Innovative Idea

A Variable Frequency Drive Trainer for STEM Integration in Agricultural Mechanics

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Introduction and Need for Innovation

Agricultural mechanics is an important component of school-based agricultural education programs (McCubbins, Wells, Anderson, & Paulsen, 2017). Professional standards (American Association for Agricultural Education, 2017) require teachers to "be aware of cutting edge technology" (p. 2) and to "teach students how to use technology appropriate to the agricultural industry" (p. 2). Additionally, Stripling and Ricketts (2016) identified integrating STEM in agricultural education programs as a priority for the profession. Writing almost 20 years ago, Shinn (1998) identified the paradox of rapidly increasing applications of technology in agriculture coupled with a "decreasing emphasis on technology in . . . secondary agricultural education programs" (p. 2). Experts perceived that agricultural mechanics was low tech, used outdated equipment, did not address higher-level technology skills, and ignored emerging areas such as electronics and electrical controls (Shinn, 1998). We developed the instructional model described in this poster as an aid to integrating STEM-based, advanced electrical control applications into high school and university agricultural mechanics programs.

How it Works

The speed (RPM) of an alternating current (AC) induction motor is determined by the number of poles in the stator windings and the frequency (cycles per second) of the applied AC voltage. As its name implies, a variable frequency drive (VFD) controls motor speed by altering the frequency of the voltage supplied to the motor. A VFD consists of three functional groups: an AC to direct current (DC) converter, a DC filter, and an output inverter. The AC to DC converter consists of diodes arranged as a bridge rectifier; these diodes allow current to flow in only one direction, producing a pulsating, half-wave DC output. The DC filter consists of a series-connected inductor and one or more parallel-connected capacitors. The inductor filters the current wave and the capacitors filter the voltage wave resulting in a pure DC signal to the output inverter. The output inverter consists of two insulated-gate bipolar transistors (IGBTs) per output phase. These IGBTs act as solid-state switches controlled by the VFD's programmable microprocessor. The microprocessor is capable of switching the IGFTs thousands of times per second and at specific intervals, resulting in a three-phase AC variable voltage and a pulse-width modulated (PMW) frequency output. The duration of the "on" pulse determines the output voltage while the interval between "on" pulses determines the output frequency and thus the motor speed.

We developed a fully functional VFD trainer (Figure 1) for use in high school and university agricultural mechanics courses and for student recruitment activities. Students learn to program the trainer to set minimum and maximum motor speeds, acceleration and deceleration rates, and to select keypad or terminal board control (via the attached switches and potentiometer). In addition to controlling speed, students can program the VFD to allow reversing motor rotation and dozens of other options.

Costs and Resources

Development of the trainer began with the selection of the VFD and motor combination. After evaluating various manufacturers, we selected the Lenze (Uxbridge, MA) SMVector ESV371-1S model VFD. This VFD accepts 120/240 VAC single-phase input and outputs 240 VAC three-phase at a rated output of 2.4 A at a variable frequency of 0 - 500 Hz. The VFD has a NEMA

Type-1 enclosure and is rated for control of three-phase motors of 0.5 HP (0.37 kW) or less. The cost for the VFD was $251 per unit. We selected a Leeson (Grafton, WI) model C4T34FB5B 208-230 VAC three-phase motor for use on the trainer. The motor's rated power (0.33 HP or 0.25 kW) and current draw (1.4A @ 230 V) were within the capacity of the Lenze VFD. The totally enclosed, fan-cooled (TEFC) motor has a rated speed of 3450 RPM at 60 Hz and costs $184 per unit.

We also purchased a 120 VAC, 3-prong power cord; a SPST switch; a 15-ampere cube fuse with a DIN-rail mounted finger-safe fuse holder; one 15 VDC-rated rotary on-off switch; one 15 VDC-rated SPST toggle switch; one linear-taper 5K ohm potentiometer; and PVC enclosures. These components were surface-mounted on a piece of 24-in x 48-in x ¾-in display board and wired with individual AWG-16 THHW conductors (DC control devices) and AWG-12 THHW conductors in flexible non-metallic conduit (motor). The total cost for the trainer was $534.70. Similar, commercially available trainers retail for $2,595 per unit (Learning Lab, 2015).

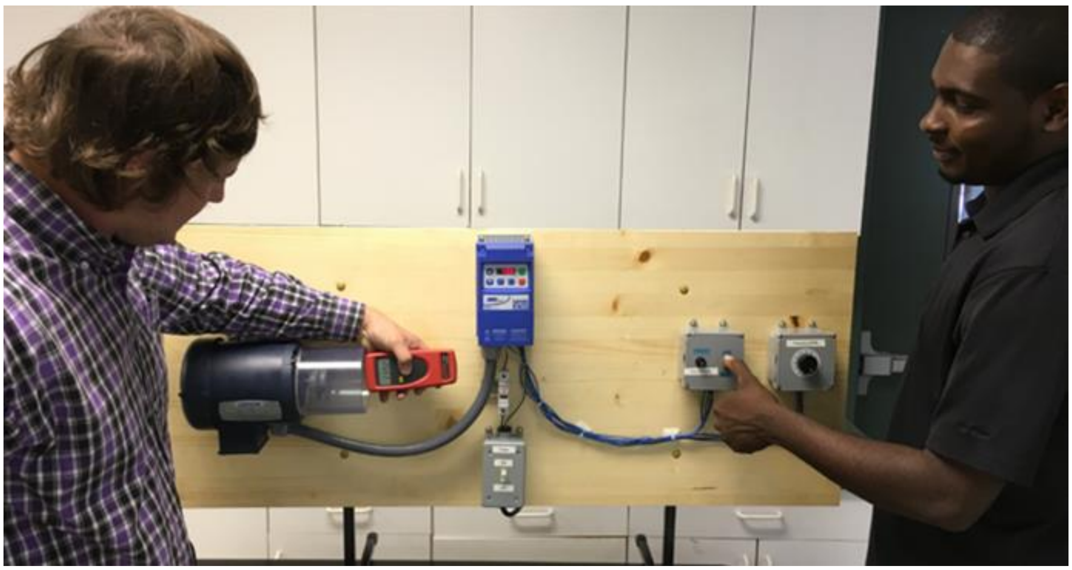

Figure 1. The completed VFD trainer in use. Students are reversing motor rotation and measuring deceleration with a digital tachometer

Results to Date/Implications

To date, we have primarily used the VFD trainer with visiting school groups to demonstrate advanced motor control concepts and STEM principles in agricultural mechanics. Student and teacher interest has been high, with several teachers taking photos and asking for materials lists.

Future Plans/Advice to Others

We will incorporate the VFD trainer into our university electricity class, teacher inservice workshops, and school visits. We are developing short videos demonstrating how to program and operate the VFD trainer. Use of modern, industry-relevant trainers is an excellent method of integrating relevant STEM concepts into the curriculum while also modernizing the content and image of the agricultural mechanics instructional programs.

References

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