

The Crucial Role of Inverter Drives in the Efficient Hospital

a report by

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As our energy reserves dwindle, the spectre of climate change looms ever larger and energy costs continue to rise, it becomes ever more imperative to take action on energy savings. This requirement is so critical that it has even been enshrined in law by the new building regulations. Part L, which concerns energy efficiency is now 'live' and mandates a substantial improvement of between 23 and 28% in the energy performance of non-domestic buildings. This applies to hospital buildings as well as to commercial buildings.

While this sounds so draconian as to be unachievable, in many cases it is actually more than achievable because the air-conditioning systems of modern buildings offer the greatest potential for energy savings. The various fans, pumps, cooling towers and humidification systems of today's hospitals comprise some 40% of that building's energy costs. Particularly where older heating, ventilation and air conditioning (HVAC) systems are concerned, there is invariably enormous scope for energy savings.

Inevitably, environmental conditions vary day to night, day to day and season to season over an extremely wide range, and air-conditioning systems are of necessity designed to cope with that. Unlike many commercial buildings that shut down during the night, hospitals operate 24/7, day in and day out and stable conditions must be maintained throughout. Hospital indoor air quality is critical. It cannot be too dry, too cold or too hot. Pressure must be maintained at higher levels in some areas, and lower levels in others, yet doors must open easily. Aspects of sterility and isolation further complicate the control of HVAC systems in hospitals beyond that of most commercial buildings.

Unfortunately, when the majority of our buildings' air-conditioning systems were designed and installed, energy efficiency was not a priority and systems were designed to meet the lowest installed cost. Despite the need for close building environmental control over wide-ranging outdoor conditions, the control mechanisms employed were crude and simplistic. In variable air volume (VAV) systems, damper and vane

control of air-handling fans, throttling of chiller pumps and on-off control of many functions was the norm in matching the capacity of the system to the actual requirements of the building.

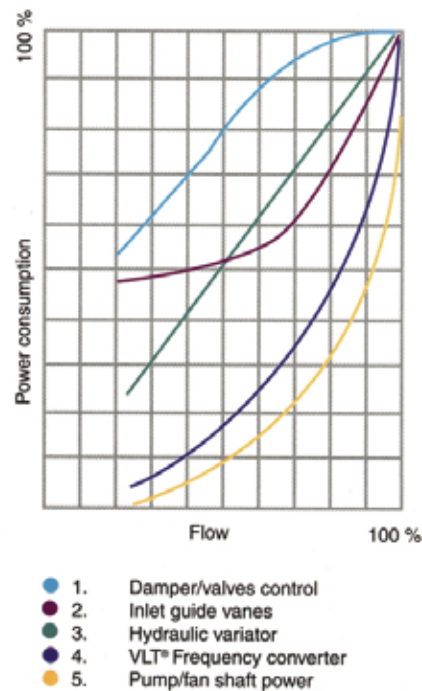
The systems being installed in modern buildings these days could not be more different. This revolution in efficient air-conditioning systems is due to the development of the most improbable and complex device to touch all of our lives – the microprocessor. These mini-computers in a single electronic chip have ushered in an age of superior building management systems (BMS) linked via fieldbus networks such as BacNet to a complex network of sensors and variable speed drives controlling the motors that drive the numerous fans and pumps that constitute a modern, efficient climate control system. The result is a much more stable, comfortable working environment right through the year, even on the hottest days.

While the modern BMS has made an enormous contribution to overall control of the system and fieldbus networks have simplified connectivity throughout the building, the greatest contribution to energy efficiency has come from variable speed control of the fan and pump motors themselves. This is where the largest consumption of energy takes place and where the need for efficiency is greatest. Considering the widely varying conditions under which a UK building climate control system is required to work, it is inevitable that all of the fans and pumps must by definition be oversized a great deal of the time. In point of fact, even under the most extreme operating conditions the vast majority of systems are designed with what can only be described as a generous 'service factor' and seldom work beyond 75% capacity. At every stage of the design process, margins were built in to ensure no-one erred on the side of incapacity.

Inefficient throttles and dampers were then employed pretty much all of the time to control a system more than fit for purpose. The problem with this is that all of the fans and pumps employed in buildings are centrifugal devices that operate to well-



Figure 1: Power Consumption of Different Systems



established and disadvantageous affinity laws governing their power consumption and noise production. The most critical of these laws is that the power absorption of a centrifugal fan or pump is a direct function of its speed cubed. The noise of a fan is directly proportional to its speed to the power five. This means that running fans and pumps at full speed when full output is not required, i.e. most of the time, is both energy inefficient and excessively noisy. Speed control of these fans and pumps would therefore offer greater efficiency, superior control and reduced noise levels.

The most practical form of fan and pumps control is to vary the speed of the drive motor and while there have historically been a number of alternatives available, these were complex, maintenance-hungry and expensive. In recent years, however, variable speed drives (VSDs) have become highly cost-competitive and significantly more efficient. Their big advantage is that they offer close, accurate speed control of standard alternating current (AC) induction motors, themselves the most efficient and reliable prime mover available. This is by far the most numerous type of motor used in existing HVAC systems and it is from this that an enormous energy-saving opportunity stems. The cube law characteristic of fans and pumps, while causing high energy absorption at full motor speed, provides an enormous reduction in energy taken as speed is reduced. Theoretically – based upon the cube-law rule – a speed reduction of 25% would result in a 42% reduction in energy absorbed. A 50% reduction,

not at all uncommon, would reduce energy by 87.5%. In practice, however, damper and vane systems do offer energy reductions as they are closed down, (see Figure 1) but nowhere near as significantly as does variable speed control. At 50% flow, damper control of an air-handling fan might offer 30% reduction and inlet vane control at a 50% reduction but this is still a long way short of the 87.5% offered by motor speed control.

Rapid advances in VSDs over the last 10 years have revolutionised the technology for HVAC applications to the point where it is rare for a major new hospital project not to have full VSD control of the HVAC system linked to the BMS. This ensures close control over environmental conditions and, particularly important in hospitals, control over flow between wards to prevent the potential spread of infection.

Many viral conditions such as severe acute respiratory syndrome (SARS), bird flu or a number of potent viruses demand isolation of the patient in an environment from which the virus cannot easily travel into the general environment. This can be achieved by maintaining a negative pressure in the isolation wards, and this is best achieved by accurately controlling supply and extract fan speeds, maintaining a differential between supply and return air flows. Velocity sensors installed in the supply and extract ducts can be connected direct to Danfoss VLT® HVAC drives so that all air-flow differential calculations are carried out directly by the drive, and the motor speed is finely regulated.

Similarly, for sterile environments where a clean, filtered air supply is required, variable speed control of the fans ensures that air flow is maintained constantly even over a dirty high-efficiency particulate air (HEPA) filter so long as the fan is sized for 'worst case' conditions and run at reduced speed while the filter is in clean conditions. Simply instal a static duct pressure sensor just past the HEPA filter, connect that to the VSD and allow this simple closed-loop control to maintain duct pressure and ensure air flow is delivered at all times. Equally, the drive can be programmed to flag up a dirty filter condition for maintenance purposes.

It is application benefits such as these that are responsible for the proliferation of VSDs. There has also been a huge reduction in cost per kW of installed power and inverter drives themselves are vastly more compact and efficient than previously. It is now common practice in many installations to install the VSD near the motor/pump/fan it operates instead of mounting it in a central control panel. The main advantages of this 'decentralisation of control' are that it reduces the size of the main switchboard

or control panel and results in simpler installation and easier commissioning. However, to ensure long-term reliability of the VSD and protection of personnel in the plant room for such an installation, it is important to ensure that the 'enclosure protection' of the drive is not compromised. The availability of IP66 enclosures, facilitated by the reduction in internal heat production, ensures both the integrity of the panel and the safety of the personnel.

Along with this is the array of software facilities that make their integration into an overall building environment absolute child's play. Inverters are now effectively an intelligent part of the intelligent hospital. Early inverters simply varied their output frequency and voltage in ratio, varying the speed of the motor but with no control over its torque or efficiency. No matter how efficient at full speed and full load, an induction machine at less than full load suffers a severe drop in efficiency and also exhibits a very poor power factor. Modern inverter drives not only control the speed of the motor but, by virtue of powerful digital control algorithms, automatic energy optimisation (AEO) actually tunes the inverter to the driven motor, forming a matched pair so that overall efficiency is maintained at the optimum at all loads and speeds. In addition, the intervention of the inverter between the motor and the mains supply means that the pair exhibit a power factor close to unity, a significant benefit in its own right.

At the heart of the Danfoss VLT inverter is a powerful mini-computer not only controlling the supply to the motor, but also offering important fan and pump control functions previously supplied as discrete modules. Flow compensation responding to pressure sensors mounted close to the fan or pump maintain pressure constantly at the discharge end of the system, offering further energy savings. Inbuilt multiple proportional integral derivative (PID) loops and smart logic controllers also offer advanced control of the system external to the BMS expanding its capacity.

Fire override mode ensures inverter operation to destruction if necessary and the stairwell pressurisation feature ensures that stairwells remain smoke-free in the event of a fire. Sleep mode detects low or no flow, boosts the system pressure and then goes to 'sleep' pending a drop in pressure, when it automatically ramps up to operating conditions.

The energy-saving capacity of VSDs is best illustrated where older fan and pump systems have been refurbished and variable speed drives incorporated, providing a before and after comparison. There are many of these and in some cases the savings are quite spectacular with rapid payback of the initial investment:

- Belfast International Airport has fitted Danfoss VLT inverters to 28 of its air-handling units (AHUs) and expects to save over 1,000,000 kWhrs worth £60,000 per annum, and will recover the total installation costs in around eight months.
- Dairy Crest fitted a VLT inverter to an 11kW boiler forced draft (FD) fan saving 47,000 kWhrs per annum and recovered the capital cost in under nine months.
- Diageo fitted a Danfoss VLT inverter to a 132kW duty/standby pump pair and realised 37,000kWhrs savings per year with investment payback in 18 months at an energy cost of a margin of 2p per unit.

Of course, these savings also represent an enormous saving in carbon emissions, with these three alone representing well over 500 tonnes of carbon emissions. Danfoss estimates that the annual energy efficiency contribution of one year's production of their VLT drives alone represents the power output of a major nuclear power station. Savings in carbon today can of course be traded on the carbon market to further reduce the payback period of the initial investment.

In the UK, further cost reduction can be achieved by setting the inverter costs against corporation tax, as they attract an enhanced capital allowance (ECA). These were put in place by the government to stimulate the uptake of energy-efficient technology. The exact value of this allowance varies with a company's circumstances, but as a rule of thumb it is worth a reduction in capital cost of approximately the ruling bank rate of interest. Other countries also offer incentives to stimulate the adoption of such energy-efficient technology.

The case for intelligent inverter speed control of fans and pumps in buildings is therefore well made and more than adequately demonstrated. The downside? Well, quite simply there isn't one. Even the initial capital cost is so quickly offset by the returns that there is no more effective use of a company's capital resources. The upside of their adoption is a previously undreamed of efficiency, putting substantial amounts of cash back where it belongs on the bottom line, enhanced levels of year-round comfort and a vital reduction in carbon emissions when the fight against global warming is the duty of all of us. ■

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