A New Approach to VFD System Specifications and Rebates

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Abstract. *Variable frequency drives (VFDs) are used to provide flexibility and efficiency enhancements for agricultural pressurized irrigation systems. Standard 6-pulse VFDs commonly used for agricultural pumps can also create real problems with the pump motor and nearby electrical systems, unless mitigated by special equipment.*

With support by the California Polytechnic State University (Cal Poly) Irrigation Training and Research Center (ITRC), Pacific Gas and Electric Company (PG&E) recently began a new rebate program for installing VFD systems for pressurized irrigation. A major component of the new rebate program is the requirement to comply with a detailed set of minimum VFD system design and installation specifications.

It was recognized that specifications were needed for farmers to receive comparable quotes for a good-quality VFD system, without needing to know all the technical details. Instead of a more typical qualified product list, which requires continuous time and effort to maintain, the specifications focus on minimum performance-based criteria and therefore provide flexibility for the VFD system designer. This paper provides an overview of the specifications' content and rebate program implementation.

Keywords. Agriculture, pumps, pump drives

Introduction

Variable frequency drives (VFDs) provide speed adjustment for three-phase alternating current (AC) irrigation pump induction motors. VFDs are typically sold as part of a package, or VFD system.

A VFD system is defined as the combination of a VFD module and other supplemental components. Common component examples include:

- An enclosure housing some or all of the components (including the VFD itself). Good enclosures are rated to provide a specific level of protection from physical damage or dust and moisture ingress.
- Cooling devices or sub-systems. Operating a VFD creates heat that must be dispersed, so that component temperature ratings are not exceeded.
- Devices designed to mitigate a variety of potential problems, as detailed in the next section.
- Convenience-related items that enable advanced operational features or improved user interfaces.

A conceptual diagram of a VFD system is shown in Figure 1.

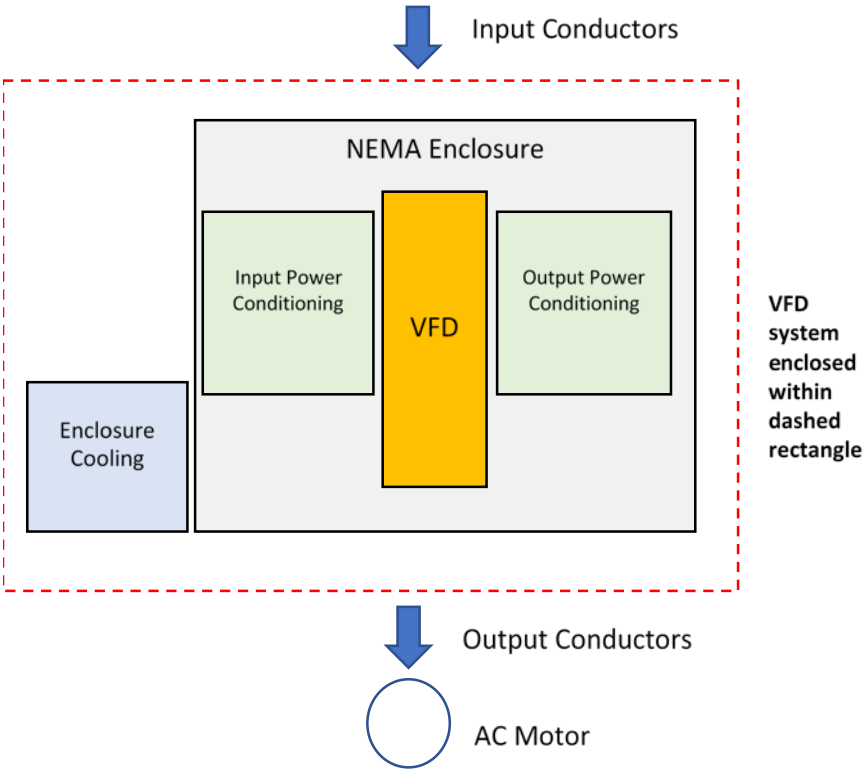

Figure 1. Major potential components of VFD systems

Other key points include:

- VFD systems are typically purchased in one of two ways:
  - Through a distributor of a major VFD manufacturer as part of a pre-packaged system with a variety of ordering options
  - Through an Underwriters Laboratory (UL) panel shop that constructs custom VFD systems
- The VFD module, typically provided by major manufacturers, is only one part of a VFD system.
- There are usually a number of options or add-ons that can be provided in the VFD system. Some of the add-ons can be considered essential for the customer's application, while others may be simply for convenience.
- VFD systems are typically designed by technical VFD experts and licensed electrical engineers.

Incentivizing VFDs: A First Attempt

Pacific Gas and Electric Company (PG&E) took the initial approach of providing a general rebate to those installing a *VFD* on pressurized irrigation systems. The initial rebate was $40 per VFD horsepower, without many qualifications. The rebate value was computed as the historical average value of the first year energy efficiency gains (energy savings in kilowatt hours (kWh) and demand reduction savings in kilowatt (kW)) from over 500 paid custom VFD energy efficiency applications, multiplied by $0.09 per kWh and $150 per kW. The rebate value was subsequently reduced to $30 per VFD horsepower due to incentive budget concerns.

PG&E experienced extensive participation in the initial rebate program through the efforts of PG&E customer representatives, irrigation system owners, and with the support of enterprising irrigation dealers that helped customers fill out applications. In terms of participation level, the initial rebate program was a success. However, it became clear that the lack of specifications or qualifications for rebated VFD installations presents risks for the two primary stakeholders: PG&E, and the farmer or VFD owner. These risks are discussed in the next section.

Rethinking the Rebate Program

PG&E contracted with the Cal Poly Irrigation Training and Research Center (ITRC) to develop minimum specifications for on-farm VFD systems delivering water to pressurized irrigation systems. Preliminary discussions identified risks, as listed in Table 1, to be mitigated with the new specifications.

Table 1. Potential risks of purchasing and operating a VFD system without specifications

Risk Category	Affecting Farmer	Affecting Others Nearby	Affecting PG&E
Uncertainty in what is included with the VFD system, or the expected performance	X		X
Paying more for less energy efficiency or other performance characteristics	X		
Power quality degradation (including harmonic distortion) emanating on-farm and going back into the grid	X	X	X
Decreased pump motor life due to voltage spikes (additional heat) and bearing damage	X		
Electromagnetic and radio frequency noise that can interfere with the performance of nearby sensors and radio systems[1]	X	X	

[1] *While this may sound exotic, real problems can happen when operating any of the following close to the VFD: drones, remote monitoring or control systems, and local automation based on analog sensors. The magnitude of the risk depends on installation-specific details.*

While some of these risks are well-documented in publicly available technical articles, these topics are rarely discussed during the bidding or purchasing process of VFD systems within the agricultural market. Additional objectives of the VFD systems specifications included:

- Providing minimum performance-based requirements, that are intended to be:
  - Flexible, such that future advancements in VFD technology and components will not require rewriting to the specifications. However, that does not mean the specifications are unchangeable.
  - Understandable and achievable by trained technical sales staff, without necessarily requiring a licensed electrical engineer or extensive details of the infrastructure situated on the primary transformer winding (the utility-owned equipment).
  - All-inclusive for the design, installation, field configuration and documentation of a basic VFD system installation.
- Eliminating the need for the farmer and vendor to know all the technical VFD details.
- Establishing a relatively simple means for the utility to administer a complex incentive program.

New Rebate Program

A new VFD rebate program based on compliance with the ITRC specifications was rolled out on Jan 1, 2018. The program provides the following rebates:

- For a 75 horsepower (HP) motor or smaller: $60 per motor HP plus $2,000
- For a greater than 75HP motor: $60 per motor HP (booster pumps are limited to a maximum of 150 HP and well pumps are limited to a maximum of 600 HP)
- For VFD incentive applications that do not meet the ITRC specifications, customers can still receive $20 per motor HP (booster pumps are limited to a maximum of 150 HP and well pumps are limited to a maximum of 300 HP)

The specifications and PG&E rebate program details are hosted on the ITRC website at www.itrc.org/vfd. Participation in the rebate program also includes key procedural requirements and record documents as follows:

- The certification number or Underwriters Laboratory (UL) File Number, proving that the VFD system designer is listed by a certifying agency for the design and fabrication of VFD system equipment.
- Two documents (or invoices) with a written statement proclaiming that the VFD system meets the specification requirements regarding both design and installation.

Major Initial Specifications

A non-exhaustive list of unique and important specifications includes:

- There is a minimum efficiency (the ratio of power output to power input) for both the VFD and the complete VFD system.
- The VFD system must be designed and fabricated by a UL-listed panel shop for UL508C VFD systems.
- New VFD-driven motors must be designed for VFD applications and be equipped with shaft grounding rings and insulated bearing carriers, depending on the application and horsepower.
- A minimum level of VFD input surge protection is required.
- Some harmonic mitigation is required, depending on the size of the motor. Additionally, there exist multiple options for the level of compliance, or the specific equipment used.
- Application-specific RF-shielded VFD cable must be used.
- Specific installation and configuration tasks are listed in the specifications, including a minimum amount of documentation and training that must be supplied to the owner.

Initial Reactions and Lessons Learned

Reactions and feedback from VFD vendors and farmers were received in two ways. Multiple workshops were held with farmers and VFD system vendors, and an online question-and-answer platform was provided from the specifications website.

In addition to the expected level of general hesitation to accept change, some important insights were gained based on valuable feedback from farmers and vendors:

- Some vendors are unaware of the complexity and technical details of the products they sell.

- Nuisance VFD system tripping is occurring at unexpectedly high levels, either from poor VFD input power quality (voltage spikes, sags, harmonics or phase imbalances) or insufficient cooling and maintenance.
- There is a pattern of premature motor failures in new VFD system installation and retrofits. While many VFD vendors are uncertain as to the exact cause of the problem, some examples of "current industry standards" can be part of the problem. Major examples include:
    - Selecting new pump motors, or keeping existing motors that are not designed for VFD applications and have insufficient insulation ratings.
    - Under-sizing the pump motor so that normal operations require that it operate overloaded (at a service factor of 1.1 or greater), in relatively hot environments, without shading.
    - Neglecting to follow VFD manufacturer recommendations in the selection and installation of VFD to motor cabling.

It appears that the new specifications will help with many of shortcomings of "current industry practices".

Future Work

Based on a balance of continued feedback and new information, it is anticipated that the specifications will be modified over time. It is also anticipated that the specifications may motivate VFD vendors to consider alternative design options so that the performance and reliability of on-farm VFD systems improve over time and keep pace with market demands and technological advances.

Conclusion

Prior to the project, publicly available performance-based specifications for agricultural VFDs did not exist. As such, the specifications provide a number of direct and indirect benefits to the pressurized irrigation industry:

- A list of topics that can be discussed and considered with VFD vendors, and ultimately modified if needed – even for VFD system purchases outside of PG&E's service area.
- Simplification of the process of ordering a VFD, both for farmers and irrigation/pump dealers, because the key requirements are already taken care of. All that is left is identifying add-on, convenience items to meet customer-specific needs and preferences.

Furthermore, the new rebate program, combined with the new specifications, is expected to:

- Enhance energy efficiency and flexibility for on-farm pressurized irrigation systems by promoting VFD use. Moreover, the additional flexibility provided by the VFD enables farmers to more easily experiment with advanced irrigation and chemical/fertilizer injection strategies.
- Improve the reliability of pump operations in the future by:
    - Reducing future power quality degradation that would likely to have occurred without the specifications.
    - Providing incentives for good design and installation practices, such as proper motor selection, grounding, etc.
- Improve the conditions for the adoption of other advanced on-farm technologies such as drones, instrumentation, remote monitoring and automation by reducing future electromagnetic noise and radio frequency interference.