Theory Of Operation - Autotransformer Starter

The autotransformer reduced-voltage starter places the motor on the secondary of the autotransformer while starting. The taps on the autotransformer limit the voltage applied to the motor to 50%, 65% or 80% of the nominal voltage.

With autotransformer starting, the line current is always less than the motor current during starting because the motor is on the secondary of a transformer during acceleration. If a motor is connected to the 50% tap of the autotransformer, the motor current would be reduced to 50% of the normal starting value, but the line current would be only 25% of the normal starting current. The difference between line and motor current is due to the transformer in the circuit. The lower line current is the reason the autotransformer starter is a very popular type of reduced-voltage starter. Since the motor starting current is greater than the line current with an autotransformer starter, the starter produces more torque-per-ampere of line current than any other type of reduced-voltage starter.

Most motors can be started at 65% of line voltage. If the torque that the motor supplies to the driven equipment is not sufficient on the 65% voltage tap, a higher torque on the 80% tap is available. Similarly, if too much torque is applied to the load with 65% voltage, or if the voltage dip associated with 65% starting is too high, the 50% tap is available. This versatility makes the autotransformer starter very popular. Figure 6 shows the typical schematic diagram for a two coil autotransformer starter. The circuit for a three coil autotransformer starter is similar except that an additional transformer winding would be inserted in the L2 leg. It should be pointed out that there are no significant disadvantages to using a two coil autotransformer design since the starting currents will be approximately balanced in each phase.

Initial pressing of the start button energizes timing relay TR. An instantaneous normally open contact on TR closes around the start button to provide a normal three wire control scheme. An additional normally open instantaneous contact on TR closes, energizing contactor 1S. The 1S contactor connects the autotransformer to line 2. An interlock on the 1S contactor closes to pick up contactor 2S. This connects the autotransformer primary windings to line 1 and line 3. The motor is now connected to the line through the autotransformer taps.

After a preset time delay, the timing contacts on the TR timing relay change state, causing contactor 1S
to open. The 2S coil does not drop out until the RUN starter has been energized. To insure that contactor 2S remains energized until after the RUN starter has picked up and sealed in, the normally closed RUN interlock that is in series with the 2S coil is of the late-break type. Once the 1S contact has opened, the motor is momentarily connected to the lines through the windings of the autotransformer with the transformer acting as a reactor. The RUN starter then shorts out this portion of the autotransformer windings, supplying full line voltage to the motor.

With electromechanical contactors, the transition time between the reduced voltage and full-voltage step is typically 50 milliseconds or less. By energizing the RUN starter before the 2S contactor is dropped out, the motor is assured to have closed-circuit transition starting. This means that at no time during the starting cycle is the motor disconnected from the line power.

If the motor were to be disconnected from the line even for a brief period, it would act momentarily as a generator. If the motor is then rapidly reconnected to the line it could result in a large transient. The "power" that is fed back into the line by the motor probably would not be in phase with the line voltage and current. The transient associated with open-circuit transition starting could be sufficient to cause nuisance tripping of breakers. In addition, there would be a torque surge associated with the motor rapidly accelerating to get "in step" with the line power. The rapid torque surge may cause additional stress on the motor and the driven load.

The normal medium duty starting cycle per NEMA standards for autotransformers rated 200Hp or less is one 15 second "ON" period each four minutes for an hour, or 15 starts per hour. For starters rated above 200Hp, the starting duty cycle is one 30 second "ON" period each minute for three times total. This can be repeated after a two hour and one hour rest, respectively. Most standard motors have a much lower starting capability than the autotransformers can provide.

These starting duty cycles represent the length of time the autotransformer can be connected in the circuit. The length of time the autotransformer is connected can be longer than either 15 seconds or 30 seconds provided a longer period of time is allowed for the autotransformer to cool. This means that if a 100Hp motor requires the autotransformer to be connected in the circuit for 25 seconds, there would be no problem in starting the motor, provided a sufficient time, such as 20 minutes, were provided between starts to allow the autotransformer to cool. Care must be taken not to exceed the temperature ratings of the autotransformer and power wire insulation systems and assure that the thermal overload protection does not trip. Consulting the equipment manufacturer is recommended when deviating from standard duty cycles.

The chart below shows the line current as a percent of full load versus motor speed as a percent of synchronous speed, with a typical autotransformer type starter starting a NEMA design B motor when the autotransformer is connected on the 65% tap.
The timer on this starter should be set so that the transfer point always occurs between 80 and 85% speed. This can be done by using a tachometer on the output of the motor shaft. However, the most common method is to listen to the motor while it accelerates. While starting, the motor usually emits a low frequency vibration which gradually increases in pitch as the motor accelerates. When a loaded motor is connected with less than nominal voltage, it can only accelerate to some speed below full load. The timer should be set so that the transfer to full voltage occurs just before the motor stops accelerating.

The autotransformer starter is the most popular of the electromechanical reduced-voltage starters. Its popularity is attributed to the fact this type of starter can reduce the inrush current in the distribution system to the lowest level of all the different electromechanical types of starters. In addition, the taps on the autotransformer permit adjustment of voltage and motor torque. It is ideally suited for starting most industrial loads.