Unique Challenges in Low-Voltage Caterpillar Drive Vehicles

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What comes to mind when you imagine a typical agricultural field, vineyard or orchard? You might picture narrow, long rows of dense crops, uneven soil, water puddles and mud, and the occasional animal running about. Navigating such an environment is certainly different than navigating the roads in town, and so any vehicle designed to operate in an agricultural setting has to easily handle all of the difficulties presented by such a tough landscape. This is the challenge of today's agricultural vehicle designers in a nutshell. Specifically, the complications of driving through such terrain have led engineers to the conclusion that specialized drivetrain designs are the only way to deliver reliable vehicle solutions into this market. More so, as vehicle operations became more automated and entire vehicles even perform their tasks autonomously, the need for ag-vehicle specific drive solutions is greater than ever.

To categorize the challenges found in low-voltage caterpillar drive vehicles, let us categorize the discussion into these topics:

- Route Adjustment
- Speed Control
- Off-Road Environments
- System Safety
- Unique Applications

Below we will talk through each one of these points, offering a description of the particular technical challenge faced in the design of agricultural vehicles, and then we'll outline ways that these conditions can be addressed with specific modern drivetrain technologies.

Route Adjustment

There is no such thing as a straight path on an agricultural site! Potholes, uneven ground, tree wells, mud puddles, and any other surface obstruction can all cause an autonomous vehicle to venture off course. This is a primary design consideration for all tracked vehicles, to be able to make tiny but precision trajectory adjustments smoothly, without stopping the vehicle, and without lurches in speed or position.

Traditionally, hydraulic drive power has been used for caterpillar track vehicles, but the pressure gradient and sheer mass of hydraulic power plants make precise route adjustments practically impossible. Modern vehicles have replaced hydraulic drivetrains with electric Permanent Magnet Synchronous Motors (PMSMs), which is the same motor technology found on electric passenger vehicles such as Tesla's Model 3 car. While these brushless, high torque motors are fantastic for low-weight, distributed track power, their true value in precision steering is achieved only when coupled with an advanced Inverter / Controller. A caterpillar-specific inverter allows for very precise, high torque rotational control, allowing one of the vehicle's tracks to pull out of a low or high point in the ground, and realign the vehicle smoothly with angle adjustments measured in fractions of a degree.

Speed Control

When a tracked vehicle is brought off-course by uneven terrain, the special inverter and controller set mentioned above solve our problem by offering precise realignment. Besides these 'reactive corrections', we also have the persistent issue of maintaining proper vehicle trajectory as a function of the speeds of each caterpillar track. In other words, if one of the tracks on the vehicle is traveling at a slightly different speed than the other track, the vehicle will drift to one side. This creates the need for continuous speed regulation not just of the vehicle overall, but of each track, and therefore each motor powering the various drive sprockets in each track. This could require the very precise synchronization and tiny ongoing adjustments of multiple motors, occurring very frequently throughout the vehicle's travel.

Implementing a solution here requires a few different techniques. First, the motor controllers and motors must all be synchronized using active feedback on motor speeds, motor torques, shaft speeds (through gear reduction), shaft positions, and track speeds. Speed and course settings must be polled at high frequencies (multiple times per second), filtered for bias and large deviations, and then translated into specific motor adjustments. To do this, a high-powered microcontroller, multiple onboard sensors and motor registers, and real-time vehicle positioning systems must be utilized. Over time, system calibration and proper maintenance must also be employed to keep these systems working accurately. A self-checking system to alert of maintenance needs is even better yet.

Off-Road Environments

Beyond terrain differences alone, an agricultural vehicle must also handle wide variations in operating conditions brought on by environmental factors. In dealing with environmental variables, we start with the initial design of the system and selection of its parts. Just as it's important to synchronize and assure the correct RPM and torque at each motor shaft, it's just as important to assure that this energy is being consistently and evenly applied to the vehicle track. The mechanical system employed in gear reduction from the motor and through sprockets to drive the track has to offer low slip, low deflection, and high torque changes consistently over the life of the system.

Further, the design of the drivetrain should include features that protect and assure such requirements of the mechanical drive system are met, warding off impacts from hard climate and off-road use. Excessively hot or cold temperature, moisture, dirt and debris should not affect the performance of this mechanical system. Ways to serve these needs include: implement a drivetrain with a high-quality tachometer on each drive shaft, utilize non-clutched bidirectional continuous variable transmission (CVT) technology, select materials for their corrosion-resistant properties, and limit selection of components that require spare parts or frequent maintenance.

System Safety

As the autonomous vehicle industry moves beyond its hydraulic roots into electrical drive and electronic control solutions, the dilemma of providing ample torque to independent tracks remains. Most modern electric agricultural vehicles use powerplants in the 450 Volt range, using high voltage fed to asynchronous motors to provide high motor torque on demand. Both the presence of high voltage electricity and the asynchronous motors are not ideal for the confined, variable landscapes of agricultural sites. The alternative and preferred solution is to couple a low-voltage powerplant with the mechanical power transmission concepts mentioned above. This approach allows for a much lower operating voltage – astonishingly, a 48 Volt powerplant coupled with a cutting-edge wiring and control scheme allows today's drivetrains to achieve maximum motor torque at zero RPM, solving the need for pre-loaded high volt torque found in high-voltage systems.

The achievement of a 48 Volt powerplant is not just a benefit to operator and maintenance safety, but also to general safety while the system is in use. With low motor RPMs, synchronized and directly controlled motor torque, precise trajectory adjustment, and ultra-fast response times, an agriculture vehicle using the described advanced drivetrain features is safer to work around and be in the presence of overall. The days of lurching hydraulic drives with loud gas-powered engines, or very heavy 450 Volt electric chassis that risk run-away gliding in wet terrain, can be put behind us.

Unique Applications

The benefits of using an advanced low-voltage drivetrain allows vehicle designers an ever-increasing series of opportunities for future advancements. With safer, lighter, more nimble agriculture vehicles, fully autonomous and semi-autonomous navigation options become increasingly attractive. A common option provided by these drivetrains is the use of 'Follow-Me' technology. With Follow-Me navigation, a semi-autonomous vehicle can carefully track and follow a walking human or another vehicle, transporting tools, equipment, or performing automated tasks along the way. Stepping up to fully-autonomous navigation, GPS and onsite transponder technologies can allow agriculture vehicles to perform entire workflows without intervention, fulfilling long-duration tasks even across concurrent days or weeks. All of these features are afforded by a custom-designed, agriculture vehicle specific drivetrain based on the technology described in this article.

PeK Automotive's EV48 Drivetrain – Solving All of the Above Challenges in One Package

Now that you are familiar with the possibilities achievable with a cutting-edge, customized ag vehicle drivetrain, you might wonder how to implement these benefits for your next ag vehicle project. PeK Automotive Company is an Engineering Manufacturer in the Autonomous Vehicle market, and we proudly offer our EV48 Drivetrain System, offering all of the benefits described above. Our EV48 Drivetrain includes:

- Brushless Motors
- Continuous Variable Transmission
- Mechanical Drivetrain
- 'IntEn' Power Inverter
- 'IntC' System Controller
- Multiple accessory options such Follow Me modules, remote controls, power and battery units, and more

Whether you're a vehicle designer working on tomorrow's generation of caterpillar drive vehicles, or a vehicle owner looking to upgrade your existing fleet, PeK can assist in customizing, providing, installing, and operating an EV48 Drivetrain System specific to your needs.

Whether you choose to purchase from PeK or not, the features we have written about here found in a modern low-voltage drivetrain match the direction we envision the autonomous vehicle industry to follow into the future. We hope that this information is helpful to the design, purchase, or use of electric track-driven vehicles. We invite you to visit our System Evidence web page here for more information.

For more details on PeK Automotive's EV48 Autonomous Vehicle Drivetrain technology and solutions, please visit http://48ugv.com/, see our demonstration videos here, or contact PeK Automotive Slovenia at info@pekauto.com, +386-307-77-050.

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