Example of One Page Concept Paper

Executive Summary

Dynamic Capacitive Wireless Charging System for Autonomous Material Handling Vehicles

Khurram Afridi
Associate Professor
Electrical and Computer Engineering
Cornell University

Motivation: Warehouses and factories are being transformed by electrically powered autonomous material handing vehicles (AMHVs), which swiftly pick and carry material from one place to another, dynamically navigating obstacles and human co-workers, and dramatically increasing productivity. The limited energy capacity of batteries is a major hurdle in achieving the full productivity benefits of AMHVs. Currently, these vehicles are taken offline and plugged in for recharging, or their drained batteries are swapped with pre-charged ones. Both approaches impose substantial additional costs and require additional space due to the need for spare vehicles or batteries. An alternative approach is to charge AMHVs wirelessly from the floor while they are performing their tasks, including when they are in motion, i.e., dynamic wireless charging. This substantially increases productivity and reduces the need for on-board batteries (decreasing costs). Unfortunately, state-of-the-art inductive wireless charging solutions are expensive and do not scale well for dynamic applications.

Objective: The objective of the proposed research is to dramatically improve the cost-performance tradeoff for dynamic wireless charging systems through fundamental advancements in high-power dynamic capacitive (as opposed to inductive) wireless charging systems, develop a 3.7-kW dynamic capacitive wireless charging system capable of in-motion charging of AMHVs, and utilize this to demonstrate the techno-economic feasibility of delivering high constant power at high efficiencies to vehicles traveling at speeds appropriate for AMHVs in warehouses and factories.

State of the Art: Researchers have traditionally focused on inductive wireless charging, which uses magnetic field coupling between coils, to transfer energy. A major shortcoming of inductive wireless charging is that for magnetic flux guidance and shielding, it requires expensive and brittle ferrite cores, making it expensive, bulky, and difficult to embed in the floor. My group has recently developed a capacitive approach for wireless charging that utilizes electric field coupling between plates to transfer energy. The relatively directed nature of electric fields eliminates the need for ferrites or dielectric materials, allowing the capacitive system to be much smaller, lighter, less expensive, and easier to embed in the floor. The capacitive wireless charging approach is especially suited for AMHVs since its lower profile compared to inductive systems allows it to fit in the limited space underneath the AMHV chassis.

Intellectual Merit: To achieve the goal of high-performance cost-effective dynamic wireless charging systems for AMHVs, a number of innovations and fundamental advances are proposed in this effort. The novel approach of absorbing parasitic capacitances into split-inductor matching networks will enable compact wireless charging systems capable of delivering high power at high efficiencies. The metasurface based field-sculpting capacitive coupler concept introduced and developed here will drastically reduce fringing fields, enabling much higher levels of power without safety and electromagnetic interference concerns. Finally, the study of the design-space of the new "active variable reactance" (AVR) rectifier, which can compensate for large misalignments and distance variations while operating at fixed frequency, will enable dramatic advances in delivering high constant power to moving AMHVs.

Impact: Dynamic capacitive wireless charging of AMHVs presents a new opportunity for cost reductions in warehouses and factories through increased productivity. Our preliminary analysis suggests the possibility of substantial cost reductions through reduced downtime with the use of dynamic capacitive wireless charging instead of wired charging in warehouses. Our work to date demonstrates the tremendous potential of dynamic capacitive wireless charging systems in enabling efficient, high power transfer density, low profile, light weight, cost effective wireless charging of AMHVs from the floor. The proposed technologies promise major improvements in power transfer capability, size, efficiency, range, and safety of dynamic wireless charging systems for AMHVs. These advancements would result in the need for fewer and further-spaced wireless charging pads, making the technology even more cost-effective, and help accelerate the adoption of autonomous AMHVs by making them less expensive, truly autonomous, and more productive. This will revolutionize warehouse and factory automation.

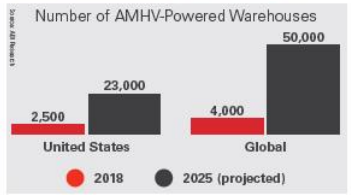
Mini-poster or illustrations

DYNAMIC CAPACITIVE WIRELESS CHARGING SYSTEM FOR AUTONOMOUS MATERIAL HANDLING VEHICLES

Khurram Afridi | Cornell University

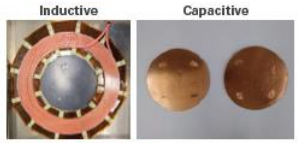
MOTIVATION

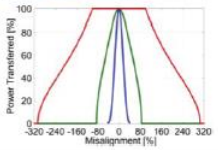
+ Low energy density of batteries limits productivity benefits of autonomous material handling vehicles (AMHVs)
+ Dynamic (in-motion) wireless charging can increase productivity and reduce the need for on-board batteries

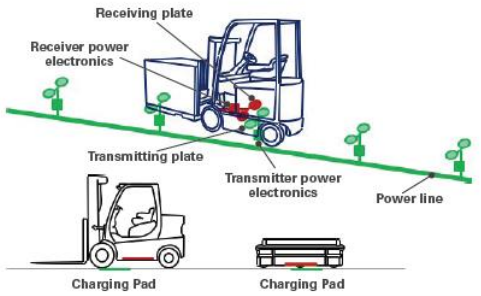


	WIRED CHARGING	DYNAMIC CHARGING
CHARGING TIME	12 hr	0 hr
OPERATING TIME	12 hr	24 hr
NUMBER OF VEHICLES	200	100
COST OF VEHICLES	$6,000,000	$3,000,000
COST OF BATTERIES	$450,000	$45,000
COST OF CHARGING INFRASTRUCTURE	$75,000	$750,000
TOTAL COST	$6,525,000	$3,795,000
COST REDUCTION		42%

OBJECTIVE: Develop dynamic capacitive wireless charging system capable of in-motion charging of AMHVs







PRELIMINARY RESULTS