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Model and Control Development of Hybrid Fuel Cell and Battery Power System for UAS (Quadcopter)

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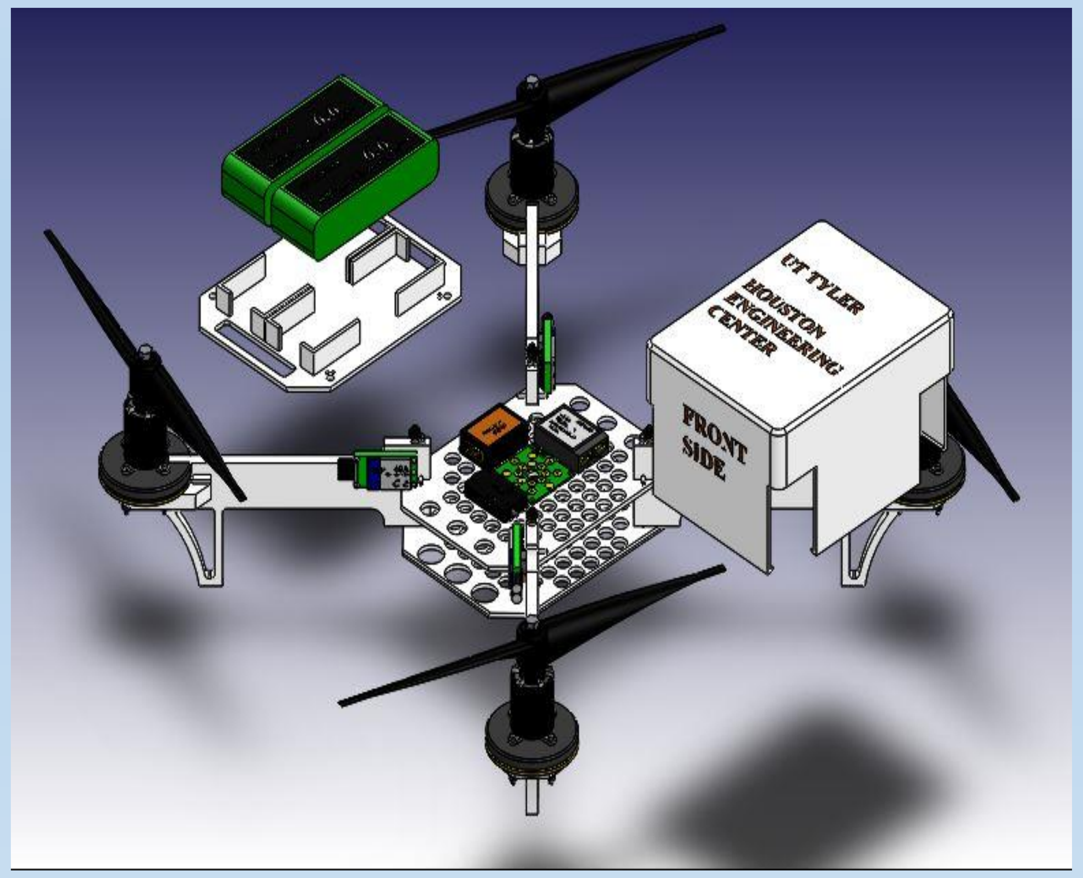
BACKGROUND

- With the advent of reliable technologies and ease of maneuverability, Unmanned Ariel Systems (UAS) are finding ways toward various fields including disaster relief, and hazard inspection at plants.
- Since applications of UAS are increasing, there is more concern about the reliability and durability of the flight given current battery-powered UAS are only limited to maximum flight time of 30 to 45 minutes.
- With the use of hybrid combination of fuel cell (FC) and battery, the UAS becomes environmentally friendly system and *flight duration can significantly increase, up to 3 hours*.
- With the use of Model Predictive Control (MPC) over classical PID controllers, the system can achieve robust control of motor speed and enhanced power management.

Quadcopter Model



A student design team built quadcopter and shared this model for analysis

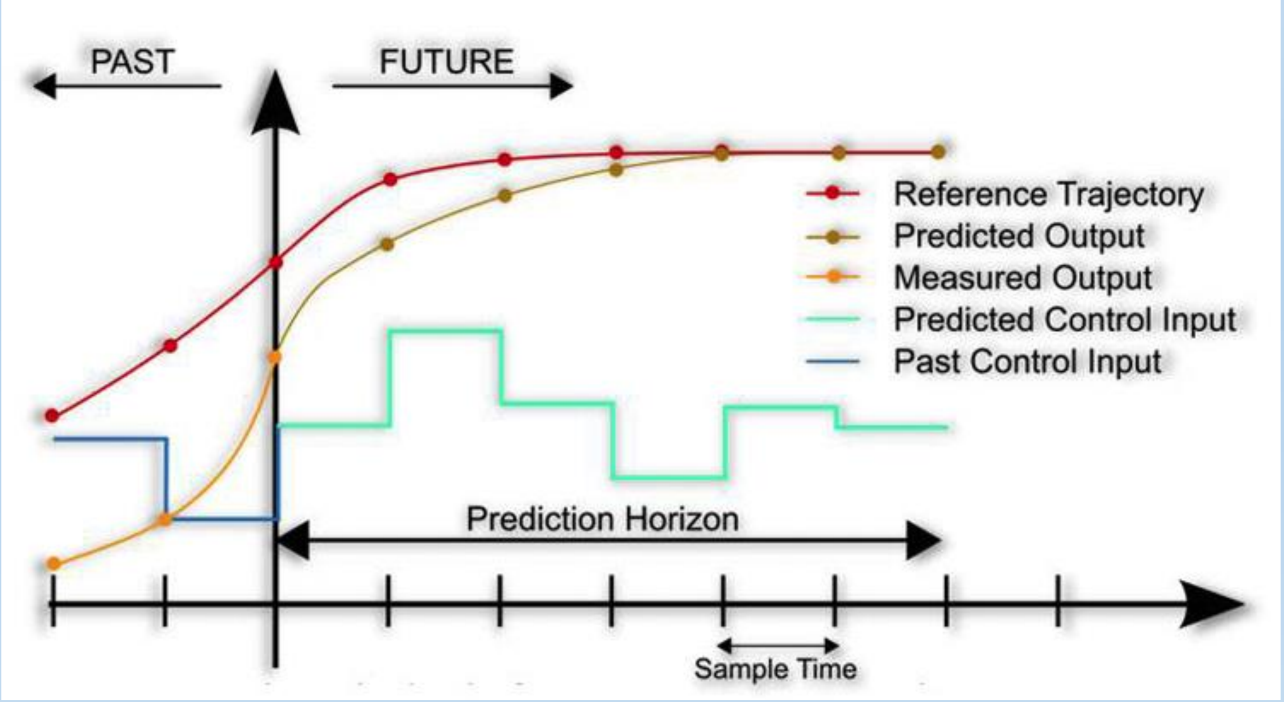
PURPOSE

- To model UAS motors, FC and battery using given specifications.
- To develop and tune controllers for controlling motor speed and improving FC and battery power management.
- To compare system performances for PID and MPC control architecture.

METHODS

- Due to their maturity and reliable performance, *hydrogen FC and Lithium Polymer (LiPo) battery* are chosen and modeled in Powersim or PSIM® and MATLAB & Simulink®.
- Due to non-linear dynamic behavior, classical PI controllers were employed to control output of the two power sources and control speed of 4 Brushless DC (BLDC) motors (operates at 12-24V) separately.
- For comparison, MPC is employed to system outputs for power management and motor speed control.

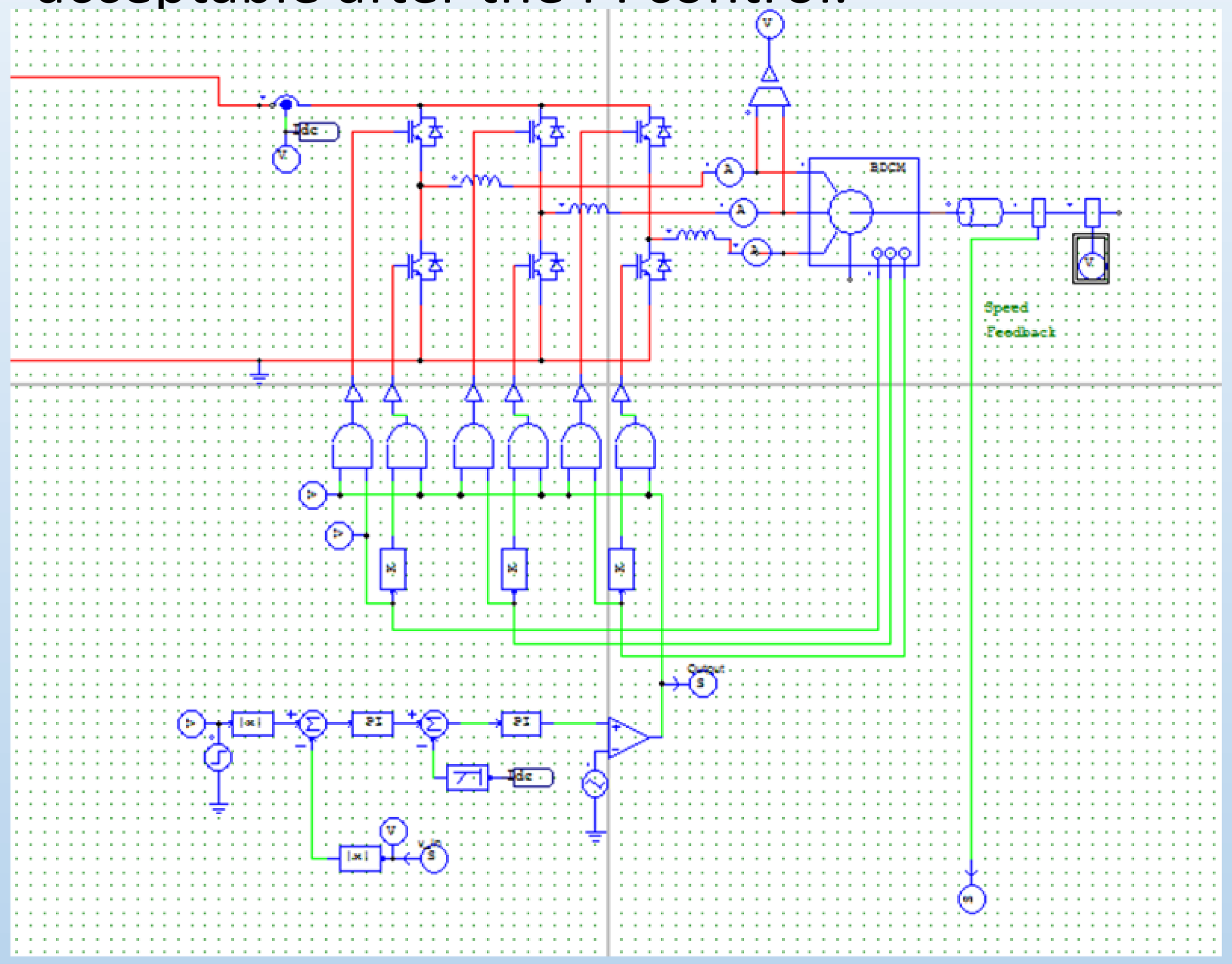
Principle of MPC



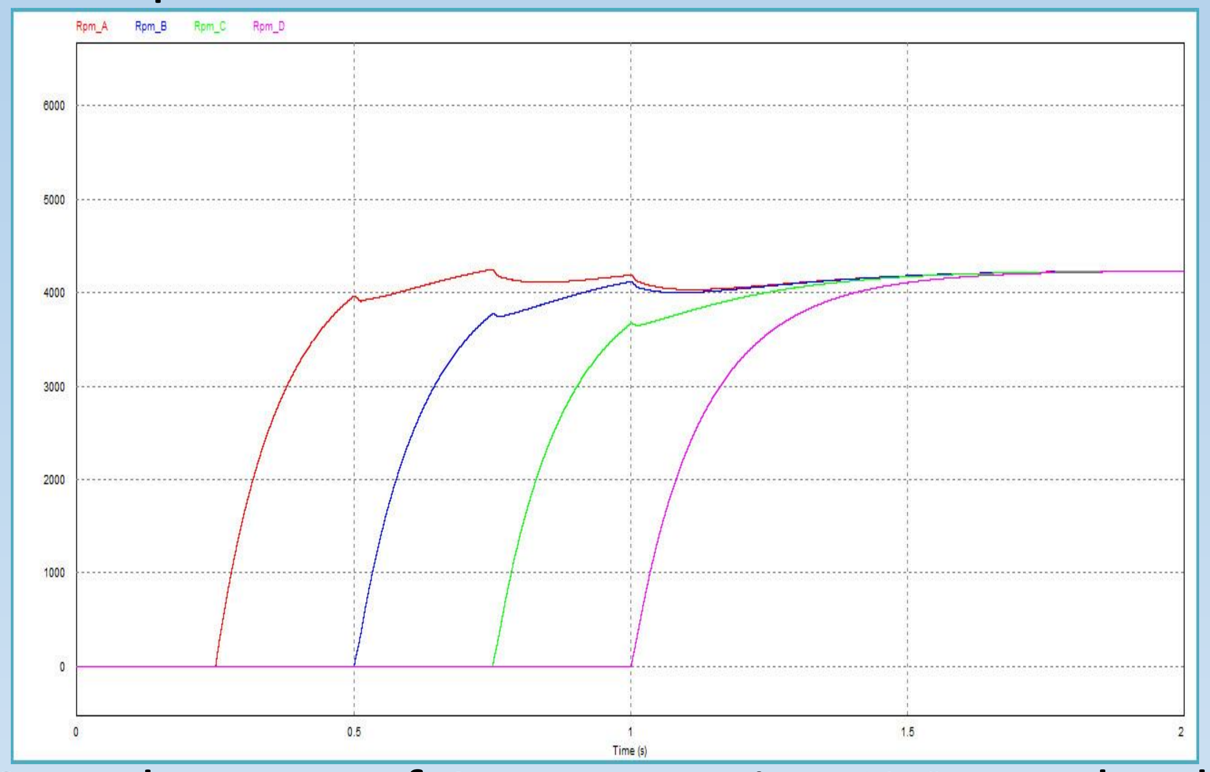
MPC is suitable to centralize control strategy for processes with nonlinear dynamics like fuel cell, and a highly interacting multiple variable system.
Reference: Aspen Technology, Inc.

SIMULATION & RESULTS

- Voltage and current outputs from FC and battery models showed accurate design comparable to literature specifications including *200 W delivery needed to operate Quadcopter*.
- At selected operating speed of *4200 rpm*, 4 BLDC motors were powered by LiPo battery only at startup and then FC only at about 20 V after warm up.
- During the transition period from battery voltage to FC voltage, ripple was seen in motor speed, which was minimized using PI control.
- Rise time and settling time was acceptable after the PI control.

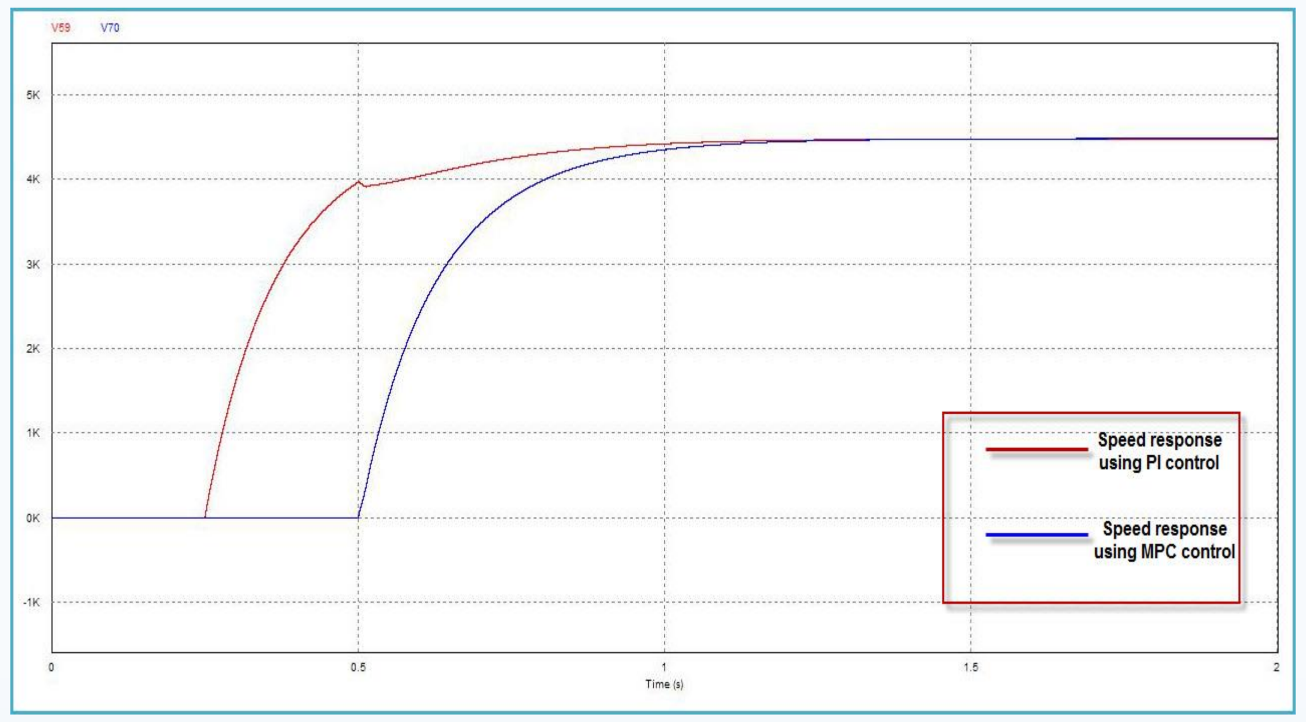


Example of a motor with PI control in PSIM®



Speed output of 4 motors using PI Control only

- *Application of MPC on the motors was able to eliminate the ripple that was seen for PI control,* but it added delay.



Comparison of motor speed control strategies

CONCLUSIONS

- A reliable hybrid fuel cell and battery powered UAS system-level model was simulated to provide continuous power to 4 BLDC motors, used in the designed Quadcopter, using PSIM®.
- With the use of MPC, a slight improvement was observed in the speed control of motors.
- Submission of collaborative, spin-off proposals to Google Faculty Award and NASA T&I Innovation Grant.

FUTURE WORK

- Further in-depth analysis of MPC and PI control strategies on motor speed and power delivery.
- Submit year-end report of full analysis.

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