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# Retrofitting of a Conventional IC Engine Powered Vehicle to a Hybrid Powertrain System

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***Abstract: A Forward Wheel Drive light duty IC engine powered vehicle can be converted to a hybrid powered system for increasing its fuel economy and decreasing its emissions. This can be done by applying a split parallel system where one axle is powered by the stock IC engine and the other is powered by the battery and the electrical motors. The motors will be mounted inside the wheels itself, according to the Through the Road (TTR) - In the Wheel (IWM) system.***
***Keywords: TTR-IWM hybrid, ICE to hybrid conversion***

## I. INTRODUCTION

Hybrid power systems are systems consisting of two power sources (generally mechanical and electrical), used to power any machine. Such power systems are starting to be widely used around the world in the automobile industry to reduce polluting emissions and to increase the overall efficiency of the vehicle. Nowadays, conventional IC (internal combustion) engine powered light-duty vehicles can also be converted into a hybrid system.

For converting a conventional forward wheel drive (FWD) light-duty IC engine driven vehicle into a hybrid powertrain system, the best method is using a split parallel set-up with TTR (through the road) - IWM (In the wheel) motor set-up.

In this method the two axles of the vehicle are powered independently. Thus, in case of FWD vehicles, the front axle will be powered by the stock engine while the rear axle will be powered by electric motors. In TTR-IWM set-up, the electric motors are housed directly inside the rear wheels, which are powered by a battery. The motors used are generally hub motors for ease of installation and working.

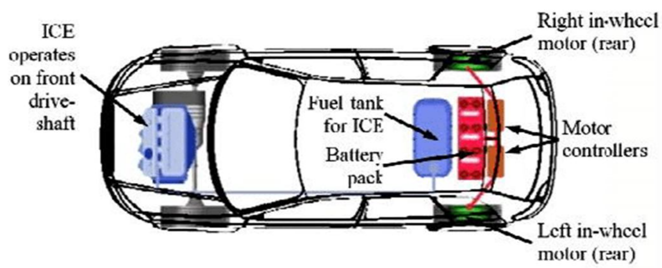


Fig. 1. Split-parallel through-the-road hybrid electric vehicle configuration [1]

Series type of hybrid powertrain is not used as the application is for a light-duty operation. Series type of hybrid powertrains are better suited for heavy duty applications such as trucks which have high torque requirements. Moreover, they have low efficiency as in that type the energy conversion takes place in two stages, first in conversion from mechanical to electrical energy and then again from electrical to mechanical energy. This results in lower efficiency.

Also, single axle parallel type of hybrid system is not used because it is simply difficult to implement it in an existing IC engine powered vehicle as the motor has to be installed in the mechanical power train. It is complicated TO introduce another power source in a mechanical powertrain which will require changes in the camshafts or the axles.

## II. OPERATION OF A TTR-IWM HYBRID POWER-TRAIN

In a parallel type of powertrain system, the final propulsion power for the vehicle is obtained from two separate sources. One source is the IC engine. In this power delivery takes place in one-direction only, i.e. from the engine to the wheels. The second source is the battery connected electric motor where the power flow can take place in two directions, i.e. from the battery and motor to the wheels and also from the wheels to the battery ( regenerative braking / generator ). A typical power-train block diagram is illustrated in the figure.

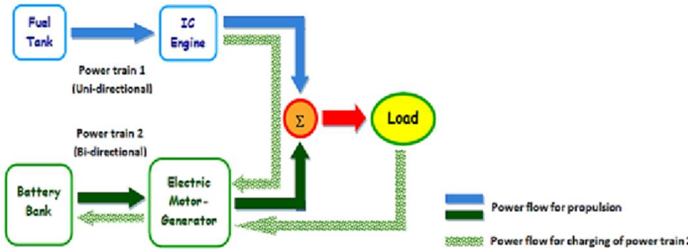


Fig.2. Power flow paths of a parallel hybrid electric vehicle.

In a split parallel TTR-IWM type of system, the two power sources are used by dividing their power delivery in two axles respectively. Thus, one power source will deliver power to one axle of the vehicle only. Thus, it is easier for conversion of an existing IC engine vehicle in a hybrid system as no change in the mechanical power-train is required. The electric motors are placed in the non- powered wheels of the vehicle which are powered by a battery. The general structure of the TTR-IWM system is shown in fig.1.

Some drawbacks of this kind of system are-

*1)* Dimensional restraint on the size of the hub motor due the size of the wheel hub. This directly affects the maximum capability of the motor.
*2)* Reduced operating modes and flexibility in power distribution.
*3)* No change in the IC engine's size, weight or specification can be done.

Because of the above mentioned drawbacks, the vehicle cannot be started by purely using electric power as that torque will not be enough to start the vehicle due to the size of the motor. Also there can be no flexibility in the operation of the IC engine, i.e. the engine will either be on or off. Thus, the electric power will assist the engine in most scenarios.

Keeping in mind all the afore-mentioned considerations the vehicle will be able to principally operate in the following modes-

*a)* Only the IC engine powers the vehicle.
*b)* Only the electric motors power the vehicle, i.e. the engine is off or idling.
*c)* Both the engine and the motors are providing propulsion power to the vehicle.
*d)* The wheels' mechanical energy is converted to electrical energy and stored in the battery through a in wheel generator (regenerative braking). Here the IC engine is idling.
*e)* When the IC engine is powering the vehicle and the generator absorbs this power to charge the battery.

## III. SYSTEM ARCHITECTURE OF A TTR-IWM SYSTEM

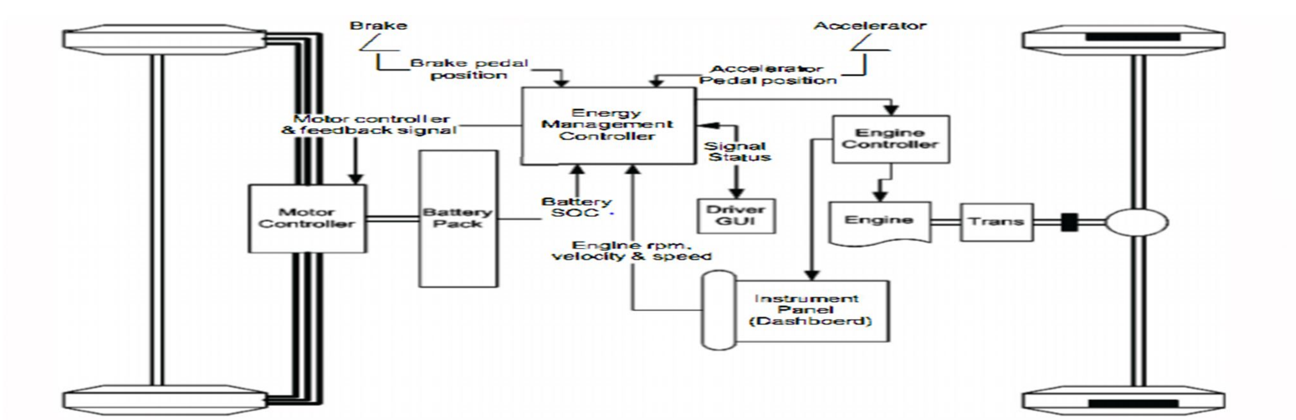


Fig.3. System Architecture of TTR-IWM hybrid system block diagram.

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The figure shown shows the basic block diagram of the architecture of such a system [1]. At the centre of the system is the EMS (Engine Management System). This is the main controller of the system. This takes inputs from various sensors such as the APP ( Accelerator Pedal Position), TPS ( Throttle Pedal Sensor), BPP ( Brake Pedal Position, vehicle speed, engine speed, motor speed, battery SOC ( State of Charge) etc. After taking such inputs from the vehicle, the EMS chooses the best strategy which should be applied. The EMS is already pre-programmed on which strategy must be applied when. After choosing the required strategy, the EMS relays the information and required control commands to the ECU ( Electronic Control Unit). The ECU then carries out the control commands by triggering the required devices and motors.

In a TTR-IWM split parallel system the most important inputs are the APP and TPS. This is because these inputs directly give the information about the drivers' requirements. When the driver presses the accelerator pedal, the driver requires more power, when the position of the pedal is unchanged, the driver is cruising and when the pedal is not pressed the driver does not need power. From this information the EMS decides how much power is required from the electric motors for maximum efficiency. Then according to the battery SOC, it gives control commands to the ECU. This ECU then conveys the commands to the motor controllers which may increase or decrease the speed of the electric motors according to the need.

## IV. MAIN MECHANICAL CHANGES FOR RETROFITTING A CONVENTIONAL VEHICLE WITH TTR-IWM SYSTEM

For converting a conventional IC engine vehicle into a TTR-IWM type hybrid vehicle some changes will have to be made to the mechanical components of the existing vehicle. Some of the most important changes to be done are (referred from [3])-

### A. *Thermal Management System*

The vehicle's IWM system is subjected to very high temperature because of the large amount of load on the motor controllers. For this system, a fire retardant space with suitable fire- proof lining must be made in the vehicle. This space will be used for housing the battery and the motor controllers. During the operation of the vehicle, the temperatures of these devices increases drastically and above a certain temperature the motor controllers and battery lose their efficiency and may even prove to be a fire hazard. To prevent this problem cooling fans and devices must be mounted in the space, to control and maintain the optimum temperature for operation of the motor controller and battery. The cooling system can be triggered by the ECU when the temperature in that space increases beyond a threshold temperature ( which can be sensed by a suitable temperature sensor). For this system the amount of cooling required and optimum operating temperature must be calculated and simulated.

### B. *Regenerative Braking System*

In a retrofitted TTR-IWM vehicle regenerative braking is an important energy saving mechanism. It absorbs the kinetic energy of the wheels through the in wheel generator (in the motor) to absorb and store this energy in the battery when the brake pedal is pressed. To best use this energy the mechanical brakes must not be applied directly when the brake pedal is pressed. This is because mechanical brakes convert kinetic energy into heat energy, which gets lost and cannot be regenerated. Hence, it is better to use regenerative braking when braking demands are not high, or at the start of braking to absorb the highest amount of energy from the wheels.

To carry out this operation, some changes are required to be made in the brake pedal, by which at the start the regenerative braking is done and afterwards the mechanical brakes are triggered. According to [3] one way to carry it out is as follows-

*1)* Triggering regenerative braking for the first 30% of the brake travel.
*2)* Triggering both the regenerative and the standard car brakes for the next 70% of the brake travel.

The changes in the brake pedal can be seen as shown in the figures below, which are taken from [3].

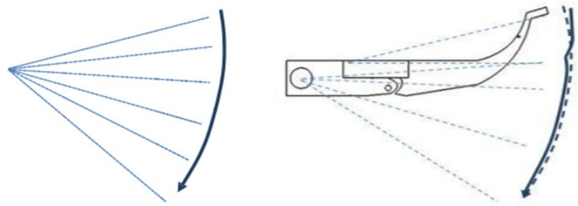


Fig. 4. (LEFT) Conventional brake pedal travel path. (RIGHT) Brake pedal adaptation for regenerative braking and its new travel path.

### *C. Brake Assembly*

If the stock car has the traditional drum brakes in the axle which is to be powered by electric motors, they have to be replaced with disc brake assembly to accommodate the hub motors which have to be housed on the axle.

Disc brakes are preferred because they take up less space and have the same performance, if not better than that of drum brakes. However to accommodate this brake assembly and to attach the motor to the axle, some changes are to be made to the knuckle assembly to perfectly house and attach every component.

## V. CONTROL OBJECTIVES OF A TTR-IWM HYBRID SYSTEM

The main aim of a hybrid vehicle is to increase the efficiency and fuel economy of a vehicle and to reduce the emissions released by a regular IC engine vehicle. For achieving this, one of the major components of the hybrid system is its control strategy. This control strategy is fed into the EMS which is programmed to select the best strategy according to the driver requirements, the battery level and various other factors to give maximum efficiency and performance.

Hence, the main objective of a hybrid system is to manage the power distribution between the two power sources and their switching. The main objectives are ( from [1])-

*A.* To satisfy driver requirements of power requirements for accelerating, cruising and braking.
*B.* To minimize fuel consumption and emission for more efficiency and range.
*C.* To maintain a reasonable level of battery SOC so that no external charging of the battery is required for the vehicle.
*D.* To recover maximum amount of braking energy.

It can be observed that all the above points are interdependent and to achieve one objective other objectives must invariably be taken care of. For making the best possible control strategy for a TTR-IWM split parallel type of hybrid system, its drawbacks and limitations must be understood and taken care of. The major primary limitations of this hybrid system are-

1) Normally, as an IC engine operates at a very low efficiency while accelerating from standstill or low speeds, and thus in other hybrid systems only power from electric motors is used. Due to limitations on the size of motor which can be used, the torque generated from the motors is not very high. Due to this a TTR-IWM hybrid vehicle cannot be accelerated from standstill or low speeds from the electric motors alone. Also, if power from both the engine and electric motors is used, even less torque is taken from the engine because of available motor torque. This may lead to even less efficiency in operation. Thus, TTR-IWM can only be accelerated from standstill or low speeds by the stock IC engine.
2) Battery charging of such a hybrid system can only take place when the vehicle is moving, i.e. when kinetic energy is available to be absorbed. Thus, this leads to limitations in instances when the battery can be recharged from the engine power.

Hence, the best strategy which can be used in such a retrofitted vehicle according to [1] is the electric strategy. Here the main power unit is the stock IC engine and the electric motor-generator unit (MGU) is used as a power buffer for compensating the differences in the power requirement. Hence, the motor is turned on when there is a lack of propulsion power and it acts as a generator when brake power is to be absorbed. The improved fuel performance is obtained from shifting the IC engine's operating point closer to the optimal point of best fuel economy and efficiency. At the same the battery SOC is maintained to predefined levels.

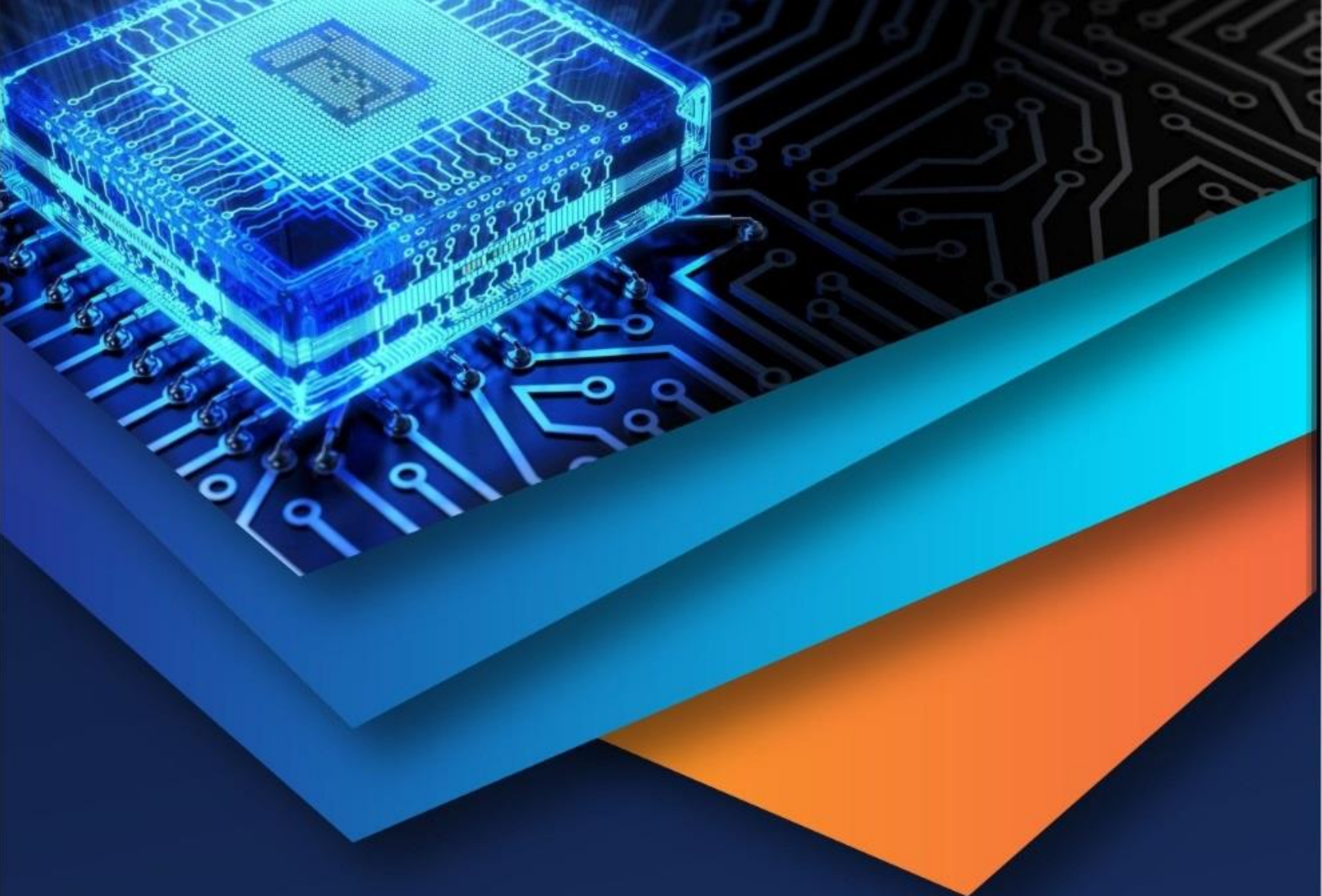
To determine these optimal modes of operation of the engine, various simulations and experiments are to be performed to find the best operating mode for a given driver requirement.

## VI. CONCLUSION

An existing stock IC engine car can be converted to a hybrid system by using a split parallel TTR-IWM type of hybrid powertrain system to increase the fuel efficiency and fuel economy of the car. The report describes how the system operates and how it can be implemented in a stock car. It also gives a basic overview of how the control strategies for this hybrid system can be defined while considering the limitations of the TTR-IWM system, for which simulations are necessary.

## REFERENCES

[1] Zulkifli, Saiful & Mohd, S. & Saad, Nordin & A.R.A.Aziz, "Split-Parallel Through-the-Road Hybrid Electric Vehicle: Operation, Power Flow and Control Modes", 10.1109/ITEC.2015.7165774, 2015.
[2] Zulkifli S, Saad N, Mohd S, "Power Engineering and Optimization Conference (PEDCO)", Melaka, Malaysia, Ieee International IEEE) p. 11-6, 2012.
[3] S A Zulkifli et al 2015, "Design and development of split-parallel through-the road retrofit hybrid electric vehicle with in-wheel motors", IOP Conf. Ser.: Mater. Sci. Eng. 100 012039, 2015.

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