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# Smart Redundant Electronic Energy Delivery Electric Vehicle Interface

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**Abstract:** This is a concept realised were a fuel driven vehicle is operated in Series Hybrid and Parallel Hybrid. The changeover from Series Hybrid, Parallel Hybrid and driven on Fuel only takes place on the Go. Take-off is usually in Series mode were battery is charged and wheels are driven on electric motor. In idling condition, the engine charges the battery till full charge. Once Battery is fully charged, engine is turned off. During fuel run of the vehicle, the motor is powered up to assist the engine which is Parallel Hybrid mode. Brakes applied puts the motor in series operation or parallel operation in generator mode loading the wheels to charge the battery. Fuzzy logic plays a vital role in driving the system to operate in series or parallel operation and depending on amount of applying the brakes. This redundant way of operating the motor puts the system in a smart energy delivery to the wheels.

**Keywords:** IC Engine, Series Hybrid EV, Parallel Hybrid EV, Regenerative Braking, Fuzzy Logic, BLDC Motor, Drive Shaft.

## I. INTRODUCTION

Conventionally Hybrid Electric Vehicles (HEV) are of two types. Series Hybrid Electric Vehicle and Parallel Hybrid Electric Vehicle. Both are unique in their applications. Both need a braking system which are a dream yet to be a regenerative [1]. The motors driving the wheels operate as regenerative brakes along with conventional friction braking system. It delivers a distributed control on to the wheels. Keeps the regenerative battery drained for the next energy packet capture from the wheels. Regenerative braking applies engine retarding function as in Internal Combustion Engine drive of the vehicle which is a need during rolling downhill.

A logic control transfer of the motor as generator takes place in two ways. One is to deliver power to wheels and the other to extract power from the wheels. Quantity of power drive on to the wheels and power extract from the wheels depends on various conditions in run of the vehicle [1]. Fuzzy Logic caters these demands. Safety is achieved through Anti-Lock Braking (ABS) triggered by commands served by fuzzy logic. Very much functionally same as ABS, a logical make and break of drained battery connected to the generator applies a load on the running wheels [2]. Drive battery bank in turn gets burp charged from the regenerative battery. Fuzzy Logic controller delivers functions to drive motors to run the wheels as well as reducing the speed or halting. These functions switching between Fuel run, Series HEV and Parallel HEV constitutes to be a Smart Redundant system. This stoops to save fuel in large extents.

## II. SMART HYBRID EV

This is an approach were electric motors are coupled to the drive shafts of the fuel driven vehicle. The engine and motors are operated in Series Hybrid and Parallel Hybrid. The changeover is made depending on terrine conditions and is done on the Go. During Take-off the system puts Engine power and motor power into series and vehicle gear shifted to Neutral. In this condition Drive battery gets charged from the engine and wheels are moved on electric power. In idling condition, the engine charges the battery. Battery Charging takes place till it reaches full charged condition and the engine is turned off. While the vehicle is running on engine, the motor is gradually put to Parallel Hybrid condition and starts assisting the engine. The sensors keep a track of power draw from the wheels and proact to the sudden changes and needs of power to deliver from motor.

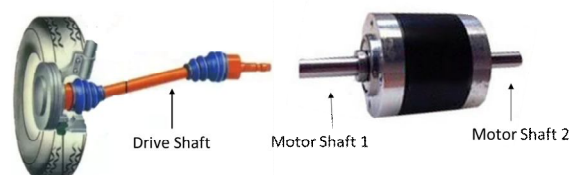


Fig.1 Motor Coupled between Drive Shaft and Gear Box

Fig.1 illustrates coupling of BLDC motor between drive shaft and the gear box. Motor drive between gear box and the wheel gives birth to a smart HEV which can be switched between Series or Parallel. This establishes a link to connect the engine to wheels as well as motor to wheels allocating series or parallel operation. BLDC motor is a double shaft type motor which is engineered to couple with the gearbox in one end and the other end with the drive shaft. Similar arrangement is made on both the drive shafts. This arrangement facilitates the engine to drive the wheels without turning ON the motor. Similarly disengaging the gearbox or driving the gearbox to neutral, the motor can drive the wheels. Another condition is while engine is driving the wheels, motor can be powered up with a calculated amount of energy delivery to wheels assisting the engine. This is done by sensing the power needs at the wheels, Available stored energy and the power delivery capable for the engine.

During braking, the motor is operated as generator and in series with the engine bringing down speed of vehicle and charge the battery on the regenerative power delivered by the generator. During this condition once there is a need of heavy braking, the parallel operation is brought to connectivity. Further need of braking puts the vehicle to operate friction brakes. Fuzzy logic plays a vital role in efficient series and parallel operation as well as amount of applying the brakes to draw power from the wheels. This behaviour of the system and redundancy in operation establishes the name Smart Redundant Electronic Energy Delivery Electric Vehicle Interface.

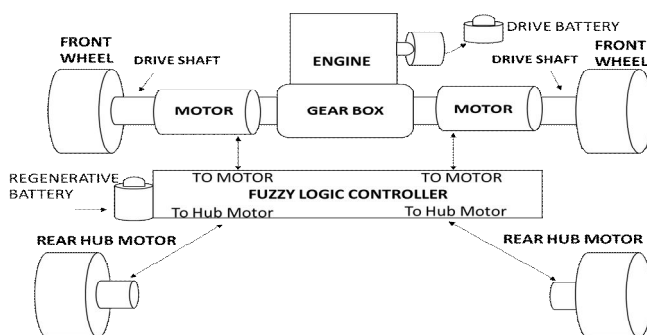


Fig.2 Smart Redundant Electronic Energy Delivery Electric Vehicle Interface.

Fig.2 Illustrates the concept of Smart Redundant Electronic Energy Delivery Electric Vehicle Interface. Logical decisions on set points puts the vehicle in Series Hybrid or Parallel Hybrid. Decisions are taken depending on the terrain conditions and drive situations. Switching of series and parallel takes place on the go. Fuzzy logic makes the system effect efficiency in the run.

### III.SERIES HYBRID ON THE GO

The engine runs to charge the Drive battery. Gear box is shifted to neutral where the drive line gets disconnected from the drive shaft. This leaves the motor alone to be connected to the drive shaft. In this condition when motor is operated takes the wheel load on to self alone.

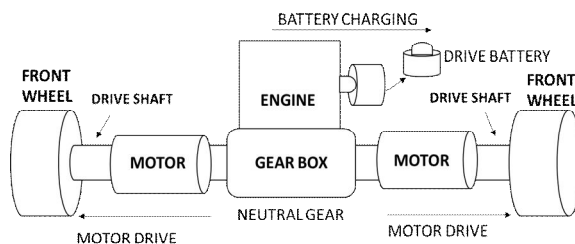


Fig.3 Series HEV

As illustrated in Fig.3, Engine drives the alternator to charge the Drive Battery and delivers power to motor [5]. Gear box is shifted to Neutral. This puts engine power to dispense its power to battery and motor through alternator. Mechanical energy of the engine is delinked from delivering to the wheels. Energy transfer takes place in the directions as indicated in the Fig.3. This forms series configuration of engine and motor. In between alternator and motor battery gets charged. Motors are powered to 3000W each to carry vehicle load and reach a maximum speed of 50KM/h. While braking motors are configured to get connected to Regenerative battery where it gets charged for the time period of braking [4]. Amount of charge delivered in regenerative braking depends on the speed of the vehicle, depression of the brake pedals and weight of the vehicle.

#### IV. PARALLEL HYBRID ON THE GO

The engine runs to drive the wheels. Gear box is shifted to drive mode usually top gear, where drive line gets connected to the drive shaft. This leaves the motor also to be connected to the drive shaft. In this condition when motor is operated takes the wheel load assisting the engine.

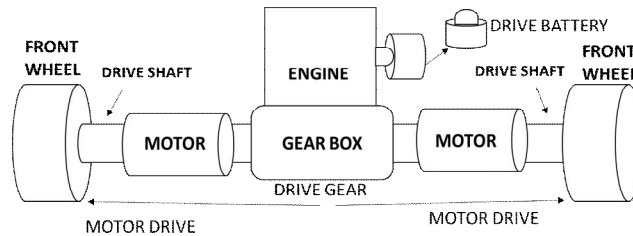


Fig.4 Parallel HEV

As illustrated in Fig.4, Engine drives the wheels through gear box. Motor sitting on the drive shaft is in parallel to the engine drive. Gear box is shifted to Drive in a forward gear and usually top gear. This puts the engine to dispense its power to the wheel as well as motor power also to the wheels. Mechanical energy of the engine also is delivered to the wheels. Energy transfer takes place in the directions as indicated in Fig.4. This forms to be a parallel configuration of engine and motor. In this alternator gets relinquished from charging the drive battery. Motors are powered to 3000W each to carry vehicle load and reach a maximum speed of 50KM/H without engine energy being used. Amount of energy delivered from the motor depends on the need of power to the wheels. This is decided logically by the fuzzy logic controller. While braking motors are configured to get connected to Regenerative battery where it gets charged for the time period of braking [3]. Amount of charge delivered in regenerative braking depends on the speed of the vehicle, depression of the brake peddles and weight of the vehicle [2].

#### V. SERIES AND PARALLEL HEV ON THE GO

Fuzzy logic plays a role considering all the terrain conditions and switches the system into Series Hybrid and Parallel Hybrid. The switching on the Go depends on following conditions.

During Take-off the gear is shifted to neutral where drive battery gets charged and vehicle is moved on motor till it reaches a speed of Top gear level. While idling and halted condition the engine charges the drive battery. Once the drive battery is fully charged the engine is turned off till there is a discharge in the drive battery. During Series hybrid condition, braking puts the motor to operate as a generator to charge the regenerative battery [3]. This drives the vehicle to reduce in speed and in some conditions to a halt position.

Regenerative braking applies vehicle in retarding function as in Engine run which is a need during rolling the vehicle downhill. Further need of braking puts the vehicle to operate friction brakes. Fuzzy logic plays a vital role in deciding regenerative braking and friction braking. Brake pedal position defines the amount of load to be applied on the generator which is calculated by fuzzy logic.

When the vehicle has reached to a speed where it is to the level of top gear, the motor is gradually put to Parallel Hybrid condition and starts assisting the engine. At that speed the gear is shifted from neutral to top gear. This puts the system to operate in Parallel hybrid. The sensors keep a track of power draw from the wheels and react to the sudden changes and needs of power to be delivered from the motor.

Till the drive battery can deliver energy the motor keeps assisting the engine. This takes place by adding power to the demand on the engine reflects to reduction of power draw from the engine. An effective reduction on fuel consumption and utilising regenerative power stored in the drive battery is brought in. When brake is applied the system throws into series hybrid and Regenerative braking retards as in Engine run till brake pedal is released [6].

As engine is delinked from the wheels it saves fuel burn due to retard as well as power pulses are dropped in the regenerative battery. Switching of the modes between Series HEV and Parallel HEV takes place on the go and does not disturb the conventional operation of IC engine drive.

Manually a conventional IC Engine drive also can be operated. This redundant operation in transferring power drive gives smartness to the system. Thus, the name Smart Redundant Electronic Energy Delivery Electric Vehicle Interface.



### VI. FUZZY LOGIC ROLE AND REDUNDANCY

Series or Parallel operation is selected by speed of the vehicle. And it is logically done. Once it is Parallel or series its respective Fuzzy Logic decision is made [7].

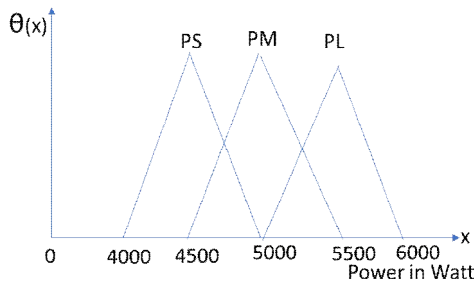
#### A. Fuzzy Logic of Series HEV

1) *Peddle Position*: PS – Small Power      PM – Medium Power      PL – Large Power      {PS, PM, PL}

Defining Peddle Position range, Membership Function of the input variables. We use Triangular Membership Functions.

Range for Speed (40 to 60):

PS: 40 to 50      PM: 45 to 55      PL: 50 to 60



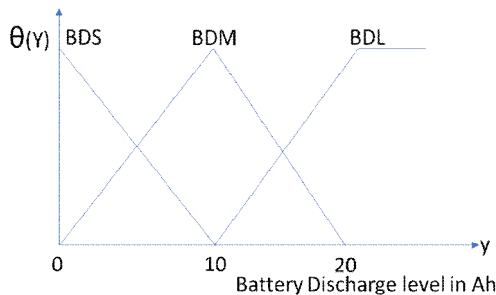
$$\begin{aligned} \theta_{PS}(x) &= x - 4000 / 4500 - 4000 & || & \theta_{PS}(x) = 5000 - x / 5000 - 4500 \\ \theta_{PM}(x) &= x - 4500 / 5000 - 4500 & || & \theta_{PM}(x) = 5500 - x / 5500 - 5000 \\ \theta_{PL}(x) &= x - 5000 / 5500 - 5000 & || & \theta_{PL}(x) = 6000 - x / 6000 - 5500 \end{aligned}$$

2) *Drive Battery Status*: BDS – Small Discharge      BDM – Medium Discharge      BDL – Large Discharge      {BDS, BDM, BDL}

Defining Battery discharge range, Membership Function of the input variables. We use Triangular Membership Functions.

Range for Speed (40 to 60):

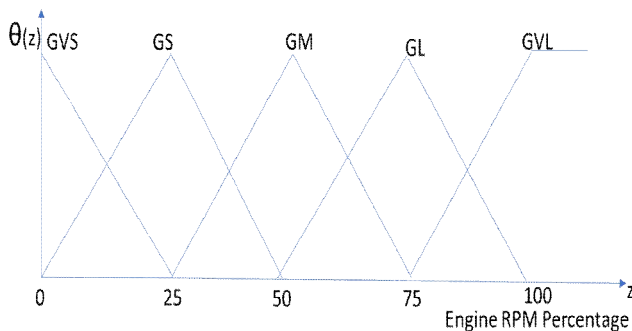
BDS: 0 to 10      BDM: 0 to 20      BDL: 10 to 20



$$\begin{aligned} \theta_{BDS}(y) &= 10 - y / 10 - 0 \\ \theta_{BDM}(y) &= y - 0 / 10 - 0 & || & \theta_{BDM}(y) = 20 - y / 20 - 10 \\ \theta_{BDL}(y) &= y - 10 / 20 - 10 \end{aligned}$$

Membership function for Engine RPM Percentage:

GVS: 0 to 25      GS: 0 to 50      GM: 25 to 75      GL: 50 to 100      GVL: 75 to 100



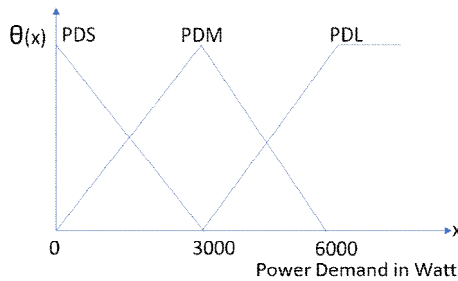
$$\begin{aligned} \theta_{GVS}(z) &= 25 - z / 25 - 0 \\ \theta_{GS}(z) &= z - 0 / 25 - 0 & || & \theta_{GS}(z) = 50 - z / 50 - 25 \\ \theta_{GM}(z) &= z - 25 / 50 - 25 & || & \theta_{GM}(z) = 75 - z / 75 - 50 \\ \theta_{GL}(z) &= z - 50 / 75 - 50 & || & \theta_{GL}(z) = 100 - z / 100 - 75 \\ \theta_{GVL}(z) &= z - 75 / 100 - 75 \end{aligned}$$

**B. Rule Base For Engine Rpm Percentage**

BATTERY PEDAL	BDS	BDM	BDL
PS	GVS	GS	GM
PM	GS	GM	GL
PL	GM	GL	GVL

1) Fuzzy Logic of Parallel HEV

a) Power Demand: PDS – Small Demand    PDM – Medium Demand    PDL – Large Demand    {PDS, PDM, PDL}



$$\theta_{PDS}(x) = 3000 - x/3000 - 0$$

$$\theta_{PDM}(x) = x - 0/3000 - 0 \quad || \quad \theta_{PDM}(x) = 6000 - x/6000 - 3000$$

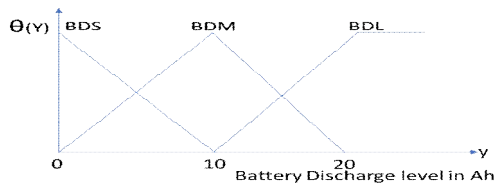
$$\theta_{PDL}(x) = x - 3000/6000 - 3000$$

2) Drive Battery Status: BDS – Small Discharge    BDM – Medium Discharge    BDL – Large Discharge    {BDS, BDM, BDL}

Defining Battery discharge range, Membership Function of the input variables. We use Triangular Membership Functions.

Range for Speed (40 to 60):

- BDS: 0 to 10
- BDM: 0 to 20
- BDL: 10 to 20



$$\theta_{BDS}(y) = 10 - y/10 - 0$$

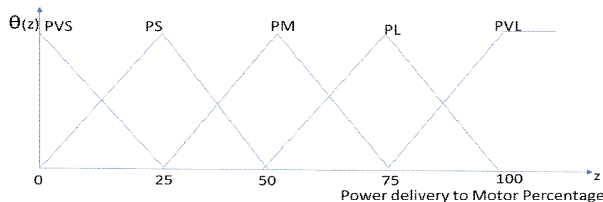
$$\theta_{BDM}(y) = y - 0/10 - 0 \quad || \quad \theta_{BDM}(y) = 20 - y/20 - 10$$

$$\theta_{BDL}(y) = y - 10/20 - 10$$

Membership function for Power delivery to Motor Percentage:

A power governing action takes place to deliver only the required power to the motors and effectively carry the wheel load [8].

PVS: 0 to 25    PS: 0 to 50    PM: 25 to 75    PL: 50 to 100    PVL: 75 to 100



$$\theta_{PVS}(z) = 25 - z/25 - 0$$

$$\theta_{PS}(z) = z - 0/25 - 0 \quad || \quad \theta_{PS}(z) = 50 - z/50 - 25$$

$$\theta_{PM}(z) = z - 25/50 - 25 \quad || \quad \theta_{PM}(z) = 75 - z/75 - 50$$

$$\theta_{PL}(z) = z - 50/75 - 50 \quad || \quad \theta_{PL}(z) = 100 - z/100 - 75$$

$$\theta_{PVL}(z) = z - 75/100 - 75$$

**C. Rule Base For Power Delivery To Motor Percentage**



BATTERY POWER	BDS	BDM	BDL
PDS	PVS	PS	PM
PDM	PS	PM	PL
PDL	PM	PL	PVL

### VII. PERFORMANCE

Power delivery to the wheels is from two sources. Both the sources are used in series or parallel configuration as per running conditions of the vehicle. The motor added on the drive shaft first kills friction with minimum expenditure of stored energy. Secondly this stored energy is derived by avoiding frictional losses due to braking. These two energy captures serve smoothening the vehicle run and saving the fuel burn. Terrine conditions impeding the performance of the engine is avoided. This gives a better health and life to the engine since the engine experiences capacitive load rather to terrine conditions. Fuel consumption fell drastically.

### VIII. CONCLUSION

Fuzzy logic caters a fast and accurate tuning of energy sources. Motors and the engine perform to give a better driving conditions, faster pick up and most importantly it saves huge amount of fuel being burnt for its own survival. Efficiency with respect to conventional vehicles is much higher.

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