Engineering Analysis

U.S. Department of Energy Workshop on Standards for Distribution Transformers

November 1, 2000

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Engineering Analysis Translates Efficiency Improvements into Cost

- **The engineering analysis develops cost-efficiency schedules for each product class**
- **Cost-efficiency schedules are used to perform life-cycle cost analyses and to estimate payback periods**

The Engineering Analysis May Use One or More of Three Approaches

- **The *efficiency level approach* relies on costs provided by manufacturers to estimate the costs for various efficiency levels**
- **The *design options approach* uses estimates of the costs of particular designs that increase efficiency**
- ***Cost assessment approach* estimates the manufacturing costs of efficiency levels by analyzing existing transformers, possibly including teardown of some units on the market**

The Efficiency Level Approach Has Advantages and Disadvantages

- **Advantages**
  - **Less detailed information is needed**
- **Disadvantages**
  - **Difficult to independently verify accuracy of information**
  - **Uncertainty about the costs of efficiency improvements**

The Design Options Approach Also Has Advantages and Disadvantages

- **Advantages**
  - **Leads to better understanding of technological and cost aspects**
  - **Leads to consensus in manufacturing cost estimates**
- **Disadvantages**
  - **Requires much detailed information from manufacturers**
  - **Department must model efficiency improvements**
  - **Design combinations may be less cost efficient than manufacturers could develop**

The Cost Assessment Approach Is the Most Demanding

- **Advantages**
  - **Confidence in the impartiality of the results**
  - **Would yield a clear understanding of the cost-efficiency tradeoffs**
  - **Based on analysis of existing transformers**
- **Disadvantages**
  - **Department must develop a detailed manufacturing cost model**
  - **More time and effort may be required than for other approaches**
  - **Often will not consider new technologies**

The Department Solicits Comments on the Engineering Analysis

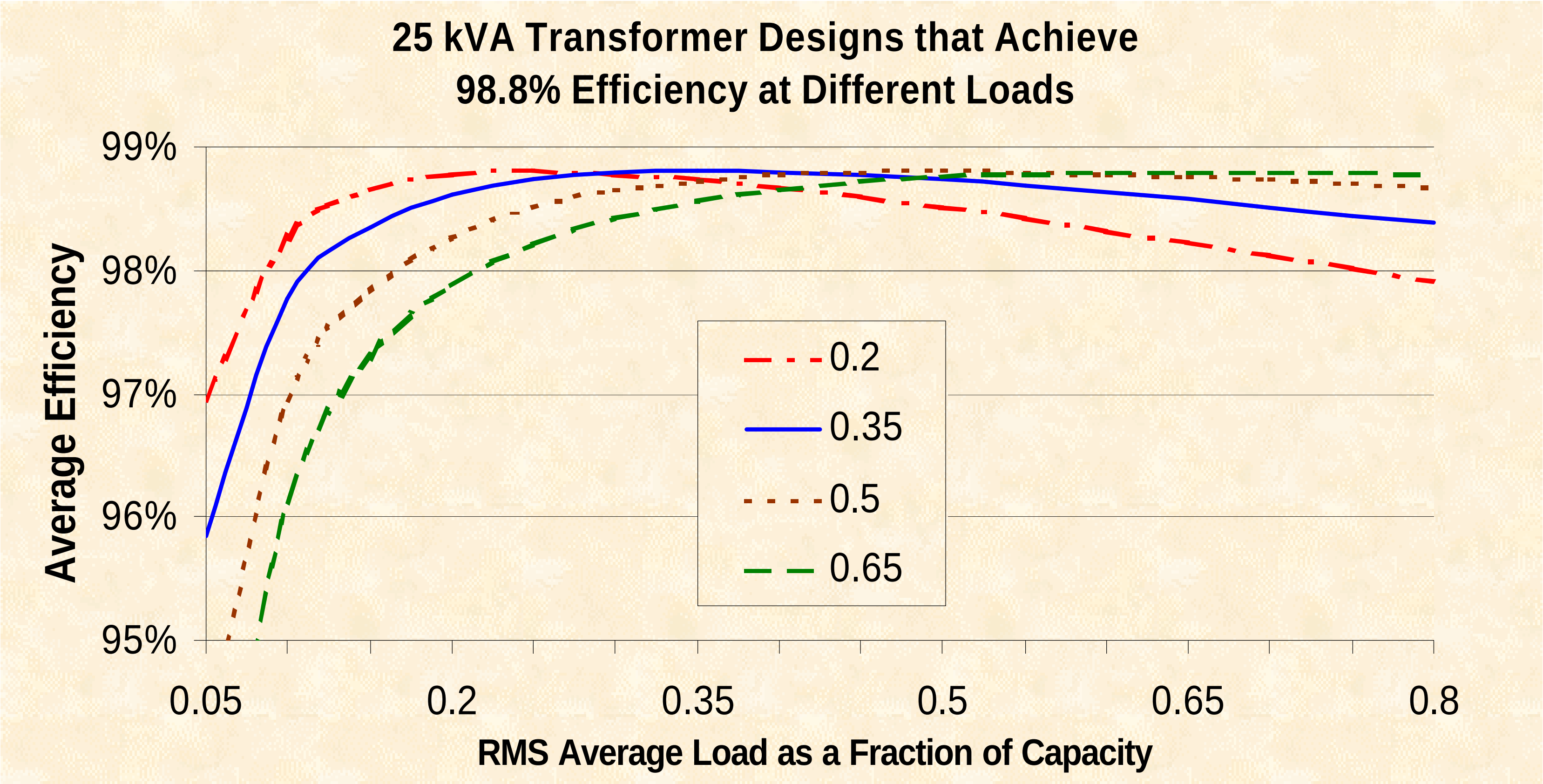
- **Efficiency level approach is least costly, but may leave some questions unanswered**
- **Cost assessment approach is rigorous, but most costly**
- **Design options approach is intermediate in cost and rigor**
- **A combination of approaches may be best**

Transformer Loading Is an Important Analytical Parameter

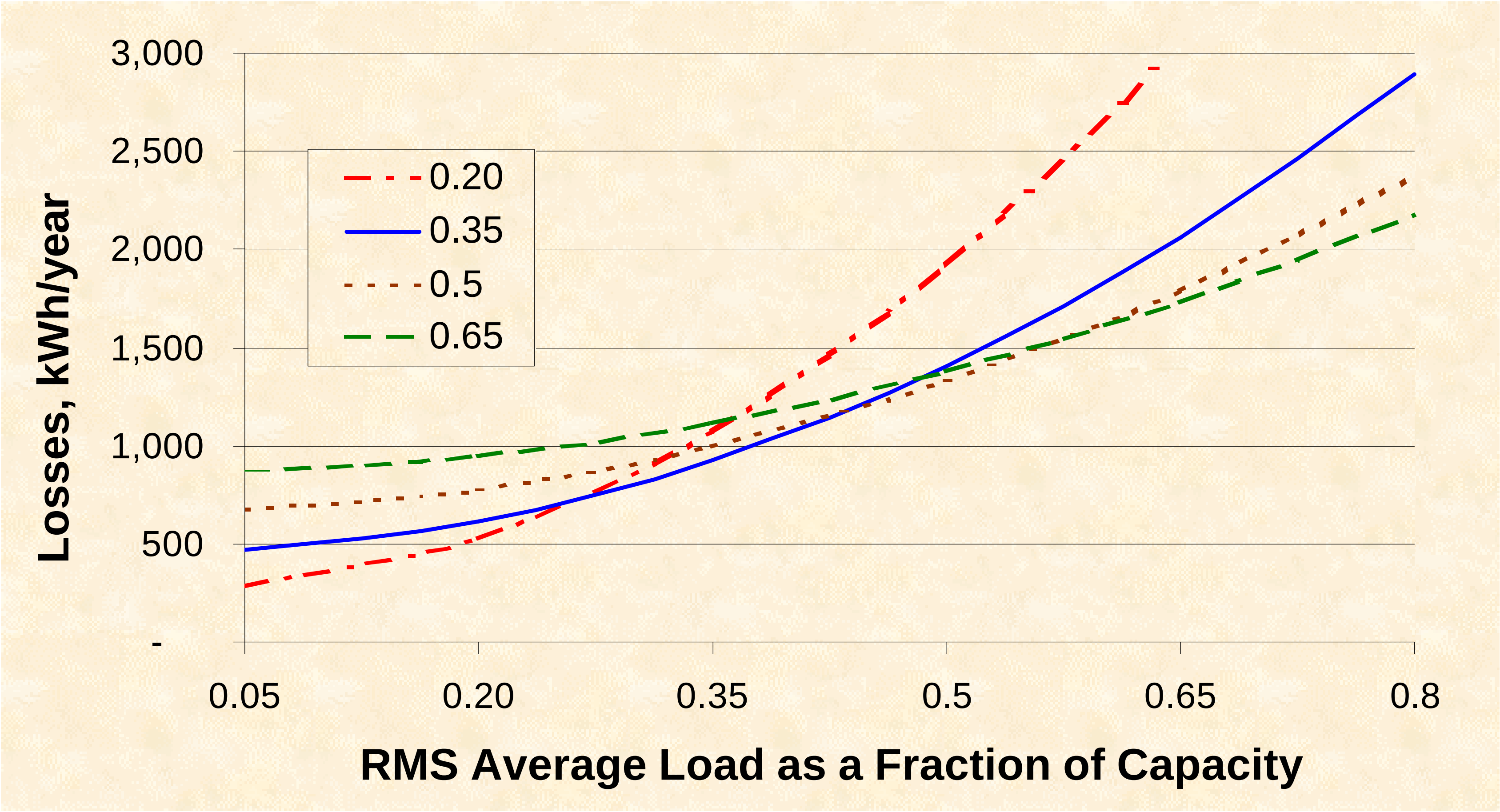
- **Transformers have “load” and “no-load” losses**
- **No-load losses occur all the time**
- **Load losses are proportional to the square of the current supplied**
- **Efficiency is highest when a transformer is loaded so that load and no-load losses are equal**
- **Transformer design can be adjusted to improve efficiency at the expected average loading**

Corrected 11/02/00

Transformers Most Efficient When Loading Matches Design Loading



But, Efficiency Isn't the Whole Story



There Are Also Economic Tradeoffs in Design for High and Low Loads

- **For highest efficiency at high loads:**
  - **More wire and/or more expensive wire**
  - **More labor intensive winding construction**
- **For highest efficiency at low loads:**
  - **More and/or higher quality steel**
  - **More labor intensive core assembly**

Transformer Loading Data and Estimates Span a Wide Range

- **NEMA TP 1 uses 50% for medium-voltage and 35% for low-voltage transformers**
- **The Cadmus Group reports an average of 16% ± 3% for 89 low-voltage C&I transformers**
- **Square D reports an average of 29% for *daytime* spot measurements of 89 low-voltage transformers in DOE's Forrestal Building**
- **Square D reports about 19% average loading on a 75 kVA low-voltage transformer in its Monroe, NC plant**

Data and Estimates of Transformer Loading Span a Wide Range (con't)

- **Average load on 256 medium-voltage (5 – 2000 kVA) transformers at ORNL is about 24%**
- **Square D reports 50% loading on two 25-kV 2000-kVA transformers at its Monroe, NC plant**
- **Square D data shows 31% average loading for five 1000-1500 kVA, 4-kV transformers at its Monroe, NC plant**
- **ORNL analysis of FERC Form 1 data shows the 1998 average loading of investor-owned utility distribution transformers is between 23% and 26%**

The Objective Is to Set Efficiency Standards at Realistic Load Levels

- **RMS average load has the main effect on economic efficiency**
- **Peak loads may be important because load losses may contribute more to peak loads than do no-load losses**
- **Transformers of different size and type are believed to be loaded differently – but data to determine the differences are lacking**

The Department Needs Peak and Average Transformer Loading Data

- **Billing data combined with transformer characteristics (capacity, no. phases, etc.)**
- **Measured loads on medium voltage transformers in non-utility applications**
- **Loading differences, if any, between high and low primary voltage transformers**
- **Low voltage transformer loading**
- **Applications and loading of single phase LV transformers**
- **Frequency and causes of LV transformer failure**

Information on how transformer sizes are selected or specified for all applications