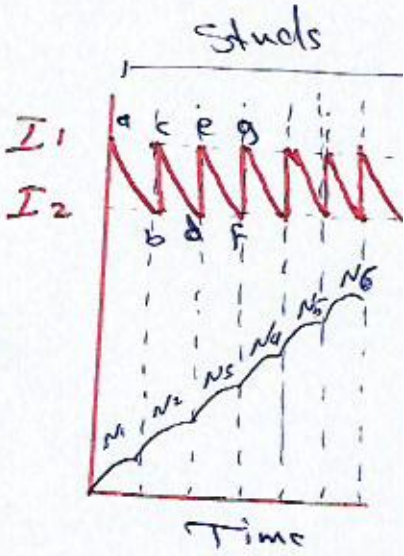
Resistance starting of DC Motor Design



Stud 1

$$I_1 = I_{max} = \frac{V}{R_1}$$

$$I_2 = I_{min} = \frac{V - E_{b1}}{R_1} \quad \text{— (1)}$$

Stud 2

$$I_1 = \frac{V - E_{b1}}{R_2} \quad \text{— (2)}$$

from (1) and (2)

$$I_2 = \frac{V - E_{b2}}{R_2} \quad \text{— (3)} \qquad \frac{I_1}{I_2} = \frac{R_1}{R_2}$$

Stud 3

$$I_1 = \frac{V - E_{b2}}{R_3} \quad \text{— (4)}$$

from (3) and (4)

$$I_2 = \frac{V - E_{b2}}{R_3} \qquad \frac{I_1}{I_2} = \frac{R_2}{R_3}$$

$$\vdots$$

$$\therefore \frac{I_1}{I_2} = \frac{R_{n-1}}{R_a}$$

, n = No. of studs

$n-1$ = No. of section

$$\therefore \frac{I_1}{I_2} = \frac{R_1}{R_2} = \frac{R_2}{R_3} = \frac{R_3}{R_4} + \cdots \frac{R_{n-1}}{R_a} = K$$

* if $n = 6 \Rightarrow \frac{R_5}{R_a} = K \Rightarrow R_5 = KR_a$

$\therefore R_4 = K \cdot KR_a = K^2 R_a$, $R_3 = K^2 \cdot KR_a = K^3 R_a$

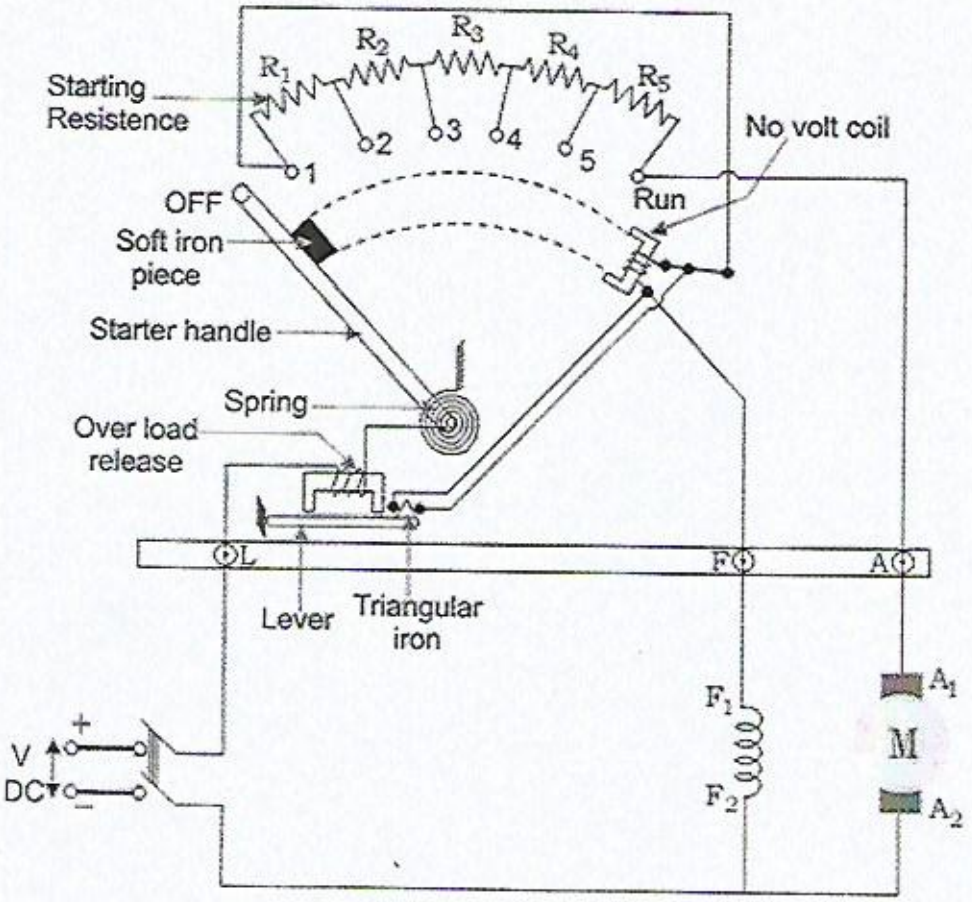
$\cdots R_2 = K^4 R_a$, $R_1 = K^5 R_a \Rightarrow \frac{R_1}{R_a} = K^5 = \frac{R_1}{R_a} = K^n$

$$\therefore \frac{R_1}{R_2} = K^{n-1} = \left(\frac{I_1}{I_2}\right)^{n-1}$$

DC Motor Starter

Three point starter

Let us now look into the construction and **working of three point starter** to understand how the starting current is restricted to the desired value. For that let's consider the diagram given below showing all essential parts of the three point starter



Three Point Starter

Construction of 3 Point Starter

Construction wise a starter is a variable resistance, integrated into number of sections as shown in the figure beside. The contact points of these sections are called studs and are shown separately as **OFF, 1, 2, 3, 4, 5, RUN**. Other than that there are 3 main points, referred to as

1. 'L' Line terminal. (Connected to positive of supply.)
2. 'A' Armature terminal. (Connected to the armature winding.)

3. 'F' Field terminal. (Connected to the field winding.)

And from there it gets the name 3 point starter. Now studying the construction of 3 point starter in further details reveals that, the point 'L' is connected to an electromagnet called overload release (OLR) as shown in the figure. The other end of 'OLR' is connected to the lower end of conducting lever of starter handle where a spring is also attached with it and the starter handle contains also a soft iron piece housed on it. This handle is free to move to the other side RUN against the force of the spring. This spring brings back the handle to its original OFF position under the influence of its own force. Another parallel path is derived from the stud '1', given to the another electromagnet called No Volt Coil (NVC) which is further connected to terminal 'F'. The starting resistance at starting is entirely in series with the armature. The OLR and NVC acts as the two protecting devices of the starter.

Working of Three Point Starter

Having studied its construction, let us now go into the **working of the 3 point starter**. To start with the handle is in the OFF position when the supply to the DC motor is switched on. Then handle is slowly moved against the spring force to make a contact with stud No. 1. At this point, field winding of the shunt or the compound motor gets supply through the parallel path provided to starting resistance, through No Voltage Coil. While entire starting resistance comes in series with the armature. The high starting armature current thus gets limited as the current equation at this stage becomes $I_a = E/(R_a+R_{st})$. As the handle is moved further, it goes on making contact with studs 2, 3, 4 etc., thus gradually cutting off the series resistance from the armature circuit as the motor gathers speed. Finally when the starter handle is in 'RUN' position, the entire starting resistance is eliminated and the motor runs with normal speed. This is because back emf is developed consequently with speed to counter the supply voltage and reduce the armature current. So the external electrical resistance is not required anymore, and is removed for optimum operation. The handle is moved manually from OFF to the RUN position with development of

speed. Now the obvious question is once the handle is taken to the RUN position how is it supposed to stay there, as long as motor is running ? To find the answer to this question let us look into the working of No Voltage Coil.

Working of No Voltage Coil of 3 Point Starter

The supply to the field winding is derived through no voltage coil. So when field current flows, the NVC is magnetized. Now when the handle is in the 'RUN' position, soft iron piece connected to the handle and gets attracted by the magnetic force produced by NVC, because of flow of current through it. The NVC is designed in such a way that it holds the handle in 'RUN' position against the force of the spring as long as supply is given to the motor. Thus NVC holds the handle in the 'RUN' position and hence also called **hold on coil**.

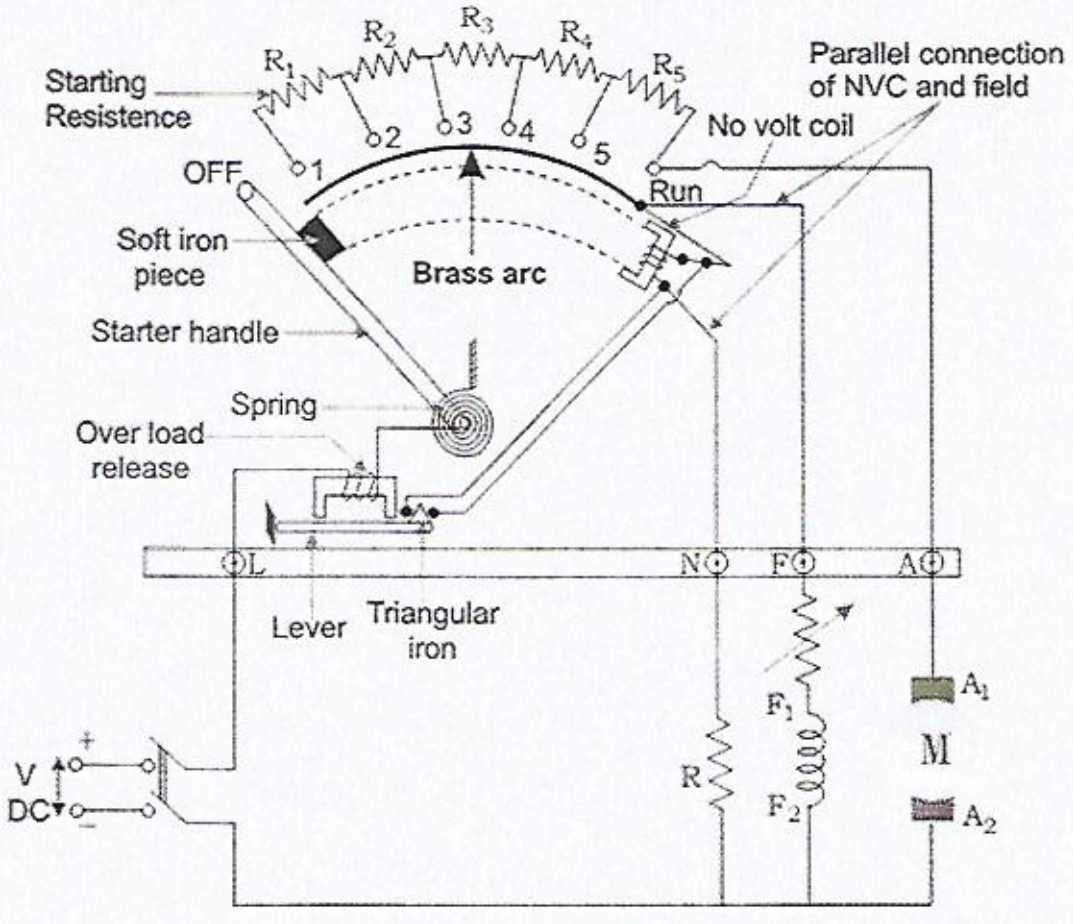
Now when there is any kind of supply failure, the current flow through NVC is affected and it immediately looses its magnetic property and is unable to keep the soft iron piece on the handle, attracted. At this point under the action of the spring force, the handle comes back to OFF position, opening the circuit and thus switching off the motor. So due to the combination of NVC and the spring, the starter handle always comes back to OFF position whenever there is any supply problems. Thus it also acts as a protective device safeguarding the motor from any kind of abnormality.

Drawbacks of a Three Point Starter

The **3 point starter** suffers from a serious drawback for motors with large variation of speed by adjustment of the field rheostat. To increase the speed of the motor field resistance can be increased. Therefore current through shunt field is reduced. Field current becomes very low which results in holding electromagnet too weak to overcome the force exerted by the spring. The holding magnet may release the arm of the starter during the normal operation of the motor and thus disconnect the motor from the line. This is not desirable. A four point starter is thus used.

Working Principle of Four Point Starter

The **4 point starter** like in the case of a 3 point starter also acts as a protective device that helps in safeguarding the armature of the shunt or compound excited DC motor **against the high starting current produced in the absence of back emf at starting**. The 4 point starter has a lot of constructional and functional similarity to a three point starter, but this special device has an additional point and a coil in its construction. This naturally brings about some difference in its functionality, though the basic operational characteristic remains the same. The basic difference in circuit of 4 point starter as compared to 3 point starter is that the holding coil is removed from the shunt field current and is connected directly across the line with current limiting resistance in series. Now to go into the details of **operation of 4 point starter**, lets have a look at its constructional diagram, and figure out its point of difference with a 3 point starter.



Four Point Starter

Construction and Operation of Four Point Starter

A 4 point starter as the name suggests has 4 main operational points, namely

1. 'L' Line terminal. (Connected to positive of supply.)
2. 'A' Armature terminal. (Connected to the armature winding.)
3. 'F' Field terminal. (Connected to the field winding.)
4. Like in the case of the 3 point starter, and in addition to it there is, A 4th point N. (Connected to the No Voltage Coil NVC)

The remarkable difference in case of a 4 point starter is that the No Voltage Coil is connected independently across the supply through the fourth terminal called 'N' in addition to the 'L', 'F' and 'A'. As a direct consequence of that, any change in the field supply current does not bring about any difference in the performance of the NVC. Thus it must be ensured that no voltage coil always produce a force which is strong enough to hold the handle in its 'RUN' position, against force of the spring, under all the operational conditions. Such a current is adjusted through No Voltage Coil with the help of fixed resistance R connected in series with the NVC using fourth point 'N' as shown in the figure above.

Apart from this above mentioned fact, the 4 point and 3 point starters are similar in all other ways like possessing is a variable resistance, integrated into number of sections as shown in the figure above. The contact points of these sections are called studs and are shown separately as OFF, 1, 2, 3, 4, 5, RUN, over which the handle is free to be maneuvered manually to regulate the starting current with gathering speed.

Now to understand its way of operating lets have a closer look at the diagram given above. Considering that supply is given and the handle is taken stud No.1, then the circuit is complete and line current that starts flowing through the starter. In this situation we can see that the current will be divided into 3 parts, flowing through 3 different points.

1. 1 part flows through the starting resistance (R_1+ R_2+ R_3.....) and then to the armature.
2. A 2nd part flowing through the field winding F.
3. And a 3rd part flowing through the no voltage coil in series with the protective resistance R.

So the point to be noted here is that with this particular arrangement any change in the shunt field circuit does not bring about any change in the no voltage coil as the two circuits are independent of each other. This essentially means that the electromagnet pull subjected upon the soft iron bar of the handle by the no voltage coil at all points of time should be high enough to keep the handle at its RUN position, or rather prevent the spring force from restoring the handle at its original OFF position, irrespective of how the field rheostat is adjusted. This marks the operational difference between a **4 point starter** and a 3 point starter. As otherwise both are almost similar and are used for limiting the starting current to a shunt wound DC motor or compound wound DC motor, and thus act as a protective device.