International Journal of Power System Operation and Energy Management

Volume 1 | Issue 1 Article 12

July 2011

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Recommended Citation

J, Martin Anandaraj and M, Ramyaa A. (2011) "Improving fuel economy of a Hybrid Electric Powertrain by Downsizing," *International Journal of Power System Operation and Energy Management*: Vol. 1 : Iss. 1 , Article 12.
Available at: https://www.interscience.in/ijpsoem/vol1/iss1/12

Improving fuel economy of a Hybrid Electric Powertrain by Downsizing

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Abstract* — This paper aims at the development of a hybrid electric powertrain which is focused on grater fuel economy by downsizing when compared with present and future developed powertrains. In this work, the proposed hybrid vehicle is powered by four systems, a rule based system (RBS) which mainly explores the engine efficiency; a Speed Control System (SCS) which is focused on the speed control of Traction Motor and individual Front Wheel Motors; a Powertrain Feedback System (PFS) which mainly monitors the powertrain efficiency so as to maintain vehicle dynamics appropriately and a Selective Perpetual Motion System (SPMS) through which power management is achieved. The system is preset to work under three driving cycles, an economy mode where the vehicle is operated typically at low speeds or in traffic; a power mode where the vehicle is in steady state driving; a super power mode where more torque and power required to drive the vehicle under heavy load conditions or in hill climbing. The vehicle is designed to work under different configurations of power, torque and voltage to achieve the mode of drive cycle. The current supplied to the motor(s) is kept constant and nominal in rating. In this manner, a brief study about the transient analysis of the proposed vehicle is done, suffering no performance disadvantages to the conventional vehicles.

Keywords – Hybrid Electric Vehicles, Powertrains, Energy

I. LITERATURE REVIEW

For many years great consideration has been given to the problem of reduction of fuel consumption of automobiles and other highway vehicles. Along with very significant consideration has been paid to reduction of pollutants emitted by automobiles and other vehicles. To a grade, effects to solve this problems conflict with one another. For example, increased thermodynamic efficiency and thus reduced fuel consumption can be realized if an engine is operated at higher temperatures. Thus there has been substantial interest in engines built of ceramic materials withstanding higher combustion temperatures that those now in use. However, higher combustion temperatures in gasoline-fuelled engines lead to increase in certain undesirable pollutants, typically NO_x [1].

Another possibility for reducing emission is to burn mixtures of gasoline and ethanol (“gasohol”) or straight ethanol. However, to date ethanol has not become economically competitive with gasoline and consumers have not accepted ethanol to any great degree [2]. One proposal for reducing pollution in cities is to limit the use of vehicles powered by internal combustion engines and instead employ electric vehicles powered by rechargeable batteries. To date, all such electric cars have a very limited range, typically no more than 100 miles, have insufficient power for acceleration and hill climbing except when the batteries are fully charged, and require substantial time for battery recharging [3]. Thus, while there are many circumstances in which the limited range and extended recharge time of the batteries would not be an inconvenience, such cars are not suitable for all the travel requirements of most individuals. Accordingly, an electric car would have to be an additional vehicle for most users, posing a substantial economic deterrent. Moreover, it will be appreciated everywhere that most electricity is generated in coal-fired power plants, so that using electric vehicles merely moves the source of the pollution, but does not eliminate it. Furthermore, comparing the respective net cost per mile of driving, electric vehicles are competitive with ethanol-fuelled vehicles, much less with conventional gasoline-fuelled vehicles [4].

Much attention has also been paid over the years in the development of electric vehicles including internal combustion engines and powering generators, thus eliminating the defect of limited range exhibited by simple electric vehicles. The simplest such vehicles operate on the same general principle as diesel-electric locomotives used by most rail systems. In such systems, an internal combustion engine drives a generator providing electric power to traction motors connected directly to the wheels of the vehicles. The same drive system may be employed in smaller vehicles such as an automobile or truck, but has several distinct disadvantages in this application. In particular, it is well known that a gasoline or other internal combustion engine is most efficient when producing near its maximum output torque.

Typically, the number of diesel locomotives on a train is selected in accordance with the total tonnage to be moved and the grades to be overcome, so that all the locomotives can be operated at nearly full torque production. Moreover, such locomotives tend to be run at steady speed for long period of time. Reasonably efficient fuel use is thus achieved. However, such direct drive vehicle could not achieve good fuel efficiency in typical automotive use, involving many short trips, frequent stops in traffic, extended low speed operation and the like.

So-called “Series-Hybrid” electric vehicles have been proposed wherein batteries are used for energy storage devices, so that the energy can be operated in its most fuel-efficiency output power range while still allowing the electric traction motor(s) powering the vehicle to be operated as required. Thus the engine may be loaded by supplying torque to a generator charging the batteries while supplying the electric power to the traction motor(s) as required, so as to operate efficiently. This system overcomes the limitations of electric vehicle noted above with respect to limited range and long recharge times. However, such series hybrid electric vehicles are in-efficient and grossly uneconomical, for the following reasons.

In a conventional vehicle, the internal combustion engine delivers torque to the wheels directly. In a series hybrid electric vehicle, torque is delivered from the engine via a serially connected generator, battery charger, inverter and the traction motor. Energy transfer between those components consumes at least approximately 25 % of engine power. Further such components add substantially to the cost and weight of the vehicle. Thus, series hybrid vehicles have not been immediately successful [5].

A. *Golden Age (1880 – 1920)*

The history of electric vehicles has been discussed in many articles and in journals. In this work it is limited to come out with the earlier electric vehicles' development and to show some applications of the same.

Early Electric Cars

The first ever propelled road transport vehicle was an "*Electric Tricycle*" developed by W. Ayrton and J. Perry of England in 1882 [6]. The vehicle has a configuration similar to that of a bicycle and designed to be lightweight in nature. As a note, this invention has been carried out only five years after the "*Invention of the Automobile*" by Benz and Daimler [7]. This invention caused successive development of a "*Horseless Carriage*" by Jeantaud and Krieger of France in 1902 [8].

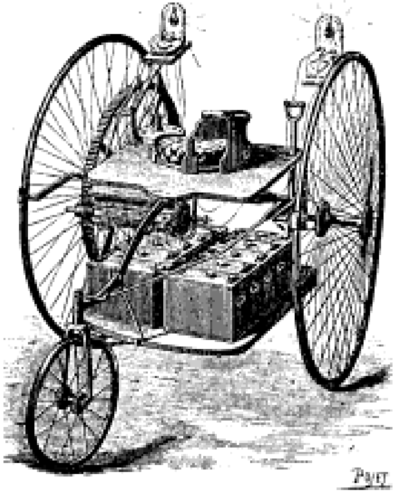

Figure – 1, W. Ayrton & J. Perry's Electric Tricycle of 1882

Figure – 2, Jeantaud and Krieger's Electric Horseless Carriage of 1902.

These zenith developments of First Generation Vehicles were based on a constraint **"*Sophisticated Transportation*"**. And it was found that they served well and the further developments on electric utility vehicles were carried out.

Electric Utility Vehicles

The electric vehicles were so commercialized in the early 1900s and they replaced the horse driven vehicles simply providing cost advantage. Literature review shows that the electric vehicles resulted up to 25 % cost advantage when compared with conventional horse driven vehicles. As an exemplar, the early "*Ransomes Front Wheel Driven Orwell*" was a best development for cost effective and sophisticated transport [9].

Figure – 3, Ransomes Orwell

The early electric vehicles proved that they were particularly suitable for short distance drives and frequent / stop drives like urban delivery works. Later on, they found to be suitable for municipal services and utility duties also. The "*Electric Hearse*" found in Milan was a paramount model. The first prototype was made in 1913 and they had been raised to 37 in numbers on 1930 [10]. Typically, the electric vehicles were also used in fire brigades and in post offices for commercial purposes at Germany, Italy and in France.

Figure – 4, Electric Hearse of Milan around 1917

Electric Passenger Cars

The earlier development of horseless carriage originated to develop electric passenger cars basically in to two main categories like "*Open Type*" and "*Closed Type*", among them the open type electric cars reflected the sportive versions of gasoline cars and the closed type cars particularly designed for city use. The electric cars were presumed to be an expensive product for upper classes since it replaced horse and buggy and much more expensive than gasoline cars when compared.

It was shown in a catalogue of 1914 that the electric cars were ranged $ 2000 – 3000 where a gasoline car was available for $ 950 in price [11]. The electric passenger cars were sooner or later replaced by gasoline cars not only on the cost aspects but also based on technical design advancements since the gasoline cars introduced new terms in trend like "cruising and power". And the trends of electric passenger cars were simply quoted as ***"The Gasoline Cars so change the public's desire for transportation that the electric was no longer adapted to that new desire. This was a serious disadvantage"*** [12].

Figure – 5, Open Type Electric Vehicle driven by King Victor Emmanuel III of Italy

Figure – 6, Closed Type Electric Vehicle as City Car

Later fewer applications of electric vehicles were found in racing and in public transports like buses. The electric bused found in 1924 consumed only 2.57 pence per mile where a gasoline vehicle consumed 4.07 pence per mile. The notable disadvantage found with those electric buses was the electrical or mechanical failures.

First Generation Hybrids

The idea of making Hybrid Vehicles exists from the early decades of 1900s. The first hybrid ever made on road was an *"Auto-Mixte"* developed in 1896 by the Belgian company Pieper. Literature shows that there were many prototypes and physical models made in the area of hybrid technologies to conquer the crisis of as Riding with sophistication and cost advantage mentioned earlier. In 1901, two Petrol-Electric Vehicles were made by the company *"Fabrique de Nationale d'Armes de Guerre"* in Herstal. In 1902, Series Hybrid concepts were developed in France whereas Lohner-Porsche were started manufacturing the same.

Figure – 7, First Hybrid Vehicle of Thury in 1904

In 1904, a hybrid car of 100 HP power was developed by Thury of Geneva [g] which is of parallel hybrid kind. This was the very first hybrid car ever made before it seems. It was made with a two or four stroke in cylinder V type internal combustion engine which delivers 8 or 16 HP power, a shunt wound electric motor and a common driving shaft with two clutches. The battery provided was a 60 V range weighing 150 Kg or a 80 V range weighing 500 Kg. The efficiency of the car ranged 5 or up to 40 kilometers. And in addition to that, the vehicle can be run in three modes like pure electric, pure gasoline and or hybrid. More over it can be used as a mobile power plant [13].

Why Hybrid Vehicles

Since, fossil fuels replaced the effective utilization of basic hybrid vehicles and electric vehicles after 1927, they are considered to be the prime source to generate enormous power. Advancement of civilization was also a root cause to look after a new trend. Recently, Powertrain Efficiency and Fuel Economy were considered as a significant area of research to solve the crisis of pollution and fuel economy. There were many researches had been carried out concerning the energy efficiencies of vehicles with alternative powertrains in order to find betterment in solving the crisis, among them Hybrid Powertrains are seems to be the best one when compared [14]. In this chapter, we limit ourselves with a common evaluation of powertrain parameters and efficiencies of hybrid vehicles with conventional IC engines, advanced IC engines of tomorrow, FCVs and EVs.

Component Mean Efficiencies over Normal Drive Schedule

Table – 1 represents the component mean efficiencies of various powertrains. For all powertrain configurations the generator efficiencies ranges from 85% to 92% whereas the battery efficiencies ranges 80% to 95%. The electric motor and control system efficiencies seem to be a constant since they vary only a 3% among them. Although, the transmission efficiencies in all powertrains are the same the total energy efficiencies are not the same. In that regarding, HEV with Lithium battery configuration produces total drivetrain efficiency at a maximum value of 76 %. Next to that a 72 % of total efficiency is attainable in HEV with Lead Acid (Pb/A) battery configuration whereas the possible total efficiency of both BEV configurations result in 65% and 57% only [15].

Electric	**G**	**B**	**EM**	**T**	**D**

Drivetrain Configuration	(%)	(%)	(%)	(%)	(%)
BEV (NiMH)	85	80	86	98	57
BEV (NiMH)	92	81	89	98	65
HEV (Pb /A)	92	90	89	98	72
BEV/HEV (Li)	92	95	89	98	76

Table – 1, Component Mean Efficiencies of Powertrains over a Normal Drive Schedule

Future Powertrain Efficiencies

It is a key to study about future possible powertrain efficiencies now days. Typically, the powertrain is designed such as it has a primary engine, transmission, electric drive train, the total powertrain energy efficiency are not the same. Table – 2, shows a study about the same in several possible powertrain configurations exists today and or may exist tomorrow. Even though the BEVs produce a total energy efficiency of 65% they seem to be least confirming public desires of power and acceleration when compared.

In addition to that hydrogen fuelled FCVs stand second in producing maximum total energy efficiency around 39 %, they are also not preferred since production of fuel cells cost more and results in discharge of enormous heat [16]. When considering a eco friendly approach, both hybrid powertrains (series and parallel) plays a vital role and can produce a maximum total energy efficiency of 36% [17].

Powertrain Efficiency	Primary Engine (%)	5 Speed Trans (%)	Electric Drive (%)	Total Powertrain Efficiency (%)
Battery Powered	-	-	65	65
Hybrid (Parallel)	36	92	68	30
Hybrid (Series)	40	-	72	29
Fuel Cell (Methanol)	40	-	72	29
Fuel Cell (Hydrogen)	47	-	72	34
Conventional (Developed)	24	92	-	22
Conventional (Today)	18	92	-	16

Table – 2, Future Possible Efficiencies of Alternative Powertrains of Vehicles

Energy at Wheels

Table – 3 shows engine to wheel efficiencies of different powertrain configurations under normal driving schedule. The energy at wheels of IC engines today and IC engines to be developed using TDi, VVA, VVC, HCCI, etc., ranges from 14 % to 20 %. Since, they lose energy at idling and supplies huge amount of energy to powertrains when compared. In other hand, HEV configurations are in a way ahead with efficiency of 29%. It is clearly shown that the energy out from powertrain, energy to powertrain and total energy supplied to wheels in both HEV and FCV configurations are similar. Even the HFCV configuration produces more vehicle efficiency as an end result though they are not preferred as explained earlier [18].

Vehicle	**A**	**B**	**C**	**D**	**E**	**F**	**G**
BEV	100	95	146	17	0	163	61
HEV (Parallel)	100	95	327	14	0	340	29
HEV (Series)	100	95	327	14	0	340	29
FCEV (Methanol)	100	95	327	14	0	340	29
FCEV (Hydrogen)	100	95	279	14	0	293	34
ICEV (Developed)	100	100	452	10	27	489	20
ICEV (Today)	100	100	625	10	75	700	14

Table – 3, Vehicle Energy Calculated as Energy at Wheels to the Total Energy Supplied to Wheels

[A - Consumed Energy at Wheels, B - Energy out from the powertrain, C - Energy to powertrain, D - Energy used for extra loads, E - Energy during idling, F - Total energy supplied and F - Vehicle overall efficiency (%)]

II. OBJECTIVE AND SUMMARY

The objective of this work is to develop a Duel Fuel Hybrid Electric Vehicle (HEV) system and use it for the design of power management and fuel efficiency. The basis for the HEV system is the high fidelity of conventional vehicle system previously developed and utilized around the automakers. To construct a HEV system, some of the main modules require modifications, e.g. the engine needs to be reduced in size/power, and the electric component models need to be created and integrated into the system.

This HEV system effort will focus on series architecture post-transmission configurations, where the electric motor is mechanically coupled to the output shaft, which drives normally the transmission system. A forced-feedback system can be employed so as to enable studies of control strategies under realistic transient conditions. The HEV system will be implemented to allow for easy reconfiguration of the system and to enable the designer to select proper models depending on specific simulation goals. Two control systems are investigated in this project: a rule-based and a dynamic programming feedback system.

After the invention of steam engines, fossil fuels are the prime source to generate enormous power. Since, advancement of civilization made us to demand more fuel to drive. This ends with the research on fuel-efficient vehicle technologies. Even though alternate fuels and alternate power sources like Solar operated Vehicles (SVs), Fuel Cell Vehicles (FCVs) are playing a vital role; they confirm least public requirements when compared. In such a scenario, Hybrid Electric Vehicles (HEV) system seems to be one of the most viable technology with significant potential to reduce fuel consumption within realistic economical, infrastructural and customer acceptance constraints. There are many researches carried out in this area and many Prototypes / Concepts developed.

Toyota and Honda have already launched production vehicles and many other major automakers are expected to launch hybrid vehicles in the next 1-3 year. This project proposes a new methodology, which results in better fuel efficiency and power management under normal lifestyles. Due to the existence of dual power-sources, the additional design degrees of freedom of HEV offer extraordinary promise in fuel economy and reduced exhaust emissions, when series architecture is employed. This makes the complexity of the new vehicle system tedious and requires the application of simulations for accurate sizing and similar studies, as well as for development of control systems well ahead of the final design and physical prototyping.

Since, charging batteries and limited displacement seems to be an immense problem in present configuration of Hybrid Vehicles; it is optimum to design the vehicle with AC system which requires no additional storage batteries. Only a conventional 20 V, DC battery is used to power the electric systems available in the vehicle. Here, online current is produced and that is utilized straight away. Other unused current is converted to DC and used for secondary charging of the conventional battery.

III. PROPOSED METHODOLOGY

The project is arranged as follows. The configuration of the newly developed Hybrid Electric Vehicle system is discussed first, followed by the brief description and features of available main and other subsystems such as prime mover (ICE), alternator, traction motor, gear box, transmission system till wheels. At next, briefing of Control and Governing Systems: a Rule-based System, a Speed Control system, a Powertrain Feedback System and a Selective Perpetual Motion System are introduced. The complete hybrid vehicle simulation is then used to assess the acceleration ability and the fuel economy of the hybrid vehicle through comparisons with its conventional counterpart.

A. Proposed Hev's Architecture and It's Components

The newly developed concept of Downsizing is the key factor and that has been considered in this work. The system consists of a Power Mode Selector (PMS), Rule Based System (RBS), Fuel Injection System (FIS), Internal Combustion Engine (ICE), Planetary Geartrain (PG), Two Way Clutch (TWC), Alternator (A), Speed Control Circuit (SPC), Automatic Voltage Regulator (AVR), Traction Motor for front Wheels (FWM), Traction Motor for Rear Wheels (M), Conventional Gear Box (GB), Differential (D), Wheels (W), Powertrain Feedback System (PFS), Selective Perpetual Motion System, Conventional Battery and a Microcontroller Logic. The schematic of proposed hybrid vehicle architecture is shown in Figure – 8. The in-car architecture of the above said components is shown in Figure – 9.

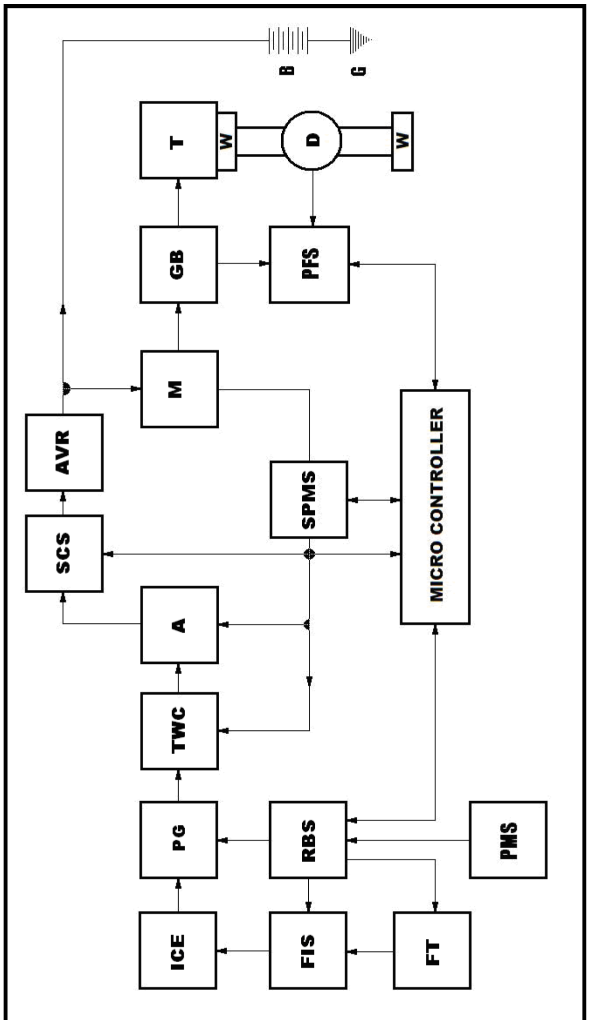

Figure – 8, Schematic representation of proposed Hybrid Electric Vehicle's Architecture.

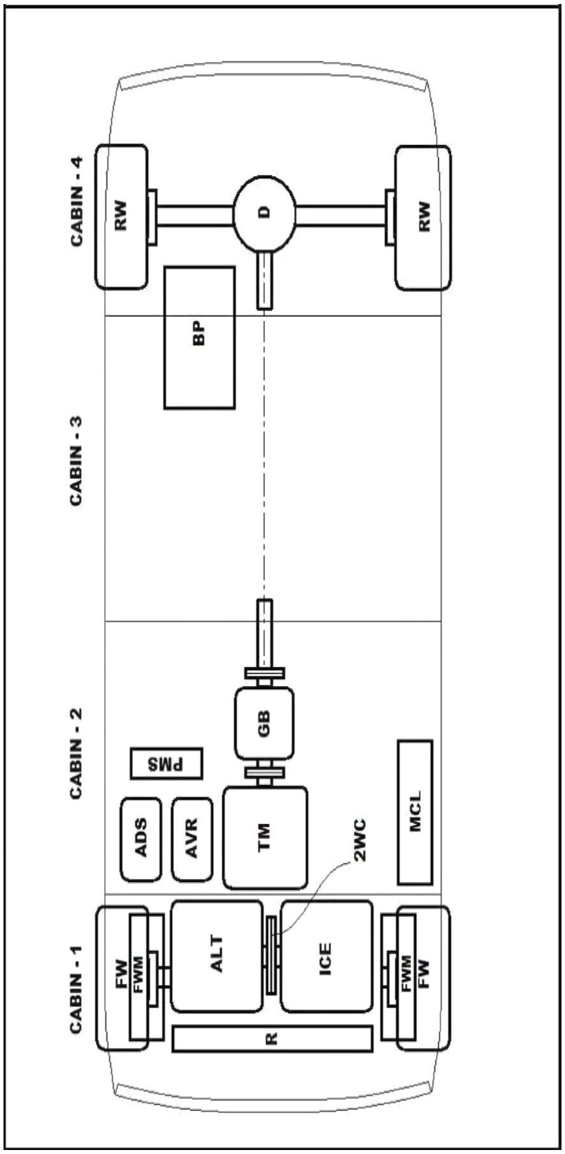

Figure – 9, In-Car Arrangement of Proposed HEV

1. Internal Combustion Engine

The Internal Combustion Engine acts as a prime mover for the alternator, which is coupled with it. Since, the reverse engineering approach is adapted, the speed and torque at which the IC Engine should operate can be predetermined by considering the input constraints of the alternator. These constrain results in the selection of a proper IC Engine that operates at an approximately constant speed and produces a torque to bootstrap the system. With the aid of an epicyclic gear train the torque can be modulated and supplied to the alternator. In general, most of the IC Engines are capable of producing 50% mechanical efficiency and a maximum of 18% powertrain efficiency. This is because of the thermal, momentum and frictional losses, which is available in all the moving parts of the vehicle system and subsystems. In addition to that, noise, vibration and harshness (NVH) are the second setback available in the IC Engine. There are several researches carried out in the area of maximizing the output power of an IC Engines to achieve more than 50% mechanical efficiency and 18% power train efficiency.

Literature survey states that the engine can produce better output when it is operated under a stipulated driving cycle. Moreover, the vibration is comparatively less when the engine is operated under an approximately constant torque. Here, the IC Engine is preset with three modes regarding the driving cycle namely Economy Mode, Power Mode and Super Power Mode. The economy mode is preferred under urban driving cycle where the engine acts as a braking system and this mode is adapted for driving cycles like down hills and long rides in national highway at where minimal power is required to drive the system. The second, power mode is preferred under the normal rural driving cycle and it is adapted to drive the system most of the time. The third, super power mode is preferred under some special driving cycles like up-hill rides and over loaded rides at where enormous power is required to drive the system.

2. Planetary Gear Train

The planetary gear train acts as a power modulation system between IC engine and the alternator. Since, the engine is operated under three different modes (economy, power and super power) the gear train should be capable of tweaking itself to associate with the input (Speed and Toque available at IC engine) and output (speed and torque required to drive the alternator). A compound gear train setup provides the three possible operating speeds for the preset modes. Then, an epicyclic gear train setup serves the desired speed and torque to propel the alternator effectively to produce three rated bandwidth of electric power. The schematic of the Planetary Gear train is shown in Figure – 1.

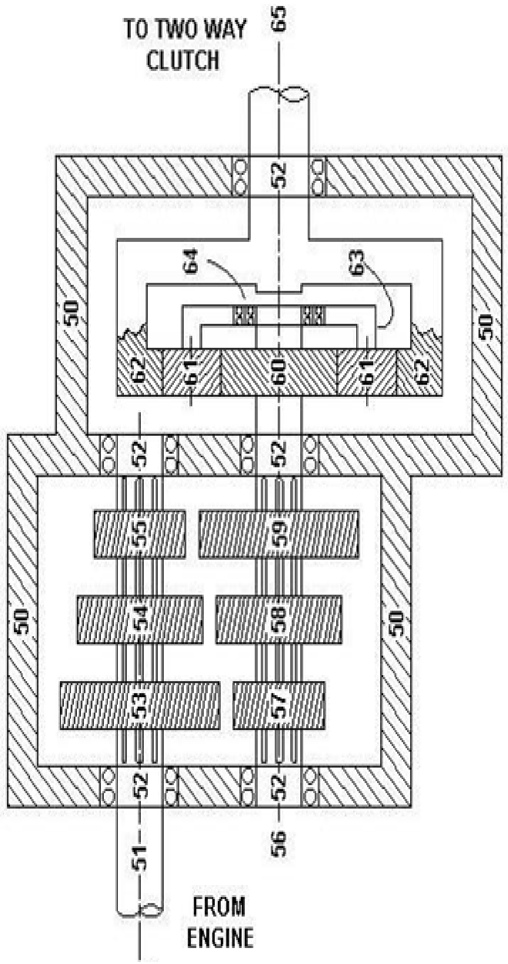

Figure – 10, Epicyclic Gear Box

Reference Number	Component Name
50	Gear Box Housing
51	Drive Shaft
52	Bearings
53 – 59	Helical Gears
60	Sun Gear
61	Planet Gears
62	Ring Gear
63	Planet Carrier
64	Support Bearing
65	Driven Shaft

Table – 4, Details of Epicyclic Gear Box

3. *Alternator*

The alternator acts as a prime mover for the motor which operates with respect to the driving cycle personalized by the driver / user. The main objective of the alternator is to produce a constant span of electric power. The generated power is then modulated and given to the electric motor through a speed control system to conserve it as mechanical power. Since, the motor output (Torque and Power required to move the vehicle) can be predetermined, the alternator can be selected as a standard 1 phase alternator which is least required to drive the motor.

4. *Traction Motors (FWM and M)*

The motor plays a vital role in the hybrid system and acts as an energy source to the conventional gearbox and transmission system. Since, the road dynamics, driving cycle are varying with time, the motor have to be flexible while distributing the output parameters (Speed and Torque). Since, starting torque is required more and optional overloading is present, Slip Ring Induction Motor is preferred. In this work, two individual motors (FWM) are fixed at the front axle for the ease of design and assembling. And for rear wheels one single traction motor (M) is provided. The microcontroller is designed in such a way that it should deliver opt electric input to these motors.

5. *Powertrain Feedback System (PFS)*

This module analyses weather the set speed, torque and power are available at the vehicle through the feedback devices. The gross load, design speed and power are preset for the type of gear engagement made at the gearbox. The actual speed and power that is available at the wheels is measured through sensory devices. Then, both the design and actual speed, power is compared and a feedback is sent to the Micro Controller unit. The powertrain efficiency is monitored and effectively achieved through the Micro Controller unit.

6. *Speed Control System (SCS)*

Speed Control System (SCS) is used to achieve the speed control of the traction motor based on the load requirement given by the driver / driving cycle. The alternator produces a maximum span of electrical voltage (say 110 V) and that can be modulated through speed control system by varying the voltage and power, where a speed control circuit is used to vary the voltage via varying either the resistance or frequency.

Here, the system is allowed to sense what type of gear engagement is made (normally, 4 forward and 1 reverse) at gear box and under which mode the vehicle is running. Then the preset electric load is supplied to the traction motor to produce efficient power to drive. Moreover, at the idling state i.e. when the accelerator pedal is not actuated, the motor is not allowed to run and the generated voltage is converted to D.C Voltage and stored in the conventional battery. The above mentioned Speed Control System can be used as Braking System by implementing the same circuit and components in the Brake Pedal. Simply, the output of this circuit actuates the conventional braking system available in the car.

7. *Selective Perpetual Motion System (SPMS)*

A Selective Perpetual Motion Cycle is applied to the system by correlating the alternator / motor output. When the vehicle is at the steady state driving (normally at top gear engagement), the alternator is allowed to run for a while at that momentum. At that time, the series configuration is switched to parallel configuration through Ward Leonard method. A parallel shaft output is taken from motor and connected to the alternator input shaft and drives the alternator. And the IC Engine is allowed to run at idle speed to achieve fuel economy. Since, minor losses are present at both the alternator and motor, this method is worth for a while until the alternator goes beyond the set voltage bandwidth.

8. Rule Based System (RBS)

Rule based system mainly explores the engine efficiency, so that in incorporates with the powertrain feedback system always. This system focuses few rules as follows:

1. When the engine is cranked, the engine should run at an appropriate speed, which is sufficient to drive the alternator through the epicyclic gearbox.
2. This system should sense which power mode (Economy, Power and Super Power) is selected and it should propel the engine to the set speed for selected power mode.
3. At the selective perpetual motion cycle, the IC Engine should be kept at idle speed.

9. Automatic Voltage Regulator (AVR)

Automatic Voltage Regulator is a simple transformer which can provide an approximate constant output voltage over a span of input voltages (say from 90 V – 110 V input voltage it can deliver a constant output voltage of 110 V in a tolerance limit ± 5 %. This system is preferred for the smooth and sophisticated performance of traction motors.

10. Two Way Clutch (TWC)

Two way clutch is located in-between the Planetary Gear Box and Alternator. As mentioned earlier, when the vehicle works under selective perpetual motion cycle, the IC engine should be disengaged from alternator and a parallel shaft connected to the motor should be engaged to the alternator. For that, the design of a two way clutch is devised and the schematic representation of the design is shown in Figure – 11.

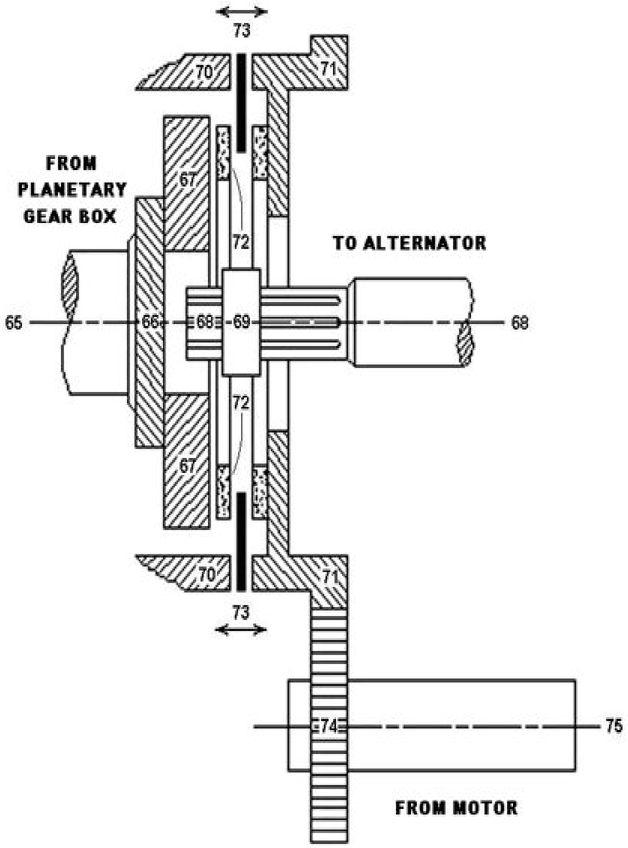

Figure – 11, Schematic representation of Two-Way Clutch

11. Vehicle Governing System(s)

As mentioned earlier the vehicle consists of four control and governing systems. For the ease of simulating the hybrid architecture the systems' input / output constraints are to be defined. In this session, the overall communication between those systems with the microcontroller is discussed. For better control, the microcontroller is allowed to have bi-directional communication with all available systems. The schematic representation of communication of all systems with microcontroller is shown in Figure – 12.

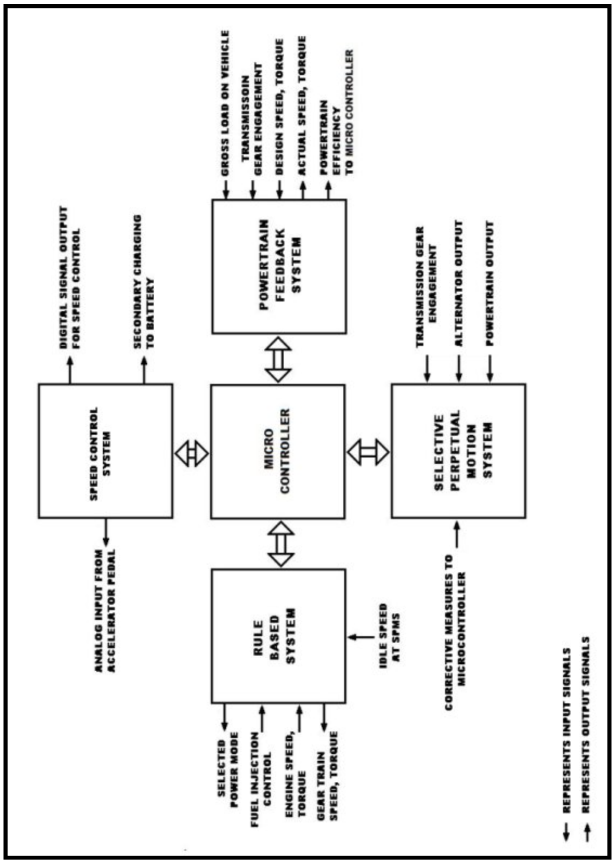

Figure – 12, Communication between Control / Governing systems and Microcontroller

IV. MODES OF OPERATION

As discussed earlier, the proposed HEV consists of three different operating cycles namely Economic, Power and Super Power Mode. All these modes are predefined with sets of operating Parameters / Variables such as Maximum on Road Speed, Power & Torque at Wheels and Fuel Consumption IC Engine… etc., In other words, the limitations of the HEV is well explained to the user, so that He / She can decide in which mode He / She wants to drive the vehicle based on what Need / Requirement. In order to get these cycles working, lots of Reverse Engineering approaches are to be done on the powertrain. The general design considerations of each mode are discussed below.

1. Economic Mode

If the user is looking for an Economic Drive, the powertrain is designed to produces less power and torque at the wheels which results in a low on road speed. Here, the economy of the vehicle is compromised with the powertrain's power and torque. This can be achieved by allowing the IC Engine to run at low speed (say 2000 r.p.m), which results in low production of electricity at the Alternator. And the traction motor may produce relatively low torque and power.

2. Power Mode

In this mode, the powertrain is designed to produce moderate on road speed, torque and power. For that, the IC Engine is allowed to run at 3000 r.p.m. Hence, the other subsystems produces relatively moderate outputs which results in better on road performance. This mode is preferred for urban driving conditions. Even though, the powertrain produces lesser economy when compared with economy mode, it is designed in such a way that the economy of powertrain should be higher than that of available on road passenger cars' economy.

3. Super Power Mode

This mode is designed for heavy duty / hill climbing / off road driving cycles. The economy of the powertrain is compromised with the performance of the powertrain. When the user wants to drive the vehicle at its maximum on road speed with maximum torque and power, the IC Engine is allowed to run at 4000 r.p.m which makes the alternator to produce maximum electricity and the traction motor produces maximum power and torque.

Table – 5, shows the selected Parameters / Variables for all 3 possible driving cycles.

Parameter	Economy	Power	Super Power
Vehicle			
On road speed	70 kmph	100 kmph	130/50 kmph
Power at wheels	20 kW	30 kW	40 kW
Torque at wheel	75 N.m	100 N.m	130 N.m
Motor			
Power	25 kW	35 kW	45 kW
Torque	> 75 N.m	>100 N.m	>130 N.m
Speed	1440 rpm	1440 rpm	1440 rpm
Input Voltage	150 V	150 V	150 V
Input Current	20 A	20 A	20 A
Alternator			
Power	30 kW	40 kW	50 kW
Torque	> 75 N.m	>100 N.m	>130 N.m
Speed	1440 rpm	1440 rpm	1440 rpm
Output Voltage	> 150V	150 V	150 V
Output Current	20 A	20 A	20 A
IC Engine			
Power	35 kW	45 kW	55 kW
Torque	> 75 N.m	>100 N.m	>130 N.m
Speed	2000 rpm	3000 rpm	4000 rpm

Table – 5, Operating Parameters / Variables

V. CONCLUSION

The main reason for why there has not been much information and investigation on shuffle of HEV is due to the fact that most of the HEVs are made as concept cars and or under test vehicle categories. Commercializing such vehicle requires huge investment in men, materials and money. It seems that fuel prices and availability are an ever ending crisis and consumers are having a mind for not to put their money in a showcase. Nevertheless, many researches show that HEVs are one of the inevitable results for present scenario. In this present work, a new methodology of constructing a Hybrid Electric Vehicle is shown. And the components and their designs were discussed. It is proposed to make a prototype of above discussed model and then to test the powertrain.

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