Analysis of Regenerative Energy Potential in More Electric Aircraft (MEA)

Shrey Naik
M.E Student (Power & Energy Systems)
Department of Electrical and Electronics Engineering
Goa College of Engineering, Farmagudi

Nilesh Waman Shenvi Borkar
Associate Professor
Department of Electrical and Electronics Engineering
Goa College of Engineering, Farmagudi

Raghavendra Naik
Assistant Professor
Department of Mechanical Engineering
Goa College of Engineering, Farmagudi

Abstract

Optimum utilization of Electrical Energy on board an aircraft is a major concern because the aircraft technology is advancing more towards an electrically optimized aircraft. The major objective of More Electric Aircraft is that it basically uses Electrical Energy instead of conventional mechanical, pneumatic or hydraulic energy. This improves the response time of the systems on aircraft to a considerable extent and also reduces weight of the aircraft. This Paper shows how Regenerative Energy on a MEA can be used in an efficient manner rather than wasting it as Heat on damping resistors which is a norm today. Control surfaces like Flaps, Ailerons, and Rudder etc. of the aircraft are potential regenerative energy areas which can be exploited to utilize this energy in a more energy efficient manner. In MEA Electromechanical (EMA) or Electro-hydraulic (EHA) actuators are used to actuate these control surfaces which allow bidirectional flow of power and hence giving an opportunity to harvest regenerative energy. In this paper an EMA is used which consists of dc-dc H Bridge Converter, DC Motor, Rotational to Translational Interface and Aileron to show how regenerative power can be utilized with the help of Energy Storage Systems ESS. The simulation is carried out in MATLAB/Simulink and the results are presented.
Keywords- Regenerative Power, MEA, EMA

I. INTRODUCTION

Going for worldwide vitality enhancement of aircrafts, the idea "More Electric Aircraft" (MEA) turns out to be all the more intriguing for the aeronautical business. Electric gear is supplanting hydraulic, pneumatic and mechanical hardware in the spaces of impetus, control and helper frameworks [1]. Consequently, all electrically controlled subsystems get to be parts of power distribution system (PDS), which unites every electrical sources and loads of an aircraft by power distribution bus framework.

In Contrast to conventional aircrafts the MEA will be more efficient, responsive and reliable at the same time it will also reduce the maintenance cost. Ordinary flight control actuation, known as fly-by- wire, is controlled electrically, however fueled powerfully, these frameworks depend on a complex circuit of high pressure hydraulics running all through the aircraft to supply the pressure expected to move every control surface. The objective of power by-wire [2] is to essentially decrease or dispense with through and through the water driven association, and its related dangers, by giving electrical power straight to the actuation mechanisms. Electro-mechanical (EMA) and Electro-hydrostatic (EHA) flight actuators are utilized as a part of a more electric aircraft rather than customary pressure driven actuators with a focal fluid powered framework [3,4]. The EMA and EHA utilize motors powered from power distribution bus [5] through inverters.

Presently the aeronautical industry dissipates the regenerative energy from the EMA in damping resistors which require additional cooling systems which are bulky and at the same time expensive. This paper shows how this regenerative energy can be channeled in a more efficient way using ESS. This reduces the weight, improves the efficiency and reliability.

II. REGENERATIVE ENERGY HARVESTING SYSTEM

The Regenerative Energy system consists of the Power distribution system, EMA and the ESS. The synchronous generators on board the aircraft produce AC power which is converted into DC power by a rectifier. The input side of the EMA is fed from the rectifier through a Filter which attenuates noise. The energy storage system (ESS) is connected to the DC bus and regenerative power is stored in it and utilized whenever necessary. For this purpose, a bidirectional dc-dc converter with high power density and efficiency is needed. Many topologies are available and can be used for this purpose but the H bridge has 4 quadrant working capability hence it is used for simulation in this paper. Fig.1 depicts the System.
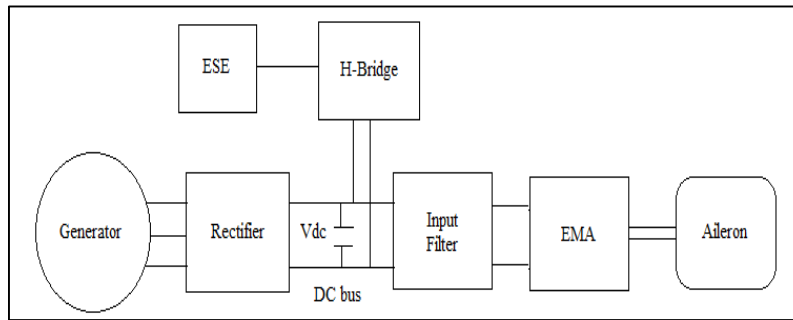
Fig. 1: Block Diagram of Regenerative system

III. DESIGN OF CONTROL SURFACE IN MATLAB/SIMULINK(AILERON)

Aileron is a control surface which is used to roll the aircraft in either direction and is basically depicted as an airfoil. EMA is used to actuate this control surface in MEA and regenerative energy in this part is harvested. The aileron model is simulated in MATLAB/Simulink using Sim-mechanics tool and is further integrated with the controller and converter. The Figure for aileron physical model is shown in FIG.2.
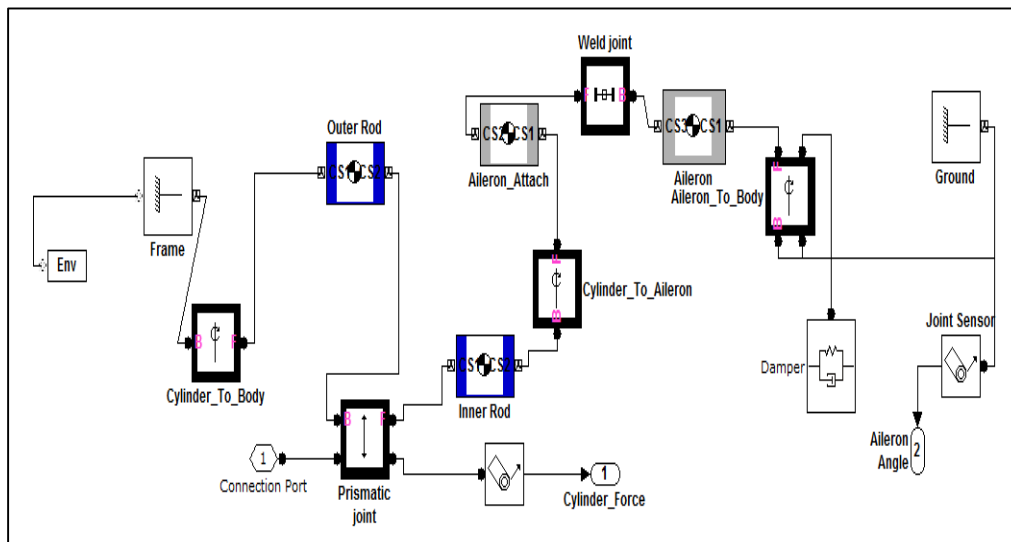

Fig. 2: Aileron Model

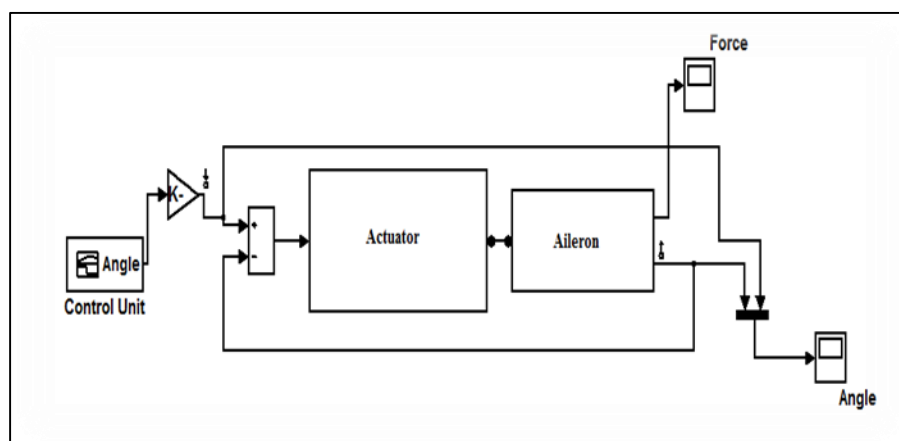## IV. H-BRIDGE CONVERTER AND CONTROLLER

Fig. 4: Control Block of EMA

An H-Bridge converter consists of four switches which are connected in bridge configuration. The most important characteristic of this converter topology is that it can be used in all four quadrants hence it is a suitable choice for EMA and regenerative power

management systems. For the purpose of this paper the converter is used with a control strategy to control both speed and current of motor.

The outer loop is the speed loop and inner loop is current loop and both are controlled using a PI regulator. The Fig below shows the Converter with its controller interfaced to a DC motor.
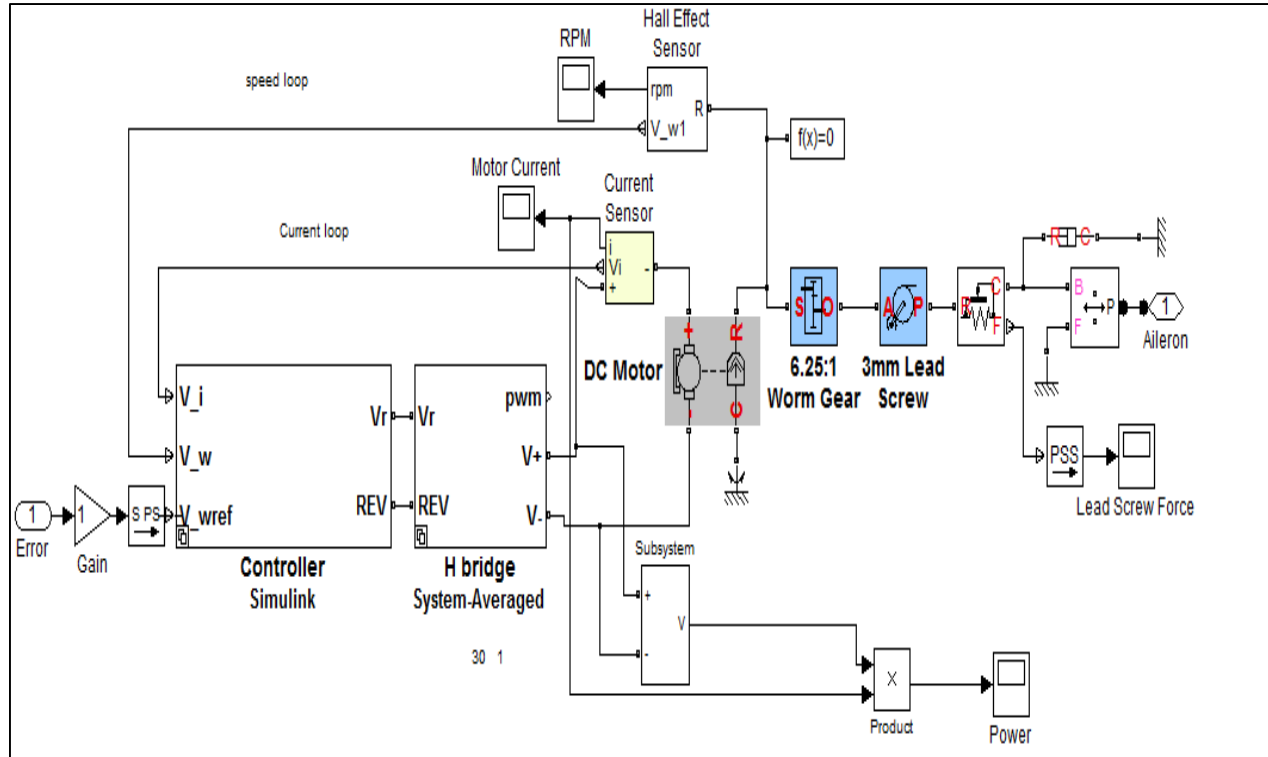

Fig. 3: H-Bridge and its controller

As can be seen in the Fig.3 the load connected to the motor is the aileron but the rotational motion of motor shaft is converted into translational motion using a lead screw and the torque is increased using the Worm Gear of 6.25:1 ratio.

Regenerative power is calculated by multiplying current drawn by motor and the terminal voltage produced by the H-bridge.

V. ELECTRO-MECHANICAL ACTUATOR(EMA)

Electro-mechanical actuators use electric motors instead of other drivers for actuating the desired surface. EMA's have a very high efficiency compared to pneumatic, hydraulic or mechanical actuators and in Fig.4 the simulation control diagram of EMA is shown. The control unit sets the Angle to be tracked by the aileron. Using a proportional controller this angle is tracked whereas the controller of motor regulates the speed and current. Force on actuator and angle tracked by actuator is plotted and shown in Fig.5 and Fig.6.at the same time the plots for electric power and motor speed is also plotted to show regenerative potential in the system.
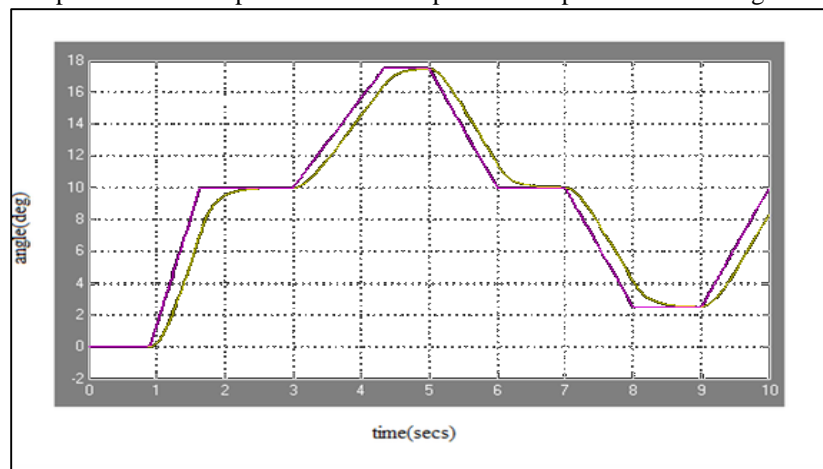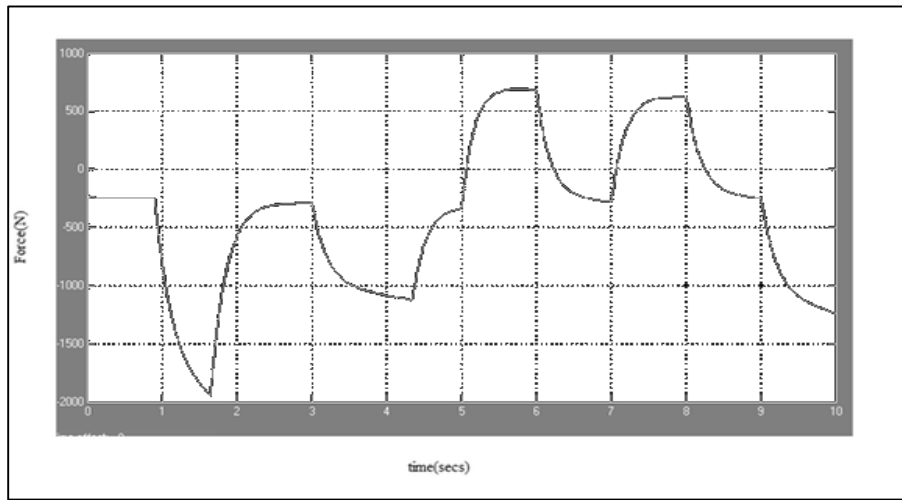

Fig. 5: Angle Plot

Fig. 6: Force on Aileron

VI. POWER CURVES AND ANALYSIS

Plot of DC motor electric power is given in Fig.7.from the plot it is evident regeneration is possible and hence it is also harvestable.at the same time a good energy storage system can back this configuration. Various power management strategies can be used in this type of system but load following strategy works the best. In load following strategy use of ESE is minimized hence capacity of ESE on aircraft is reduced considerably. This reduces the cost and improves efficiency. Load following strategy appears to be most suitable for MEA, Load following curve is shown in Fig.8.
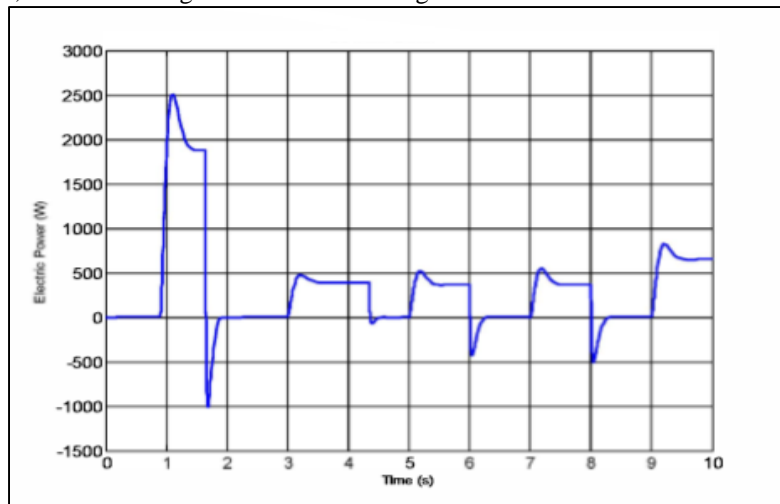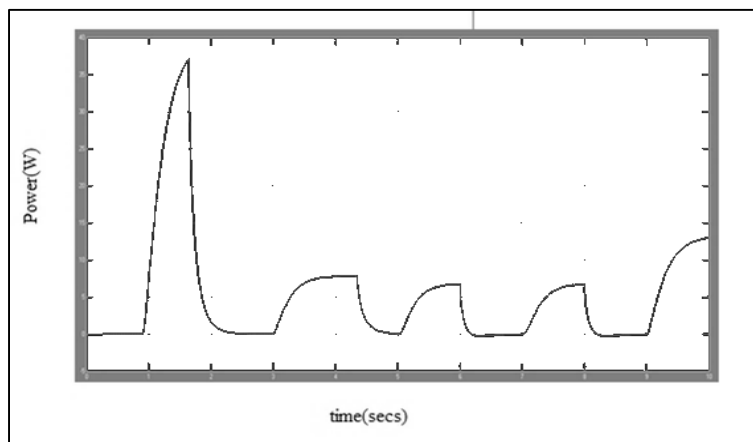

Fig. 7: DC motor Power

Fig. 8: Load Following curve

VII. CONCLUSION

From the simulation results and extensive literature, it can be concluded that the regenerative energy on MEA is not only harvestable but also economical. The potential area of regeneration on MEA are the control surfaces of the aircraft which direct the aircraft in desired direction and at the same time are actuated by Electromechanical actuators.

It is also seen that a proper energy storage system is required to store this energy and then utilize it for further use on aircraft.

The aircraft aileron was designed and its control system was tuned to track the desired angle as shown in Fig.5.The DC motor power clearly shows regeneration in Fig.7 and hence the simulation results are supporting the theory of extracting regenerative energy on MEA. The regenerative power occurs as a transient disturbance on the DC bus and results in intolerably large voltage swings on the bus. If this part of energy is not utilized well, it may damage the flight control actuation and other loads on the DC bus. Hence, the individual component design must take into account the system level transient phenomena that occur due to the process of the regeneration of power.

Regeneration can occur both when an actuation method is requested to process a reference movement with aiding aerodynamic forces and when a quick response from an actuator is requested resulting in a high cost of deceleration. Within the first case the supply of regenerative energy is an aerodynamic drive that acts on the flight surface in the identical path because the actuator action. In the second case the regenerative energy comes from energy saved in the inertia of the relocating actuator's elements.

ACKNOWLEDGEMENT

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