

SPARKING A REVIVAL

Significant technical changes in the all-electric Formula E World Championship could provide a route back to the front of the grid for one of its longest-serving manufacturers. By **Andrew Charman**

TEN years in, the electric motorsport pioneer Formula E has come a long way.

Regarded as an oddity over its first season in 2014-15 – emphasised by a lack of battery longevity requiring mid-race pit stops in which drivers changed their car – it is now a fully-fledged FIA World Championship. The series races at a combination of prime city centre venues and classic motorsport circuits and is contested by major brands currently including Jaguar, Porsche, Nissan, Maserati and Cupra – OEMs seeing great advantages in being associated with ‘zero-emission’ motorsport.

The cars are now fast to Formula One levels and make great use of the innovation that electric power allows them, such as energy regeneration and the mandatory use of ‘attack modes’ that produce extra potency over a short period, resulting in races that are typically intriguing from start to finish.

And more changes are coming: even as Porsche driver Pascal Wehrlein celebrated his Season 10 championship on 21st July at the 2023-24 finale at London’s Excel (Formula E again doing things differently to traditional motorsport with seasons that run from early winter to early summer), teams were already deep into planning for Season 11. The cars that line up at Sao Paulo in Brazil on 7 December will be very different to what has gone before, with the arrival of the Generation3 Evo era.

Generation games

First some history – the cars that took their final bow in London in July were the championship’s ‘Generation 3’. The Formula E car’s first incarnation, used over the opening four seasons, had a 0-62 mph time of three seconds and a terminal speed of 225 km/h (140 mph) thanks to a rear-mounted motor putting out 150 kW (raised in season 2 to 170 kW), and a range of around 50 km, necessitating pit stops midway through the 45-minute races with drivers jumping out of one car and into another.

“The other teams are more in evolution, us in revolution”

The base cars were and still are built by Spark Racing Technology, founded in 2012 by now Ferrari F1 Team Principal Frederic Vasseur, to a design by renowned single-seater manufacturer Dallara. Fortescue Zero (formerly WAE Technologies/Williams Advanced Engineering) currently supplies the battery packs, while in season one McLaren developed the electric motor which was coupled to a Hewland five-speed gearbox.

From season two teams were permitted to produce their own motor, inverter, gearbox and cooling system and at the time nine teams, including the UK-based squad representing Indian automotive giant Mahindra, chose to go the manufacturer route.

Season five saw the launch of the Gen2 car – a new lightweight battery pack doubled the range to 100 km while battery recuperation jumped from the 150 kW of Gen1 to 250 kW, producing enough energy to last an entire race without the car-swap pit stop. This ►





LEFT Mahindra's first test of next season's Gen3 Evo. The complexities of the new car offer the team the opportunity to leapfrog back to the front of the field

was despite power also being ramped up to 250 kW which raised the cars' terminal speed to 174 mph (280 km/h).

By now the technical format of the cars was more to what has become typical among owners of electric road vehicles – no more traditional gearboxes but transmissions using the capability of the motor and varying among the manufacturers, some opting for two or even single speeds.

Also introduced was 'Attack Mode' – at each circuit a section was designated around the outer edge of one corner and cars were obliged to take this route once in a race, boosting their power by 25 kW for a number of pre-determined minutes.

The series gained FIA World Championship status in Season 7, 2020-21, and two years later the Gen3 car debuted. This was very different to its predecessors, its aggressive dart shape reputedly visually inspired by the look of a fighter jet. Its recyclability, from body panels to battery packs, was heavily promoted but the most significant changes were in the powertrain.

The rear motor jumped by 100 kW to 350 kW, giving the car a potential terminal speed of 322 km/h (200 mph), while a second motor was added on the front axle, its purpose purely to provide regenerative energy. The Gen3 car is actually 60 kg lighter than the Gen2, partly due to having a smaller battery pack and no rear brakes – the cars are expected to produce 40% of their required energy by means of regenerative braking, compared to 25-30% on the Gen2 and this has changed the entire format of Formula E races.

The battery pack was also updated to accept 600 kW ultra-fast charging with the intention of recharging cars during pit stops, though at the time of writing this innovation is yet to be introduced to races.

Already development is underway on Formula E Generation 4, scheduled to be introduced for the 2026-27 season. But before that comes an interim step – unveiled at the Monaco e-Prix in April was the Generation 3 Evo car, to be used for the next two seasons and a significant development of the Gen3.

The primary updates focus on new tyre compounds produced by championship supplier Hankook, a stronger body with less aero drag and notably, all-wheel drive:

the front motor will now fulfil both regeneration and propulsion requirements, putting 50 of the car's 350 kW through the front wheels but only at certain times – during the qualifying duels, at the race start and while cars are in Attack Mode. The Gen3 Evo can now accelerate through 60 mph in 1.82 seconds, 30% faster than a Formula One car.

Drive and grip

According to Josef Holden, Technical Director at Mahindra Racing, the new tyres and all-wheel-drive are the fundamental updates on the Gen3 Evo. "The tyre being a softer compound all over has quite a big

BELOW The driveshaft on the front wheel is evidence of a major change on the Gen3 Evo, which will use the front powertrain for propulsion for the first time



All pictures: FIA/Formula E

effect on the dynamics of the car – from a kinematics point of view, how we optimise performance from a vehicle/tyre duo,” Holden tells Race Tech.

“The four-wheel drive is a strong element, even just during practice sessions. Previously you’d take the power hike from 300 to 350 kW as the delta where you were going to be in attack mode and full quali mode. Now it comes with a balance shift – for example you will be doing 300 kW two-wheel drive in free practice but go out for your qualifying run and you will be in four-wheel-drive. You need to ensure from a chassis setup and balance perspective that you are detailing what’s controlled

BELOW New, softer-compound Hankook tyres are a fundamental change that could shake up the established order



versus what is underlying car and driver interaction – it throws a big curve ball into the whole weekend.”

Even before the required additional development, in simulation and at the track, the new elements greatly affect the powertrain build process: “It fundamentally changes what we need in terms of torque requirement from the rear axle. The front powertrain is spec across all of the manufacturers and teams, but how you optimise that in the control system development is where everybody will be spending the majority of their time, us included.

“The change we need to get a grip on is how much time does the rear powertrain actually spend at 350 kW versus the amount of time with power on the front axle. Therefore it alters the duty cycles, the prove-out requirement. It doesn’t necessarily change what you’d want in peak torque on the rear axle, so as a result we will still target what we believe in this stage of the Gen3 evolution to be optimum.”

“The four-wheel drive throws a big curve ball into the whole weekend”



ABOVE The Gen3 Evo car retains its futuristic visual appearance

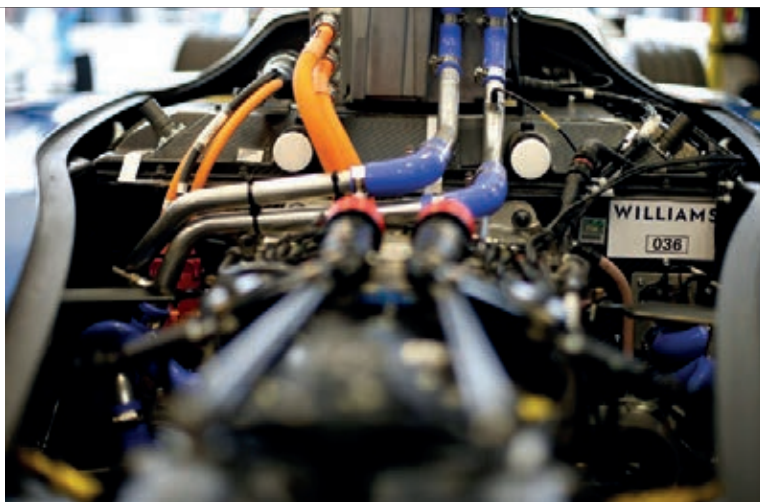
Holden adds that the tyres and all-wheel drive are a re-baselining exercise for the series as a whole. “(For Mahindra) the two main challenges are how do we ensure we adapt to those changes better than the competition, and secondly how do we know where the competition are? How do we benchmark them?”

Even the bodywork update is significant – the changes a consequence of the more significant regeneration in Gen3 that in turn resulted in wholesale changes to the format of races and therefore a complete revision of race strategy. Teams are now concerned with generating and effectively using energy, while coping with the most recent rule set that requires the taking of Attack Mode twice in a race – either for two lots of two minutes or for one minute and three minutes – and with more power, now increasing to the 350 kW qualifying trim. ►

This has produced 'Peloton Racing', more familiar in a top cycle race – typically the Formula E field now circulates as one close pack with much place-changing as drivers decide when to try and make a break. This results in many instances of front wings being damaged, wrecking a driver's race, and the Gen3 Evo addresses this with not only stronger bodywork but a shape with less aerodynamic drag.

"From season seven to 10 you've gone from time-based to lap-based and then peloton races – these can have many overtakes in a single race which completely changes the strategic element, for the whole team. Previously the driver might have said 'go now' but if you do that at the start of the race in somewhere like Shanghai or Tokyo you are in trouble," Holden says.

Nyck de Vries, who with Edoardo Mortara comprises the Mahindra driving strength, concurs with this view. The Dutchman, 2021-22 champion in a Gen2 car, says that the peloton racing of Formula E is very uncommon in conventional series. While preferring to see a little more conventionality he admits to Race Tech that he likes the fact the Formula E is a bit different: "it doesn't need to be conventional and it's not. It being electric racing cars automatically makes it innovative and different but on some occasions we are a little too extreme on the unpredictable side of it."



De Vries is not yet too familiar with Gen3 Evo. "In terms of technicality the biggest difference is the front motor accelerating the attack mode, qualifying and race start. Tyres will be a big thing and with the bodywork (they are) trying to reduce the drag effect a little bit – when losing front wings you won't be losing any performance. It allows people to go around without (a front wing) which is fine, in fact it's better when it's gone because you can't break it and risk it getting tangled up."

Evolution and revolution

For Mahindra the introduction of Gen3 Evo is more significant than for rivals – the manufacturer is undertaking a root-and-branch rebuild of its

ABOVE The Gen1 powertrain, relying on the expertise of the Williams and McLaren F1 spin-offs, was like nothing seen before in motorsport

BELOW Start of a revolution: the very first Formula E race, at Beijing, China on 13th September 2014





LEFT Today the series is established and racing at prime venues, including Monaco

BELOW Mahindra was part of Formula E from the start, here with Bruno Senna in Malaysia in November 2014...

Formula E presence as it seeks a route from its current backmarker status back to the wins of its early years in the series. The car's integration has been planned ever since the announcement in April but for Mahindra this includes installing a completely new powertrain produced by an as-yet unnamed new supplier. "As a team it will be a bigger change and we obviously hope to make a bigger step forward," de Vries adds.

"We've been doing offline development work for quite some time, but only in the past few weeks have we reached the point of getting on top of the physical hardware, delivery, integration, running in anger," Holden says.

"Through to the Valencia test (in November), race number 1 in December and the Gen3 Evo race cycle is a continuous development piece. At present we are focused on ensuring that when our full architecture turns up for race one we know from a reliability perspective it will be able to last the season, but also that we are already at the baseline performance levels that we targeted, so that we can separate what is fundamental hardware performance versus what is optimisation of the system, car and driver interaction."

He admits that the team has long known it needed to increase the capability it has as a manufacturer. "We've been sort of between manufacturer and competitor size but doing both those activities forces you to be very sequential – with Gen3 particularly we were one of the last cars to turn up in Valencia in race trim.

"Now we've bifurcated – the race team are exclusively responsible for ensuring our on-track performance, continuous development that feeds into what we expect next year. But the manufacturer element has switched, now fully ►



BELOW ... and remains so today, Edoardo Mortara here on his way to pole position in Berlin in May 2024





focused on the delivery of Season 11 and the best that it can be for race one.

"We've increased around 30% in size – some personnel have been with us for some time, some are still coming in over the next weeks and months. We are fundamentally increasing our capabilities across the whole area of vehicle performance, tyre science, design, control systems, software, the lot."

The future is now

All this effort is focused on a car that will be raced for just two seasons before Formula E introduces its Generation 4 machine – in May 2024 the FIA published a technical road map for this car, indicating that it will remain an all-wheel drive machine with 600 kW of power in qualifying, up to 450 kW in the race and 700 kW of recuperation, split 50 per cent between the front and rear axle. The FIA expects Gen4 cars to be seven per cent faster than the Gen3 Evo while the road map also indicates that the Gen4 era could be extended by a further two years over the standard four seasons.

Four manufacturers have already committed to Gen4, including the revived Lola, and while Mahindra is not yet among them, Holden clearly has some grasp of the car. "Yes, we are looking at Gen4 already," he says, adding that Gen3 Evo development will provide some future proofing for Gen4. "The underlying performance targets for Gen4 are quite different from Gen3 and Gen3 Evo, but from a power level and torque level it will be for us an evolution and not a complete starting from scratch.

"From battery, aero, control, total power, tyres again, it will be all-change for Gen4. Normally over the four-year period your activity on the homologation side would take a bit of a dip but for us it's staying high. (Our) Gen3 Evo has a completely new rear end, new architecture, new supplier and partner on the powertrain side – as a result we are experiencing a very similar cycle to what we expect to do with Gen4."

And finally, how much prospect of seeing the much-vaunted but so far never used in-race fast charging?

ABOVE Remember these? Changing the entire car, rather than just the tyres or the driver, at the mid-race pit stop was a feature of the Gen1 racing that went against the entire DNA of the sport

According to Holden, Mahindra as a manufacturer is committed to validating technology that has a direct relevance to the switch to electric in road cars – but the racing cannot suffer as a result.

"The difficulties we face in the introduction are how you bring something to track that is so ambitious – car and boost-charging tech that ensures you add to the racing, rather than cause disruption to it. I think at this stage we are still going through that validation process."

Back to the front?

The official representative in Formula E of Indian automotive giant Mahindra has a long and at times glorious history in the championship, having competed in every season and built its own powertrains since Season 2, collecting five race wins and a best championship finish of third in 2016-17.

The last of those victories, however, came in 2020-21 and over the past three championships of 11 contending teams Mahindra has ended the season 8th, 10th and 10th. It is a squad badly in need of a reset and a visit to its headquarters, adjacent to the M40 motorway in Banbury on the former site of English motorsport dynasty Prodrive (which has moved to new premises a quarter of a mile up the ▶

“The front powertrain is spec, but how you optimise that in the control system development is where everybody will be spending the majority of their time”



LEFT Mahindra's Nyck De Vries, in the centre of the picture, battles in the Portland e-Prix, a race where the Peloton racing first became evident



LEFT The Gen3 Formula E car stood out for its dramatic body shape, inspired by fighter aircraft

road), suggests that Mahindra regards the arrival of the Gen3 Evo as the catalyst for that reset.

A tour of the premises reveals not only the standing of Formula E today as a top-level international championship but also the ambitions of Mahindra. The facilities feel almost 'F1 light', extending to a pair of simulators (which both drivers each spend two full days on before every race) and a 'remote garage' – a sealed room in which during races six engineers are directly connected to and liaising with the team at the venue. Six is a maximum mandated by the FIA, and monitored accordingly – on the wall are mounted two cameras, one connected to the race team, the other to the FIA rule-makers...

Fightback from COVID hit

The current Mahindra team comprises around 80 staff with a core group of 70 based at Banbury, including around 40 who travel to races. But that 70 look virtually lost in very open-plan offices that could easily accommodate double their number.

Recruitment is the current prime concern of senior consultant Tony Ross, recently brought into Mahindra to provide team principal Frédéric Bertrand with engineering guidance – Ross's CV includes 20 years in F1 with Williams and Mercedes, before clocking up two double Formula E World Championships as chief engineer at the Mercedes team between seasons five and eight.

The biggest challenge within Mahindra, Ross tells Race Tech, is to achieve the transition from the Season 9 hiatus (caused by the COVID pandemic) to attempting to win the World Championship in the



future. "You need stability, you need to build a team up, to grow, adjust and adapt," he says.

"One of the reasons (Mahindra) hasn't been so successful is that it doesn't have the biggest of budgets – now obviously you can't have everything and you have to cut your cloth but Fred (team principal Frédéric Bertrand) basically has the vision.

"It's a great team in terms of the individuals here and their abilities. (Success is about) working on the procedures and process as well to produce a cohesive engineering structure, that actually moves in one direction. I'm not here to say you need to fit this widget and suddenly it will all happen."

Ross is working closely with Holden and another recent recruit Jeremy Colancon – twice Formula E

ABOVE Just as in F1, a 'Remote Garage' of a mandated maximum of six personnel monitors and contributes to all aspects of a race weekend performance



LEFT Mahindra team principal Frédéric Bertrand celebrates pole position in Berlin. He is focused on making such celebrations a more regular occurrence

race engineer of the year, he has been brought in as performance director to take over the day-to-day running of the race team, allowing Holden to move into a more overt technical director role. The early focus will be on powertrains, particularly as for Mahindra this will be all-new in Season 11. "In qualifying there is no reason why we can't be at the front," Ross says. "Obviously it's not going to happen overnight, but it's about putting in the building blocks to build on this from Season 10, with a new powertrain from Season 11.

"It's an interesting one because in terms of powertrain efficiency some of the more established teams are already there so their potential for gains is less. It's more of a challenge for them, plus with the new regulations, four-wheel-drive, traction control and such, from a technical side it does provide quite an interesting cycle, an opportunity."

And Ross is optimistic: "The progress we've made in Season 10 is not stunning but going in the right direction. We had pole for Edou in Berlin, now we need to have that a few more times – it's a good starting point."

To Mahindra team principal Frédéric Bertrand – recruited in late 2022 after a decade at the FIA including overseeing Formula E – the arrival of Gen3 Evo is highly important, perhaps for Formula E but definitely for Mahindra: "The change is huge, because we can change. What was done previously (in the team) was not that bad, but it was not evolving quick enough. When other teams are in front and further improving you don't recover the gap, even if you improve at the same level. So you lose pace rather than gaining or at least compensating.

"The new car for us is definitely a challenge because we are changing everything in a short time. We have worked in a philosophy that is definitely more ambitious, and probably more ambitious in the way we do it.

"If you do not from the beginning do all you can with all the small details in Formula E, you end up with a cumulative amount of small details not tackled, which creates a significant gap. That gap you have to live with and even if you correct a few of those areas, you don't correct all of them.

"Definitely the gap between where we



ABOVE Understanding the changes in the Gen3 Evo is the job of Mahindra Technical Director Josef Holden

were and where we will be is important – mostly on efficiency, probably on driveability and hopefully also the potential for improvement through the season because we will be better in control in many areas where we were a bit weak in the past two years, not only because of the hardware but also the staff. We had not enough and not necessarily the right people in place – not because the ones before were not good but because in some areas we were missing, (for example) control software – that area was poor."

“We are increasing our capabilities across the whole area of vehicle performance, tyre science, design, control systems, software, the lot”

Bertrand admits that a complete redesign is a bit of a gamble. "We don't have so many references from the past powertrain which we could just have an evolution of – all the other teams are more in evolution, us in revolution, the only hope we have is that by doing a revolution we have compensated more than (what is) the gap."

"We know this will not necessarily put us in a position to fight with the top-level teams, but will definitely put us back consistently and genuinely into the midfield. Today we are at the back, and because our drivers and team do a good job we are able to fight P8 to P12. I would

like us to be more consistently in the top 10, so that we more regularly score points, and not because others don't score but because we deserve them. We want to be there because we perform."

The mindset of the Mahindra squad and the depth of the facilities in Banbury suggests a team that will still be part of Formula E into the Gen4 era, though this is still to be confirmed and Bertrand does not give away many clues. "It's difficult because even if the manufacturer is as successful as Mahindra is right now it means spending money until you get the result – it's much easier if you get the result," he says.

Three-step recovery plan

"Even the top manufacturers right now, the time they needed to perform properly was a minimum three seasons, a bit more for some and spending more than probably we have spent up to now. Our goal is to make sure that the people in the top management at Mahindra understand; say you have £20 million – on one side you can put it in a race team and some nice French guy says let's keep the consistency and in three years' time we will get the result you deserve, while on the other side you have dealerships, customers and with that money you could do this and that."

Bertrand remains optimistic because he says the Mahindra recovery plan has

always comprised three steps. "Step one was Season 10, not too much in results but how we structure the team. The second step is Gen3 Evo, making sure the car helps us in the competition, to say P5 or 6 – I would not complain if it's 2 or 3 but let's be realistic. Then Gen4 should be bringing us podiums. We hope to do the third step, we don't want to remain in the middle of the river."

And Gen 4? "It's coming slowly into place. The timing is a bit difficult – we need to start developing Gen4 if we want to be ready but we still don't have the result from Gen3 Evo. You need to have trust on the other side..." **ET**