SUPERVISORY CONTROL OF AN HEV USING AN INVENTORY CONTROL APPROACH

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***Abstract*— Hybrid electric vehicles (HEV) are those equipped with two or more energy sources, usually, a fuel tank with its associated internal combustion engine (ICE) and an electrical storage system (ESS), typically a bank of batteries. In order to efficiently operate the system it is necessary to determine the instantaneous power split between the two sources when the vehicle performs a predetermined duty cycle. In this work, this problem is posed as an optimal control problem with constraints, specifically, as an inventory control problem and solved using dynamic programming (DP). Results obtained for the HEV being developed in the Applied Electronics Group, School of Engineering, National University of Río Cuarto are shown.**

***Keywords*— optimal control with constraints, dynamic programming, supervisory control of hybrid electric vehicles.**

I. INTRODUCTION

HEVs are those whose architecture includes two or more energy sources, usually a fuel tank and a bank of batteries. These energy sources are associated to energy converters such as an ICE and an electric motor respectively. These vehicles take advantage of the cleanliness and high efficiency of electrical traction and overcome its main drawback that is its low range. ESSs currently available have a low energy density. This is compensated in HEVs by the high energy density of fossil fuels, usually two or three orders higher than that of ESSs.

Energy storage elements and converters can be arranged following different topologies. Figure 1 shows a scheme of the so-called “series” configuration. In this configuration, an electric motor moves the wheels. An ESS that may consist of a bank of batteries and/or ultra capacitors feeds this motor. On the other hand, the ICE is fed by the fuel tank and drives an electric generator. This generator provides electric power to the traction motor when the power demanded by the driver exceeds that provided by the ESS. On the contrary, when the power provided by this generator exceeds that demanded by the driver, this excess is used to recharge the ESS.

Hybrid electric as well as purely electric powertrains have the advantage of "regenerative braking". This involves using the electric motors as generators during braking, transforming the mechanical energy into electrical energy. In this way the kinetic energy stored by the vehicle is recaptured by the ESS. The double arrows that connect the wheels to the ESS (see Fig. 1), represent this reverse energy flow.

For the same performance target, the ICE and ESS of a HEV can be of smaller size than those of a conventional or a pure electric vehicle. However, the whole system performance will also depend on how they interact. At first sight, it seems that the ESS should mainly perform velocity changes, taking advantage of the reversibility of the electrical path, whereas the ICE should supply the rest of the power. The nominal power of the latter should be such that it could be used most of the time near its optimal operation point. In this way, consumption as well as gas and sound emissions would be reduced.

HEVs need an electronic power manager that must determine at each instant the amount and direction of the flow in each path. This higher-level control is usually known as “supervisory control”. Power electronics devices control each particular power converter according to the commands from the supervisory control.

The coordination between sources and physical and operational limitations of the many devices involved force trade-offs. Hence for an efficient operation of a hybrid powertrain it is necessary to optimize the supervisory control strategy. An HEV designed for city use is being developed by our research group. It is in city use where the advantages of HEVs are most noticeable, because of the frequent acceleration and deceleration. The purpose of this work is to contribute to the definition of an optimal strategy for the supervisory control of this vehicle.

This problem, as an optimal control problem, may be posed in different forms depending on the objective desired, the model considered, the control action and the constraints imposed. However, there are some common features to all approaches. Concerning the control objective, it is natural to consider minimizing fuel consumption while not degrading the vehicle dynamical response. Concerning the dynamical models, they unavoidably include combinations of linear and non-linear, discrete and continuous, algebraic and dynamical systems. Moreover, they are subject to constraints not only on the control variables but also in the state