

## AUTOMOTIVE START-STOP SYSTEMS:

One of the ways to reduce the fuel consumption of a vehicle is to turn off the engine when it stands still, even if it's only for a short time. In modern cars this function is controlled by Start-Stop systems.

**A few decades ago, German scientists conducted traction tests of an Audi LS with an engine power of 55 kW. The tests showed that the car consumes 0.35 cc's of fuel while idling and 1.87 cc's while starting. So, it is clear that turning off the engine during a standstill which lasts more than 5 seconds allows you to save some fuel.**

**The possibility of reducing fuel consumption by switching off the engine during even a very short stop and then restarting it, led to the development of control systems that perform these operations automatically.**

The solution introduced by **Volkswagen** at the beginning of the 80's provides a good example of such systems. The engine could be turned off by the driver or automatically, depending on the vehicle's speed, the engine's temperature and the position of the gear-change lever. The



engine was turned over by a starter when the driver put the car in the first or second gear and pressed the accelerator pedal without releasing the clutch. When the vehicle's speed fell below 5km/h, the system stopped the engine by closing the idle run air duct. If the engine was not sufficiently heated, the temperature sensor prevented it from turning off. It was done in order to reduce starter wear, because starting a heated engine requires much less time than the start-up of a cold one. Furthermore, the control system reduced the load of the accumulator by switching of the heating of the rear window.

Now it's more frequent that cars are equipped with similar control systems, responsible for starting and stopping the engine. These systems are usually called Start-Stop, Start & Stop or Stop-and-Go.

## Starter Motors in Start-Stop systems:



In the majority of Start-Stop system solutions used in cars, the engine is turned over by a conventional starter. However, as the car is started very frequently, the starter has to be more durable than a regular starter. That is why it is equipped with a more powerful electric motor and brushes that are more resistant to wear. Moreover, they changed the one-way clutch in the coupling mechanism and corrected the shape of the pinion teeth.

All these innovations translate into a lesser amount of noise emitted by the running starter, which is of no small importance for the driving comfort if taking into account the fact that we start the engine very often.

## Reversible Alternators:

Even a modernized and strengthened starter isn't adapted for continuous operation. Nevertheless, the situation is different for an alternator whose rotor is rotating from the moment the engine turns over, till it stops. This is probably the origin of the idea that one could rotate the alternator with crankshaft during the start-up, so that it would transform into the electric motor. The **Valeo** Company developed such a starter-alternator for Start-Stop systems, called **StARS (Starter Alternator Reversible System)**.



The system is based on a reversible electric motor that serves the functions of both starter and alternator. The reversible alternator can easily be mounted in the place of the classical one. It permits a very gentle start-up. In comparison with the conventional starter, there is no coupling process, so no additional sounds connected with this operation are emitted.

During the start-up, the reversible alternator becomes an electric motor. Therefore, its armature windings have to be supplied with alternating voltage, while the direct current has to be delivered to the excitation winding (of the rotor). In order to obtain the alternating voltage from an on-board alternator, the use of a so-called inverter is required.

Furthermore, the armature windings cannot be supplied with alternating voltage through the voltage regulator and diode bridges, because at this time they have to be removed from the windings. In the moment of starting, the reversible alternator becomes the electric motor of an output not exceeding 2-2.5 kW and developing a torque of 40 Nm. This allows the engine to be started within 350 to 400ms.



The moment the engine is put in motion, the alternating voltage stops flowing through the armature windings. The reversible alternator again becomes an alternating current generator with the voltage regulator and diodes connected to the armature clips in order to be able to supply the vehicle's electrical system with constant voltage.

Additionally, other manufacturers equip the engine with an extra conventional starter and reversible alternator to turn over the engine for the first time after a longer stoppage period.

Considering construction solutions, the Valeo type alternators can be divided into two groups. The alternators of the first type have integrated parts, rectifying diodes, voltage regulator and an inverter. In the alternators of the second group, the diodes, the voltage regulator and the inverter are a distinct system, mounted separately outside the alternator. It is easy to recognize them, as the plus terminal is divided into three segments, each corresponding to one of the three stator windings.

### Principle of Operation:

The reversible alternator fulfils the functions of both the alternator and the starter motor. When the rotor is driven by the motor's crankshaft, the rotor's magnetic field will cause the induction of alternating voltage in the stator phases. The frequency of the alternating voltage will be proportional to the rotor's speed of rotation and phase displacements resulting from the winding arrangement on the circumference of the stator. The application of the rectifier circuit and voltage control allows the automotive electrical system receivers to be supplied with voltage.

When the alternator transforms the alternating current generator into an electric motor, it's the



stator's spinning magnetic field that is responsible for the rotation of the rotor. At that moment, the direct current is delivered to the rotor winding (the rotor becomes an electromagnet), while the inverter, which transforms the constant voltage into a three-phase system of alternating voltages, and supplies the stator windings of the alternator. Moreover, both the rectifier circuit and the voltage regulator don't take part in the process of feeding the stator windings with the system of alternating voltages.

The change of the stator magnetic field in relation to the magnetic field of the rotor forces the rotor to rotate. The supply of the following stator windings is switched in such a way, that the stator magnetic field changes appropriately to the position of the rotor. Thanks to this, the highest power output can be achieved.

In order to determine the optimum time for the inverter control system, the position of the rotor to switch the phases uses Hall sensors. On the basis of their signals, a simple logic circuit defines the right phase switching sequence.

However, at the moment of starting, the phase switching sequence of the system of voltages created by the inverter is random and doesn't necessarily have to correspond to the proper phase. Nevertheless, it is enough for the rotor to start moving and next the Hall sensor turns on. In a split second this information is transferred to the inverter control system and the phase switching sequence is changed, so that it corresponds to the position of the rotor. In this way, the reversible alternator fulfils the role of an electric motor and can achieve a maximum torque, able to start a car engine.



## Diagnostic:

Depending on the rotor position, the phase switching control system requires, that after such an alternator is repaired, the Hall sensors should be properly positioned. Otherwise, the generator won't have enough power to rotate the crankshaft.

Till now, there is only one known instrument that can diagnose and test the Valeo ST35 series reversible alternators: The VC-09ST bench top tester, produced by MOTOPLAT.

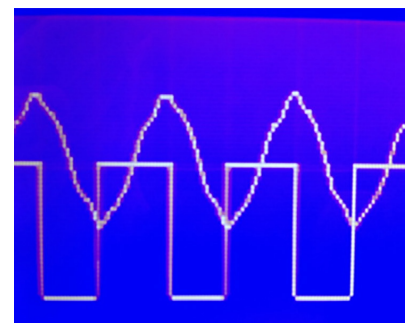
In order to check an alternator by means of this device, one has to do the following:

First you install the VC-09ST on your current test bench. Then you mount the alternator on the test bench connect it to the VC-09ST and next, as it is done in the case of a conventional alternator, you test the parameters. In other words: you check power and voltage values according to the rotational speed. After this test, the Hall sensors should be positioned and on the screen of the tester you can check whether their position is correct or not. On the screen will appear an oscilloscope graph of the signal received from the Hall sensor (the rectangular wave) and the one of the phases. The correctness of the Hall sensor's position is displayed on the basis of points where both waves intersect each other.



After checking the parameters and adjusting the Hall sensors, there is no need to start the alternator as an electric motor because of two reasons. The first reason is technical: in order to check the motor's parameters, a proper brake would be indispensable. The second and most important result from the very principle of operation of reversible alternators:

***If we deal with an alternating current reversible generator, it will be 100% efficient as an alternator. For example an alternating current generator and at the same time its Hall sensors are correctly positioned, it will be 100% efficient as an alternating current motor, for example in this case, a starter.***



The VALEO IST reversible alternators works in the same manner as the Valeo ST35 series alternators, but their structure is more complicated because the inverter, diodes and the voltage regulator are integrated on the backside of the alternator. As with the Valeo ST35 series alternators, the only known tester that can be used to check and control Valeo IST alternators is the MOTOPLAT VC-07 USB



In order to check an alternator with this device, you first install the VC-07 USB to your current test bench. Then you mount the alternator on the test bench and connect it to the VC-07 USB. The tester sends a digital signal to the alternator to make it start charging and then control the voltage within the LIN data bus.

Next, the parameters are tested, as in the case of a conventional generator. This means that you check the power and voltage values according to the rotational speed. In the case of these types of alternators, there is no need to check the settings of Hall-effect sensors.



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