OAK RIDGE NATIONAL LABORATORY
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FACT SHEET

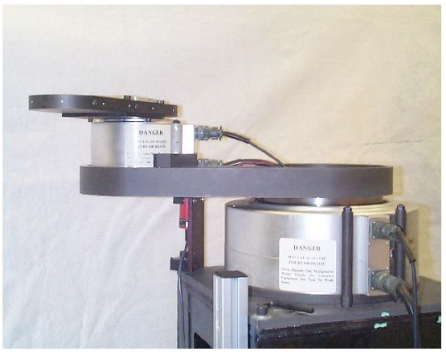
ESTD
Engineering Science & Technology Division

ROBOTICS AND ENERGETIC SYSTEMS RESG GROUP

Improving the Energy Efficiency of Industrial Controllers

Based on Energy-Limiting Control Designs

A promising means to improve the energy efficiency of industrial processes and machinery is to develop controllers that require less power. Traditional industrial controllers exploit linear feedback to provide local stability of the process (e.g., proportional integral derivative (PID) control). These controllers require excess control energy because constant high-gain feedback is required to provide stability and robustness to the system dynamics. To reduce the overall energy consumption of the system, a feed-forward component can be incorporated in the control design to accommodate for the system dynamics. By including a feed-forward component in the design, more knowledge of the system dynamics is incorporated, resulting in less energy consumption for equal performance (i.e., constant high-gain feedback is not required to ensure stability).



The following table compares experimental results obtained by applying preliminary amplitude-limited control designs and a benchmark controller (each with an adaptive feed-forward control component) to a 2-link robot manipulator. The table indicates that the new amplitude-limited controller results in a reduction of maximum required torque by a factor of 8-10 for equal performance.

	Energy-Limited Controller		Benchmark Adaptive Controller	
Max. final tracking error (deg)	Link 1: 0.08,	Link 2: 0.06	Link 1: 0.1,	Link 2: 0.1
Time to reach a 2% envelope (sec)	Link 1: 0.56,	Link 2: 0.42	Link 1: 1.03,	Link 2: 0.46
Maximum Computed Torque (Nm)	Link 1: 168.0,	Link 2: 25.5	Link 1: 1343.0,	Link 2: 246.0

Disadvantages of standard industrial controllers:

- No intelligent control component.
- Require excessive energy to account for worst-case system disturbances.
- Large errors can drive system actuators into saturation.

Advantages of intelligent energy-limited controllers:

- Compensates for model uncertainty.
- Limits the maximum power required by a controller to an a priori selected limit.
- Leads to a reduction in the root-mean-square of the energy consumption by the controller.
- Only requires software upgrades to current industrial controllers, leading to a more pervasive impact than hardware modifications that require industrial investments and production downtime.
- Preliminary work in amplitude-limited controllers has been proven to reduce the maximum required motor torque by a factor of 8-10.

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