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DC METERING AND TRACEABILITY

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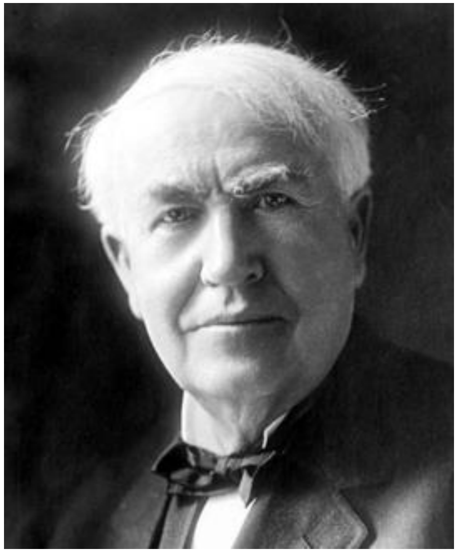
DC – EDISON MAY WIN IN THE END

- Edison thought DC was the winning form of electricity.
- Maybe in the end he will be right.



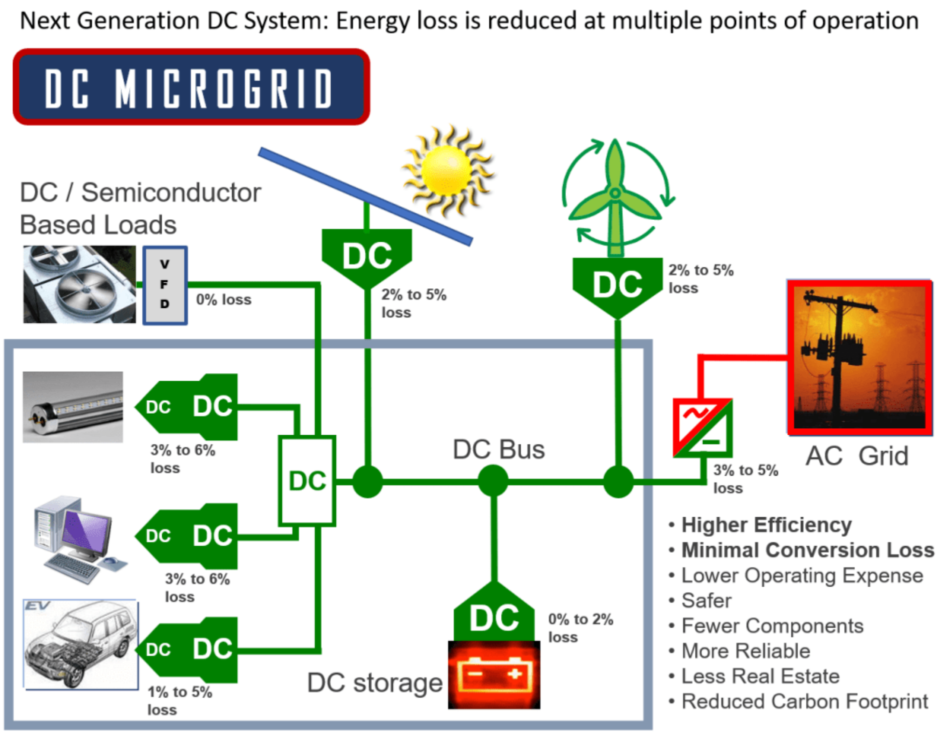
♦ Today almost everything we use could, WITHOUT MODIFICATION, be run from DC

DC – EDISON MAY WIN IN THE END

- Who would have imagined 10 years ago the cars powered by DC electricity would be the future of transportation.

DC – EDISON MAY WIN IN THE END

- DC micro-grids prove effective for shared cogeneration and storage



DC METERS – TOMORROW's CASH REGISTERS

- If you are going to sell it, you have to measure it.
- Real needs are driving the urgency for DC metering
- California has passed legislation requiring DC metering standards by December 1, 2020
- Yesterday ANSI SC32 voted out a DC Metering Standard

BACKGROUND

- DC Energy – the definition
  - Power $W(t) = V(t) \cdot I(t)$
  - Energy

$$E(t_0 + T) = \int_{t_0}^{t_0+T} W(t)\,dt = \int_{t_0}^{t_0+T} V(t) \cdot I(t)\,dt$$

Four quantities to measure:

Voltage, current, time, simultaneity

CHALLENGES

- Same definition as AC energy
- Voltage
  - For DC voltages we are limited to resistive dividers to get from system voltages to ADC levels
    - Generally this is not an issue.
- Current
  - DC meters may use shunts, Hall effect sensors, or more sophisticated devices such as zero flux transducers
  - Both high current and low current applications present issues at high accuracy

CHALLENGES

- Time Interval
  - Neither measurement nor accuracy is an issue
- Simultaneity
  - Modern sampling ADCs make true simultaneity easy
- So why is DC metering considered so difficult?
  - EVSE manufacturers demanded a relaxation of accuracy requirements to 5% and a delay of up to a decade to comply.

CHALLENGES

- DC may not really be DC
- There may be 10% of AC ripple on top of the voltage at frequencies in the 60Hz to 360Hz range
- There may be high frequency saw-tooth waves in the 20kHz to 250kHz range
- Loads may vary rapidly including large instantaneous steps

DEVIL IS IN THE DETAILS

- Modern AC meters use a variety of signal processing techniques to enhance accuracy.
  - Any DC content of the signals is removed
  - Algorithms such as FFTs and digital transforms make use of the AC nature of the signals to improve accuracy

- For AC, small, inexpensive CTs are available with inherent accuracies of ±0.02 percent

DC CURRENT MEASUREMENT

- SHUNTS
  - For high currents shunts are generally large and produce very low signal levels
  - A 1mΩ shunt in a 100A meter produces 10W with only a 0.1V signal
  - At 1.5 amps the signal is only 0.0015 volts
  - DC offsets can easily be larger than the signal and there is no simple signal processing trick to eliminate them
  - Shunts generally have fairly high temperature coefficients

CURRENT MEASUREMENT

- Hall effect sensors
  - Hall effect sensors are generally in the 1% to 5% accuracy range
  - Closed loop sensors may be better than 1%
  - Cost is generally high compared to shunts
  - Temperature dependence may be an issue

CURRENT MEASUREMENT

- Zero flux transformers/flux gates
  - Can be very accurate <0.1% over a wide temperature range
  - Measure AC and DC
  - Are VERY expensive compared to all other techniques
  - Few sources, large in size

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ESTABLISHING TRACEABILITY

- Normally one starts by sending a measurement device to NIST for calibration as a primary reference standard
- Unfortunately, NIST has no primary DC Energy Standard and does not offer that service
- So if you want a traceable measurement you have to start from basic measurements and qualify your own primary standard

ESTABLISHING TRACEABILITY

- The Validation Process
  - A primary reference standard candidate is constructed using multiple current sensors with AC/DC measurement capabilities
    - Precision zero flux transformer for high current 10 – 1000A
    - Precision shunt 0.1 ohm, 1 ppm TC with integrated PT100 temperature sensor

ESTABLISHING TRACEABILITY

- Current Measurement is validated in multiple ways
  - AC accuracy is validated against a Fluke 6105A with basic uncertainty of <50ppm
  - DC accuracy is validated against the Fluke 6105A up to 10A

- Above 10A a pair of precision shunts are used
  - An 0.100 Ohm shunt for 0.01 to 21 amps
  - A 100uOhm shunt for 10 to 1000A

ESTABLISHING TRACEABILITY

- Voltage Measurement is validated directly with the Fluke 6105A in both AC and DC modes
  - The Fluke 6105A has a basic uncertainty of <50ppm

- Because the system is fully calibrated in AC and DC modes it is also capable of mixed signal measurement of any kind
  - AC validation resolves any issues of timing and simultaneity

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TESTING DC METERS

- TESCO is currently testing a production meter for compliance with ANSI C12.32 (Draft of 10/6/2020

- TESCO is currently testing a production meter for compliance with ANSI C12.32 Draft of 10/6/2020
  - DC 120V-250V
  - 80A Self-contained
  - Accuracy class 1%

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EXAMPLE RESULTS

- Accuracy testing

ACCURACY TESTS (METER SN M2200000007)					
Nominal Voltage	Nominal Current	Test Time (sec)	Standard WHrs	Meter WHrs	% Error
250	80	180	989.67	989.458	-0.021%
250	50	288	995.84	997.334	0.150%
250	30	480	998.17	999.744	0.157%
250	20	720	999.74	999.946	0.020%
250	10	1440	1,005.28	1005.47	0.019%
250	5	2880	1,012.52	1008.48	-0.399%
250	1	14400	1,063.83	1054.1	-0.914%
120	80	375	994.61	996.006	0.140%
120	50	600	997.60	998.525	0.092%
120	30	1000	1,000.55	1001.56	0.101%
120	20	1500	1,002.01	1003.21	0.120%
120	10	3000	1,006.28	1006.72	0.044%
120	5	6000	1,013.61	1007.04	-0.648%
120	1	30000	1,061.62	1054.2	-0.699%

EXAMPLE RESULTS

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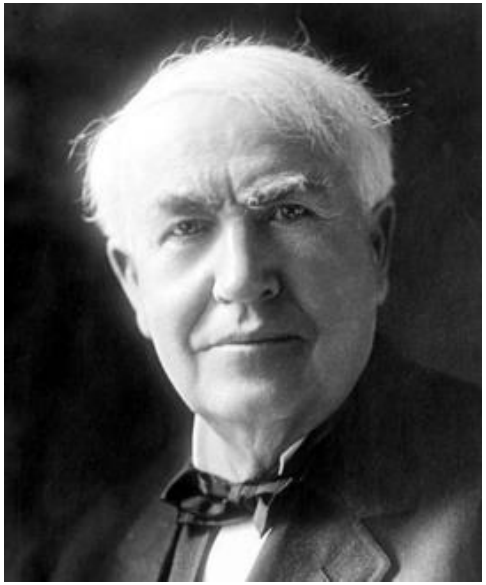
- Temperature Testing

Voltage	Current	23°C Error	Change at 70°C	Change at -40°C
250	80	0.060%	0.054%	1.67%
250	20	-0.059%	-0.260%	1.85%
120	80	0.097%	-1.261%	1.68%
120	20	0.340%	-1.145%	0.13%

- Results well within the requirements for an AC or DC meter of Accuracy Class 1%

CONCLUSION

- DC Metering is here today
- Today's technology can deliver cost effective DC metering with accuracies and environmental performance similar to AC meters.



Edison is smiling today!!!!

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Questions and Discussion

TESCO – The Eastern Specialty Company

Bristol, PA

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This presentation can also be found under Meter Conferences and Schools on the TESCO website: tescometering.com