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DESIGN AND ENERGY MANAGEMENT STRATEGY FOR PLUG-IN-HYBRID ELECTRICAL VEHICLES FOR FUEL COST REDUCTION

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Abstract: Electrical transport is viewed united of the foremost viable ways in which of reducing carbonic acid gas emissions and fuel dependency. However, a way to manage the Plug-in Hybrid electrical Vehicles and electrical Vehicles for the optimum fuel consumption continues to be a very important challenge. the main focus of this thesis is that the strategy wont to management Plug-In Parallel-Through- The-Road hybrid electric vehicles. 1st the vehicle design is studied and modeled; then a hybrid phase space theory is introduced to formulate the matter of hybrid vehicle system style that includes each continuous and distinct dynamics, and a rule-based control for power management is given to improve fuel consumption.

Index Terms - **Plug-In Hybrid electrical vehicles (PHEV), parallel-through-the- road PHEV (PTTR PHEV), rule-based control, hybrid system theory, fuel consumption.**

I. INTRODUCTION

The goal of this paper is to style a bearing strategy, that aims to handle the energy management drawback for a parallel-though-the-road plug-in hybrid electric vehicle. the first objective is to analyze and notice a decent drive train model, that higher represents the hev architecture. In accordance with this objective, the primary contribution of this research is that the development of a through-the-road parallel plug-in HEV model with Simulink and State flow in Matlab. The secondary objective is to find a decent rule-based management to completely utilize the advantages of the PHEV. The system is needed to optimize use of low-cost energy and to reduce the utilization of fuel.

II. PLUG-IN HYBRID ELECTRICAL VEHICLES

A plug-in hybrid electric vehicle (PHEV) may be a hybrid electric vehicle that utilizes reversible batteries, or another energy storage device, which will be remodeled to full charge by connecting a plug to an external electrical power supply (usually a standard electric wall socket). A PHEV includes the characteristics of each a traditional hybrid electric vehicle, having an electrical motor and an enclosed combustion engine (ICE), and of an electrical vehicle, having a plug to attach to the electrical grid. so as to grasp higher these sorts of vehicle, within the second section the principal HEV architectures are mentioned and in the third section the Plug-In HEVs are explained. Air Pollution, Fuel Cost, and Oil Demand. Emissions of gases from cars are liable for up to eighty % of the pollution in massive cities, numerous communities have passed laws that need automobile makers to scale back emissions to assist combat air pollution. More- over, air pollution may be a major issue for cities round the world, the planet Health Organisation (WHO) is revealing these days that seven million individuals died from contaminated air worldwide in 2012, which means one in eight deaths worldwide are caused by pollution. Fig.1 shows the greenhouse emission pollution trend of last years.

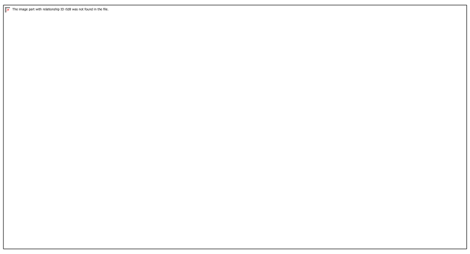

Fig 1: Global green house gas emissions

A way to scale back emissions is to burn less fuel per mile traveled. a number of the additional economical vehicles accessible today will travel forty to forty five miles per gallon of gasoline. otherwise to reduce emissions is to use different fuels. analysis on alternative fuels that manufacture less air pollution is already underway. Automobile makers are also researching electrical vehicles, that don't manufacture any emissions. However, all-electric vehicles aren't nonetheless sensible for long-distance use. Most electrical vehicles are power-driven by batteries, and may solely go eighty miles about before the batteries have to be compelled to be recharged, and recharging takes up to eight hours. World inexperienced house gas emissions Recently, many automobile makers have introduced vehicles referred to as hybrid electric vehicles. These vehicles can travel up to seventy miles per gallon of gasoline, and that they produce common fraction the emissions of a regular vehicle. So, several governments have an interest in promoting hybrid electric vehicles and alternative alternatives to standard burning engines due to considerations regarding energy security, oil dependence, air pollution, and world climate change. In fact, as oil costs rise, shown in Fig. 2, the oil demand is increasing, shown in Fig. 3, as consequence of world population growth. HEVs come through larger fuel potency than conventional vehicles, though the extent of improvement in efficiency depends greatly on the precise configuration of their system. HEV scale back the nation's state on foreign petroleum. In addition, they will manufacture 30gas emissions and emit fewer health-harming pollutants. Moreover, they can achieve up to doubly the fuel economy of conventional vehicles while not the requirement for brand new infrastructure or supplying stations, as a result of they are power-driven by a mix of burning engines and battery-operated electric motors.

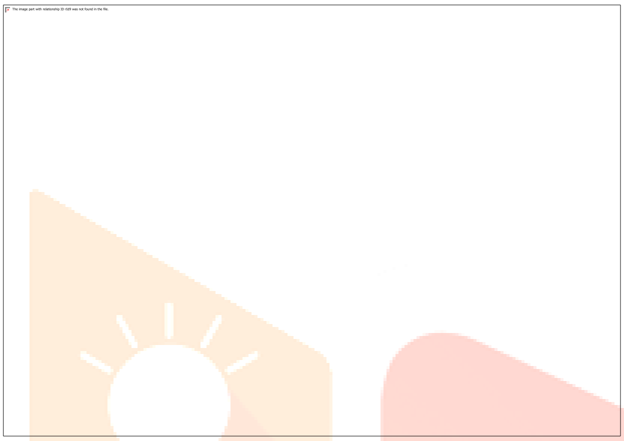

Fig.2: Historic oil costs

Fig 3: Oil consumption

III. HYBRID ELECTRICAL VEHICLES

A hybrid electric vehicle may be a form of hybrid vehicle and electric vehicle which mixes a traditional internal combustion engine (ICE) system with an electrical propulsion system. These propulsion systems may be combined in numerous ways in which to accomplish totally different objectives and, the presence of the electrical powertrain is meant to understand higher fuel economy than a conventional vehicle or better performance. The HEVs have an electrical drive train equipped with a

Fig 4: Power flow of a Hybrid electrical Vehicle.

Fig 4: Power flow of a Hybrid electrical Vehicle.Bidirectional energy device whilst, the standard burning engine is employed as a unidirectional energy source. the foremost common follow as associate HEV energy storage device is victimization an electro-chemical battery, and radical capacitors or flywheels may be integrated as a secondary energy source. The management strategy of an HEV will be designed for numerous purposes, supported the various mixtures of power flows and, so as to satisfy load requirements, the HEV can select any power flow path. This liberty to pick various power flow combinations creates abundant more flexibility of operation than the standard vehicles. Moreover, in an HEV drive train, vehicle braking energy may also be recuperated with efficiency [1]. Fig. 4 illustrates the overall construct and power flow of a typical HEV.

As illustrated within the Fig.4, considering the drive train as a mix of fuel energy and electric energy, the HEV can add the subsequent modes: ICE only drives the load; motor (EM) solely drives the load; each ICE and EM drive the load at a similar time; ICE charges the Energy Storage System (ESS) and therefore the motor (EM) propels the vehicle (series HEV); ESS is charged by load throughout regenerative braking; ICE charges ESS; ESS is charged by ICE and regenerative braking; ICE delivers power to drive the vehicle and to charge the ESS. supported totally different mixtures of electrical and mechanical traction, HEV drivetrains are divided into 3 basic architectures: series, parallel, and series- parallel hybrids [2]. the precise alternative of a HEV configuration depends on many factors as well as the sort of the application, value and weight concerns and expectations of the targeted customers. Series Hybrid electrical Vehicles A series HEV typically consists of associate ICE directly connected to an electrical generator; during this way, the electrical motor provides all the propulsion power. the electrical generator is connected to the DC power bus via a controlled power electronic converter. associate ESS is connected to the DC power bus through a bidirectional controlled DC/DC converter. The traction motor is connected to the DC power bus by a motor controller, that may be a bidirectional controlled DC/AC inverter. The vehicle controller manages power flow supported power demand and power demand from alternative elements [3]. The configuration of a series HEV is portrayed in Fig. 5.

Fig 5: HEV Series drive train

Configuration series HEV, due to no mechanical association between the ICE and drive wheels, it's doable the ICE very on the point of most efficiency. an electrical generator drives the ICE in an economical operational region to charge the ESS, as an on-board generator, maintaining battery state of charge (SOC). Thus, the control of a series HEV is less complicated compared to alternative HEV drive trains. At a similar time, multiple energy conversion exists in a series HEV: energy of the ICE is reborn into voltage via the generator; and voltage is reborn into energy via the electrical motor. Unfortunately, the inefficiencies of the generator and traction motor could cause important losses, and therefore the electric generator adds extra value and weight. as a result of the electric motor provides the only real propulsive power to the vehicle, so as to satisfy vehicle performance, in terms of acceleration and grade ability, the electric motor and the ESS should be properly sized. the most blessings are: ICE operates on the point of most efficiency; less complicated mechanism than the others hybrid; Weight may be reduced since there aren't any mechanical components. the most disadvantages are: wants a larger sized motor than the others hybrid; tough to use for general purpose. Parallel Hybrid electrical Vehicles In parallel HEVs, the ICE isn't directly connected to the generator, as nonparallel HEVs. Instead, the ICE is directly coupled to the transmission. Output forces of the ICE and therefore the EM are mechenically coupled through a torque coupler, and no energy conversion occurs. Thus, the energy loss is low, that will increase overall drive train efficiency. The coupling device might be a sequence drive, a belt drive, or a casing [3]. this sort of configuration offers freedom to decide on a mix of traction sources. By merging the 2 totally different traction sources, a smaller and additional economical ICE and smaller battery capability may be used, that reduces drive train mass. For these reasons, the drivetrain is more compact, however the ESS contains a higher size as a result of it should contain the facility from the EM and therefore the

ICE. an infatuated generator or a motor-generator can be wont to maintain the ESS in an exceedingly SOC range. The result's that the management of parallel HEV drive train is more difficult than a series HEV. looking on the position of coupling device, a parallel HEV can be divided into 2 categories: the pre-transmission and therefore the post-transmission. Fig. six and seven illustrate the various configurations. Occassionally, in an exceedingly post- transmission parallel hybrid the ICE and the EM drive separate sets of wheels, and the two torques are coupled through the road. this sort of parallel HEV provides all-wheel drive capability. The Fig. 6 shows parallel through-the-road HEV configuration. Pre-transmission configuration Post-transmission configuration Parallel-through-the-road.

Fig 6: HEV parallel drive train

Configurations the most blessings are: Has versatile operational modes; improvement of the scale of the motor and the engine. the most disadvantages are: inflated weight; difficult management logic. Power-split or Series-Parallel Hybrid electrical Vehicles The Series-Parallel HEVs incorporate power-split devices permitting that the facility ways from the engine to the wheels may be either mechanical or electrical. A basic a part of this design is that the planet wheel unit, that has a decoupling of the power equipped by the engine from the power demanded by the driver. In fact, whereas some of the generated power by the ICE is delivered to the road, the surplus power is given to the generator, and therefore the EM gets the power from the generator and the battery [3]. associate example power-split HEV design is shown in Fig 7: HEV Series-Parallel drive train.

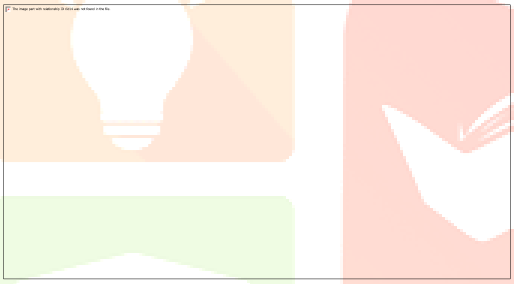

Fig 7: HEV Series-Parallel drive train.

Configuration By adding an influence split unit between the generator, the EM, and therefore the ICE, the series-parallel hybrid HEV combines 2 manner of using: the mechanical mode (parallel hybrid) and the electrical mode (series hybrid). This style guarantee edges in terms of the convenience of packaging and the reduction of overall weight; and make sure the advantages and the disadvantages of each series and parallel configurations. In addition, the complexness of the combined HEV drive train design brings a additional complicated management strategy. the most advantages are: each advantages of parallel and series. the most disadvantages are: extra mechanical connection; Higher cost; additional difficult management strategy. Plug-In HEV A plug-in hybrid vehicle is an HEV with the flexibility to recharge its energy storage system with electricity from the electrical utility grid. The PHEVs have A battery pack (or ESS) of high energy density which will be outwardly charged by connecting a plug to an external electrical power source, and may run solely with electric power for longer than regular HEVs [4]. The conversion of standard HEVs into PHEVs has been achieved, so as to extend the potency of HEVs associated thus to increase the all-electric range, either by adding or by exchange the high-energy ESS. In each cases, the battery pack should be ready to store enough voltage from external charging in addition as from regenerative braking and must be able to provide the keep electrical energy to a traction motor system. The ESS may be easy recharged by an ac outlet charger, as an example also within the garage, therefore it ought to would like of A battery charger composed of an ac-dc device with power issue correction, and a programmable digital controller with a correct voltage-current profile. It is necessary a bidirectional dc-dc device and charge-discharge profile to transfer energy between the ESS and therefore the traction motor system. edges and Obstacles of PHEVs The principal good thing about PHEVs is that the vehicle isn't any longer keen about one fuel supply. the first energy soure is electricity generated victimization totally different materials resembling coal, natural gas, wind, hydroelectric, and star energy. The secondary energy source may be a liquid fuel such as gasoline, diesel, or ethanol. the first reason to explore PHEV technology is its ability to reduce the crude oil consumption. the overall consumption benefits of a PHEV are a combination of the charge-depleting and charge-sustaining mode improvements. PHEV technology conjointly doesn't have solely benefits. The principal technical obstale considerations the ESS value, volume, and life that has got to be studied fine to be extremely usable. additional keep energy means that more miles that the vehicle may be driven electrically. However, increasing the ESS also will increase vehicle cost and means an even bigger size of the pack. Plug-in Parallel-through-the-road HEV A Plug-in Parallel-through-the-road hybrid vehicle (PTTR PHEV) has a similar configuration of a PTTR HEV with the flexibility to recharge its ESS outwardly from the electrical grid. it's simply been widely described, within the previous sections, what it means that HEV associated configuration TTR with its own blessings and disadvantages. The design is portrayed in Fig 8.

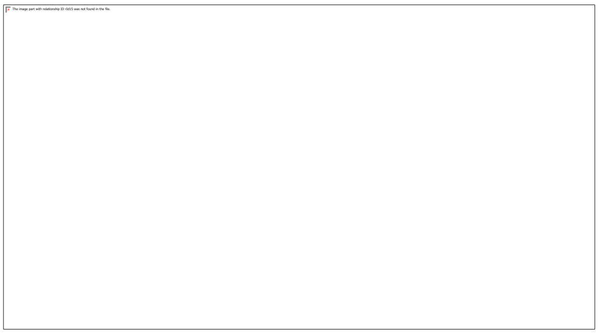

Fig 8: HEV Plug-In PTTR

Configuration ICE : the interior Combustion Engine is an engine during which the combustion of a fuel happens with air in an exceedingly combustion chamber. In an ICE the enlargement of the high-temperature and hard-hitting gases, made by combustion, apply direct force to the element of the engine, for this reason it's conjointly referred to as thermal engine. regarding the facility flow, the engine receives the fuel from the reservoir and provides the torque, controlled by the eu, to the shaft. ECU : The Engine management Unit may be a form of electronic control unit that controls a series of actuators on associate ICE, that is connected to the front axle of the vehicle, to make sure optimum engine performance. this is often doable by reading values from the engine sensors, deciphering the information victimization operation tables, and adjusting the engine actuators consequentely. HCU : The Hybrid management Unit is that the most vital a part of the entire vehicle since it's liable for ever-changing between the engine and therefore the motor. Moreover, all analog and digital signals, that govern the functions of the vehicle, are sent to the present block to be ready to be processed. OBC : The On-Board Charger works to remodel AC power, of the external electric grid, into DC power so as to recharge the electrical vehicle's battery pack. ESS : The Energy Storage Systems consists by Lithium-Ion batteries. the electrical energy is keep here, in order to be used for the electric drive of the vehicle and for the right operation of internal components. regarding the facility flow, the ESS receives the electricity from the OBC and from the Rectifier, throughout the braking and therefore the charge sustaining mode, and provides power to the DC-DC device and to the Inverter, during the electrical or hybrid mode. DC-DC device : The DC to DC device may be a class of power converters and it's an electrical circuit that converts a supply of DC (DC) from 310 voltages of the ESS to 12-24 voltages, by storing the input energy quickly so emotional that energy to the output at a distinct voltage. The cell battery configuration should give virtually a similar power all the time thanks to the fastened voltage of the battery. By introducing DC/DC converters it may be chosen and controlled the voltage variation and therefore the power to produce to the interior components. InvRect (Inverter-Rectifier): The electrical converter may be an device that converts electricity derived from the DC ESS supply to AC (AC) which will be wont to drive the electrical Motor. The Rectifier is a similar device to an inverter except that it will the opposite, changing AC power to DC power. MCU : The control Unit is a device that serves to control in some preset manner the performance of the electric motor. It might embrace manual or automatic elements for beginning and stopping the motor, choosing forward or reverse rotation, selecting and control the speed, regulating or limiting the torque, and protective against overloads and faults. EM : the electrical Motor is that the electric machine that converts voltage into mechanical energy, and operates through the interaction between an electrical motor's magnetic flux and winding currents to come up with force at intervals the motor. The EM may be power-driven by alternat current of the inverter, throughout the electric and hybrid mode of the vehicle, and {might} give power to the ESS, during the the breaking and the charge sustaining mode. it's been used the Remy HVH250 Series motor. HVAC : The heating, ventilation and air con system is liable for the cabin air condition. during this scheme, the HVAC represents all the opposite blocks that receive the facility from the Dc-Dc Converter. The PHEV and totally different HEV configurations were argued with their blessings and disadvantages. The 3 basic sorts of hybrid vehicle, the series, the parallel and therefore the power-split, have distinctive characteristics. it had been represented however these types of vehicle have similar elements however the connections utterly different. The management logic of the series hybrid vehicle is less complicated than the parallel hybrid and power-split vehicle. On the opposite hand, the parallel hybrid vehicle will have a smaller sized motor than the series hybrid vehicle, and therefore the power-split vehicle has each blessings of parallel and series, however higher cost. in conclusion the Plug-in parallel-through-the-road configuration was shown and examined.

IV. DYNAMICS VEHICLE MODELING

The longitudinal dynamics are wont to analyze the vehicle model, and a backward-looking simulation model is developed for hybrid vehicles [5], The vehicle speed, that is outlined by the driving cycle, is employed to calculate the friction force, through the vehicle dynamics; when that, the force request upstream of the casing is computed, through the driveline model; at the end, each fuel consumption and battery SOC are calculated, through the hybrid power train model. Fig 9: info flow in an exceedingly backward machine.

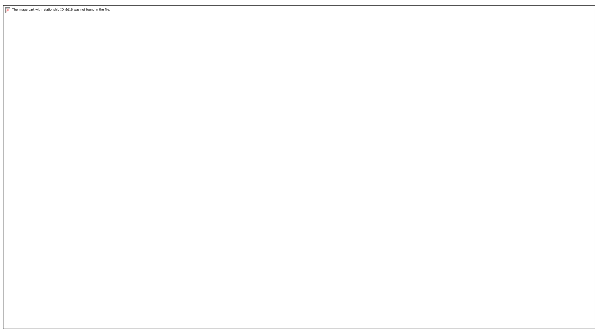

Fig 9: info flow in an exceedingly backward machine.

As simply illustrated, from the driving cycle inputs, it's calculated the friction force at the wheels as: Ftrac = Finertia + Froll + Faero + Fgrade(3.1) wherever Finertia is that the inertia force, Froll is the rolling resistance, Faero the aero- dynamic resistance, Fgrade the force thanks to road slope, Ftrac is the tractive force generated by the powertrain at wheels [6].Power Modeling regarding of the electrical power. Charge- depleting or electrical mode confer with a mode of auto operation that's keen about energy from the battery pack. Most plug-in hybrids operate in charge-depleting mode at startup, and switch to charge-sustaining mode when the battery has reached its minimum SOC threshold, exhausting the AER. there's another charge-depleting strategy referred to as blended mode, during which the engine supplements the battery throughout medium to serious loads. examination the 2 modes, there is no fuel saving, however one advantage of a blended mode is that it's going to afford the vehicle designer the chance to use a smaller and fewer pricey battery pack associated traction motor. Fig 10: Graphic trend of the SOC Fuel Consumption.

Fig 10: Graphic trend of the SOC Fuel Consumption.

The fuel consumption model may be a 3D look-up table that has the fuel utilized by the engine, supported the engine angular speed and therefore the force demanded. Thus, the management unit tells the number of fuel injected to the engine at each instance, based on this table. Adding the case wherever speed, force and fuel consumption are null, so as to think about the pure electrical mode. Overall design so as to check better the vehicle, Wayne State University's management team implemented a simulation model within the Matlab/Simulink, A in brief description is provided during this thesis to raised perceive however com- municate the vehicle blocks. A virtual driver is meant to follow a prescribed speed flight mere over time. This sculpturesque driver compares the reference vehicle speed and therefore the actual vehicle speed to create driving/braking decisions. the choice commands are sent to the controller, that determines correct actions of powertrain sub-systems. The modules represent the mechanical and electrical dynamics of the HEV powertrain, which incorporates the facility flows between the engine, motor/generators, and battery, shown in Fig 11.

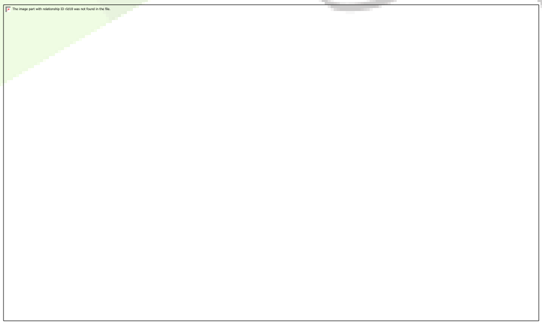

Fig 11: HEV PTTR Simulink model.

There are 2 main elements within the vehicle model: the front and therefore the rear. the primary one describes the engine power flow, wherever engine communicates with front wheel through the transmission and front differential blocks. The second describes however the battery and motor communicate with the rear wheels through the rear differential. The ESS block provides voltage for the right behaviour of DC-DC converter, HVAC, HV Heater and OBC. The forces generated by front and rear elements collaborate for the vehicle motion within the Vehicle Plant Model. inside every block there are analogic and may (Controller space Network) signals.. it's a message-based protocol, designed specifically for automotive applications. The vehicle has several electronic control units (ECU) for the subsystems: engine control module (ECM), body control module (BodyCM), transmission control module (TCM), control unit (MCU), and battery control module (BCM). These subsystems send feedback to hybrid management unit (HCU) through the Sensors. when that, these signals are wont to figure the control signals within the Controller and nosology blocks. lastly the HCU communicates with the opposite subsystems through the mechanism to get the required behaviour {of each|of each} component.

V. PHEV MODELING

Victimization Hybrid Systems the HEVs system may be divided into totally different vehicle operational modes, which might be thought-about as states, and goes from one state to a different in response to events. In every state, the vehicle dynamic system has its own continuous state area and its differential equation. Moreover, the HEV system contains many forms of dynamic behaviors, resembling switch and logic commands, continuous dynamics, distinct events and therefore the interaction between them. so as to check such complicated system, the hybrid phase space theory provides an efficient and helpful framework for HEV system analysis and design. during this paper, first off is represented a technique to study the HEV systems, and lastly it's mentioned and explained a method to model the Plug-In Parallel-through- the-road design with hybrid system theory. Hybrid System Theory The hybrid projectile systems are wont to describe systems that incorporate both continuous and distinct dynamics, however they need the most drawback within the lack of formal mathematical tools for the analysis and style of such systems. For this reason, it's introduced the Hybrid System Theory, when an summary of phase spaces. summary of projectile Systems A dynamical system describes the evolution of a state over time. bound dynamical systems may also be influenced by external inputs, which can represent either uncontrollable disturbances, or management signals. Some dynamical systems may also have outputs, which may represent either quantities which will be measured, or quantities that require to be regulated [10]. Based on the sort of their state, projectile systems may be classified into: Continuous, if the state takes values in area Rn for a few $n \geq 1$. it's used $x \in Rn$ to denote the state of a continual dynamical system. Discrete, if the state takes values in an exceedingly enumerable or finite set Q2, ...}. it's used q to denote the state of a distinct system. Hybrid, if a {part of} the state takes values in Rn whereas another part takes values in a finite set. supported the set of times over that the state evolves, dynamical systems may be classified as: Continuous time, if the set of times may be a set of the important numbers. it's used $t \in R$ to denote continuous time. Typically, the evolution of the state of a continual time system is represented by a standard differential equation. the continual time system in state area has the subsequent form: $\dot{x} = A \cdot x$ distinct time, if the set of times is a subset of the whole number numbers. it's used $k \in Z$ to denote discrete time. Typically, the evolution of the state of a discrete time system is described by a distinction equation. The linear distinct time system in state area has the subsequent form: $xk+1 = A \cdot xk$. Hybrid time, once the evolution is over continuous time however there also are discrete instants wherever some event happens. Continuous state systems may be more classified in line with the equations wont to describe the evolution of their state: Linear, if the evolution is ruled by a linear equation for continuous time, or difference equation for discrete time. Hybrid Automaton The Hybrid Automaton helps to model of these HEVs totally different system dynamics, since it's abundant descriptive power, however it's autonomous with no inputs and outputs [10]. This specific language is: Descriptive, that's be ready to capture differing types of continuous and distinct dynamics, be capable of modelling other ways during which discrete and continuous evolutions cooperate, and it doesn't enable uncertainty in non-deterministic models. Abstractable, that is be able to refine design issues for composite models to style problems for individual components, and compose results regarding the performance of individual elements to check the performance for the general system. A hybrid automaton may be a phase space that describes the evolution in time of the values of a collection of distinct and continuous state variables [11; 12]. Provinding a proper definition, a hybrid automaton H is a collection: H = (Q, X, f, Init, Dom, E, G, R) where: letter = is a enumerable set of discrete states; X = Rn is a set of continuous states; $f(\cdot, \cdot): Q \times X \rightarrow Rn$ defines the sphere $\dot{x} = f(q, x)$ for every distinct state letter $\in Q$; Init $\subseteq Q \times X$ may be a set of initial states; $Dom(\cdot): Q \rightarrow P(X)$ assigns a collection of continuous states $Dom(q) \subseteq Rn$ to every discrete state $q \in Q$; $E \subseteq Q \times Q$ is a set of discrete transitions; $G(\cdot): E \rightarrow P(X)$ assigns guard condition to each discrete transition $e = (q, q') \in E$; $R(\cdot, \cdot): E \times X \rightarrow P(X)$ is a reset map and assigns guard condition to each discrete transition $e = (q, q') \in E$ and to each state $x \in G(e)$. wherever P (X) denotes the facility set, that's set of all subsets, of X. The state of H is $(q, x) \in$ letter $\times$ X. A descriptive graph is shown in Fig. 12. The HEV dynamics are developed victimization the hybrid phase space theory [13]. The projectile behaviour of the HEV may be represented by a group of ten sets, additional formally, a hybrid dynamical system H may be a collection: H = (Q, X, V, Y, Init, f,

Dom, E, R, Φ) where: Q may be a enumerable set of distinct variables; X is a set of continuous variables; V is a finite assortment of input variables;

Figure 12: Hybrid Automaton illustration PTTR PHEV Hybrid Modeling.

Y is a finite collection of output variables; Init $\subseteq$ letter $\times$ X is a set of initial states; $f : Q \times X \times V \rightarrow Rn$ is an input-dependent vector field; $Dom : Q \rightarrow 2X\times V$ is a domain; $E \subset Q \times Q$ is a collection of discrete transitions; $G : E \rightarrow 2X\times V$ assigns guard condition to every discrete transition; $R : E \times X \times V \rightarrow 2X$ is a reset map and assigns to every $e = (q, q') \in E$, $x \in X$ and $v \in V$ a reset relation; Φ: letter $\times X \rightarrow 2V$ assigns to each state a collection of allowable inputs. Q is that the set of enumerable distinct state variables $q = \in Q$ where: q1 : begin mode. The vehicle is stopped with the motor on or off {and the|and therefore the|and conjointly the} engine off. during this mode, it also thought-about the CrankKey, that's once the driving force turns the key to start out the vehicle; q2 : electrical mode. the facility required for the propulsion is provided only by the electrical motor, in step with the state of charge of the batteries; the vehicle behaves as an electrical vehicle. This mode happens once the SOC is bigger than 25%; q3 : Hybrid mode. the facility needed for the propulzione is equipped by each the engine and therefore the motor, and the SOC is mantained between 25% and 20%. during this mode the vehicle is in cruise speed mode; this autumn : Brake mode.

The battery may be recharged due to the dynamics energy of the rear wheels throughout brake; q5 : Charge sustaining mode. so as to maintain the SOC at intervals the limits, once the charge reaches 20%, the K.E. of the rear wheels is uses to recharge the battery mechanically till 25%. is that the set of continuous state variables, outlined by x = ∈ X, respectively, representing the engine speed, the motor-generator speed, and therefore the trend of the SOC. V is the finite assortment of input variables defined by V = VD S VC where: the continual input vc = ∈ VC are the vehicle speed, the engine force and the motor torque, respectively. The distinct input vd = = ∈ VD is that the brake management signal. S is the finite assortment of output variables outlined by Y = YDYC where: the continual output yc = ∈ YC are the motor-generator and therefore the engine powers, respectively. The distinct output yd = ∈ YD representing, respectively, the active control signals once the engine is running, when the generator provides power to the motor, when the motor supplies power to the generator to charge the battery, as portrayed below: MotAsGen : Battery ←− Generator GenAsMot : Battery −→ Generator f is the input vector field. The vehicle dynamics vary in line with the various vehicle operational modes. during this model, are thought-about some assumptions. The engine starts solely throughout the Hybrid mode (it remains off during the transition between electrical and hybrid modes, as a results of braking); the engine and therefore the motor have a similar gear and the moment of inertia of the ring gear is ignored. Once the hybrid projectile system, for this specific architecture, was described, a finite graph will give a decent illustration of the distinct transitions, as shown in Fig. 13.

Fig 13: Hybrid Automaton representation for PTTR vehicle

During this paper, first off a style and analysis of {the different|the numerous} dynamics for a Plug- In Parallel-through-the-road HEV was given, by considering various doable operational modes, in terms of the hybrid system H. within the next paper, are argued and presented rule-based management for this vehicle architecture.

VI. MANAGEMENT WAYS FOR PHEV

Rule-based control strategies are basic control schemes that rely upon mode of operation. the foundations are determined supported human intelligence, heuristics, or mathematical models and generally, while not a information of a predefined drive cycle. Most of the rule-based control strategies are based on "IF - THEN" type of control rules and perform an optimal power management and an optimal fuel consumption. Thus, the powertrain controller can be divided in two parts: the supervisory control which decides the best operating mode, and the energy management which splits the demanded torque among the machines in order to satisfy the problem formulation constraints [5; 15]. Each of these controllers are described, for two rule-based controls, in the section below, and they are implemented using State Flow in Matlab, that is an environment for modeling and simulating sequential decision logic based on state machines and flow charts. Rule-Based Control The laws, that describe this control, were shown within the paper four in line with the Hybrid System modeling for the PTTR HEV. superior management 5 main states may be identified: The vehicle is stopped once the motor is on or off and therefore the engine is off. The vehicle behaves as an electrical vehicle when the SOC is bigger than 25%. The vehicle behaves as associate hybrid vehicle when it's in cruise speed mode. during this mode the SOC is mantained between 25% and 20%. The vehicle is braking and the battery can be recharged due to the dynamics energy of the rear wheels. This happens once the driving force pushes the brake pedal. The vehicle uses the K.E. of the rear wheels to recharge the battery mechanically till 25%, when the charge reaches 20%. This happens so as to take care of the SOC at intervals the bounds when the vehicle used all the battery power for the propulsion. Energy internal control looking on the state mode decided by the superior controller, the facility split among the 2 machines is decided in several ways, in line with the engine and motor-generator torques, that are the variable control input. each of the electrical and engine powers are zero. This happens once the vehicle is stopped and it's braking. solely the motor-generator power have an effect ons the vehicle. This happens within the pure electric mode, wherever the facility required for the propulsion is provided only by the electrical motor, in step with the state of charge of the batteries; and it happens throughout the brake mode, where the electric-generator power is negative. each of the motor and engine powers affect the vehicle. the facility needed for the propulzione is supplied, in equal parts, by both the engine and therefore the motor, when the vehicle is in hybrid mode; the engine power is positive and therefore the motor power is negative associated constant once the K.E. of the rear wheels are wont to recharge the battery mechanically till 25% in cruise mode. superior management There are 5 main states: The vehicle is stopped when the motor is on or off and the engine is off. The vehicle is in electrical mode when the SOC is bigger than 25% and the speed is a smaller amount than thirty five mph, that is experimental limit at intervals the battery has an optimum behaviour in real hybrid vehicles. The vehicle behaves as an hybrid vehicle when the SOC is bigger than 25% and therefore the speed is greater than thirty five mph. The vehicle is braking and the battery may be recharged due to the dynamics energy of the rear wheels. This happens once the driving force pushes the brake pedal. The vehicle uses the K.E. of the rear wheels to recharge the battery mechanically till 25%, when the charge reaches 20%, with a relentless motor torque. Energy internal control the facility split among the 2 machines is decided within the same ways in which of the previous less complicated rule-based control, except of the hybrid mode. during this state there are two cases: If the facility demanded upstream the casing is bigger than the most power that the motor will provide, then the entire power of the motor is employed for the propulsion and therefore the remaining demanded power is provided by the engine. If the power demanded upstream the gearbox is a smaller amount than the maximum power that the motor can provide, then the vehicle is in electrical mode.

VII. SIMULATION AND LEADS

In this paper are given the results of the 2 management simulations, victimization the PHEV PTTR model. so as to match the algorithms together, it's used a pre-determined force demand. when that, the 2 ways merely split a similar total torque between the two power sources, respecting the rules. The comparison of the various power split, SOC and fuel consumption enable to assess the similarities and variations among the two approaches. Drive Cycles Fuel economy and emissions are extremely influenced by the acceleration rate, range of stops, and idle time. Thus, the drive cycle contains a respectable result on measured fuel economy and emissions. This thesis uses 3 different drive cycles with varied average speeds and number of stops, since only one would not show good and complete results of each case, where the PHEV could be used. The drive cycles are described in ESA United States Environment Protection Agency website [16]. UDDS Drive Cycle The urban dynamometer driving schedule cycle simulates an urban route of 7.45 miles, with 17 stops. The average speeds is 19.59 mph. Total cycle time is 1369 seconds. It is commonly called the "LA4" or "the city test" and represents city driving conditions. It is used for light duty vehicle testing. The drive cycle is shown in Fig.14.

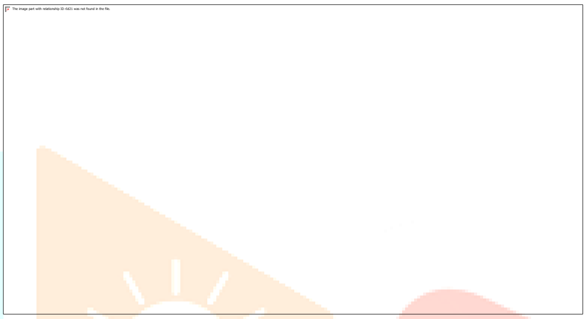

Fig 14: Hybrid Automaton representation for PTTR vehicle.

The route cycle simulates a high speed route of 10.26 miles, with no stops. the common speeds is 48.3 mph. Total cycle time is 765 seconds. It represents highway driving conditions below sixty mph. The drive cycle is shown in Fig. 16. Figure 16: HWY drive cycle using speed, brake, and acceleration signals IM240 Drive Cycle The review and mantained cycle simulates a brief route of 1.96 miles, with one stop. the common speeds is 29.38 mph. Total cycle time is 240 seconds. it's usualy used for road-side vehicle testing. The drive cycle is shown in Fig. 15.

Fig 15: HWY drive cycle victimization speed, brake, associated acceleration signals

VIII. RESULTS.

When that, a comparison between the various approaches enable to explain the variations of fuel consumption and of SOC trend. Within the last years there has been an increasing interest in plug-in hybrid electrical vehicles and their future industrial availability, thus energy management has become additional necessary and are planned many alternative architectures. the target of this thesis is to produce a bearing strategy, that aims to handle the energy management drawback for a parallel-though-the-road plug-in hybrid electrical vehicle. Thus, associate acceptable model of the vehicle powertrain is critical to check the result of any control strategy. Such model is given in paper three and is employed to figure the vehicle power and force request. the primary contribution of this analysis is that the development of a PTTR PHEV model victimization Simulink. when that, paper four provides an in depth rationalization of however the HEV dynamics are developed using the hybrid phase space theory. Finally, an optimum rule-based controller, for the planned architecture, is enforced to regulate the general behavior of the vehicle in a Matlab/Simulink/Stateflow model in order to minimize the fuel consumption, based on measured data table. It requires the definition of numerous rules of the type if-then-else and of the appropriate relative thresholds.

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