EVS32 A world of E MOTION 2019 MAY 19 22
INTERNATIONAL ELECTRIC VEHICLE SYMPOSIUM & EXHIBITION
EVS 50th anniversary 1969-2019

Development of an Integrated Motor Controller for a Plug-in Parallel Two-Wheeler Hybrid Vehicle

Dipanjan Mazumdar[1], Surajit Das[2], C Subramonium[3], S. Jabez Dhinagar[4],

TVS MOTOR COMPANY -

CONTENT

1. Why to build a hybrid and not a electric
2. Challenges of building a hybrid two wheeler
3. Options of integration for a hybrid two wheeler
   - Type of hybrid configuration
   - Type of motor
   - Type of battery charging options
   - Hardware management
4. Development of solution
   - Integration of hardware
   - Complete architecture
   - Software solutions
5. Testing – one case study example
6. Conclusion

Developing a Two Wheeler PHEV

factors which are yet acting as barrier for two wheeler EV revolution are

Hybrid vehicles can pave the way for the electric revolution. It can bring the confidence to regular IC user about the reliability of electric Power train
A hybrid vehicle will also upgrade the dealership, service and spare part network acting as bridge between IC engine two wheeler & Electric two wheelers.

- **Aim for building a hybrid two wheeler:** 50 % improvement in millage & 30 % reduction in emission

Key integration issues of building a two wheeler PHEV have been addressed in this paper. The focus of the paper is not into detail design of the controller, battery or motor but to resolve their integration issues.

Challenges of building a hybrid two-wheeler

Concept and benefits of a hybrid vehicle is well known, there are many hybrid busses and cars available in market, yet hybridization of any two-wheeler model has not happened yet. The key challenges in building a two wheeler PHEV are:

Options of Integration for a hybrid two-wheeler

1. Chassis mounted motors vs Wheel hub mounted Traction Motor

- Chassis mounted shaft rotating traction motor is connected to the wheel via chain, belt or gear mechanism. This provides the flexibility of introducing different transmission ratios, but requires more space for packaging
- Second option is to use a wheel hub mounted traction motor which obviously eliminates the requirement as well as any possibility of transmission. Its silent but there is a limitation on the maximum size and power of the traction motor.

For this project a hub mounted traction motor was selected in order to maximize the utilization of the available space and to get the silent start feature

2. Series hybrid vs Parallel hybrid

- For series type a bigger battery and an adequate motor power is required to deliver the vehicle requirements such as acceleration, top speed and basic min range (without switching ON the engine). Once the battery reaches the threshold the controller would switch ON the engine, which would charge the battery back. Normally such engines are of constant speed type and have an alternator in order to charge the battery back.
- In parallel hybrid configuration both the engine as well as the traction motor can propel the wheel together or independently.
- **LIMP HOME option is very critical function for a two wheeler which gives the flexibility to the user to use the vehicle in case any one of the power train is drained of its energy source or developed any kind of malfunction. Hence for this project parallel hybrid concept was chosen**

Options of Integration for a hybrid two-wheeler

3. Charging back the traction battery - HEV vs PHEV

- It largely depends on the type of hybrid vehicle being developed whether the traction motor would support the engine in the initial phases of its operation or whether it would support the engine at the higher RPM zone. The first option would result in more fuel saving whereas the other one would result in more power being delivered to the wheel for a similar class of vehicle.

In this project the aim was to deliver higher millage hence the plug in architecture was selected.

- In a HEV separate battery charger is not required as alternator does the activity. Essentially a HEV battery charges itself back from the engine itself But the moment the battery size is so big enough that the alternator alone cannot charge the battery pack completely and external charging is required it is called PHEV (Plug in Hybrid electric vehicle). Charging from grid reduces the cost of running drastically as grid electricity is cheaper than gasoline, but it also brings the burden of battery charger. For a two-wheeler both on-board charger or off-board charger can be used as the size of the traction batteries are not as big as cars. It also requires a charging socket to be installed in the vehicle which shall meet required safety norms.

4. **Combining multiple controllers in the vehicle**

- Two wheeler hybrid is still relatively less complex than a 4 wheeler or a hybrid Bus. Hence it provides two options to deal with the hardware architecture . First one is to build a combined multipurpose controller integrating all the EV powertrain functions such as BMS+ motor controller+ DC/DC & VCU. Second option is to decentralize them and having individual hardware for all of them and allowing them to communicate among them

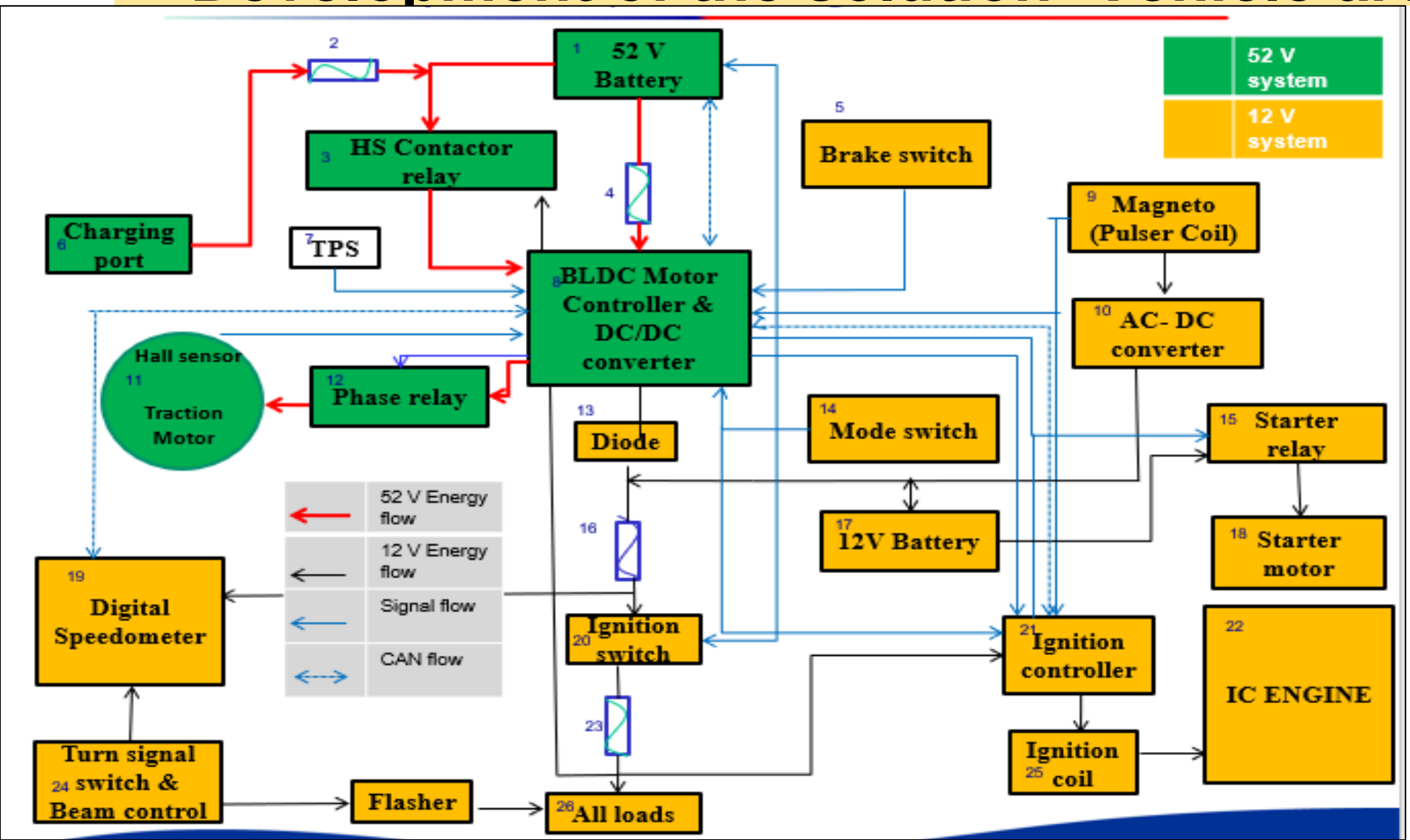
Development of the solution- Integrating the hardware

Integration of DC/DC Converter, Motor controller & Vehicle control Unit

- In the two-wheeler-PHEV wiring harness system, DC/DC converter is a device which handles both the 52 V as well as the 12 V, hence the operation and safety requirements are very high for a DC/DC converter. In case of a malfunction or a short circuit there are chances that the 52 V can appear across the 12 V loads and damage them. Even worse many 12 V devices have electrolyte capacitors which are rated for 23 V, in case 52 V appears across these capacitors it can even result in blast of capacitors.

- The DC/DC converter is switched ON the moment the vehicle is switched ON and it does operate at a switching frequency which falls under EMI/EMC range. The HCU is well designed to handle designed to meet the required EMI/EMC regulations as well as all kinds of probable short circuit. In order to make the DC/DC safer as well as to solve the Space & packaging constraints it was proposed to integrate the DC/DC converter along with the HCU

Development of the solution- Vehicle architecture



Limp Home Option- In order to provide stand alone limp home mode to the customer it was decided to not to integrate the engine ignition control along with the HCU. The advantage having a separate ignition unit, separate AC/DC converter and a separate magneto is that in the event of battery SOC being completely depleted or in case of a serious malfunction with HCU, still the user can start the vehicle reach to nearest service station or home.

Development of the solution- Mode of operation

ECO mode: In Eco mode the traction motor is started first and continues till the predefined vehicle speed is reached. Once the speed is reached the control system triggers the starter motor which in turn cranks the engine. The engine continues to drive the vehicle till its top speed. When the vehicle speed is reduced below the threshold speed the engine is again switched off by the control system and the traction motor is switched on.

- The type of the vehicle was a scooter, hence the engine was mounted on the swingarm and the traction motor was connected to the engine via a chain drive. A special sprocket was designed to integrate on the traction motor which connects up with the chain drive as it is located on the hub of the rear wheel. One challenge which remains in this kind of power train is how to decouple the hub mounted traction motor from the engine, because otherwise the wheel when rotated by traction motor would end up rotating the piston

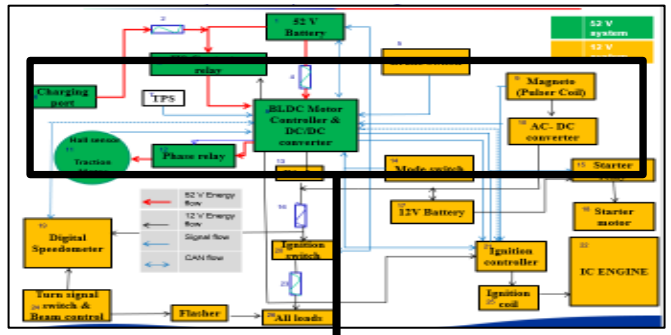
Power Mode: The vehicle is powered with both the powertrains together from the beginning of the trip, hence the acceleration is more than conventional IC engine vehicles of similar engine capacity. But while getting more acceleration compared to IC engine scooters, because of the additional motor assist the fuel consumption by the vehicle is less as the motor is powered by the battery. The traction motor is designed in such a way so that it can assist up to a speed of 50 km/h beyond which the engine alone is capable of driving the vehicle to its top speed *[*]*

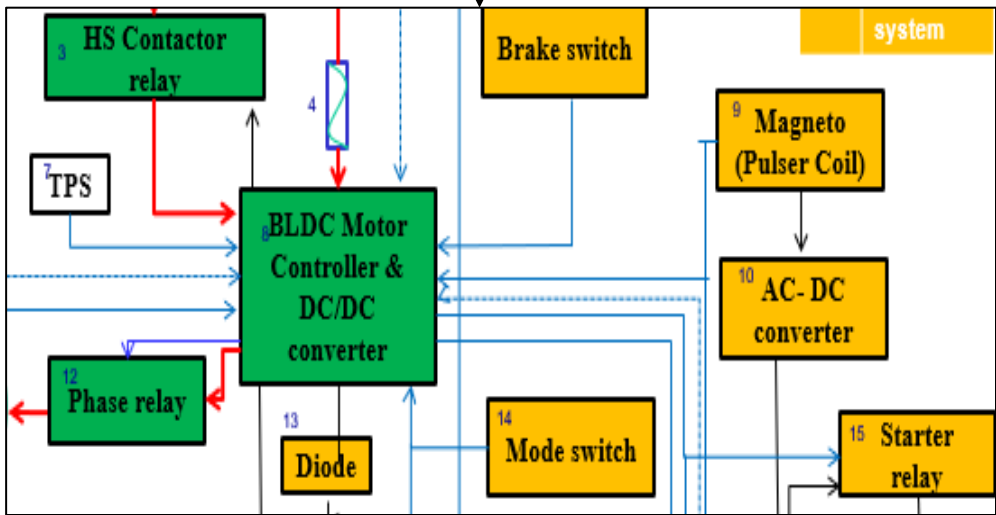
Development of the solution- Integrating software solution

[*]

[*]

[*]





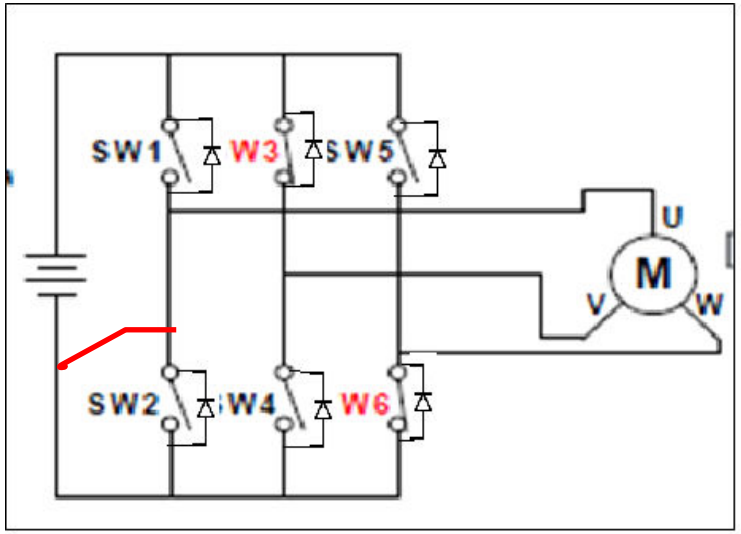
[*] Patents Pending

Testing of the solution

Unique scenario in parallel two-wheeler hybrid vehicle with hub mounted motor

- In a hub mounted hybrid vehicle, the wheel is always rotating while running irrespective of whether it is driven from the MCU or engine, unlike the body mounted shaft rotating motors which can be decoupled from the wheel. So in case of a malfunction or a short circuit it is possible that the rotor (having the magnets) will be rotating against the stator and keep producing the back emf.

- The best possible solution is to physically disconnect at least two-phase wires so that even though the traction motor can be driven by the engine, the back emf would not flow through the switch circuit.
- A electro mechanical switch which can handle the phase current and voltage was developed and introduce in the hybrid powertrain



Above is a typical 3-Phase BLDC motor commutation sequence. Now assuming there is a short between the phase U and Ground shown above via the red line. A very high current proportionate to the back emf / coil resistance would be flowing through the freewheeling diode. In case, if any of the switch is ON then immediately it will get damaged

Conclusion

- Most of the ideas were prototyped, developed and evaluated. The results are very promising and meeting the expectations. It has met the expectations of developing a two-wheeler PHEV
- The results are very promising and it reconfirms the benefits of a PHEV. For a two-wheeler segment a PEV can act as the missing bridge towards electrification from existing IC engine drive vehicles
- It is also verified that though the space constrain is a big challenge for developing a two-wheeler hybrid vehicle but if the integration of various system is done carefully, this challenge can also be met.

Working Prototype of 2W Plug in PHEV

Indian auto blogs https://indianautosblog.com/tvs-draken-tvs-graphite-tvs-scooty-hybrid-indoensia-p133396

Above is an image of one of the early prototypes of a two-wheeler parallel PHEV which was demonstrated in an exhibition.

Thank you for your attention!

Contact details:

Name Dipanjan Mazumdar

E mail : m.dipanjan@tvsmotor.com

Website: www.tvsmotor.com