reduced voltage starting. It replaces mechanical components with electronic components. The key to the solid state starter is the silicon control rectifier or SCR. During acceleration of the motor, this device is responsible for controlling motor voltage, current and torque.

By looking at the graphs in Figure 11, you can see how well the solid state reduced voltage starter controls the current draw and the starting torque.

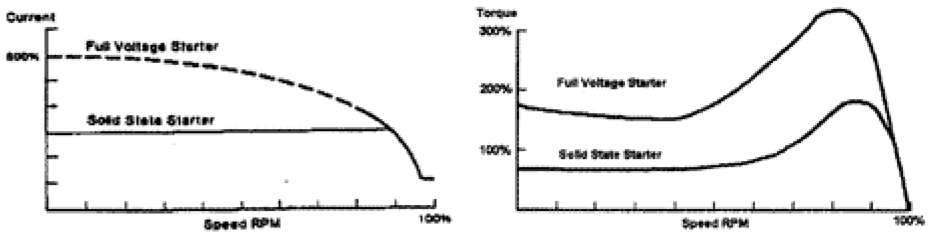


FIGURE 11. CURRENT VERSUS MOTOR SPEED, AND TORQUE VERSUS MOTOR SPEED

The SCR has the ability to rapidly switch heavy currents. This allows the solid state reduced voltage starter to provide smooth, stepless acceleration. In fact, it provides the smoothest acceleration of any of the reduced voltage starting methods.

When the motor is started, the order of events is as follows:

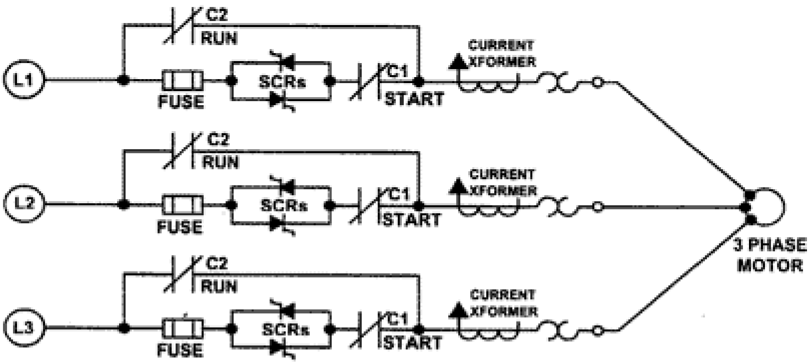


FIGURE 12. SOLID STATE REDUCED VOLTAGE STARTER
(SHOWN HERE WITH REVERSE PARALLEL WIRING TO ALLOW FOR MAXIMUM CONTROL)

Order of Events when a Motor is Started (SOLID STATE):

1. Start Contacts (C1) close
2. SCRs gradually turn on and control motor acceleration until it approaches full speed
3. The Run Contacts (C2) close when SCRs are fully on
4. The Motor is connected directly across the line and runs with full power applied to motor terminals

COMPARING THE REDUCED VOLTAGE STARTERS

The charts on the next two pages will enable you to make a side-by-side comparison of the different types of reduced voltage starters. You may find this information useful as you work with a customer to select the right equipment for his application.

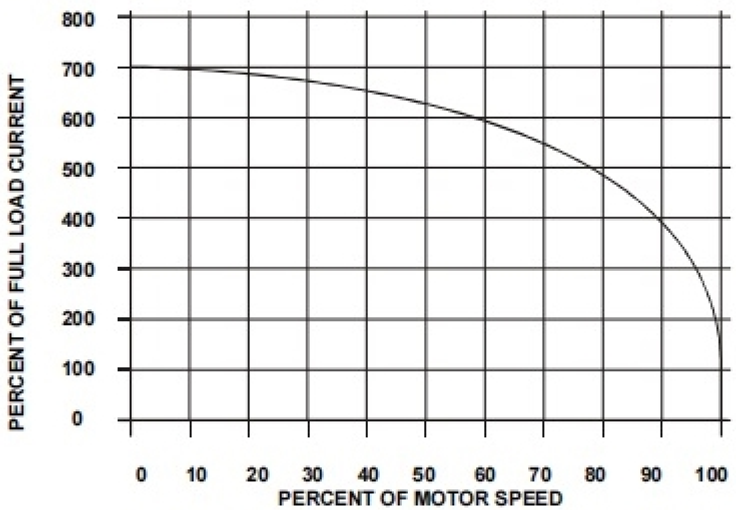


FIGURE 3. INRUSH OF CURRENT AT STARTUP CAN BE 6 TO 8 TIMES FULL LOAD OPERATING CURRENT

If the utility's power distribution network is already loaded close to capacity, the current inrush from starting up the large motors can result in anything from flickering lights to brownouts. (It can also cause nuisance tripping of circuit breakers and protective devices on the system.)

For this reason, many utilities impose limits on the amount of power that their customers can draw at any one time, enabling them to maintain a balance in their distribution system. Reducing the voltage to the motor terminals at start-up reduces the current surge.

A typical NEMA design B induction motor generates about 150% of its normal full-load torque during start-up. That torque is applied to the driven equipment almost instantaneously.

In some applications, the stress of this start-up shock can cause excessive wear on equipment components. There are also applications where start-up shock can damage items, jostle products on conveyors, and make materials fall off assembly lines.

Reducing the voltage applied to the motor at start-up also reduces the torque produced by the motor, and the shock transmitted to the load.

WHAT TYPES OF REDUCED VOLTAGE STARTERS ARE THERE?

There are five main varieties of reduced voltage starter. These are:

- Primary Resistor

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- Autotransformer
- Part Winding
- Wye Delta
- Solid State

We will look at each type of reduced voltage starter and explain how it works. At the end of those explanations, we will compare the different methods side-by side. We will briefly list the advantages, disadvantages, and typical applications for each reduced voltage starter type.

PRIMARY RESISTOR

Figure 4 shows a typical electrical diagram for a primary resistor reduced voltage starter. Developed in the early 1900's, this simple unit is one of the first reduced voltage starters put into use.

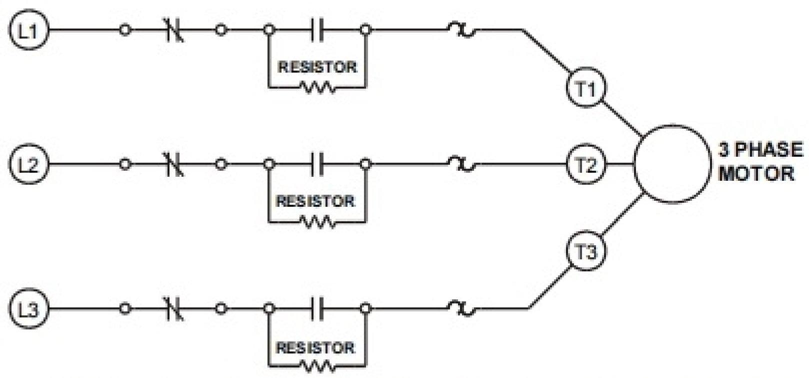


FIGURE 4. TYPICAL ELECTRICAL DIAGRAM FOR A PRIMARY RESISTOR REDUCED VOLTAGE STARTER

As you can see, there is a resistor for each of the three phases of current. Resistors do exactly what the name suggests. They resist the flow of current. When the motor is started, the resistors resist the current flow, resulting in a voltage drop. Approximately 70% of the line voltage is sent to the terminals of the motor at start-up.

A timer closes a set of contacts after the motor has accelerated to a pre-determined point. This removes the resistors from the circuit, and lets full power through to the motor.

Primary resistor starters are known for their smooth starts. Standard primary resistor starters like the one in Figure 4 offer two-point acceleration, meaning one step of resistance. If you want extra-smooth starting, just add additional stages of resistors and contactors, as shown in Figure 5. This may be needed in a paper or fabric handling application, where even a small jolt may damage the product.

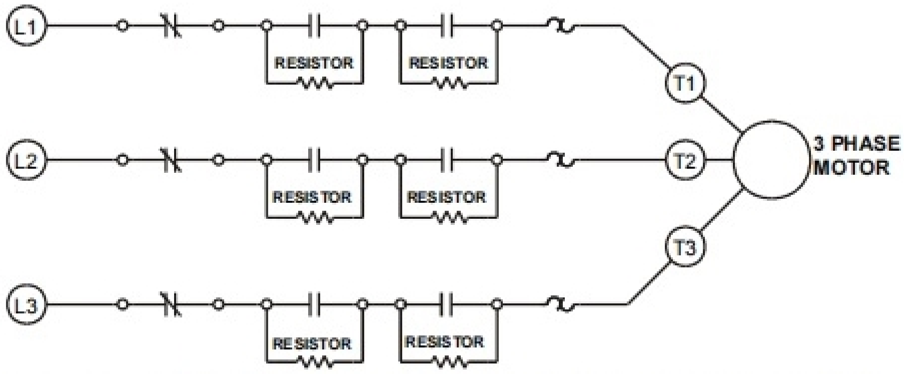


FIGURE 5. ELECTRICAL DIAGRAM FOR A PRIMARY RESISTOR REDUCED VOLTAGE STARTER WITH AN ADDITIONAL STAGE OF RESISTORS AND CONTACTORS

Autotransformer

Autotransformer starting is one of the most effective methods of reduced-voltage starting. It is preferred over primary resistor starting when the starting current drawn from the line must be held to a minimum, yet the maximum starting torque per line amp is required.

Instead of using resistors, this type of starter uses taps on the transformer windings to control the power input to the motor. The taps are typically set up to provide 80%, 65% and 50% of the line voltage, respectively.

These taps provide built-in flexibility. Activating any one of the three taps on the windings allows you to supply differing amounts of current to the motor. In Figure 6, the motor is receiving voltage through the second of the three taps.

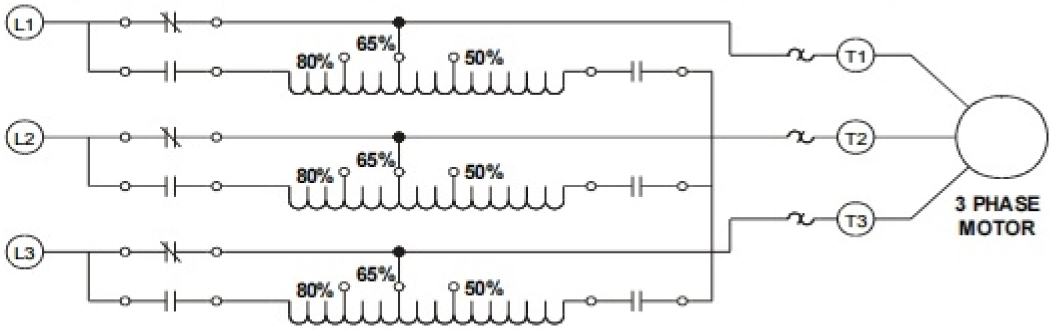


FIGURE 6. TYPICAL ELECTRICAL DIAGRAM FOR AN AUTOTRANSFORMER REDUCED VOLTAGE STARTER

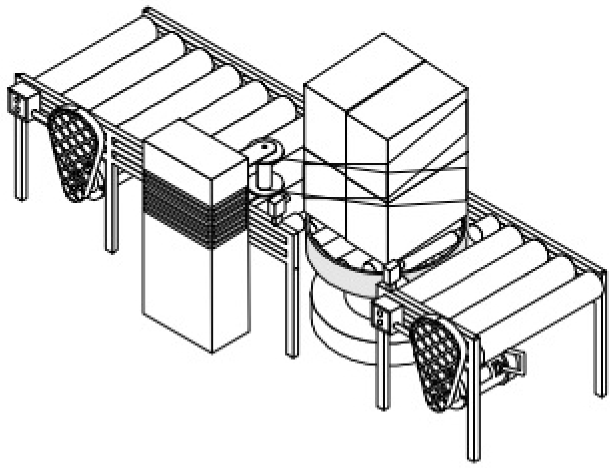
This type of starter can supply more current to the motor than other reduced voltage starters, while keeping the voltage low. The transformer steps up the current to make it greater than the line current input during start-up.

IN THE WORKPLACE

This conveyor application uses an autotransformer reduced voltage starter. When the conveyor is started, only 65% of the line voltage is applied to the motor. This allows for a smooth, gentle acceleration of the conveyor from a stop.

Without the autotransformer, the boxes would tip over, and would be out of alignment as they reached the wrapping area, pictured here.

The taps offer application flexibility. If shorter boxes were run on the conveyor, perhaps the 80% tap could be used, as the risk of tipping the boxes would be lower.



PART WINDING

The part winding method requires that the motor have its windings divided into two (or more) separate sets, as shown in Figure 7.

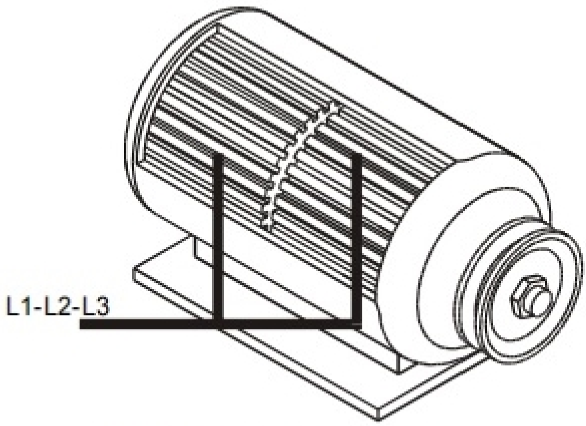


FIGURE 7. PART WINDING IN ACTION

These identical winding sets are intended to be operated in parallel. At start-up, power is applied to only one set of windings. As the motor comes up to speed, power is then applied to the other winding set for normal running.

When the windings are energized in this manner, they produce reduced starting current and reduced starting torque.

Most dual voltage (230V/460V) motors are compatible with the part winding starter at 230 volts.

WYE DELTA

Wye delta starting requires the motor to have connection points to each of the three coil windings. They must be specially wound with six leads brought out, to allow for wye and delta connections.

Figure 8 shows the configuration of the windings as they are connected during start-up.

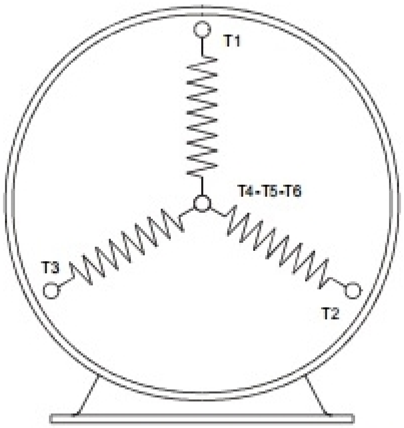


FIGURE 8. WYE CONFIGURATION AT START-UP

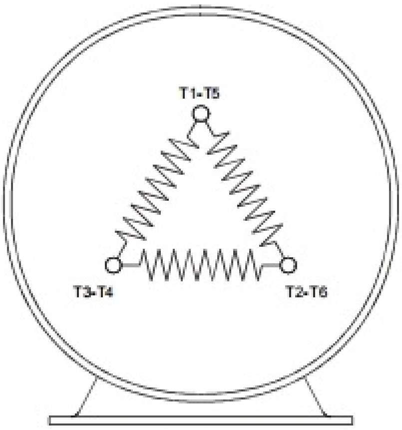


FIGURE 9. DELTA CONFIGURATION AS MOTOR NEARS FULL SPEED

This is called the wye configuration, because it is shaped like the letter "Y." The wye connection results in the line voltage being applied to an electrically larger winding, reducing the line current. This provides 33% of the normal starting torque and 58% of the normal starting voltage.

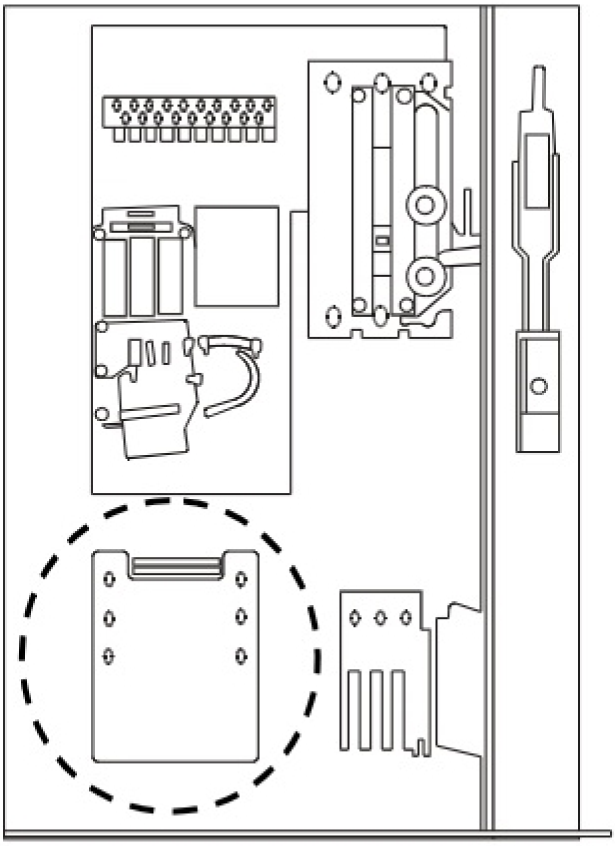


FIGURE 10. CLOSED TRANSITION USES AN EXTRA CONTACTOR AND A SET OF RESISTORS

After a pre-determined time, the starter electrically switches the windings over to the delta configuration, shown in Figure 9.

This configuration is named for its resemblance to the Greek letter "delta." The windings are now connected in their normal run configuration, with every winding receiving full voltage.

There is an important consideration with the wye delta of starter. At the point of transition, where the starter switches from wye to delta, the motor must disconnect and reconnect. This type of wye delta starter, called open transition, can have a momentary hitch in operation, allowing a momentary inrush of current.

Another type of wye delta starter, called closed transition, uses an extra contactor (shown in Figure 10) and a set of resistors to keep the motor on-line during the transition. This costs a little more than the open transition style, but eliminates the inrush concern.

SOLID STATE

The solid state reduced voltage starter is the newest method of reduced voltage starting. It replaces mechanical components with electronic components.

The key to the solid state starter is the silicon control rectifier or SCR. During acceleration of the motor, this device is responsible for controlling motor voltage, current and torque.

By looking at the graphs in Figure 11, you can see how well the solid state reduced voltage starter controls the current draw and the starting torque.

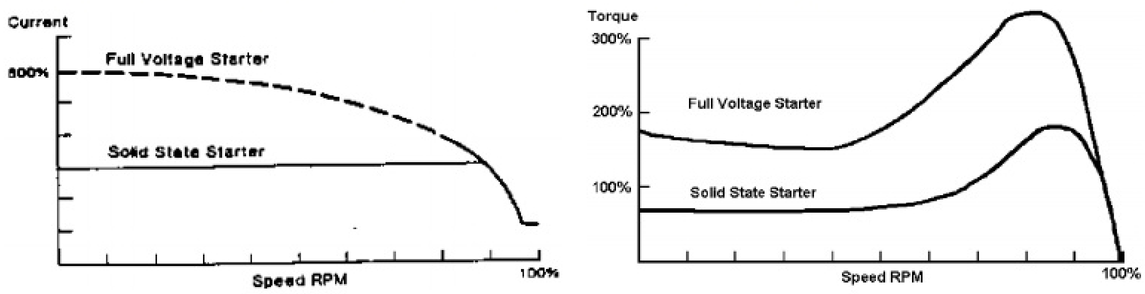


FIGURE 11. CURRENT VERSUS MOTOR SPEED, AND TORQUE VERSUS MOTOR SPEED

The SCR has the ability to rapidly switch heavy currents. This allows the solid state reduce voltage starter to provide smooth, stepless acceleration. In fact, it provides the smoothest acceleration of any of the reduced voltage starting methods. When the motor is started, the order of events is as follows:

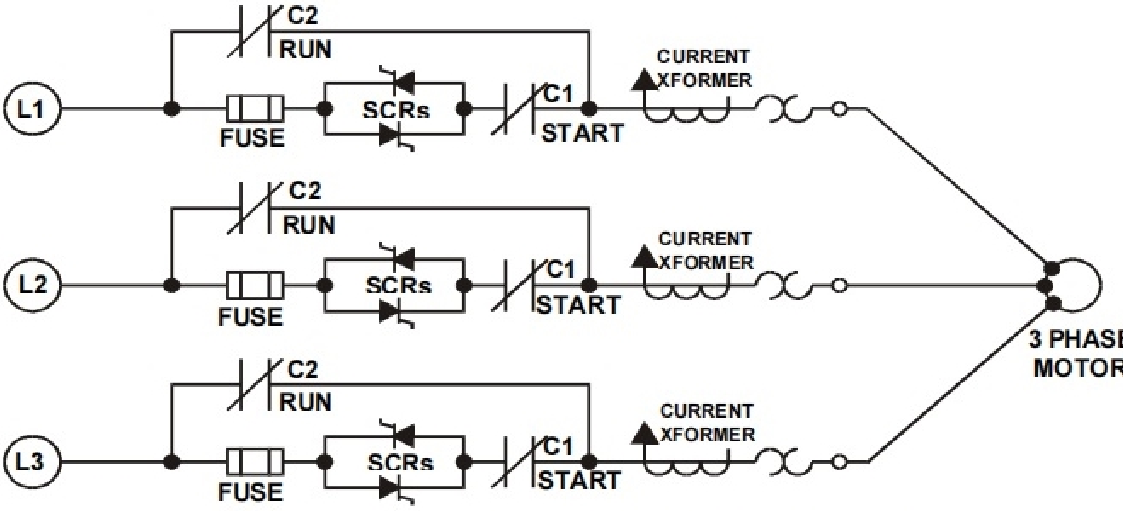


FIGURE 12. SOLID STATE REDUCED VOLTAGE STARTER
(SHOWN HERE WITH REVERSE PARALLEL WIRING TO ALLOW FOR MAXIMUM CONTROL)

1. The Start Contacts (C1) close.
2. The SCRs gradually turn on, and control the acceleration of the motor until it approaches full speed.
3. The Run Contacts (C2) close when the SCRs are fully on.
4. The motor is connected directly across the line, and runs with full power applied to the motor terminals.

COMPARING THE REDUCED VOLTAGE STARTERS

The charts on the next two pages will enable you to make a side-by-side comparison of the different types of reduced voltage starters. You may find this information useful as you work with a customer to select the right equipment for his application.

Starter Type	Starting Characteristics			Standard NEMA Motor	Transition Type	Extra Accel. Steps Available	Install Cost
	Volts at Motor	Line Current	Starting Torque				
Primary Resistor	65%	65%	42%	Yes	Closed	Yes	High
Auto-Transformer	80% 65% 50%	64% 42% 25%	64% 42% 25%	Yes	Closed	No	High
Part Winding	100%	65%	48%	*	Closed	Yes**	Low
Wye Delta	100%	33%	33%	No	Open***	No	Medium
Solid State	Adjust	Adjust	Adjust	Yes	Closed	Adjust	Highest

* standard dual voltage 230/460 V motor can be used on 230 V systems
** very uncommon
*** closed transition available for higher cost

Starter Type	Advantages	Disadvantages	Applications
Primary Resistor	• Maximum starting torque • Smooth acceleration • High power factor during start • Up to 5 acceleration points available	• Low torque efficiency • Resistors generate heat • Long starts require expensive resistors • Difficult to change starting torques under varying conditions	• Belt and gear drives • Conveyors • Textile machines
Auto-Transformer	• Highest torque per amp • Three starting torques available through taps • Good for slow starts • Motor current exceeds line current at start	• Most expensive at lower HP designs • Low power factor • Large physical size • Distinct switching transitions during tap changes	• Blowers • Pumps • Compressors • Conveyors
Part Winding	• Least expensive method • Starts most dual voltage motors • Small physical size • Only two half-size contactors are required • Typically limits motor torque and current to 50% of normal at start-up	• Bad for slow starts and high inertia loads due to poor starting torque • Special motor required over 230 V • Requires a 9-lead wye or a 6-lead delta winding • Offers only a single step • Motor will overheat if first acceleration step exceeds 5 seconds	• Reciprocating compressors • Pumps • Blowers • Fans
Wye Delta	• Good for slow starts and high inertia loads • High torque efficiency • Eliminates the resistor and autotransformer losses at start-up • Good for stringent inrush restrictions • Good for frequent starts • In widespread use in Europe	• Requires special wye-delta motor • Low starting torque may not be able to start heavy loads • Momentary inrush during open transition period	• Centrifugal compressors • Centrifuges
Solid State	• Energy-saving features available • Rugged and reliable with no moving parts at all • Soft starts • Adjustable acceleration time • Capable of rapidly switching heavy currents • Usually self-calibrating • Adjustable braking	• High cost • Specialized installation and maintenance • Electrical transients can damage unit • Requires good ventilation, and supplemental cooling in some environments • May need to be oversized for high-inertia loads • May create noise and/or harmonics	• Machine tools • Hoists • Packaging equipment • Conveyor systems

A reduced voltage starter that is perfectly suited to one application may be totally inappropriate for another. You will need to obtain the following application information from the customer:

· Motor nameplate full load amps, locked rotor amps, horsepower rating, and (if available) motor torque/speed curve. These (and the motor load requirements) are the most important factors in determining the size of the starter required.

- Starting and stopping requirements
- Longer start and stop times will allow for smoother starts and stops.
- A pulse start and/or a jog option may be useful for applications such as dough mixers, coal handlers, or plastic extruders.
- Some customers don't require a smooth stop. For others, it's a necessity. A pump application will require a soft stop to prevent damage from water hammer.
- A conveyor application may require a soft stop to prevent product from being damaged.

Torque requirements of the driven machinery and the load inertia

Number of starts required per hour

This is necessary because there could be an issue with heat dissipation if the number of starts per hour is excessively high. If applicable, this figure should include the number of times in a typical hour that jogging may be required.

Overload protection required

Remember that starters all offer overload protection, which is gauged on Class.

A Class 10 starter will trip if current draw is 6 times the motor's full load amps for more than 10 continuous seconds. Likewise, a Class 20 starter will trip in 20 seconds.

Electrical service range

Find out the customer's electrical needs and match them in the product catalog.

Is the customer running 480-volt, 240-volt, or some other line voltage?

Inrush limitations imposed by the utility

Cost limitations

Environmental Concerns

Talk with the customer about the application environment. Solid state starters can be hampered in harsh environments, such as extreme heat. An enclosure and/or special cooling system may be required for such an environment.

Enclosure type required

Enclosures provide protection for both the operator and the equipment. The customer has a number of options available. Work with the customer to determine which enclosure type is appropriate to the application.

NEMA 1 – General Purpose. This enclosure type is for general purpose, indoor use. It is suitable for most applications where unusual service conditions do not exist. It provides protection from accidental contact with enclosed equipment.

NEMA 12 – Dusttight. This enclosure type is for indoor use. It provides protection from dripping non-corrosive liquids, falling dirt, and dust.

NEMA 3R – Raintight. This enclosure type is intended for outdoor use. It provides protection against falling rain and sleet, and damage from external ice formation. It has a gasketed cover.

NEMA 4 – Watertight. This enclosure type is intended for indoor or outdoor use. It provides protection from splashing or hose-directed water, wind-blown dust or rain, and damage from external ice formation.

NEMA 4X – Corrosion Resistant. This enclosure type is intended for indoor or outdoor use, where corrosion resistance is required. It is constructed of stainless steel, polymeric, or fiberglass. It also provides protection from splashing or hose-directed water, wind-blown dust or rain, and damage from external ice formation.

Requirements for Reduced Voltage Starter Selection

Reduced Voltage Starters have properties that are more suited to specific applications. To make the proper selection, the following is needed:

Motor nameplate full load amps, locked rotor amps, HP rating, motor torque/speed curve if available

Starting and stopping requirements - Longer start and stop times allow for smoother operation. Pulse start and/or jog option is useful for dough mixers, coal handlers or plastic extruders. Pump applications require smooth stops to prevent water hammer damage.

Torque requirements of machinery driven and load inertia

Number of starts required per hour - Heat dissipation could pose a problem if the number of starts is excessively high.

Overload protection requirement - Overload protection is based on class. Class 10 starters trip of the current draw is 6 times the motor's fill load amps for more than 10 continuous seconds. A Class 20 starter trips in 20 seconds

Electrical service range (line voltage)

Enclosure type

There is a wide assortment of Reduced Voltage Starters available including 200-690 VAC input, up to 700 HP at 230V and up to 1600 normal duty amps. Before making your final selection, consult a reduced voltage starter application specialist.

Type	Advantages	Disadvantages
Primary Resistor Starters	1. Closed transition starting 2. Smooth acceleration 3. No need for special motors	1. Voltage reduction is achieved by power loss through a resistor 2. Adjusting the starting voltage and torque is difficult
Autotransformer Starter	1. Produced maximum torque per amp of line current 2. Maximum reduction of starting current 3. Autotransformer taps permit easy adjustments to starting voltage 4. No need for special motors	1. More expensive than other starters at low horsepower
Part Winding Starter	1. Least expensive type 2. Closed transition starting 3. No heat producing devices in the starting circuit	1. Special motors are required 2. Motors will not accelerate to full speed on a single winding
Wye-Delta Starter	1. Produces high torque per amp of line current 2. Inexpensive - For most horsepower ranges has a lower cost than primary resistor or part winding starters	1. Special motors are required 2. Starting torque is fixed at 1/3 of the delta connection (full voltage) 3. Most are open transition
Solid State Starter	1. Provides smoothest acceleration 2. Adjustable current and torque during starting for highest degree of flexibility	1. Heat is given off by the SCRs when conducting current

Closed Transition — A type of wye delta starter that will not have an electrical hitch in operation as the transition from wye to delta takes place. It uses an extra contactor and a set of resistors to keep the motor on-line during the transition.

Contactor — An operating device which connects or disconnects the motor from the power supply. Specifically, such a device

	that is used when the power poles are operated by an electromagnetic circuit, through the use of a coil and magnetic armature frame.
Controller	Controllers turn on and off the electric current to the motor. A contactor is a type of controller that is controlled by an electromagnet.
Delta Configuration	The normal running electrical configuration for each of the three coils in a wye delta starter. Each coil receives 100% of the full line voltage.
Inrush	Amount of current that is drawn into a motor at start-up.
Open Transition	A type of wye delta starter that may have an electrical hitch in operation as the transition from wye to delta takes place.
Overload Protection	Overload Protection protects motors from drawing too much current and literally "burning out" due to overheating.
Reduced Voltage Starter	A starter used in applications that typically involve large horsepower motors. It is used to reduce the inrush current and limit the torque output and mechanical stress on the load.
Resistor	A device in an electric circuit designed to resist the flow of current through it.
Silicon Control Rectifier	SCR. The key component of a solid state reduced voltage starter. Controls motor voltage, current and torque during acceleration.
Taps	Used on the transformer windings of an autotransformer reduced voltage starter. These devices reduce the line voltage to start the motor with reduced current.
Torque	Turning or rotational force.

Wye Configuration	The starting electrical configuration for each of the three coils in a wye delta starter. Each coil receives 58% of the line voltage, which results in only 33% of the normal starting current.

Self-Evaluation:

Answer the following questions without referring to the material just presented.

1. Starters are made from two building blocks, _____________ and _____________ ___________.

2. Reduced voltage starters are used for two main reasons. These are:

To avoid overloading the _______ __________ ________.

To avoid unnecessary wear and tear on equipment by _______ __________ ___________.

3. The earliest developed type of reduced voltage starter is the __________ __________ reduced voltage starter.

4. Draw lines to match each type of reduced voltage starter to its common application type:

1. Solid State — A. Centrifugal compressors and centrifuges
2. Wye Delta — B. Belt and gear drives, conveyors and textile machines
3. Primary Resistor — C. Blowers, compressors and conveyors
4. Part Winding — D. Machine tools, hoists and packaging equipment
5. Autotransformer — E. Reciprocating compressors, pumps and fans

5. To allow smooth operation to continue throughout the start-up process, the ______ __________ type of wye delta starter uses an extra ________ and a set of _________.

6. The least expensive of all the reduced voltage starting methods is ______ ________.

7. The most important factors in determining the size of the starter the customer requires, are the application's __________________ and __________________.

8. Name the five types of Reduced-voltage Starters and explain its operation.

REVIEW CONCEPTS:

As the name implies, starters "start" motors. They can also stop them, reverse them, accelerate them, and protect them. Whether it's a small fan, or a gigantic piece of mining equipment, electric motors are often the driving force behind them. In fact, electric motors consume 60% to 70% of all the energy used in the United States. Starters are made from two building blocks, controllers and overload protection.

AUTO TRANSFORMER

Auto transformer starting is one of the most effective methods of reduced voltage starting. It is preferred over primary resistor starting when the starting current is drawn from the line must be held to a minimum, yet the maximum starting torque per line amp is required. Instead of using resistors, this starter uses taps on transformer windings to control the power input to the motor. Taps are usually set up to provide 80%, 65% and 50% of the line voltage, respectively.

SOLID STATE

The newest reduced voltage starter method is the solid state type. It replaces mechanical components with electrical components. The key is the Silicon Control Rectifier or SCR. During motor acceleration, this device controls motor voltage, current and torque. Fig. 11 shows how the solid state reduced voltage starter controls the current draw and the starting torque. The SCR has the ability to rapidly switch heavy currents. This allows the reduced voltage starter to provide smooth stepless acceleration - the smoothest of any of the reduced voltage starter methods.

REFERENCES:

Understanding Motor Controls, Third Edition, Stephen L. Herman, 2017

Industrial Electricity, 9th Edition, Michael E. Brumbach, 2017

Basics Series; Reduced Voltage Starter, Cutler-Hammer

POST TEST:

Name: ___________________________________ Date: _______

Yr.&Sec.: _______________ Score: ______

Answer the following question correspond to the correct answer.

1. ____________starting requires the motor have connection points to each of the three coil windings. These are specially wound with six leads for Delta and Wye connections.

2. This method simply places the motor directly on the incoming utility line, and the motor draws current as it needs it.

3. This method places a device called a drive between the motor and the incoming utility line. We will look at drives in detail in Module 20, Adjustable Frequency Drives, and will not consider them here.

4. ___________________ turns electric current to the motor on and off. A contactor is a controller that is controlled by an electromagnet.

5. ________________________ This method places a device called a reduced voltage starter between the motor and the incoming utility line to regulate the amount of current fed to the motor.

5. ______________________- protects a motor from drawing too much current and "burning out" from overheating.

6. The _____________ relay is the motor overload protection used in reduced voltage starters. It limits the time the overload current is drawn and protects the motor from overheating.

7. The _________________ method requires dividing the motor windings into two, or more, separate sets.

8. The ________________ reduced- voltage starter is the newest method of reduced voltage starting. It replaces mechanical components with electronic components.

9. _____________ starting is one of the most effective methods of reduced- voltage starting. It is preferred over primary resistor starting when the starting current is drawn from the line must be held to a minimum, yet the maximum starting torque per line amp is required.

10. __________________ starting is one of the most effective methods of reduced-voltage starting. It is preferred over primary resistor starting when the starting current drawn from the line must be held to a minimum, yet the maximum starting torque per line amp is required.

11. Draw a diagram of a three phase motor connected to wye-delta starter Controlled by Start and Stop pushbutton station.

   a. Power Circuit

   b. Control Circuit

TOPIC : Direct Current Motor Control

4.1 Manual Controller

4.2 Four point Starting Box

4.3 DC Magnetic Full-Voltage Starter

TIME FRAME : 13 HOURS

INTRODUCTION: A direct current (DC) motor is the oldest type of electrical motor that has gained widespread use in a variety of electronic devices and equipment. DC motors have different arrangements and operation peculiarities.
The common feature and the essential condition of all DC motors is the generation of a variable magnetic field that provides their non-stop operation. In an alternating current (AC) motor, a magnetic field changes polarity on its own.

A DC motor has some significant advantages, and one of them is the simplicity of its control system. Here, we'll tell you how a DC motor controller works and how you can use it. In addition, we'll share our personal experience and brief you on the design and challenges that you can meet while building your own controller.

OBJECTIVES : *In this lesson, student will be able to:*

1. Explain the construction, operation and application of different types of direct current motor controller;
2. Interpret wiring diagram od direct currect motor controller.
3. Install direct current motor controller.

LEARNING ACTIVITIES: ***Let-do-it!*** ☺

What is a DC Motor?

A direct current (DC) motor is a type of electric machine that converts electrical energy into mechanical energy. DC motors take electrical power through direct current, and convert this energy into mechanical rotation.

DC motors use magnetic fields that occur from the electrical currents generated, which powers the movement of a rotor fixed within the output shaft. The output torque and speed depends upon both the electrical input and the design of the motor.

How DC motors work

The term ‘DC motor’ is used to refer to any rotary electrical machine that converts direct current electrical energy into mechanical energy. DC motors can vary in size and power from small motors in toys and appliances to large mechanisms that power vehicles, pull elevators and hoists, and drive steel rolling mills. But how do DC motors work?

DC motors include two key components: a stator and an armature. The stator is the stationary part of a motor, while the armature rotates. In a DC motor, the stator provides a rotating magnetic field that drives the armature to rotate.

A simple DC motor uses a stationary set of magnets in the stator, and a coil of wire with a current running through it to generate an electromagnetic field aligned with the centre of the coil. One or more windings of insulated wire are wrapped around the core of the motor to concentrate the magnetic field.

The windings of insulated wire are connected to a commutator (a rotary electrical switch), that applies an electrical current to the windings. The commutator allows each armature coil to be energised in turn, creating a steady rotating force (known as torque).

When the coils are turned on and off in sequence, a rotating magnetic field is created that interacts with the differing fields of the stationary magnets in the stator to create torque, which causes it to rotate. These key operating principles of DC motors allow them to convert the electrical energy from direct current into mechanical energy through the rotating movement, which can then be used for the propulsion of objects.

Who invented the DC motor?

This amazing piece of electrical equipment has revolutionised our lives in many ways, but who invented the DC motor? As with all major innovations, there are many people who had a role to play through the development of similar mechanisms. In the US, Thomas Davenport is widely celebrated as the inventor of the first electric motor, and undoubtedly he was the first to patent a useable electric motor in 1837. Davenport, however, was not the first person to build an electric motor, with various inventors in Europe having already developed more powerful versions by the time Davenport filed his patent.

In 1834, Moritz Jacobi had presented a motor that was three times as powerful as the one Davenport would later patent, while Sibrandus Stratingh and Christopher Becker were the first to demonstrate a practical application for an electric motor, by running a small model car in 1835.

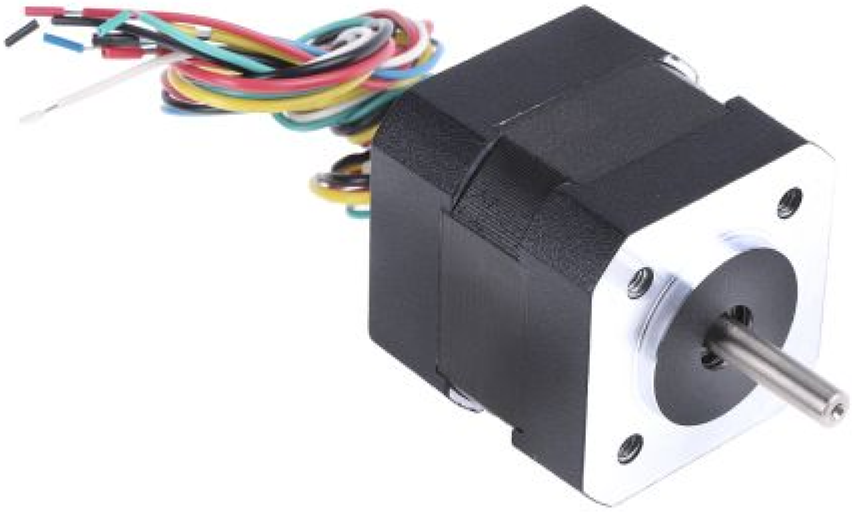
The first practical DC motor was invented some years later in 1886 by Frank Julian Sprague, whose invention lead to the first motor powered trolley system in 1887, and the first electric elevator in 1892. Sprague's DC motor was a hugely significant development, leading to a variety of applications which would reshape the face of industry and manufacturing.

Types of DC Motors

So far, this guide has broadly explained how DC motors work, the history of these mechanisms, and what they look like. While the principles are the same across variants, there are actually several different types of DC motors, which offer specific advantages and disadvantages over each other.

This section of the guide will look at the four main types of DC motor - brushless, brushed, shunt, and series.

What is a brushless DC motor?



Brushless DC motors are also known as electronically commutated motors, or synchronous DC motors, and differ to the brushed motor, thanks to the development of solid state electronics.

The key differences between brushless DC motors and other varieties is that they do not have a commutator, which is replaced by an electronic servomechanism that is able to detect and adjust the angle of the rotor.

The brushless DC motor has several advantages. Commutators use soft contacts called 'brushes' which wear down over time. A brushless DC motor is therefore more durable, and also safer than the more classical design.

How does a brushless DC motor work?

All electric motors develop torque by alternating the polarity of rotating magnets attached to the rotor and stationary magnets on the surrounding stator. At least one of these set of magnets is an electromagnet, made from a coil of wire around an iron core.

In a DC motor, DC running through the wire winding creates the magnetic field. Each time the armature rotates by 180°, the position of the north and south poles are reversed. If the magnetic field of the poles remained the same, the rotor would not turn. To create torque in one direction in a DC motor, the direction of the electric current must be reversed with every 180° turn of the armature.

In a traditional brushed motor, this would be done by a commutator, but in a brushless DC motor, an electronic sensor instead detects the angle of the rotor, with controlled semiconductor switches either reversing the direction of the current or turning it off at the correct time in the rotation to create torque in one direction.

Brushed DC motors

What is a brushed DC motor?

The **brushed DC motor** is the original DC motor, dating back to Sprague's initial design. As we have discussed already in this guide, the classic brushed motor features a commutator, to reverse the current every half cycle and create single direction torque.

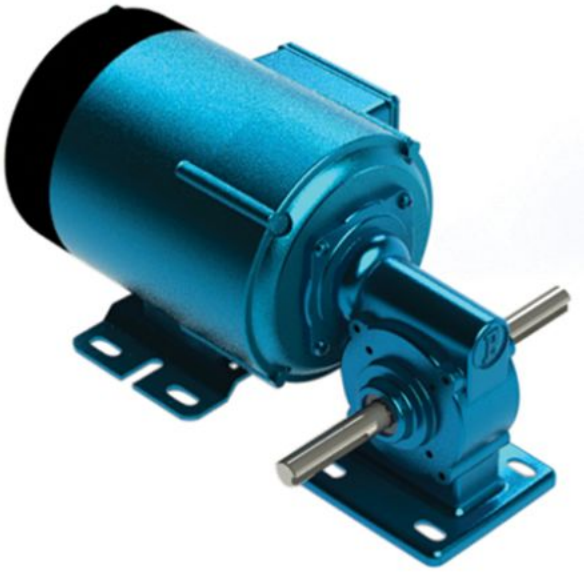
While brushed DC motors remain popular for electrical propulsion, cranes, paper machines, and steel rolling mills, many have been phased out for the more efficient brushless model in recent years.

How does a brushed DC motor work?

As has been explained in this guide already, brushed DC motors utilise soft contacts known as 'brushes' to ensure the motor rotates in one direction. Brushed motors' speed can be varied by the operating voltage or the strength of the magnetic field.

There are a few different varieties of brushed DC motors, which differ depending on the connection to the armature, which will be discussed in the following sections.

Shunt DC motors



What is a shunt DC motor?

A DC shunt motor is a variety of brushed motor that has the field windings connected in parallel with the armature. Shunt wound DC motors have a lower current because of the parallel windings.

A shunt motor is used for applications that require a constant torque, where the load is not significantly altered by speed, such as conveyor belts, mixers and hoists.

The specific field windings provide unique shunt motor characteristics that make it such an effective choice for constant torque applications. The Parvalux Shunt Brushed DC Motor shown on the left features constant speed characteristics, with the small difference between no-load and full load speed the main benefit of this type of motor.

Series DC motors

What is a series DC motor?

Series wound DC motors are the final variety of brushed motors in this guide. The key difference between this variety and the shunt motors discussed previously is that field windings are connected in a series. This means that the entire armature current passes to the field winding, creating much faster speeds.

As the supply voltage can't be adjusted, series DC motors can't regulate their speed particularly well.

While this is a problem for some applications, it makes them particularly useful for tasks that require high starting torque, such as power tools and sewing machines.

The specific characteristics of DC series motors offers a clear and distinct purpose. The Aulhaber Brushed DC Geared motor is a good example of the benefits of series wound motors, having high starting torque that is ideal for appliances.

Applications of DC motors

Thanks to the different types of DC motors available, there are a wide variety of applications for DC motors. The previous section considered some of the various applications and circumstances where DC motors are used, and the benefits of the various types of motor.

While each type has its advantages, broadly speaking, there are various uses of a DC motor. At home, small DC motors are used in tools, toys and various household appliances. In retail, the applications of DC motors include conveyors and turntables, while in an industrial setting, large DC motor uses also include braking and reversing applications.

Here are a few more specific uses for DC motors:

DC motors for fans

Although fans traditionally use AC motors, there are an increasing number of DC motor ceiling fans hitting the market. These fans are gaining in popularity as they are far more economical than their AC equivalent, thanks to the way in which they operate.

As we have learned in this guide, DC motors utilise magnetic fields to process electrical energy into mechanical energy, and by using brushless motors, DC motor ceiling fans can be operated from standard household AC electricity. The only real downside to the DC motor fan is its cost, but the energy savings easily offset this.

DC motors for pumps

Hydraulic pumps are an essential industrial tool, which are used in almost all industries including: construction, mining, manufacturing, and steel. DC motors are used to power these pumps because of their easy variable speed control and excellent response when moving.

Like ceiling fans, the DC motor pump has also benefited from the development of lower-cost brushless DC motors, which are far easier to maintain on such a large industrial scope.

DC motors for toys

DC motors for toys are a popular choice for manufacturer and hobbyists, with these 'toy motors' often used in children's toys such as remote control cars and model trains. Small DC motors work well in this setting, as they are easy to use and extremely rugged.

The wide variety of voltages for DC motors means they can be used for toys that require different speeds and movement types, and those that need a DC motor with controller.

DC motors for electric cars

While there are a variety of different motor types used in electric cars, DC motors for electric vehicles are widely used because of their energy efficiency and durability.

In addition to professional manufacturers, many hobbyists and kit car makers prefer large DC motors for their higher starting torque, particularly series wound motors, and their variable speeds with voltage input.

DC motors for robots

'Robot' is a broad term, but for many hobbyists and engineers, robots are any electromechanical device designed to achieve a specific task. DC motors for robots are used to 'actuate' something, such as tracks, arms, or cameras, with this motor particularly popular for a number of reasons.

DC motors are particularly convenient, as they have high torque and efficiency, making them ideally suited to robotics.

DC motors for bikes

Electric bikes are popular because they do not require a license, if the maximum assisted speed is under 20 miles an hour. To ensure the power levels and the torque needed, brushless DC motors are usually used for electric bikes.

Electric bikes use a compact DC motor built into the hub of the back or front wheel, or mounted in the centre of the bike and connected to the pedal sprocket.

Electric motors turn electricity into motion by exploiting electromagnetic induction.

A simple direct current (DC) motor is illustrated below.

The motor features a permanent horseshoe magnet (called the stator because it's fixed in place) and an turning coil of wire called an armature (or rotor, because it rotates). The armature, carrying current provided by the battery, is an electromagnet, because a current-carrying wire generates a magnetic field; invisible magnetic field lines are circulating all around the wire of the armature.

The key to producing motion is positioning the electromagnet within the magnetic field of the permanent magnet (its field runs from its north to south poles). The armature experiences a force described by the left hand rule. This interplay of magnetic fields and moving charged particles (the electrons in the current) results in the torque (depicted by the green arrows) that makes the armature spin. Use the Flip Battery button to see what happens when the flow of current is reversed. Take advantage of the Applet Speed slider and Pause button to visualize these forces better.

A single, 180-degree turn is all you would get out of this motor if it weren't for the split-ring commutator — the circular metal device split into halves (shown here in red and blue) that connects the armature to the circuit. Electricity flows from the positive terminal of the battery through the circuit, passes through a copper brush to the commutator, then to the armature. But this flow is reversed midway through every full rotation, thanks to the two gaps in the commutator. This is a clever trick: For the first half of every rotation, current flows into the armature via the blue portion of the commutator, causing current to flow in a specific direction (indicated by the black arrows). For the second half of the rotation, though, electricity enters through the red half of the commutator, causing current to flow into and through the armature in the opposite direction. This constant reversal essentially turns the battery's DC power supply into alternating current, allowing the armature to experience torque in the right direction at the right time to keep it spinning.

Component of Parts of DC Controllers

A DC motor contains different parts that understanding each one can assist to know deeply these parts cooperate with each other and in the end how DCs work. These components are: a stator, a rotor, a yoke, poles, armature windings, field windings, commutator, and brushes. Many of its parts are the same as parts of AC motor, but with a little change.

Stator

A stator is one of the DC motor parts that is, as the name suggests, a static unit containing the field windings. The stator is the DC Motor part that receives the supply.

Rotor

The dynamic part of a DC motor is the rotor that creates the mechanical rotations of the unit.

Yoke

Another unit of the DC motor parts is the Yoke. A Yoke is a magnetic frame made of cast iron or sometimes steel, which works as a protector. This protective cover keeps the inner parts of the motor safe and sound and also supports the armature. Yoke also houses the magnetic poles and field windings of a DC motor to help supporting the field system.

Poles

DC motor has magnetic poles that fit into the inner wall of the Yoke with the help of screws to tighten them up. Poles have two parts: The Pole Core and the Pole

Shoe. These two parts are fixed together by hydraulic pressure and are attached to the Yoke. Each part of the Poles has a specific task based on its design. The core holds the Pole Shoe over the Yoke while the Pole Shoe is structured to both carry slots for the field winding and spread the produced flux by the field windings into the air gap between the rotor and stator. It helps to reduce the loss caused by reluctance. Phentermine diet pills.

Field Windings

Made with Copper wire (field coils), the Field Windings circle around the slots carried by the Pole Shoes. The field windings form an electromagnet capable of producing field flux. The rotor armature rotates inside the field flux, resulting in the effective flux cutting.

Armature Windings

Another DC motor parts is armature winding. The armature winding of the DC motor has two constructions: Lap Winding and Wave Winding. Their difference is in the number of parallel paths. Armature Winding is attached to the rotor and alters the magnetic field in the path that it rotates. The result of this procedure is magnetic losses. Designers try to reduce the magnetic losses by making the armature core with some low-hysteresis silicon steel lamination. Then, the laminated steel sheets will be piled up together, creating the cylindrical structure of the armature core. There are slots designed inside the armature core with the same material.

DC Motor Commutator

The commutator is a split ring made up of Copper segments, Commutator is another DC motor part. The operating system of a DCs is based on the interaction of the two magnetic fields of rotating armature and a fixed stator. As the north pole of the armature is attracted to the south pole of the stator and south pole of armature is attracted to the north pole of the stator, a force is produced on the armature which makes it to turn. the process in which the field in the armature windings is switched to produce constant torque in one direction is called Commutation. the commutator is a device connected to the armature enabling this switching of current. Different segments of its cylindrical structure are insulated from each other by Mica. The commutator is designed to commute the supply current to the armature winding from the mains. The commutator passes through the brushes of the DC motor.

The basic purpose of commutation is to certify that the torque acting on the armature is always in the same direction. Naturally, the generated voltage in the armature is alternating, the commutator converts it to the direct current. To control the direction the electromagnetic fields are pointing to, the commutator turns the coils on and off. On one side of the coil, the electricity should always flow away, and on the other side, electricity should always flow towards. This ensures that the torque is always produced in the same direction.

DC motor Advantages and Disadvantages

Different sizes of DC motor parts will create different DC motors, suitable for different needs. As mentioned before, small ones can be used in toys, tools, and home appliances and larger ones are used in the elevator and hoists and propulsion of electric vehicles. Although AC motors decreased the selling of DC motors on account of simple generation and transmission with fewer losses to long distances, needing less maintenance and can be operated in explosive atmospheres, DCs still are utilized in where ACs can’t fulfill the needs. DCs have their own unique features and importance in industries that make up for lots of other advantages that AC motors have over them.

DC motors are suitable for low-speed torque, or when having an adjustable speed and constant is necessary. In other words, with DC motors the speed can be controlled over a wide range.This means they offer a wide range of speed control both below and above the rated speed. This feature of DC motors can be got in shunt types. By armature controlling and field controlling, you can enjoy this unique advantage of DC motors over AC motors. Moreover, DCs have a very high and strong starting torque compared to normal operating torque. Therefore, DCs are used in electric trains and cranes having overwhelming burdens in the beginning conditions. In addition to the above-mentioned advantages, DC motors have smaller converters and drives as well as higher motor power density. Not to mention that they have full torque at zero speed!

Being around on the market for more than 140 years, DC motors are often more affordable than AC motors and have a simpler and more efficient design. Plus, their maintenance is easy and takes little to no time. If you redesign your current installation to use an AC motor, it will cost way more than just simply replacing the

DC motor inside the installation. So, you not only repair your system by installing a new unit inside but save lots of money. Needless to say that such small replacement saves time as well and happens quickly without wasting your time. Need more advantages to fall in love with DC motor parts and structure?

Now that you've reached here you know DC motor parts and functions based on the information that Linquip provided for you in this article. Share your comments with us in the comment section and let us know your thoughts and questions while reading this article. Need to find the answer to your questions quickly and troubleshoot your DC motor part?

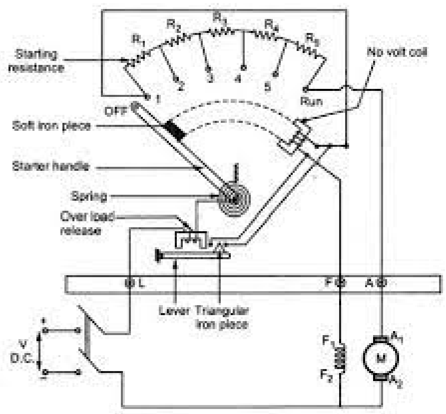
Manual Motor Controllers

Manual motor controllers are electrical devices used for motor starting and often include motor disconnect, overload protection, short-circuit protection and remote operation in one assembled unit.

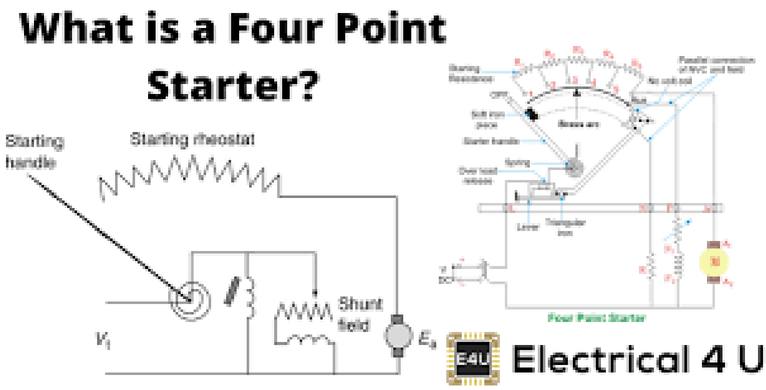
The standard manual motor controller (MMC) consists of a manual motor protection with either a toggle or rotary operator, a wiring connector, and an IEC contactor. These types of motor controllers require an upstream short-circuit protection device like a fuse or breaker to protect the motor circuit.

Combination motor controllers include motor protection functions, and do not require additional fuses or breakers.

Manual motor controllers are ideal components for group motor installations, to protect motors from faults that fuses and circuit breakers would ignore, and for applications with limited cabinet space.



A three-point starter is an electrical device, used for starting as well as maintaining the DC shunt motor speed. The connection of resistance in this circuit is in series which decreases the initial high current and guards the equipment against any electrical failures.

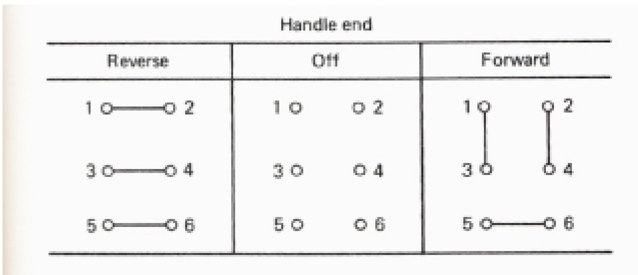


Four point starter works as a current controlling device in the deficiency of back EMF while starts running of the DC motor. A four-point starter also works as a protecting device. The main difference between a 4 point starter compared to a 3 point starter is, the holding coil is detached from the shunt-field circuit.

Reversing Motors with a Drum Switch

The drum switch is a manual switch that lets one manually reverse the direction in which a motor is turning. The switch contacts are open and closed manually by moving the drum switch from the off position to the forward or reverse position. Figure 1 shows a picture of the drum switch and Figure 2 shows a diagram of the drum switch contacts. Figure 2a shows the drum switch contacts when the switch is in the reverse position, Figure 2b shows the contacts when the switch is in the off position, and Figure 2c shows the contacts when the switch is in the forward position. When the switch is in the reverse position, note that terminal 1 is connected to terminal 2, terminal 3 is connected to terminal 4, and terminal 5 is connected to terminal 6. In the off position, all contacts are isolated from all other contacts. In the forward position, terminal 1 is connected to terminal 3, terminal 2 is connected to terminal 4, and terminal 5 is connected to terminal 6.

Above: Fig. 1: A drum switch. Notice the handle requires the operator to manually change the position of the switch from forward to reverse or to the off position.



Above: Fig. 2: (a) Contacts of a drum switch when it's switched to the reverse position. (b) Contacts of a drum switch when it's switched to the off position. (c) Contacts of a drum switch when it's switched to the forward position.

After understanding the operation of the drum switch in its three positions and the methods of reversing each type of motor, these concepts can be combined to develop manual reversing circuits for any motor in the factory as long as its full- load and locked-rotor amperage (FLA and LRA) don't exceed the rating of the drum switch. Figure 3a shows an AC single-phase motor connected to a drum switch. Notice that the start winding must be reversed for the motor to run in the reverse direction, so the start winding is connected to terminals 3 and 2.

Above: Fig. 3: (a) A single-phase AC motor connected to a drum switch. (b) A three-phase AC motor connected to a drum switch. (c) A DC motor connected to a drum switch.

Figure 3b shows a three-phase motor connected to a drum switch. Realize that with this switch, any two lines to the motor can be swapped so the motor will change direction of rotation. Figure 3c shows a DC motor connected to a drum switch. Note with the DC motor that the direction of current flow through the field is reversed to make the motor run in the opposite direction. If you're a technician, you may need to study the connections inside the drum switch when it's in the forward or reverse position to fully understand how the drum switch is used with each of these motors to reverse the direction of their rotation.

These diagrams are especially useful for installation and troubleshooting of these circuits. The drum switch can be tested by itself or as part of the reversing circuit. The motors can also be disconnected from the drum switch and operated in the forward and reverse directions for testing or troubleshooting if you suspect the switch or motor of malfunctioning.

SELF EVALUATION:

Answer the following question briefly and concise:

1. What is DC motor?
2. Explain the component of parts of DC motor controllers?
3. Evaluate the advantages and disadvantages of DC motor?

REVIEW CONCEPTS:

What is a DC Motor?

A direct current (DC) motor is a type of electric machine that converts electrical energy into mechanical energy. DC motors take electrical power through direct current, and convert this energy into mechanical rotation.

DC motors use magnetic fields that occur from the electrical currents generated, which powers the movement of a rotor fixed within the output shaft. The output torque and speed depends upon both the electrical input and the design of the motor.

How DC motors work

The term 'DC motor' is used to refer to any rotary electrical machine that converts direct current electrical energy into mechanical energy. DC motors can vary in size and power from small motors in toys and appliances to large mechanisms that power vehicles, pull elevators and hoists, and drive steel rolling mills. But how do DC motors work?

DC motors include two key components: a stator and an armature. The stator is the stationary part of a motor, while the armature rotates. In a DC motor, the stator provides a rotating magnetic field that drives the armature to rotate.

A simple DC motor uses a stationary set of magnets in the stator, and a coil of wire with a current running through it to generate an electromagnetic field aligned with the centre of the coil. One or more windings of insulated wire are wrapped around the core of the motor to concentrate the magnetic field.

Component of Parts of DC Controllers

A DC motor contains different parts that understanding each one can assist to know deeply these parts cooperate with each other and in the end how DCs work. These components are: a stator, a rotor, a yoke, poles, armature windings, field windings, commutator, and brushes. Many of its parts are the same as parts of AC motor, but with a little change.

Manual Motor Controllers

Manual motor controllers are electrical devices used for motor starting and often include motor disconnect, overload protection, short-circuit protection and remote operation in one assembled unit.

The standard manual motor controller (MMC) consists of a manual motor protection with either a toggle or rotary operator, a wiring connector, and an IEC contactor. These types of motor controllers require an upstream short-circuit protection device like a fuse or breaker to protect the motor circuit.

Four point starter works as a current controlling device in the deficiency of back EMF while starts running of the DC motor. A four-point starter also works as a protecting device. The main difference between a 4 point starter compared to a 3 point starter is, the holding coil is detached from the shunt-field circuit.

REFERENCES:

Understanding Motor Controls,Third Edition, Stephen L. Herman, 2017

Industrial Electricity, 9th Edition, Michael E. Brumbach, 2017

Basics Series; Reduced Voltage Starter, Cutler-Hammer, 2017

POST TEST:

Name: ___________________________ Date: _______

Yr.&Sec: _____________ Score: ______

Direction: Answer the following question briefly and concise.

1. How does a brushless DC motor work?

2. What is a brushed DC motor?

3. What is a shunt DC motor?

4. What is a series DC motor?

Module no. 4

TITLE	:	**DC Controllers**
TOPIC	:	**1. Manual Controller**
		2. DC Magnetic Contactor
		3. Magnetic Starter
		4. Wiring Diagrams
TIME FRAME	:	**30 HOURS**

INTRODUCTION Controllers are classified in many different types, but essentially they are either manually or automatically operated, using full or reduced voltage. This module is devoted to describing both manually and automatically operated d-c controllers and the ways in which they connected in motor circuit.

Small dc motors of less than ½ h.p. consume very little current and therefore can be started by placing full voltage across the motor terminals. Motors larger than ½ h.p. usually required a reduced voltage for starting. However, d-c motors up to 2 h.p. at 230 volts can be started with full voltage, provided the voltage can be applied without damage to the motor or machine. Large d-c motors cause large initial currents to flow because they have a low ohmic resistance and therefore use a reduced voltage for starting. If full voltage is applied to a large motor while it is at standstill, the excessive current flow may damage to the motor, trip a breaker, or burn out the fuse. To start a large motor, it is necessary to place a resistance unit in series with the motor so that the starting current is reduced to safe value. Such starters are called reduced voltage starters. As the motor accelerates, this resistance can be gradually decreased. The resistance is not required after the motor has reached the desired speed because the motor is then generating a voltage which is in opposition to the impressed voltage. Thereby preventing excessive current flow. This opposing voltage is called counter electromotive force (counter e. m. f.), and its value will depend on the speed of the motor, which is greatest at full speed and zero at standstill.

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OBJECTIVES **:** In this lesson, student will be able to:

1. Understand the function of d-c controllers
2. Identify the types, construction, application and operation of d-c controllers
3. Interpret wiring diagrams
4. Install d-c controllers

LEARNING ACTIVITIES: 1. Read and study the module

2 .Answer the pretest, self-evaluation and post test

3. Draw a diagram of D**C Controllers**

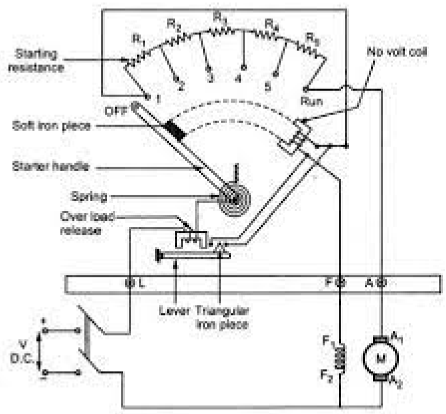
Manual Motor Controllers

Manual motor controllers are electrical devices used for motor starting and often include motor disconnect, overload protection, short-circuit protection and remote operation in one assembled unit.

The standard manual motor controller (MMC) consists of a manual motor protection with either a toggle or rotary operator, a wiring connector, and an IEC contactor. These types of motor controllers require an upstream short-circuit protection device like a fuse or breaker to protect the motor circuit.

Combination motor controllers include motor protection functions, and do not require additional fuses or breakers.

Manual motor controllers are ideal components for group motor installations, to protect motors from faults that fuses and circuit breakers would ignore, and for applications with limited cabinet space



A three-point starter is an electrical device, used for starting as well as maintaining the DC shunt motor speed. The connection of resistance in this circuit is in series which decreases the initial high current and guards the equipment against any electrical failures.

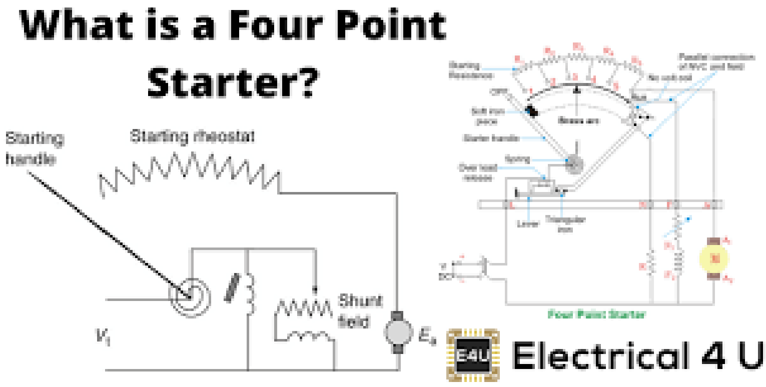
Three-point starting Box connected to Shunt Motor

A three-point starting Box consist essentially of a tapped resistance element that limits the starting current of a motor to a safe value. This type of starter can be used for starting either shunt or compound motor. He resistance unit is tapped at various points and the connections brought to contacts on the face plate, as shown in Figure 8-1. When the handle is moved from the point to point, the resistance in the circuit decreased. A coil located on the face plate acts as a magnetic holding coil and keeps the handle in place after is has been moved to the last contact. The starter gets its name from the fact that three terminals are located from the face plate. These are mark L, A, and F, signifying respectively, line, armature, and, field, and are connected internally to the handle, resistance, and holding coil.

The operation of the starter shown in figure 8-1, when connected to a motor, is as follows: When the handle is brought to the first contact point, current will flow from, L1 to terminal L and through the handle to the first contact point. From this point the current has two paths, one through all the resistance to terminal A, the other through the holding coil to terminal F. From the armature terminal, the current flows through the armature terminal to L2. From the field terminal. The current flows through the shunt field also to L2, as can be seen from figure 8-2. Because all the resistance is in series with the armature at starting position, the initial current will be limited to a safe value. As the handle is moved up, the motor will accelerate and produce a counter e.m.f., which will also restrict the current flow.

It should be noticed that when the handle is moved on the last contact point, the starting box resistance is b removed from the armature circuit, and that it has been gradually placed in the field circuit. This will have no effect on the performance of the motor because of the resistance of the starting box has a very low value in comparison to the resistance of the shunt field. Note also that the holding coil is connected in series with the shunt field. Therefore, current will flow through it when the field is excited, energizing it and causing it to become a magnet. Thus the holding coil retains the handle in position.

Should the shunt field open for any reason, the current will stop flowing in the holding coil. Spring action will cause the handle to fall back and open the circuit to the armature. The holding coil therefore acts as a safety device, because under ordinary conditions a shunt motor with an open field circuit will tend to” run away.” Because of this safety measure, the holding coil is given the name of no-field resistance.



Four point starter works as a current controlling device in the deficiency of back EMF while starts running of the DC motor. A four-point starter also works as a protecting device. The main difference between a 4-point starter compared to a 3-point starter is, the holding coil is detached from the shunt-field circuit.

Four Point Starting Box Connected to a Compound Motor

There is very little difference between the three- point and four-point starting boxes. The main difference is that the holding coil is connected across the line in series with a resistor in order limit the current in the holding coil, as shown in Figure 8-6 and 8-7, instead of being connected in the shunt-field circuit. The four-point box has four terminals on the face plate instead of three. The line leads are L1 and L2, the armature is A and the field is F.

When the handle is brought to the first contact point, current will flow from L1 to the handle and to the first contact point. From here the current has three paths, which can be followed in Figure 8-7: One path is through the resistance to the armature terminal, to the armature and series field, and out to L2. Another path is from the field terminal to the shunt field and out to L2. A third circuit is through the holding coil, the holding- coil resistor and back to L2. Because the holding coil is connected directly across the line and thus cannot hold the handle in place should the voltage fail, it is given the name of no-voltage release.

An advantage of this box over the three-point box is that a variable resistance can be placed in the shunt-field circuit in order to increase the motor speed. A disadvantage is that the speed may increase to a dangerous degree if too much resistance is added, because this is similar to running with the field circuit open. A diagram of a four-point box with an additional resistance in the field circuit is shown in Figure 8-8. In the diagrams, the terminals have been located at convenient points on the face plate in order to simplify the diagram. In actual starters the terminals are generally placed in a row either on the bottom or top of the face plate.

D-C Magnetic Contactor

D-C contactor are compact magnetic switches suitable for remote control of lighting circuits, power (motor) circuits which have separate overload protection, battery charging circuits, and other similar application requiring a safe and convenient means of interrupting such circuits. Contactors do not have overload relays.

Magnetic contactors may be single, double, or triple pole in construction. In any case, only one coil is necessary to close the contacts of the switch. Figure 8-42(a) shows the main parts of a single pole magnetic contactor of the clapper type switch consist of a holding coil, movable arm, main contacts, and auxiliary contacts. In addition, a blowout coil is located near the main contacts and is used to quench the arc that usually occurs when the main contacts are broken. This coil wound of heavy wire and is connected in series with the main line. The magnetic field that is produced by current flowing it reacts against a similar field surrounding the arc and causes the arc to move upward, thereby breaking it.

It can be seen from Figure 8-42(a) that the main contacts will make if the holding coil is energized. Only a small current to energize the coil sufficiently to attract the arms. It is obvious, therefore, that any size of magnetic contactor can be closed by sending just a small of current through the coil. An advantage of magnetic contactor is that it can be controlled by a start-stop station located at a remote point. Figure 8-42(b) shows another method of denoting a contactor. Another type of contactor utilizes a solenoid and plunger for closing the contacts. Permanent magnet blowouts are used on some contactors and are usually mounted in the arc hood. Two-pole contactors and are usually consist of two contacts connected in series for one pole and a single contact for the other pole. These contactors generally do not have overload relays. A wiring diagram of atypical double pole contactor is shown in Figure 8-42(c).

Pushbutton Station A magnetic contactor is usually controlled by means of a pushbutton statin. The common station consist of two buttons, a start and a stop button. The construction is such that when start button is pressed, two normally open is closed, and when stop button is pressed, two normally closed contacts are opened. Spring action return either button to its normal position when pressure is removed. Figure 8-43 shows several ways of illustrating a start- stop station.

To control a magnetic contactor by a pushbutton station, it is necessary to connect the holding coil to the station so that when the start button is pressed current will flow through the coil, and when the stop button is pressed the circuit through the coil will be opened. The auxiliary contacts will maintain the current through the coil when the start button is released. Figure 8-44 and 8-45 shows a circuit diagram of a magnetic contactor connected to a start-stop pushbutton station.

In the circuit of Figure 8-46, the start button is pressed, a circuit is formed from L1 through the Stop button, the start button, the holding coil M, to L2. This energizes the holding coil and causes the main and auxiliary contacts to close. The main contacts close the circuit to the motor, while the auxiliary, or maintaining, contacts maintain the current through the holding coil when the start button is released.

If the stop button is pressed, the circuit through the holding coil is opened, causing the main contacts to opened, thereby stopping the motor. Note that the auxiliary contact is connected across the start button.

Magnetic Starters (Full Voltage)

Magnetic Starters differ basically from contactors in that they are designed primarily for starting motors and consist of a contactor and an overload relay, usually of manual reset type. These starters can be used only on smaller motors, up to approximately 2 h.p. and where full voltage can be applied without damage to motor or machine. On this type of starter, overload, under voltage, and no voltage protection are provided. On a sustained overload the relay will trip and open the solenoid circuit, disconnecting the starter from the line. Voltage failure or severe voltage dip will also de-energize the solenoid circuit. This starter is illustrated in Figure 8-47 (a) and (b).

Quite often it is necessary to control the motor from more than one location, and this is easily accomplished by using several pushbutton stations. Figure 8-48 shows two start-stop pushbutton stations are connected as shown in Figure 8-49 and 8-50. It should be remembered that the stop button must always be in series with one another and in series with the holding coil, so that in an emergency the motor can be stopped from any station. Any number of Start-Stop stations can be added to control a magnetic starter if they are connected properly in the circuit. The important point to remember is that Start buttons are connected in parallel and \stop buttons in series.

Reversing Starters (Full Voltage)

A d-c motor can be reversed by reversing the current flow through the armature circuit or the field circuit. In a compound motor, this entails reversing the current through the shunt and series fields. It is therefore much simpler to reverse the current in the armature circuit. Note in Figure 8-51 that the armature is connected in such a manner that when contacts R are closed, current will flow through the armature in one direction, and when contacts F are closed, current will flow through the armature in the opposite direction, thereby reversing the direction of rotation. A Forward-Reverse-Stop station is used with this starter. It is important that the motor will be brought to a full stop before the reverse button is pressed. On this type of starter, the contacts are mechanically interlocked so that it is impossible for the R and F contacts to close at the same time.

Magnetic reversing starters are also constructed with electrical interlocks to give the additional protection against the R and F contacts closing at the same time. Figure 8-52 (a) shows the control circuit of an electrically interlocked magnetic switch. Figure 8-52 (b) shows a control circuit using front and rear contacts of the Forward and Reverse buttons.

Magnetic reversing starters come equipped with a timing relay which prevents the motor from being reversed before it comes to a full stop. In Figure 8-53 the timing relay TR opens the normally closed TR contacts. When the Stop button is pressed, the TR relay prevents them from closing until a specific interval of time is elapsed. The operation is as follows: When the reverse button is pressed, current flow from L1, the Stop button, Reverse button, Forward interlock, Reverse coil, to L2. All normally open R contacts close, including the reverse holding contacts and reverse timing contact. Normally closed R interlock opens. When the reverse timing contact close, coil TR is energized, opening the normally closed TR contacts, thereby making both the Forward and Reverse buttons in operative while the motor is running. When the stop button is pressed, timing contacts TR remain open until the TR relay has timed out. This prevents reversing the motor until it has come to a full stop.

WIRING DIAGRAM OF DC CONTROLLERS

SELF EVALUATION:

Answer the following question briefly:

4. Explain why a small motor can be started by placing full voltage across it while large motor mush be started with reduced voltage.
5. Describe the construction and operation of a three-point starting box
6. Describe the construction of Pushbutton station.
7. Explain the construction and application of magnetic starter (Full Voltage).

REVIEW CONCEPTS:

What is a Controller?

Controllers are classified in many different types, but essentially they are either manually or automatically operated using full or reduced voltage.

Small dc motors less than1/2 h.p. consume very little current and therefore can be started by placing full voltage across the motor terminals. Motors larger than ½ h.p. usually require a reduced voltage for starting. However, d-c motor up to 2 h.p. at 230 volts can be started with full voltage, provided the voltage can be applied without damage of the motor or machine. Large d-c motors cause large initial currents to flow because they have a low ohmic resistance and therefore use a reduced voltage for starting.

A three- point starting box consist essentially of a tapped resistance element that limits the starting current of the motor to a safe value.

Magnetic Starter is differ basically from contactors in that they are designed primarily for starting motors and consist of a contactor and overload relay, usually of manual reset type.

Pushbutton Stations

A magnetic contactor is usually controlled by means of pushbutton station, The common station consist of two buttons, a start and stop button.

REFERENCES:

Understanding Motor Controls, Third Edition, Stephen L. Herman, 2017
Industrial Electricity, 9th Edition, Michael E. Brumbach, 2017
Basics Series, Reduced voltage Starter, Cutler-Hammer
Electric Motor Repair, Third Edition, Robert Rosenberg

PRETEST:

Name: ________________________________ **Date :**___________

Year & Section: ________________________ **Score:**__________

Described the following:

1. **Manual controller**
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2. **DC Magnetic Contactor**
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3. **Magnetic Starters (Full Voltage)**

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   _________.

POST TEST:

Name: ___________________________ Date: __________

Year & Section: ___________________ Score: _________

Fill in the blank with the correct answer and write your answer on the space provided for.

1. **_________ a starter consists essentially of a tapped resistance element that limits the starting current of a motor to a safe value.**
2. **The resistance unit is tapped at various points and the connection brought to the contacts on the __________.**
3. **A three-point starting box when the handle is moved from point to point, the resistance in the circuit is _________.**
4. **In the operation of three point starting box when the handle is brought to the first contact point, current will flow from L1 to terminal __________.**
5. **Because of the safety measure, the holding coil is given the name of _____.**
6. **The main difference of three point starting box and four point starting box is that the holding coil is connected across the line in series with a ______.**

7. This advantage of the four-point starting box is that the speed increases the motor speed if too much _________ is added.
8. _________ are compact magnetic switches suitable for remote control of lighting circuits, power circuits which have separate overload protection.
9. _____ 12. Main parts of magnetic contactors.

13. A magnetic contactor is usually controlled by means of a ________ station.
14. _______ button has two normally closed contacts.
15. _______ button has two normally open contacts.
16. The ________ maintain the current to the holding coil when the start button is released.
17. In the control circuit the stop button is connected _____ to the holding coil.
18. In the control circuit the auxiliary contact is connected _________ to the start button.
19. A dc motor can be reversed by reversing the current flow through the armature circuit or the __________ circuit.
20. Magnetic reversing starters are also come equipped with a _______ which prevents the motor from being reversed before it comes to a full stop.
21. Draw a diagram of a small dc motor connected to magnetic starter controlled by start and stop pushbutton station. (label all parts)