**OBJECTIVE:**

The research aims at developing a prototype of power train for electric vehicle (EV) using a dual mechanical port (DMP) motor. The DMP that will be investigated is a combination of Permanent Magnet Synchronous machine (PMSM) and Induction Machine (IM). With the combination of these two motor topologies it is expected that the new motor will have high power density. The power train will be powered by an energy pack consisting of super capacitors and batteries. A scaled down prototype will be developed and tested using Hardware in Loop (HIL) technique.

**MOTIVATION:**

The rising fuel prices and political instability in the oil rich regions is threatening the energy security of India even more than before. Hence, It is getting over more important to develop alternative propulsion technologies for public transportation. In this project an effort will be made to develop a prototype of a new efficient power train suitable for electric vehicles.

An electric vehicle power train can have multiple motor to meet better driving requirements. With multiple motors the power train requires multiple power converters and complex control system making the system complicated and also increasing the power train size. In order to overcome this drawback and at the same time exploit the advantages of the multiple motors, dual mechanical port motor (DMP) can be used. Using DMP, a given power output can be achieved with smaller size of motor, reduced weight of winding and magnet materials. DMP would thus result in increased power density, reduced losses, high efficiency and increased mileage per charge for an EV. Hence in this work research on DRM design, a prototype of the DMP, its control and associated power electronic converters will be developed.

**LITERATURE REVIEW:**

As a new type of electrical continuous variable transmission, the DMP machine is very promising in many fields, such as variable gearboxes in wind power application, multi-sourced hybrid traction and so forth [11-12]. In hybrid electric vehicle, DRM is used as variable transmission to increase the performance and achieve varied operational modes [1], [2]. A DRM can give the same output power with smaller motor size and moreover the weight of winding and magnetic materials will also be reduced [4]. Electromagnetic design,
construction and the experimental validation of double rotor permanent magnet synchronous machine mainly focusing on slot-pole-slot combinations is presented in [3]. The electromagnetic performance of double rotor permanent-magnet motor is also analyzed in [4]. In [5], electrical equivalent circuit and torque equation of DRM is developed which helps in understanding the basic operation of the machine.

The steady state operation of an interior permanent magnet synchronous is analyzed in [7] using the classical d-q model. Here the basic model of an under excited PMSM is simulated for various loading conditions. Study of motor torque and torque ripple is also presented in [8] as a function of the motor speed. From there a generalized formula of torque characteristics in terms of quantity distinctive of the motor is derived. In paper [9] losses and efficiency in the drive consisting of brushless motor operating with variable structure commutator is investigated. By using finite element field solution in the motor cross section, the electromagnetic torque of a double layer interior permanent magnet synchronous motor is also analyzed in [10]

**WORK PLAN:**
The work is divided into following work packages (WP):

**WP1: Dynamic modelling of DMP motor:**
In this work package the dynamic model of the Dual Rotor Motor (DRM) will be developed. The dynamic model considers the instantaneous effects of varying voltage / currents, stator frequency and torque disturbance. The dynamic model will be derived by using a two phase motor in direct and quadrature axis. This approach is desirable because of the conceptual simplicity obtained with two sets of windings, one on the stator and the other on the rotor. The equivalence between the three phase and two phase machine models is derived from simple observations, and this approach is suitable for extending it to model an n phase machine by means of two phase machine. The concept of power invariance will be introduced: The power must be equal in the three phase machine and its equivalent two phase models. The required transformation in voltages, currents or flux linkages will be derived in a generalized way. The reference frame will be chosen to be arbitrary and particular cases, such as stationary, Squirrel cage rotor and synchronous reference frames. Electromagnetic torque will be derived with instantaneous current and flux linkages.
**WP2: Develop model of the Entire Electric Power Train**

Here the entire electric power train model will be developed. This model consists of DC/DC converter and inverter. The three phase inverter output will be given to drive the DRM. The inverter output voltage will be controlled with the switching pulses fed by the controllers based on the energy management and control strategy. As the permanent magnet rotor speed directly proportional to the supply frequency, by changing the output frequency of the inverter, that speed can also be varied. The squirrel cage rotor will also vary by changing this supply frequency as the rotating magnetic field speed changes with the supply.

**WP3: Behavioural analysis of DMP machine under various drive cycle**

Here various standard drive cycle such as New York City cycle, European Drive Cycle, Japanese Drive Cycles etc will be used to determine the behaviour of the DMP. In this step the performance of the DMP will be investigated to the usefulness in electric vehicle applications. As two rotors are there and they can be connected together with gear, obviously more torque will be produced comparing to the size of any Induction machine or Permanent Magnet Synchronous Machine. Therefore better performance is being expected for various drive cycle with DRM.

**WP4: Analysis of the functioning of the controllers and power electronic converters**

The vector control operation of Permanent Magnet Synchronous motor (PMSM) will be implemented here for the DRM. Vector control proves and provides the decoupling between torque and flux channels in the PMSM. Such decoupling need not be the only performance requirement for a drive system. The performance measure can be a simpler control strategy, a UPF operation, a mutual flux linkage control, an optimum torque per unit current etc. These performance measures can be enforced by the stator current phase control and in many cases also provide decoupling control of torque and flux. The following control strategies will be considered in the DRM drive.

a) Constant torque angle or zero direct axis current control  
b) Unity Power Factor control  
c) Constant mutual air gap flux - linkage control  
d) Angle control of air gap flux and current phasors  
e) Optimum torque per ampere
**WP5: Estimation of the size of battery and capacitor to meet the specification**

Presently batteries are used as energy storage devices in most applications. These batteries should be sized to meet the energy and power requirements of the vehicle. Furthermore, the battery should have good life cycle performances. However, in many Battery propelled electric vehicle (BEV) applications the required power is the key factor for battery sizing, resulting in an over-dimensioned battery pack and less optimal use of energy. These shortcomings could be solved by combination of battery system with super capacitors. The battery performances can be enhanced by increasing its life cycle, rated capacity, reducing the energy losses and limiting the temperature rising inside the battery. In this work package proper size and specification of battery and super capacitor will be chosen for the drive train of electric vehicle with DRM.

**WP6: Prototyping of the DMP machine, the converters and the controllers**

In this WP the prototype of the entire power train will be developed and tested in the laboratory. The prototype will be a scaled down version of the original power train by a factor 10 to 20. For example, if the actual power train is of 100 kW rating, then the prototype will be of 10 to 5 kW rating. This reduction in size will reduce the cost and ease the measurement of the system in the lab. To test the prototype the HIL technique will be used. In this technique, the vehicle dynamic will be modeled in a real time simulator such as opalRT or dSPACE. The outputs of the HIL model will be vehicle speed, torque demand and it will be required that the physical power train meets these demands. The schematic diagram of the system is shown in fig. The flywheel and the powder brakes simulate the mechanical load of the vehicle which is driven by the DMP. The three phase DC - AC inverter coupled to the DMP turns the DC bus energy into AC energy. The energy management units and the controller of the motor will ensure that the PMSM meets the required power demand.
REFERENCES:


