Switched Mode Power Supply

Operational Cost Saving Opportunities for System Designers in Control Power

Control Power and Sizing Theory

Control panels often have transformers feeding into Switched Mode Power Supplies (SMPSs) that provide 24V DC power to PLCs, I/O cards, solenoids, relay coils, and so on. The excess heat that is generated in the panel and the overall operating cost provides system designers with challenges when selecting a robust and efficient 24V DC control circuit power solution.

This white paper focuses on cost saving strategies that are related to industrial control transformers and SMPSs.

The typical structure of an industrial transformer with primary and secondary windings on a common core (laminated iron) allows for isolation and stepping down/up the primary voltage. The power rating varies widely depending on whether they are used for power distribution or control circuit applications. Transformers generally have four relevant ratings: voltage, current, apparent power, and frequency. The apparent power (the product of the rms current and the rms voltage) sets the limit on the maximum power (I2R) loss in the transformer windings that the transformer can handle and is based specifically on the heating of the transformer coils, which could damage the insulation or drastically shorten the life of the transformer.

$$P_{Cu} = I^2_{rms} R_{Cu}$$

where:

P_{Cu} = power loss for the copper windings, in watts

I_{rms} = current for the copper windings, in amps

R_{Cu} = the resistance of the copper windings, in ohms

The net result of exceeding the current ratings of any transformer is operating life reduction due to premature damage. Transformer voltage and frequency ratings serve two purposes: to limit the core losses and to prevent the transformer from saturation. Transformers are sized based on nominal and total inrush VA draw - high reactive loads draw more current during transient state of their operations.

Thermodynamics and Panel Sizing

An industrial panel needs to be sized to accommodate the heat (watt) generated within the panel. That means, if the operating temperature should rise more than the rated value of the panel then the panel should have effective means of convection. For example, a fan or an air conditioner can be used to lower the temperature to recommended operating range. The ideal solution is to use an efficient and high performing SMPS that does not demand high inrush currents from the upstream transformer yet provides industry leading power boost functionality. The following is a brief summary of the equivalent first cost (EFC), total cost of ownership (TCO) method which is a most commonly used:

$$\text{TCOEFC} = \text{Price} + \text{Cost of core loss} + \text{Cost of load loss}$$
$$\text{Cost of core loss(EFC)} = \text{A(\$/watt)} \times \text{core loss watts}$$
$$\text{Cost of load loss(EFC)} = \text{B(\$/watt)} \times \text{load loss watts}$$

where:

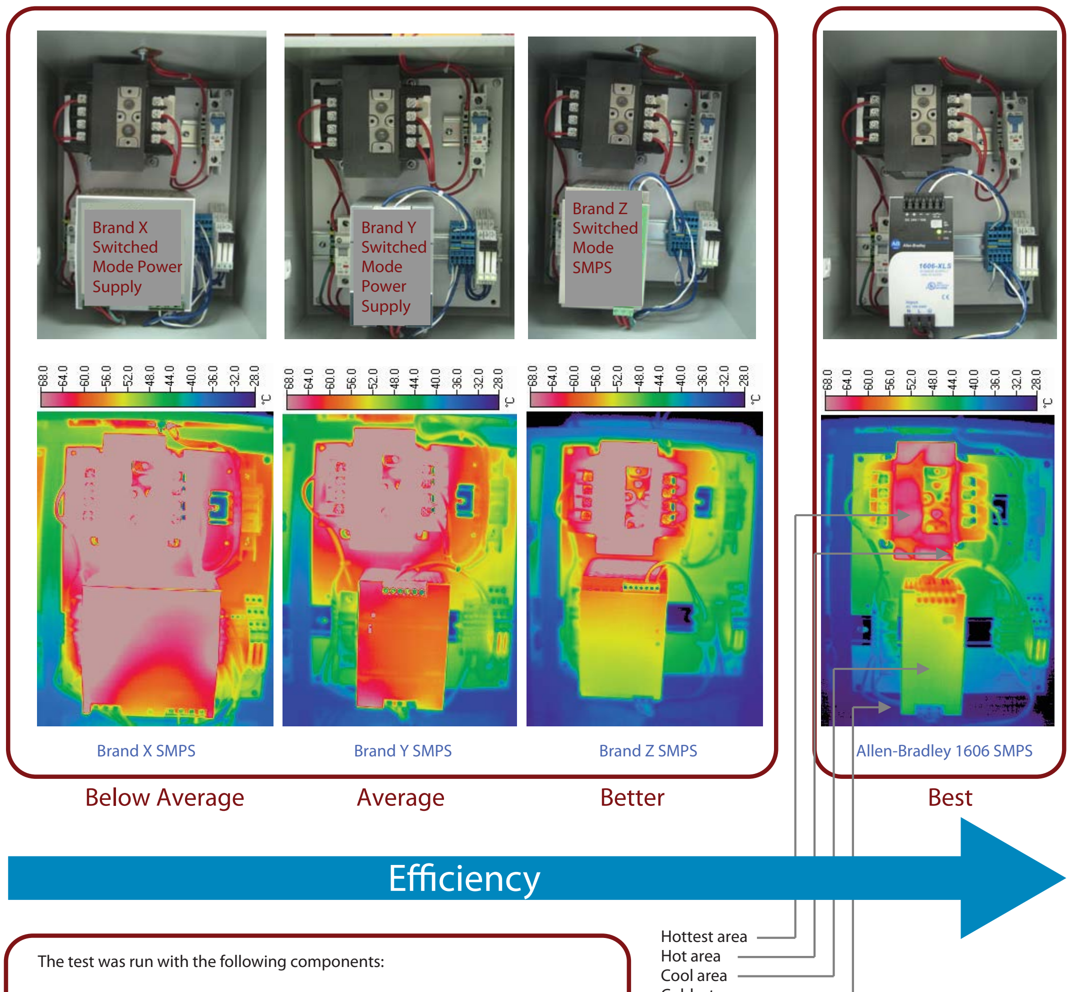
A = Equivalent first cost of no load losses

B = Equivalent first cost of load losses

An alternate approach to specific no load and load losses of a transformer is to measure energy efficiency at the specific load which is most typical of how it will be used. The general expression for energy efficiency is:

$$\textbf{\% Efficiency} = \textbf{100 (output load) / (output load +losses)}$$

Thermal images (Infrared) showing thermograms in a panel for an Allen-Bradley® 1606 SMPSs and the competitive Brand X, Y, and Z SMPSs. In the images colors closer to red (bleached-red) are higher heat loss areas and colors closer to blue (blue-green) are lower heat loss areas.



The test was run with the following components:

Allen-Bradley	10 A 24V DC	93% Efficiency
Brand Z	10 A 24V DC	> 91% Efficiency
Brand Y	10 A 24V DC	> 88% Efficiency
Brand X	10 A 24V DC	84% Efficiency

Transformer:	1497A-A8-M6-0-N	240...120V AC, 350 VA
Branch protection:	1489-A1C100	10 A
Supplementary Protection:	1492-SP1C100	10 A
Load: approx 225 watts	700-HLT1Z24	Relay Output, SPDT, 24V DC
	OHMITE	2.5 W

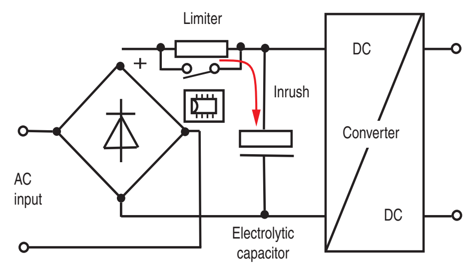
The thermal images tell a clear story, the 1606 is a very efficient SMPS, higher efficiency results in lower heat generation and energy consumption.

1606-XLS family minimizes steady state input currents as well as inrush currents. This reduces the upstream transformer current requirements and allows for a smaller, more cost effective transformer solution. The built-in Power Factor Correction (PFC) allows current draw from an upstream transformer without putting any strain on the transformer, 1606 SMPSs can automatically correct the AC input voltage – the optimal synergy approach for maximum overall efficiency within a control panel.

Inrush Characteristics of the Switched Mode Power Supply

All modern SMPSs have (Electrolytic) capacitors on the input power side and this causes the inrush current when powering up an SMPSs. An SMPS with high inrush current requires a larger more expansive transformer. Allen-Bradley 1606-XLS Power Supplies have lower current inrush.

The1606 SMPSs has significantly low inrush current requirements by means of resistors to limit inrush currents. On the AC input side of the SMPSs, this allows for smaller size 1497 transformer, as the total VA is significantly lower than the competitive Brand X SMPSs. That also means the miniature circuit breakers do not have to be rated for peak inrush currents, but can be sized for the actual operating currents.



Inrush current limiting by means of fixed resistors which will be bypassed after a certain period of time

Low inrush allows for a smaller sized up-stream transformer

The peak inrush current is only marginally higher than the maximum operating current allowing for a smaller sized VA transformer on the AC input side of the SMPSs.

For example, a 1606-XLS 10 amp, 24V DC SMPS only has 4 amps of inrush current while the competitive Brand Y SMPS has an inrush of 30 amps. That would require upstream transformer to be sized accordingly, as described in the first part of this document (Transformers Theory and Sizing).

The higher the inrush amps, the bigger VA transformer is needed. Since the transformer price depends on the VA size, customers can benefit from using a 1606 SMPS and a smaller VA transformer.

- 1606 SMPSs have high efficiency and low inrush characteristics that significantly reduce the power required to operate the SMPS.

Transformer VA and SMPS sizing as limiting factors in the panel (enclosure) sizing

Panel builders size their enclosures once they have designed the functional solution – at this point thermodynamic calculations are made to determine the enclosure size:

- Use a predetermined sized enclosure and figure out if cooling (fan/air conditioner) is required to maintain the rated operating temperature for optimal performance
- Size the panel (enclosure) based on the overall thermal heat generated by the components that are going inside the enclosure

The 1606 SMPS and the 1497 transformer combination saves panel builders money by reducing the transformer size, thus reducing the overall panel size.

The 1606 SMPS and the 1497 transformer combination save panel builders money since the heat (watt) dissipation is low. Less heat to dissipate may allow for a smaller fan or a smaller air conditioner.

Energy Savings are small if you just have one unit, but energy savings could be significant in a heavily automated facility. For example, SMPSs in I/O applications depending on the system, the overall load requirements.

The Green Power Supply, Delivers Industry's Leading Efficiency

The green 1606 SMPS product line actively promotes the environmental commitment of Rockwell Automation by avoiding unnecessary energy consumption and by using resources responsibly. The results are industry leading efficient Power Supplies. Which means the heat dissipation is significantly reduced thus there is reduced need for forced convention to keep the overall panel temperature under the operating limits. The 1606 line also features smaller foot-print sizes, allowing more space for natural convection. Due to very low thermal dissipation, the panel can be sized smaller. Going green is in fact a cost efficient solution, by reducing the need for a fan or an air conditioner, customer can save on energy costs. The 1606 power supplies achieve an efficiency of up to 96% and the heat/watt loss is minimal compared to competition brand X power supplies.

Power Boost Allows for Optimal Functionality

The 1606-XLS line features a power boost of 150% for typically 4 seconds. The 1606-XLE line allows for 120% power boost. The power boost functionality of the 1606 allows customers to size SMPSs to their normal loads as oppose to inrush/startup current requirements of the 24V DC loads. In most cases without power boost customer will have to oversize their power supply.

The operational cost savings strategy is considering the use of an efficient SMPS to reduce the excess heat generated, helping the customer save money:

- Customers are paying for the excess heat generated in the panel; inefficient use of resources resulting in increased energy bills
- Reduce need for panel (enclosure) cooling
- Smaller foot print allows for smaller enclosure, thus reducing customer's overall cost
- Power boost feature allows for smaller sized SMPSs, smaller watt sizes saves customer money
- Low Inrush allows for a smaller VA sized transformer

Rockwell Automation maintains current product environmental information on its website at http://www.rockwellautomation.com/rockwellautomation/about-us/sustainability-ethics/product-environmental-compliance.page.

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