Impact

History & Technical Data

Caltech

EAS Division of Engineering and Applied Science

SAE SOUTHERN CALIFORNIA
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history of the Impact

During the early 1980s, JPL engineers Wally Rippel (Caltech BS '68) and Dean Edwards (Caltech PhD '77) developed electric propulsion theory and hardware, which indicated that an electric car could be built with at-hand technology. This car would have a range in excess of 100 miles, accelerate from zero to sixty in less than ten seconds, and achieve an 80% recharge in less than 45 minutes with an integrated onboard charger. The enabling elements were a custom induction motor-inverter combination developed by Rippel and an upgraded lead-acid battery developed by Edwards.

In July of 1985, Rippel and Edwards met with Paul MacCready (Caltech PhD '52), President of AeroVironment (AV). They discussed the possibility of JPL and AV collaborating to design and fabricate a prototype EV incorporating a drive system developed by JPL with an aerodynamic, lightweight two-seat vehicle developed by AV. As a result of this meeting, MacCready wrote a proposal using documented inputs from Rippel and Edwards for the development of a demonstrator EV called "Electrospirit." In August of 1985, MacCready submitted this proposal to the General Motors Advanced Concepts Center.
The proposal was not funded.

In January of 1988, about two months after the SunRaycer victory in Australia, MacCready asked Alec Brooks (Caltech PhD '81) to organize a meeting at AV to discuss what kind of EV project AV could propose to GM, "now that the iron was hot." Consultants Wally Rippel and Alan Cocconi (Caltech BS '80) attended the meeting. MacCready suggested that AV propose a "bread and butter vehicle" such as an electric delivery van. Brooks, Cocconi, Rippel, and others present were more interested in a "high-performance" passenger car – something which would be fun to drive and would shatter the image of prior electric vehicles. Cocconi flatly stated that if the proposed effort were a "low-performance vehicle," such as a delivery van, then he was "not interested." The decision was made that the proposed effort should build upon the Electrospirit technologies to develop a high-performance EV.

The next step was to convince General Motors to fund this development. As the Hughes executive for the SunRaycer program, Howard Wilson was already familiar with most of the GM people who would be involved in any potential EV effort. He was able to secure near-term GM funds to validate technologies that would be incorporated in the EV prototype. Wilson and Brooks traveled extensively during this early phase to visit many of the GM groups which had been involved in previous GM EV work.

A proposal written by Brooks and Wilson titled "The Electric Vehicle – Time for a New Look" was submitted to Hughes in July 1988. The proposal went well beyond the Electrospirit in that it contained numerous new ideas from Cocconi, Rippel, Brooks, and other AV engineers. One key element of the JPL development was carried forward and improved by Cocconi: the onboard, integrated recharge system. Detailed analyses were carried out by the AV team dealing with weight, aerodynamics, energy efficiency, range, acceleration, and recharge time.

With initial funding through AV and Hughes, Cocconi initiated inverter development in February 1988 – months before the full funding. Between February and September of 1988, Brooks and Wilson met with numerous mid- and top-level GM executives and engineers to get their input and support for the EV proposal. Final approval came in September of 1988. Brooks continued in his role
as project manager.

Body design was carried out jointly by AV and GM's Advanced Concepts Center. Fiber component structural elements, designed to match the weight of stamped aluminum, were used for the body. As such, the Impact provided weight, strength, and stiffness data representative of a production vehicle using aluminum body panels. A five-cell lead-acid battery was designed by GM's Delco Remy Division with some input from AV and Rippel. The electric motor was designed by Rippel and Western Gear; fabrication of the active induction motor elements was carried out by Western Gear. The entire power electronics system, including the integrated recharge, was designed and fabricated by Cocconi.

Fabrication and extensive testing of the vehicle at the GM Mesa proving grounds were completed in December of 1989. The vehicle was first shown publicly at the January 1990 Los Angeles Auto Show; it was around this time that GM came up with the name "Impact." The Impact was the basis for GM's production car, the EV1. Internal development of the EV1 started in March of 1990, and production commenced in 1996. Production of the EV1 ceased in 1999 with the termination of the program.

technical data:

The Impact is a two-seat, fiberglass, electric prototype vehicle that uses a 409 kg sealed recombinant lead-acid battery and a high-performance induction motor drive. On-board, integrated recharge provides up to 19 kW of recharge power when connected to 240 V, single-phase.

Battery

Type	Lead acid (prototype developed by GM Delco Division)
Number of cells per module	5
Number of modules	32 (series connected for 320 volts nominal bus voltage)
Cell capacity	45 Ah
Battery energy	14.3 kWh
Battery weight	409 kg (900 lb)
Cooling	Forced air with variable speed blower, tapered wind tunnel for uniformity of battery module temps.

Configuration

Two separate drives, one for each front wheel, on-board, integrated recharge

Inverter (each of two)

Topology and switching devices	Three-phase, voltage-fed, MOSFET (IXFH21N50)
Number of switches in parallel	24 in parallel (144 per inverter, 288 total)
Bus Capacitors	Electrolytic
Switching frequency	15 kHz
Control	Scalar, mixed signal (inner loop: current-mode, outer loop: slip frequency - determined by look-up table such that efficiency is maximized for each operation point); regenerative braking controlled by initial depression of accelerator pedal; test control mode: fixed, selected slip frequency - used for gathering optimal slip-frequency data
Phase current sense	Open loop Hall (two-step automatic gain select to enable low offset under low current conditions)
Peak phase current	300 A
Rated max. kVA	70 kVA
Cooling	Forced air with variable speed blower, honeycomb heatsink
Weight	27 kg (entire power electronics unit for both drives, recharge, and aux. power)

Motor (each of two)

Type	4-pole, cage induction
Bore diameter	5.00”
Stator design	48 slots, custom winding, custom stator teeth, non-skewed
Stator outer diameter	8.00”
Stack length	3.00”
Rotor design	68 slots, copper rotor bars (non-skewed); stamped, laminated, brazed copper end rings; inconel capture rings
Speed sensor	64 pole, magnetic
Base speed	7800 rpm
Max. power	50 kW (shaft)
Max. torque	61.5 Nm (45 ft-lb)
Max. speed	12,000 rpm
Cooling	Forced air with variable speed blower, honeycomb heatsink

Reduction gear

Type	Planetary, integrated with motor
Ratio	10.5:1
Lubrication	Integrated oil pump

Charger

Type	On-board, integrated (both motors and both inverters used to provide non-isolated power conversion function)
Power Input	Single phase, 115 to 240 V
Power rating	19 kW with 240 V input
Power factor	>99%
Control	Temperature compensated battery voltage

Auxiliary Power Converter

Topology	Forward converter, half-wave
Switching device	MOSFET
Switching frequency	100 kHz
Output voltage	13.5 V nominal (adjustable), current limited
Output current rating	100 A (used to power cooling blowers plus vehicle 12 V)

Driver Display

Cabin heating and cooling

Inverter driven heat pump

Vehicle

Outline dimensions	
Wheel base	2.29 m (90”)
Drag coefficient	0.19
Frontal area	1.72 m^2 (18.5 ft^2)
Structure	Fiberglass
Weight	927 kg (2040 lb)
Max. speed	125 km/hr (76 mph)
Zero to 60 mph time	8.0 sec
Energy efficiency	84 Wh/km (140 Wh/mi)