High Performance (HP) Transformers

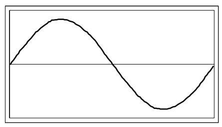
"You Don't Know How Much Energy
Is Being Wasted Behind Closed Doors – and
other stuff"

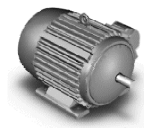
Lorenz V. Schoff
E^{2}S
Energy Efficient Solutions
"Finding Little Energy Inefficiencies, Generating Big Energy Savings"

Transformers: Opportunity to Lower Operating & Life Cycle Costs

E²S

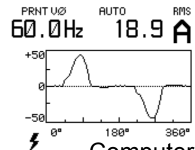
Load Profiles have changed ! Electronic Equipment draws current differently - increasing system losses



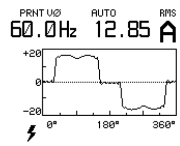


Electrical systems deliver optimum performance when feeding continuous “linear” loads:

- motors
- incandescent lighting
- resistive heating

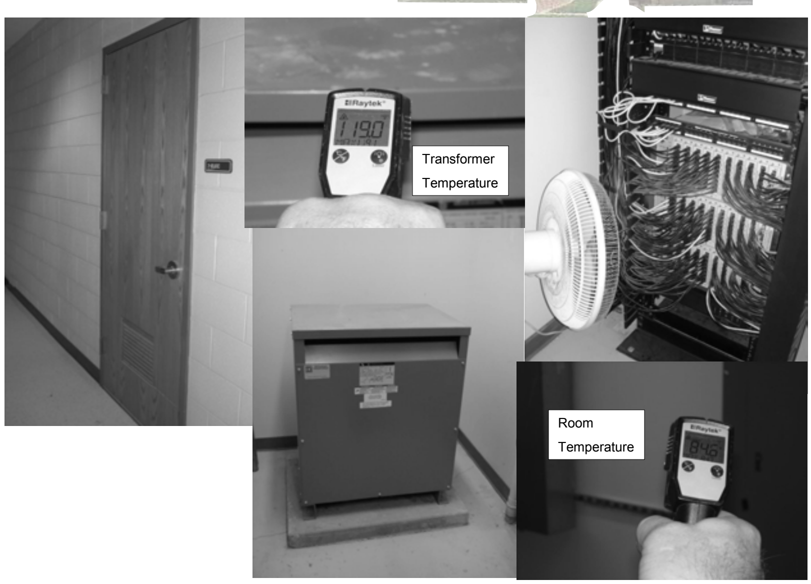


Computers are everywhere

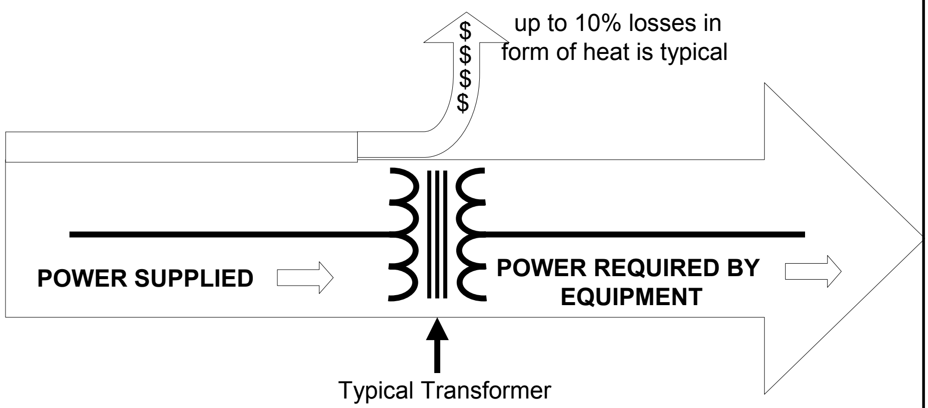


Variable Speed Drives in Ventilation and Industry

E²S

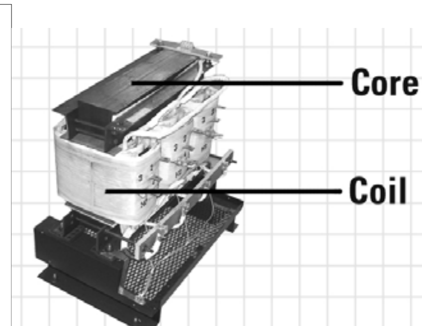


The Transformer is a key component
All electrical power flows through it



The Transformer

- Steps down high distribution voltage to match end use equipment requirement
- Losses impact operating cost
- Design impacts power quality



Embedded for the life of the electrical system – up to 50+ years

E²S

Analysis of Impact of Electronic equipment on Transformer operating cost

Transformer T_I Harmonic-Related Losses and Cost Per Year

Load = 60 kW 3-phase, on 112 kVA	P_{loss} (W)	Cost/Year
Copper loss = $\sum I_h^2 R$	2986	$1,308
Eddy current loss $P_{EC} = \sum I_h^2 h^2$	1336	$585
Total load loss $P_{LL} = \sum I_h^2 R + P_{EC}$	4322	$1,893
Base load loss = 1.05 x $I^2 R$	1575	$690
Penalty = P_{LL} - 1.05 x $I^2 R$	2747	***$1203***

Actual Total Losses **2.7 times higher** Linear Load Losses

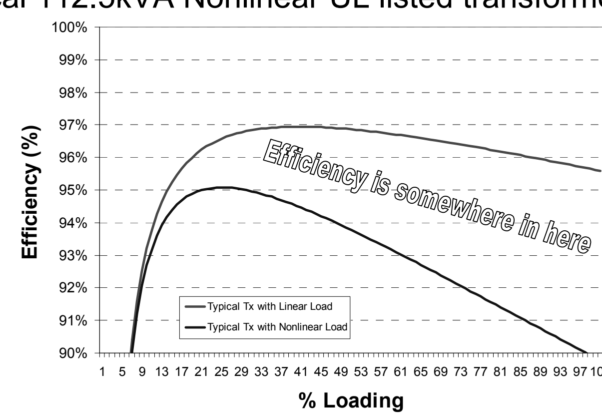
IEEE Transactions on Industry Applications, Sept/Oct. '96
"Costs and Benefits of Harmonic Current Reduction for Switch-Mode Power Supplies in a Commercial Office Building"

Tom Key, PEAC
Jih-Sheng Lai, Oak Ridge National Lab, Lockheed Martin Energy Research

E²S

Energy Deficiency

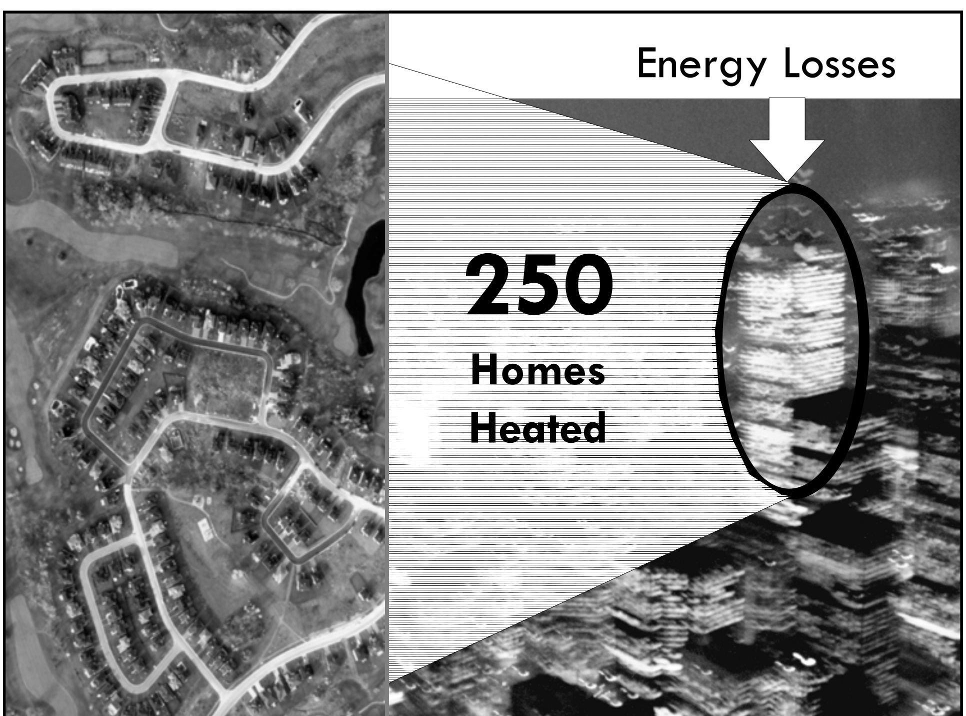
Typical 112.5kVA Nonlinear UL listed transformer



Significant variation in efficiency over load range & concentration of electronic equipment

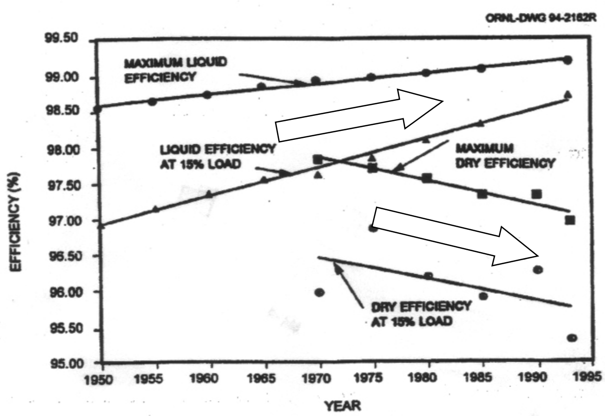
DOE Study Findings

- Aging Infrastructure
  - 70% of buildings built before 1980
  - 50% of buildings built before 1970
- CONSEQUENCE:
  - up to 70% of installed transformers are approaching end of life
- Transformers are lightly loaded
  - Less than 35% (most 10-25%)
- 60-80 Billion kWh losses annually
  - $3-4 Billion Annually
  - 9 days generating capacity
- Power Generation is large source of air pollution



45 Year Review of Transformer Efficiency

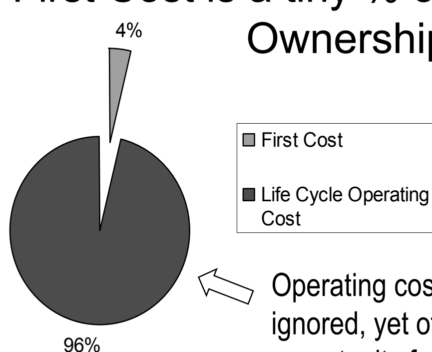
Utility **Life Cycle** purchases have driven up transformer efficiency



Commercial **First Cost** purchases have driven down efficiency

Fig. 1. Distribution transformer efficiencies over the years for 75-kVA, three-phase units. *Sources:* Barnes, P. R., et al. 1995. *The Feasibility of Replacing or Upgrading Utility Distribution During Routine Maintenance*, ORNL-6804/R1, Martin Marietta Energy Systems, Oak Ridge Natl. Lab. Also, transformer manufacturers' data.

First Cost is a tiny % of transformer Total Ownership Cost

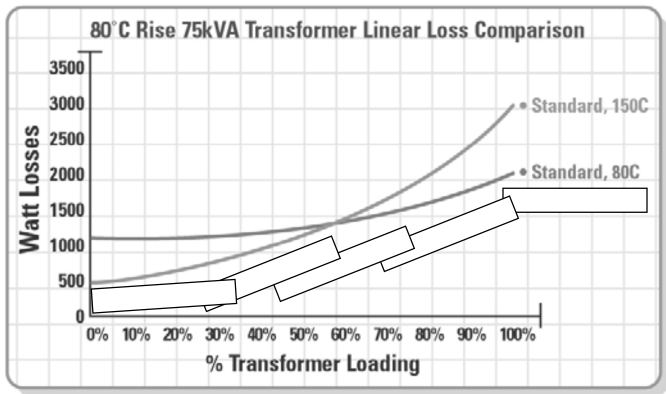


Operating cost (transformer losses) are ignored, yet offer by far the largest opportunity for savings

Why First Cost Dominates Purchasing Process

– End user, who pays for losses, is rarely involved in the purchasing process
– End user is not educated to the potential savings

E²S



- Historically, performance comparisons made at full load
  - 25-30% savings with 80C at full load
- But at avg. DOE load of 35%, 80C has 50% higher losses
  - higher operating cost in most systems - embedded for 40 years

Performance is representative, but losses vary by design

E²S

Energy Star Transformers

Commercial & Industrial Transformer Program

- Adopted NEMA TP-1 High Efficiency Transformer Standard
- Legislated in some states
- Sets substantially higher Efficiency Target @ 35% load level
  - Example: 75kVA 3-phase, low voltage: efficiency requirement: 98.0%
- Drawbacks
  - Not UL Listed to feed Electronic Equipment
  - Transformers rated for Electronic Equipment are Exempt from meeting TP-1 efficiency
  - Experience where legislated -> exemption allows substitution of cheaper lower efficiency K4 transformers are substituted where Energy Star specified

E²S

Change Mentality – Minimize Life Cycle Cost not First Cost

Embeds Savings – instead of operating cost

Opportunity

- 50-70% energy savings typical
- Over 25 - 40 years life

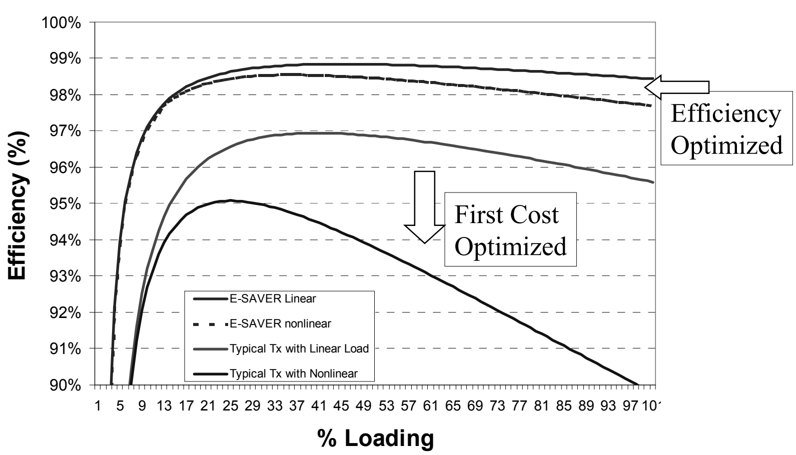
Specification

- 25% less losses than NEMA TP-1
- UL Listed for full electronic load
- Integrated revenue class metering port for field performance validation
- 25 year warranty

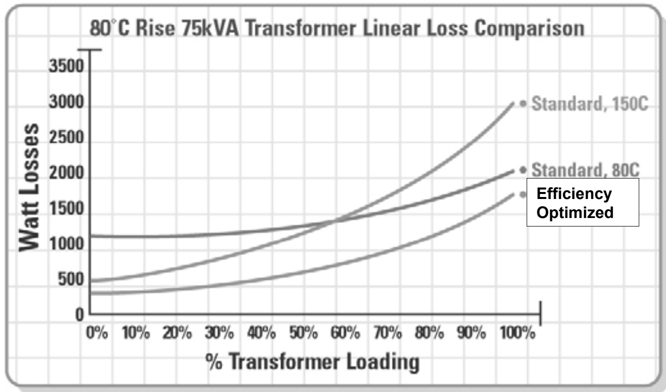
E²S

Optimizing for Efficiency

Predictable Energy Savings under all loading conditions

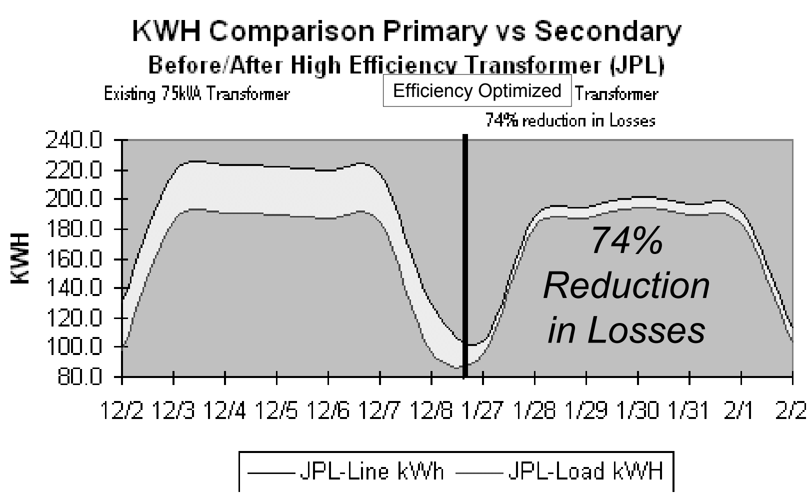


Efficiency Optimized Transformer vs. Standard and 80°C Rise Transformer



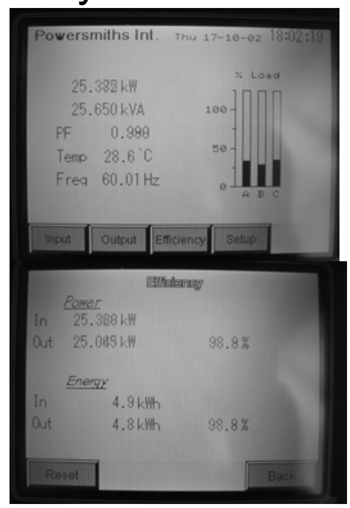
- lower losses across the full load range

Case Study – University of Texas - San Antonio



Field Validation – The Key

- Efficiency, Power Quality & Temperature Monitoring
- Preventative maintenance
- Load balancing
- Provides data for LEED reporting



Compare Products

- Annual Savings
- Avoided Cooling
- Payback
- Life Cycle Savings
- Environmental benefit

The ESP Calculator™

Energy Savings Payback Calculator

Toll Free : 1-800-747-9627 or (905) 791-1493

Project Description Project
Date 13-May-03

Data Entry

% Load during normal operating hours	35%	315
% Load outside operating hours	20%	Load kW
equipment operating hrs/ day	10	
equipment operating days/yr	260	
kWh rate	$ 0.070	
demand rate ($/kW/mo) ex. $10.00	$10.00	
Load Power Factor	0.85	
Cooling System Performance (kW/ton)	1.75	
		Nonlin Loss Mult
Other Transformer Linear Efficiency & Loss Multiplier*	96.0%	2.0
Powersmiths Nonlinear Efficiency	98.4%	

Transformers on Project

QTY	kVA
	15
	30
2	45
3	75
	112.5
	150
	225
	300
	500
	750
	1000
	1500
	2000
	2500
	3000

Energy Cost Analysis (calc)	Annual Operating Cost	kW Losses in Normal operation	kW Losses outside operating hours
Traditional Transformers *	$6,691	12.2	7.0
Powersmiths Transformers	$1,251	2.3	1.3
ANNUAL Energy Savings with Powersmiths	**$5,440**	9.9	5.7

Annual kWh savings **60,704** kWh/year
Avoided Cooling Load **2.8** tons (on peak- normal operation)
(lower losses => less heat to remove) **1.6** tons (off peak - outside normal hours)

Estimated Annual Power Quality Savings $2,000

Life Cycle Savings and Payback	First Cost	Life Cycle Operating Cost 25 years	Life Cycle Operating Cost 40 years
Traditional Transformers	$7,000	$217,265	$347,624
Powersmiths Transformers	$12,000	$31,277	$50,044
Total Life Cycle Savings	($5,000)	**$185,988**	**$297,580**
Payback on Incremental Cost	0.67	years	

Leasing Option	60 Month Term	48 Month Term	36 Month Term
Total Annual Leasing Payments	**$3,034**	**$3,701**	**$4,709**
Net Annual Cost with savings	($4,405)	($3,739)	($2,731)

Summary of Environmental Benefits

Annual Reduction in Greenhouse Gases	45 tons of CO2	351 kgs of SO2
(Per EPA)	145 tons of Coal	151 kgs of NOx
Equivalence	8 Acres trees planted	6 homes heated
	6 Car Emissions	

IMPORTANT: By using the ESP Calculator™, you are agreeing the TERMS OF USE section on page xxxxxxxxxxxxxxx
Powersmiths International Corp. is a licensed user. Content subject to change without notice

E²S

- A typical Building transformer makeup and energy savings potential

5 – 45 KVA; 5 – 75 KVA;

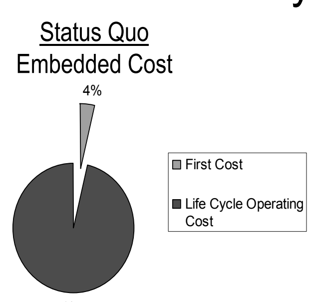
2 – 30 KVA; 1 – 15 KVA

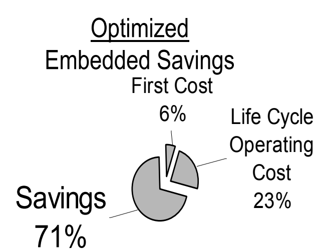
With a 6 cents a kwh Potential

Energy Savings annually $6600

E²S

Choose Life Cycle over First Cost





	Operating Cost		
	Standard	Efficiency Opt.	Savings
ANNUAL	$30,404	$5,584	$24,819
over 25 years	$760,095	$139,609	$620,486
over 40 years	$1,216,152	$223,375	$992,777

TEX – Transformer Energy IndeX

A new way to compare transformer performance

- kW delivered to Load per kW losses
- Like Miles per Gallon
- **Barrier - Efficiency 96% vs. 98% look similar**
  - but operating comparison should be 4% losses vs. 2% losses.
- TEX differentiates on operating cost
- TEX = 96/4 = 24   for 96% efficient transformer
- TEX = 98/2 = 49 for 98% transformer
- Like this car gets 49mpg, that car gets 24mpg – big difference!
- TEX = 49 vs. 24 accurately reflects difference in operating cost

Suggested Specification Content

- Move to a lifecycle specification
  - bid to include first cost and cost of losses over life
- Product features
  - Maintain TP-1 or higher efficiency under electronic equipment profile minimizing lifecycle cost
  - Built-in access port to transformer data - revenue class accurate
- Require On-Site Commissioning for efficiency & PQ after installation (Revenue Class Accuracy)
  - Only way to see if product meets specification
- Penalty Clause if performance not met (gives teeth)

University of South Carolina, Columbia

University of Massachusetts

- Plug and Phantom Loads
  - Plug loads can account for between 15-25% of electrical use in building – higher in dorms
  - Control is difficult but awareness many reduce loads – Policy on individual appliances -- individual refrigerators, heaters, microwaves and the like

E2S

- Phantom Loads
  - They are everywhere – Account for up to 5% of electrical use
  - Anything with a clock, a power cube or instant on feature
    - DVD Player
    - TV
    - Computers, printers, scanners, modems, radios, satellite receivers,

E2S

Conclusion

- Choose Life Cycle over First Cost
- Embed savings not cost -> choose higher TEX
- Validate performance in your building
- Selecting supplier that understands “real world” energy
- Manage Plug Loads and Phantom Loads