Application of a belt starter generator (reversible alternator) in a conventional vehicle, with an internal combustion engine (ICE). (Study for P0 mild hybridization)

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ABSTRACT

With the increase in demand for more efficient systems that can bring us a series of benefits and in parallel help us adapt actual vehicles to future automotive legislation, belt starter generators have become an ally for bringing several advantages when compared to conventional systems. of combustion engines, in which a conventional starter and alternator are used.
This article will present the integration process of this reversible alternator in a conventional combustion engine system, where the analyzes are initiated by software simulations, then mechanical integration studies are carried out via the project team and in the sequence the physical installation architecture is defined. for mechanical and electrical integration of the new system.
The new features in the vehicle will be tested in order to bring the comparative results both in relation to fuel consumption and recovery of energy consumed in the running cycles, as well as the possible advantages related to the adaptation of conventional vehicles to the new regulations.
The tests showed 5.7% ethanol fuel economy after a series of analysis and concept validations, showing that this technology brings real benefits when applied to conventional internal combustion engine vehicles.

Keywords: Reversible alternator, fuel consumption, energy recovery.

1. INTRODUCTION

Due to the new requirements related to motor vehicles for the reduction of gases in the atmosphere, the market demonstrates trends in carrying out component changes to improve the performance of the thermal engine and its components, such as the application of an electric motor to increase torque of the internal combustion engine at low rpm. As a result, automakers have been investing large amounts in the development of technologies and component integration involving the entire powertrain, for vehicles with hybrid technologies and even electric vehicles..[1]

In this way, the objective of the work is to demonstrate the benefits of applying a reversible alternator in a conventional vehicle, analyzing and comparing the results obtained regarding the indices of fuel consumption and energy recovery.

1.1 SIMULATIONS AND INTEGRATION - MICRO HYBRIDIZATION

Through calculations and simulations, better results can be obtained electrically and mechanically from the set to be modified. In this way, it is important to identify key assembly issues, fixings, hypotheses, etc., in the simulations. With this, obtain greater assertiveness, shorter modification and assembly time, thus reducing the costs involved for the modification. With well-defined simulations, the final result can be compared and verified through real integration.

1.2 REVERSIBLE ALTERNATOR (iStARS)

The machine used in the integration has, among the most important, the functions of generator, starter, regenerative braking and the ability to assist the performance of the internal combustion engine (boost). The technology uses the existing belt system instead of direct contact with the vehicle's ring gear. The iStARS is based on a traditional alternator, so it is a 12V synchronous machine with an integrated inverter, which in turn enables the machine to function as both a generator and a motor.

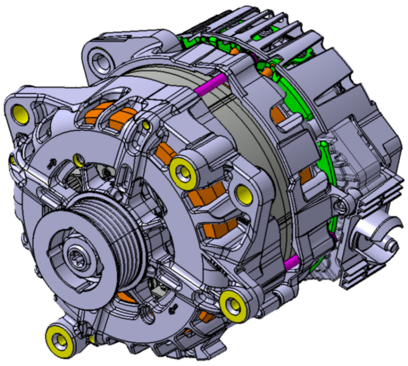

Figure 1. iStARS model used

2. METHODOLOGY

The study for the application of a reversible alternator starts with efficiency simulations via engineering software. To quantify the benefits resulting from changing the vehicle architecture.

After satisfactory results obtained from the fuel consumption simulations, the mechanical and electrical projects are started to verify the feasibility of converting the conventional architecture to a light hybridization architecture. Where the new machine is integrated, replacing the alternator and the conventional starter.

After validation of the concept in the previous stages, the construction of the parts for physical and electrical integration of the iStARS and the secondary lithium battery to store the charge recovered in the validation cycle begins.

Once the new reversible alternator system is integrated into the vehicle's architecture, the validation of concept tests will then begin according to national regulations for validation cycles on urban (FTP75)[2] and road (WLTP) routes.[5].

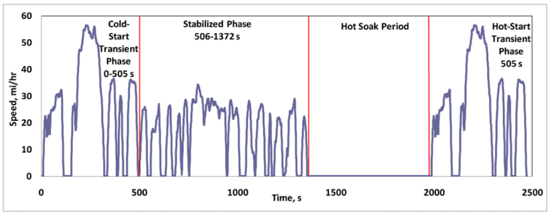

Figure 2. FTP75 Simulation scope

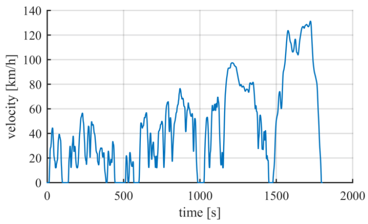

Figura 3. WLTP Simulation scope

3. RESULTS

3.1 SIMULATION

The simulation process covers the following steps:

- The simulation process encompasses the following steps:
- Vehicle data input;
- Details of simulated components and assumptions;
- Definition of the test plan;
- Results;
- Simulation analysis;
- New results defining different boundary conditions;
- Simulation conclusion.

During the simulations, taking into account various conditions and the most critical possibility of loss, the best result found was a reduction in fuel consumption of 5.4% with E100 and 5.7% with E27.

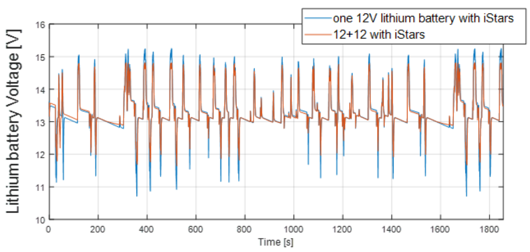

Figure 4. Software simulation model

3.2 VIRTUAL INTEGRATION

The virtual integration process consists of adapting the current system, before carrying out any physical or mechanical intervention, thus avoiding unnecessary assembly problems, etc. Some steps need to be followed, such as choosing the baseline vehicle and the machine to be applied. Thus, with the 3D model, the necessary adjustments can be made.

3.3 PHYSICAL INTEGRATION

After validation of the virtual integration, all the necessary mechanical changes were defined to adapt the new machine to the vehicle's environment. Where it was necessary to change the following components to suit the FEAD:

- Crankshaft Pulley - New welded pulley
- HVAC compressor pulley - New welded pulley
- Water pump pulley - New pulley bolted on
- i-StARS integration support - New design
- Tensioner support - New design
- Tensioner - New

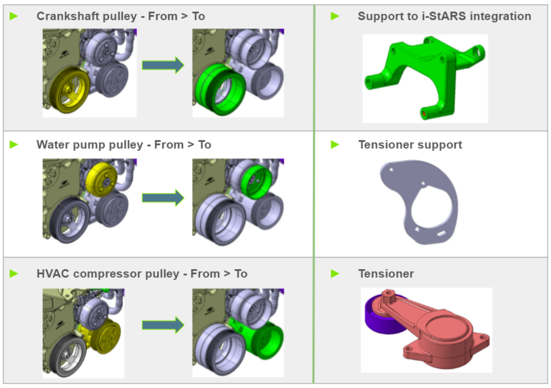

Figure 5. FEAD modifications

3.4 SOFTWARE TESTS AND CALIBRATION

After the mechanical integration of iStARS into Dragon Engine was completed, the Democar was sent for laboratory testing. Going through the following stages:

- Definition of work functions and machine calibration;
- Vehicle Safety Analysis and Validation with the system already integrated;
- Laboratory emission test (E100 fuel);
- Analysis of results and software calibration;
- Software testing and recalibration loop…

At each test round, analyzes were carried out between the work teams, and new software updates and calibrations were defined.

Taking into account the following phases of software development: First functional software; Inclusion of the Stop&Start function; Motor mode control and Regeneration mode; Investigation of recorded data; High-efficiency charging mode and variable regeneration during braking.

At each software update phase, three tests were performed under the same condition, to ensure the reliability of the results. As shown in the table below:

Fuel Economy (E100 Only)		
Software	***Test #***	***% Gain***
Baseline vehicle without Stop&Start	Test #01	Average Baseline Value
	Test #02	
	Test #03	
Democar SW version 1_New Architecture with iStARS	Test #01	3.6%
	Test #02	3.2%
	Test #03	5.0%
Democar SW version 2_New Architecture with iStARS	Test #01	0.6%
	Test #02	1.3%
	Test #03	0.6%
Democar SW version 3_New Architecture with iStARS	Test #01	2.3%
	Test #02	2.1%
	Test #03	1.9%
Democar SW version 4_New Architecture with iStARS	Test #01	2.7%
	Test #02	3.0%
	Test #03	2.9%
Democar SW version 5_New Architecture with iStARS	Test #01	-1.1%
	Test #02	-0.9%
	Test #03	-1.9%
Democar SW version 6_New Architecture with iStARS	Test #01	0.1%
	Test #02	0.3%
	Test #03	1.0%
Democar SW version 7_New Architecture with iStARS	Test #01	2.7%
	Test #02	1.0%
	Test #03	1.1%
Democar SW version 8_New Architecture with iStARS	Test #01	0.8%
	Test #02	0.9%
	Test #03	0.9%
Democar SW version 9_New Architecture with iStARS	Test #01	2.6%
	Test #02	3.3%
	Test #03	3.0%
Democar SW version 10_New Architecture with iStARS	Test #01	5.0%
	Test #02	5.3%
	Test #03	5.7%

Figure 6. Laboratory validations results

According to the results obtained in the table in Figure 6, it is noted that the best calibration adjustment achieved a result of up to 5.7% in the reduction of ethanol fuel consumption, and an average of 5.3% in the entire cycle.

4. CONCLUSION

In view of the results, it is possible to conclude that the application of a reversible alternator in a conventional vehicle is feasible and brings results consistent with the simulations carried out virtually.

The values found in the last phase of laboratory tests showed that it is possible to achieve the same level of energy efficiency and savings in fuel consumption proposed through the simulations. Finding real values of up to 5.7% fuel savings, compared to 5.4% according to calculations made considering the most critical loss conditions in the system.

5. REFERENCES

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Figure 1 - **iStARS model used**. Valeo Intellectual property.

Figure 2 - **FTP75 Simulation scope.** US Environmental Protection Agency

Figure 3 - **WLTP Simulation scope**. Global Technical Regulations

Figure 4 - **Software simulation model**. Valeo Intellectual property.

Figure 5 - **FEAD modifications**. Valeo Intellectual property.

Figure 6 - **Laboratory validations results**. Valeo Intellectual property.