Low Cost Techniques for Integrating Network Communications and Power Systems Control

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ABSTRACT

Power Management Products and Network Control Systems have been converging for some time, as more OEM manufacturers are asked to supply products that can be "networked" so that a smart factory or smart office building can talk to, control and evaluate conditions at specific equipment from a central location. Payback analysis is most easily justified based upon high performance installations. But, as in most markets, the lower end of the sophistication spectrum, which occupies the highest volume usage rates are slow to adopt as the investment cost is too high and sophisticated controls exceed the installers' capabilities.

This article reviews systems and solutions for the low sophistication end of the spectrum. A review of the basic functions and low cost approaches to addressing these needs are reviewed. A methodology of addressing the tasks and the evolution of the system description and architecture are reviewed. A series of examples solution sets from Fan speed controls to lighting systems that are cost effective are reviewed. The result is simple, low cost solutions that do not require training and electronic/software know-how. These are critical points in providing solutions that will be acceptable.

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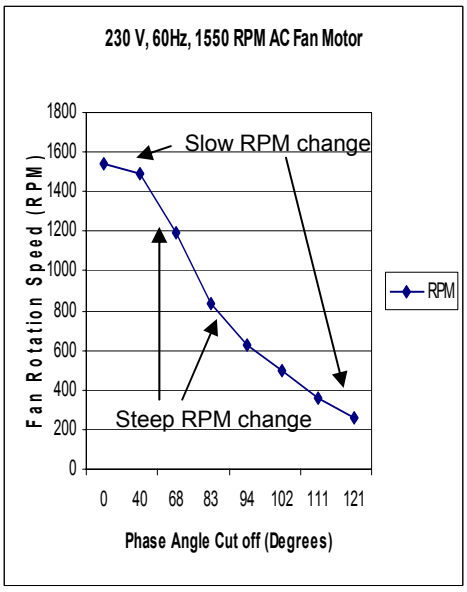
1. System Overview and Architecture

1a. Motor Drive Platform Overview

Previous Literature (PET 20030 discussed the challenges faced by Phase-Control AC drives. A TRIAC control was discussed where the performance features were significantly enhanced and the range of fan-speed, motor-hum and control-linearity were discussed. Repeated below are some if the waveforms from that prior work. The non-linearity of the phase angle impact on RPM have been leveled through the use of microprocessor control.

Figure 1a: RPM of motor changes non-linearly with phase angle shift
Figure 1b: RPM tracks within 6% of Vrms for fan motor over high speed range



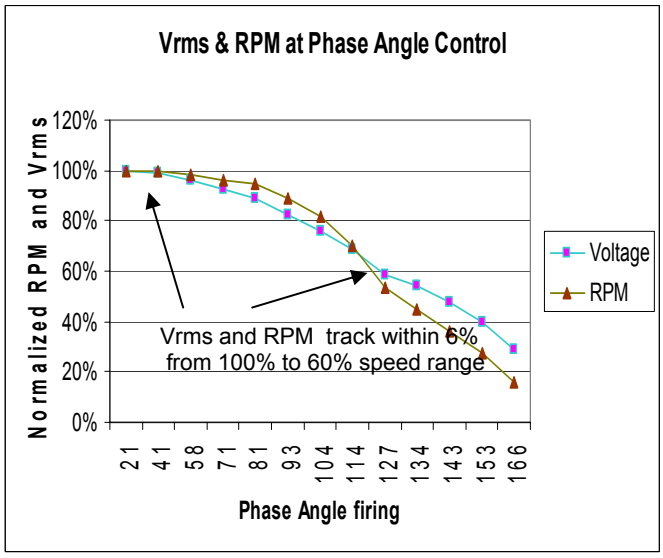
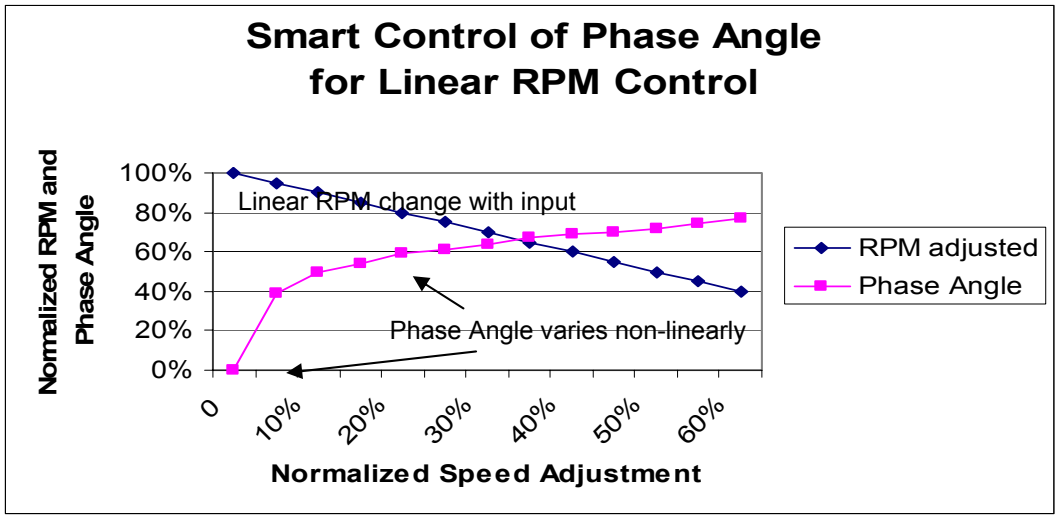
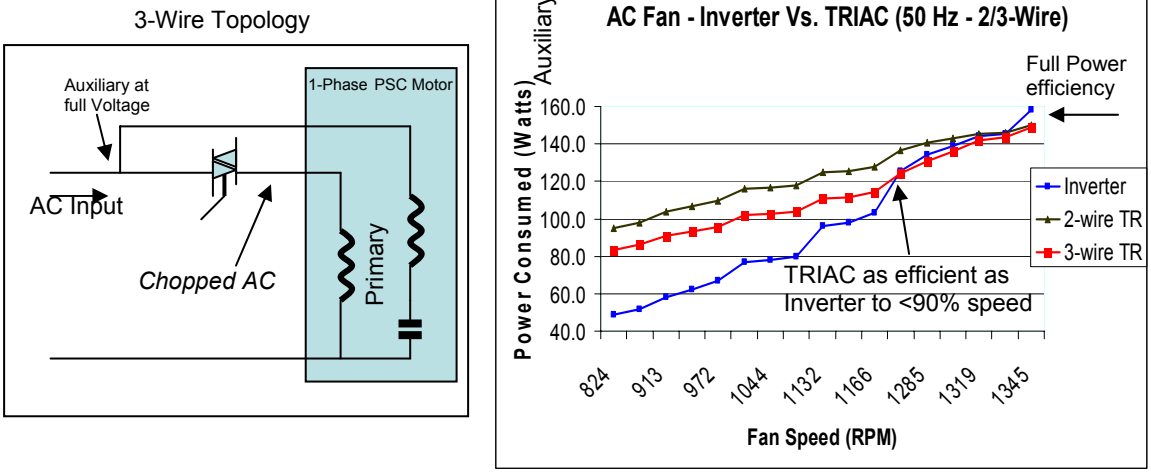


Figure 2: Linear RPM Output Using Micro-control of TRIAC Phase Angle



Additionally, we also implemented a unique 3-wire control scheme to improve the efficiency and noise of the single-phase PSC motor by using the microprocessor control. Figure 3 shows a fan being driven by a 3-wire circuit topology. The Auxiliary winding is connected directly to the AC line maintaining full voltage as the RMS voltage across the primary is reduced.

Figure 3: 3-Wire Topology & Improved Power Consumption Data



As can be see by the above, the efficiency of the TRIAC control is improved and is competitive with Inverter solutions down to almost 90% of speed and continues to provide efficiency improvements through the normal operating range of fan control.

1b. Communication and Control Console Overview

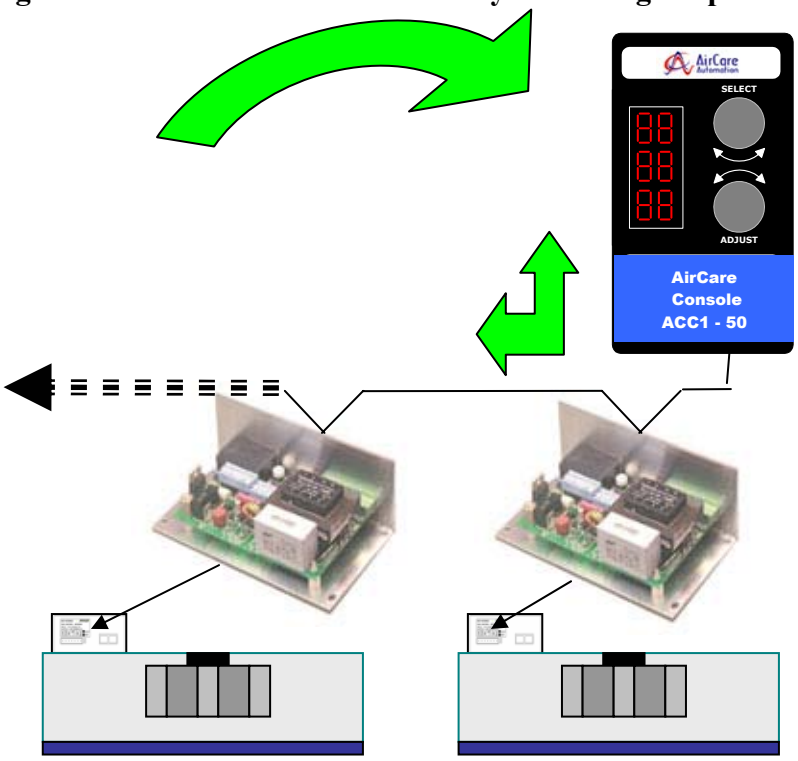
Taking the Drive to the next level, we add a communication port to the unit and create a simple, low-cost networking system. The Consoles are designed to communicate cost-effectively with the motor controllers, allowing for easy installation and set-up. The general criteria set are listed below:

Table 1: Console Success Criteria

1. **Easy to mount and attach**
2. **Simple User Interface**
3. **Supports small networks**
4. **No installer configuration required**
5. **Checks status**
6. **Speed adjust**
7. **One-Step Set-Back capability**

The resulting system configuration is shown in Figure 4 and can be expanded from systems as small as single address units (dedicated controller/drive combinations) to sophisticated networks using hundreds of drives interfacing with a simplified Console controller.

Figure 4: Low-Cost Network Drive System using simplified Drive and Console



This may look like a simple system to develop. The most complex activity and the most critical phase of the development is in the "specification-phase". A meticulous effort must be made to document the key features needed and to strip away any unnecessary features that could add complications and additional cost. Targeted motor drive systems coupled with targeted control consoles will result in low cost platforms that can not be achieved by general purpose tools.

2. Developing a System – Cleanrooms Example

The key elements of the system platform were driven by considerations of cost and complexity. In the area of the motor drive key elements of the specifications were driven by:

1) What kind of load are we driving (lowest cost option)?
2) What are the features we need to provide?
3) What levels of flexibility & variance do we need to provide?
4) What kind of control interface do we need to provide?

In the case of the Cleanroom Example the following was assessed:

1) We are driving numerous fan loads, single-phase PSC motors that are generally high efficiency products.

2) Adjust the fan speed within a range of 50% - 100% where fan speed is not the overriding factor but rather particle count or differential air pressure are the real measurable items. Each fan control needs to be individually addressable and configurable to meet the fan control criteria. Might require feedback from local pressure sensors or speed sensors. Easy to follow set-up and few command sets to keep it simple in operation.
3) Need to be able to address different voltages (115, 230, 277) different current levels (1 ampere to 8 ampere) and different control signals (digital and/or analog). Also need to allow for both global command sets and individual commands to provide speed and flexibility in the deployment of the system.
4) Numerous digital architectures are needed depending on the building automation system (BAS) in place. Decision to use a local (proprietary) loop that can be gateway to a BAS allows us to concentrate on one platform.

The resulting VariPhase product addressed the motor control aspects. Lowest cost speed-control was traded off with unique 3-wire control method to help reduce noise and energy consumption while maintaining a low cost platform. For higher efficiency platforms the use of a brushless DC ECM motor platform was used where communication interface was provided through a special card. Using MODBUS interface and 1/8th load transievers, the normal loading of a given MODBUS line was extended from 32 maximum addresses to over 100 addresses (reliably).

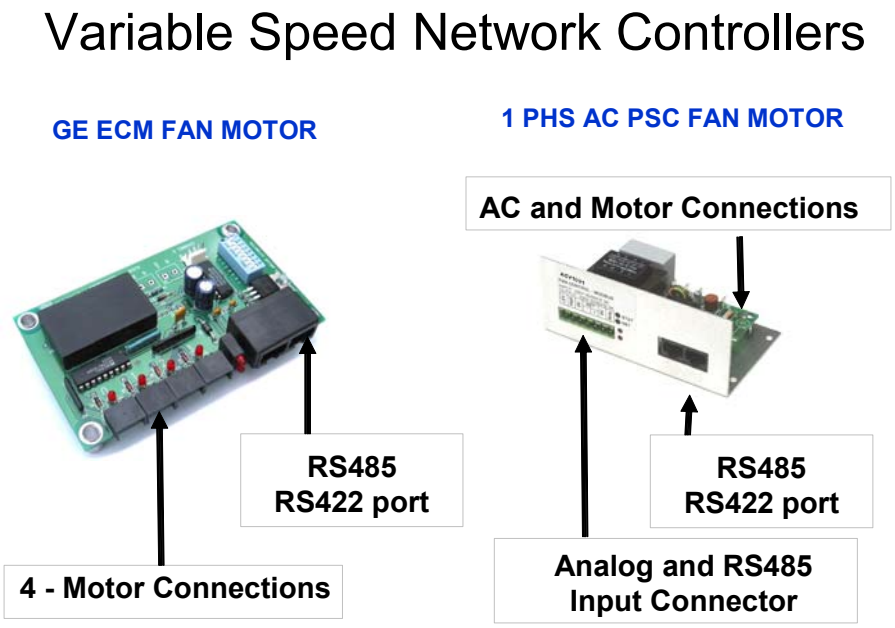
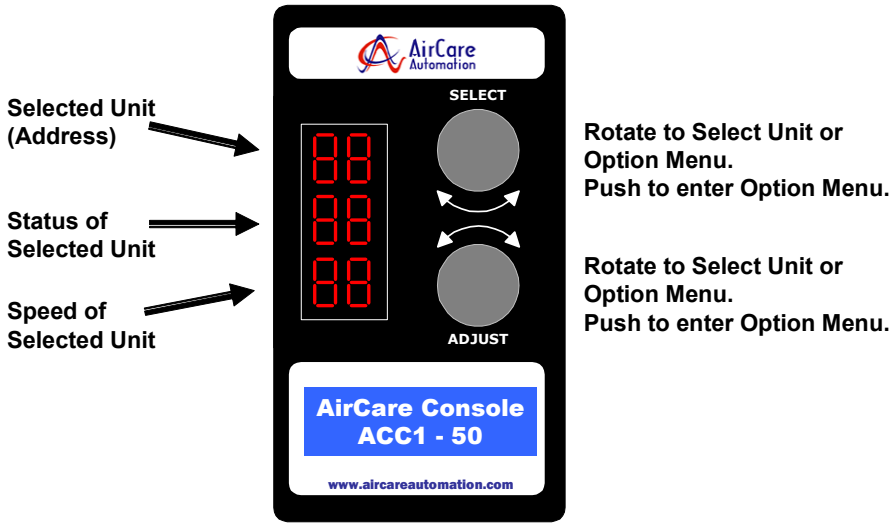


Figure 5: Single-Phase PSC motor Controller and ECM 4-motor interface

For the Console, an easy to read LED display was used along with switch rotary encoders allowed for easy adjustments and selections. All the key features and set up were addressable with 2 encoders and three LED arrays (2 digit). Thus, a single, low-cost Console could now control an array of up to 100 addresses at a cost of less than half an equivalent PLC platform.

Figure 6. Low Cost Console Description



3. Next Generation – Expanding the Concept

There are several areas where this approach can be expanded upon. The most obvious relate to:

A – larger systems

B- more complex systems

Multi-Zone Systems: For larger systems, Low cost consoles can be designed to handle several hundred addresses at one time. The challenge is in maintaining an easy to follow interface to allow for jumping across hundreds of systems. As the systems get larger, the users' budget grows and their taste for sophistication grows along with it. For simple systems that do not need fancy graphics or interfaces, this approach can be expanded to address fan facilities that go into the thousands.

Expanded Functionality: We have only addressed a narrow niche of the market. Where there are fan control systems there are often lighting systems and heating and air conditioning (HVACR) systems that are also distributed. With today's emphasis on energy conservation focusing on both lighting and HVACR, creating similar product solutions can be envisioned for these systems.

Interface Complexity: The existing systems are self-contained, self-controlled systems. There are sensors and controls that can be interfaced with the system to allow for greater integration into the BAS without having to add significant cost and complexity. Examples of potential "tie-in" solutions are:

BAS controls - Rather than complicate the low-cost system with sophisticated software and programming, an interface to a BAS / PC that can send a single signal to the Console telling it whether it is in full mode or in standby mode easily integrated. The system can be overridden locally to allow for self-control of the environment but also allow for Hi-Lo status to be set externally responding to a host of criteria. An example of this is a standard clock/calendar feature in the BAS system driving the smaller system remotely with a Hi-Lo signal.

Local automatic controls – Conditioning the system to respond automatically can be achieved by easily as well. An example of this would be to add an occupancy sensor to the self-contained system. Now, no commands are needed to go to Hi mode as the occupancy sensor determines automatically what mode to go into and the system can be configured to shut-down in an orderly fashion to the customers' desires.

4. Conclusion

We have shown above how a sophisticated network control system could be distilled down to the critical performance features at a fraction of the "smart-system" cost. By paying close attention to the "must-have" criteria and designing low cost solution sets for these "must-have" criteria, solutions can be delivered that are both cost effective and are easily integrated. The investment in "application specific" power network systems is both viable and effective in bringing sophistication previously unavailable to the small system within easy reach.