THE EASTERN SPECIALTY COMPANY

DC METERING

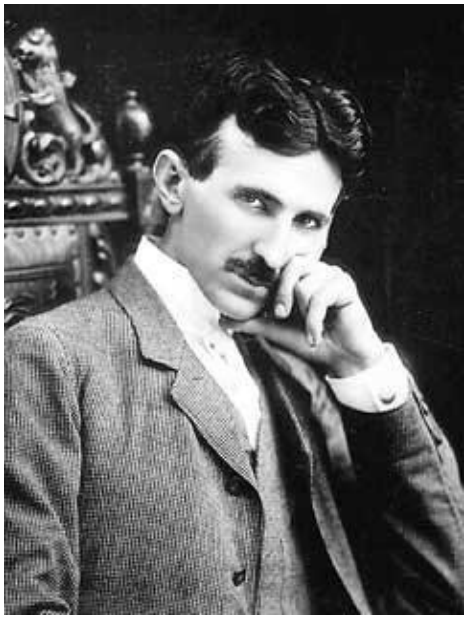
MOVING TOWARD CENTER STAGE

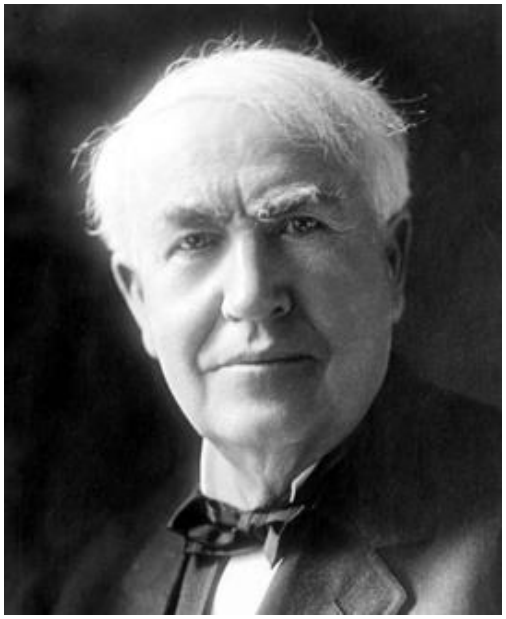
SOUTHEASTERN METER SCHOOL

Presented by: Tom Lawton
For Southeastern Meter School
Monday, March 13, 2023

DC Power – A Second Chance?

- We all know that Tesla won the current wars.
- But that was 125 years ago.
- Will Tesla and Edison move to a split decision as we progress further into the 21st century?





How we are trying to respond

or even stay ahead of the coming demand

- We have dedicated at least one session in four of the last six EEI conferences to the topic of DC metering.
- We have had an ANSI group working on DC standards for over six years
- We published ANSI C12.32 on DC Metering last year
- We are working on ANSI C12.33 on Revenue Grade DC Transducers - (met this morning at 10:00 and will have calls throughout the six months between now and the next face to face meeting)

PROVIDING THE TOOLS

- We are trying to provide the tools and the guidance to manufacturers and users alike on what to produce and how to approve and test the equipment that is approved.
- This starts by understanding what the need is and where DC metering is going.

WHERE HAS DC METERING BEEN?

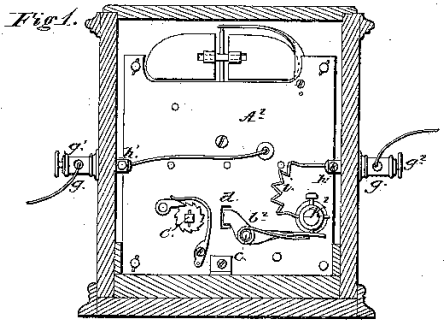
- The first electric meter in the 1870's was a DC meter.
- Much of the metering in the 1880's and early 1890's were DC meters

S. GARDINER, Jr.

Improvement in Electro-Magnetic Meters.

No. 132,569. Patented Oct. 29, 1872.

Fig. 1.



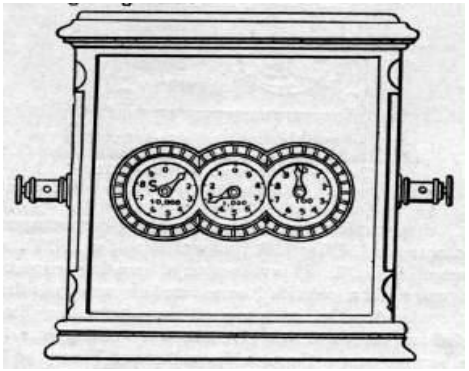


Image from original 1872 patent for Samuel Gardiner's electric meter and a rendering of the front cover

Where has DC Metering been?

- However once AC won the contract to light the 1893 Worlds Fair, Westinghouse, Tesla and team leveraged that to win the contract to provide the generators at Niagara Falls. And the war was over.

The first Power Station at the Falls

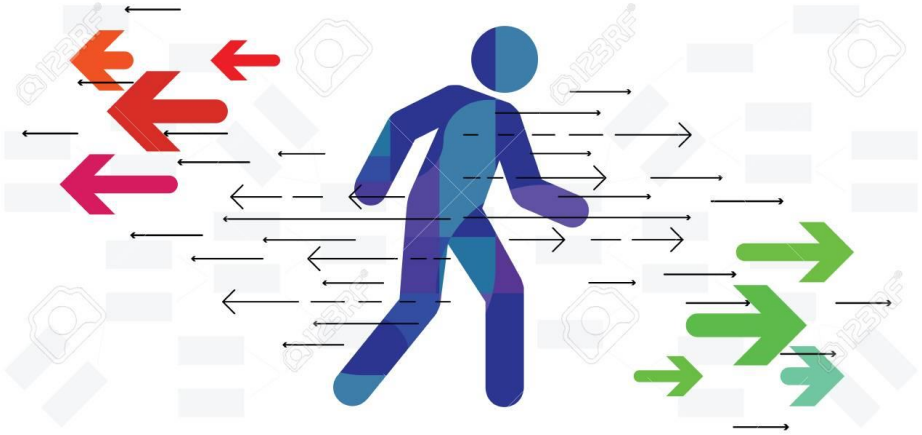
Edward Dean Adams power station at Niagara, with ten 5,000-horsepower Tesla/Westinghouse AC generators — the culmination of Tesla's dream. **(Courtesy Smithsonian Institution)**

Relics from the Origins of the Grid

- DC Metering remained for some isolated services in certain urban areas such as New York City and San Francisco
- There are still DC meters in both cities (as well as in others) for elevator services and other services.
- These meters are not ANSI meters and utilities had no traceable means to calibrate these meters over the years.
- They remained another obscure relic of the early days of our electrical grid that we kept, worked with, worked around and mainly forgot about as we do things like two phase power or DC generators.

NOT QUITE DEAD YET

- However, these “relics” are making a come back. There is suddenly a demand for DC power. Renewables are generating DC power and we are needing to both store and invert the power to AC so we can use the power on our system.
- Suddenly people are needing to meter large scale DC energy usage and wondering why we need to constantly convert back and forth between DC and AC.



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EMERGING MARKETS

Today almost everything we use could, without modification, be run from DC. There are markets that are purely DC markets and would benefit from direct revenue grade DC metering

- Electric Vehicle fast chargers
- Renewable energy generation and settlement
- Server farms
- Micro grids
- And most likely – the home of the near future

DC Fast Chargers

- 350 KwH chargers are becoming common place. The marketplace is clamoring for larger, faster, more powerful ones that are being tested now for implementation in the near future. Conversion efficiencies are already above 97%.

DC Meters for Super chargers

- These ultra fast charging stations already have localized charging peaks into the mega watts.
- The EV charging market is already a massive energy exchange market with energy charging peaks into the megawatts of energy.
- With this amount of energy comes a significant amount of revenue which requires the most accurate billing possible.

.....SO WE CAN PRESENT ACCURATE BILLS

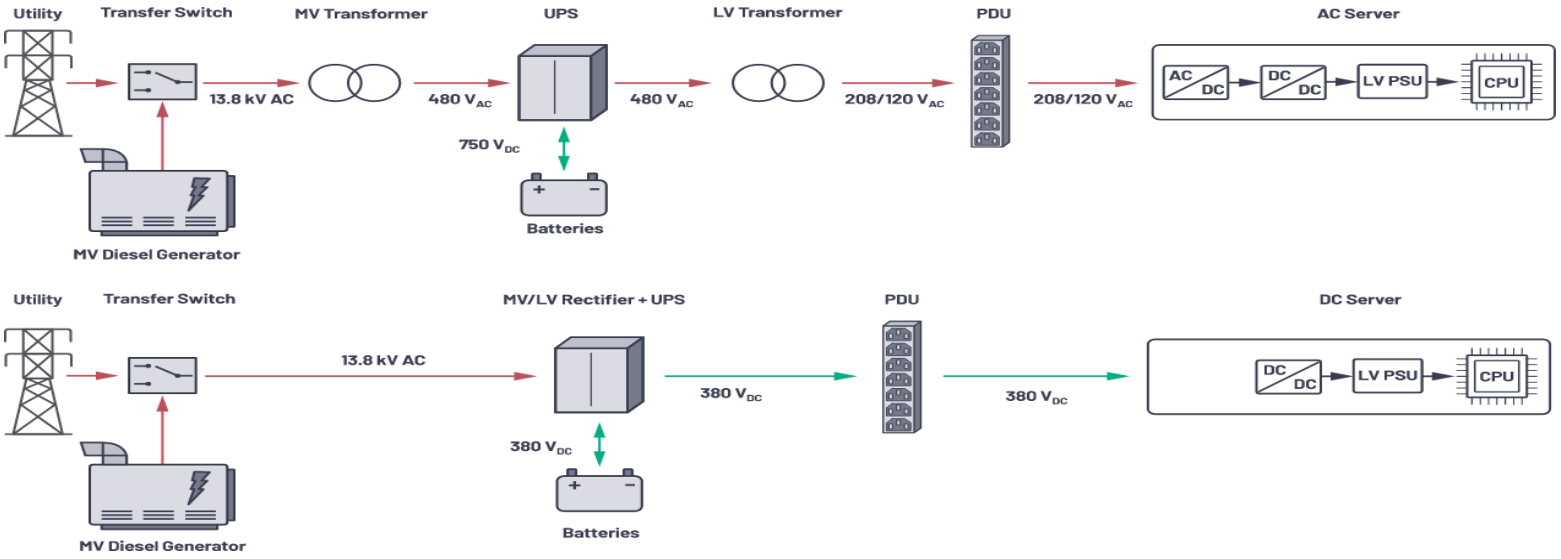
- With conversion efficiencies so high the best way to accurately meter this usage will be on the DC side.
- Regulators can determine if a rating factor for the conversion efficiency will be used as a multiplier for the metered accuracy or if this will only come into play if conversion efficiencies fall below a certain threshold as we do with power factor on the AC side.

DC Data Centers

- The two most expensive costs in a data center are energy and space.
- Data center operators have been steadily moving to DC distribution to minimize the conversions between AC and DC.
- Moving to all DC distribution has the potential for a 5 to 25% energy reduction by improving the conversion efficiencies and reducing the amount of heat generated.

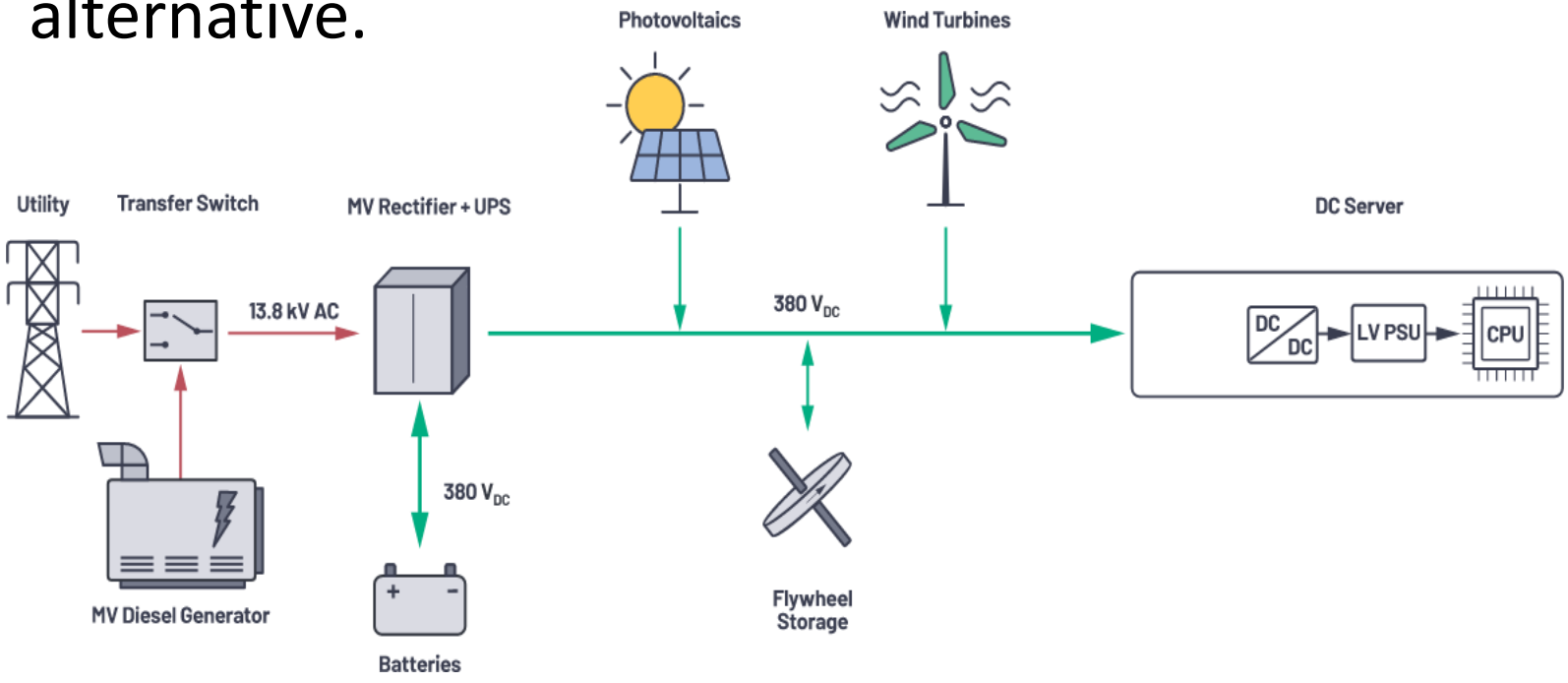
DC Data Centers

- DC also has the potential to save anywhere from a quarter to a third of the space
- And once again – requiring/demanding accurate DC metering.



…AND THEN WE HAVE THE OPTION TO ADD RENEWABLES

- And once a data center moves to DC distribution, the integration of renewable energies to further reduce ongoing operating costs becomes a feasible alternative.



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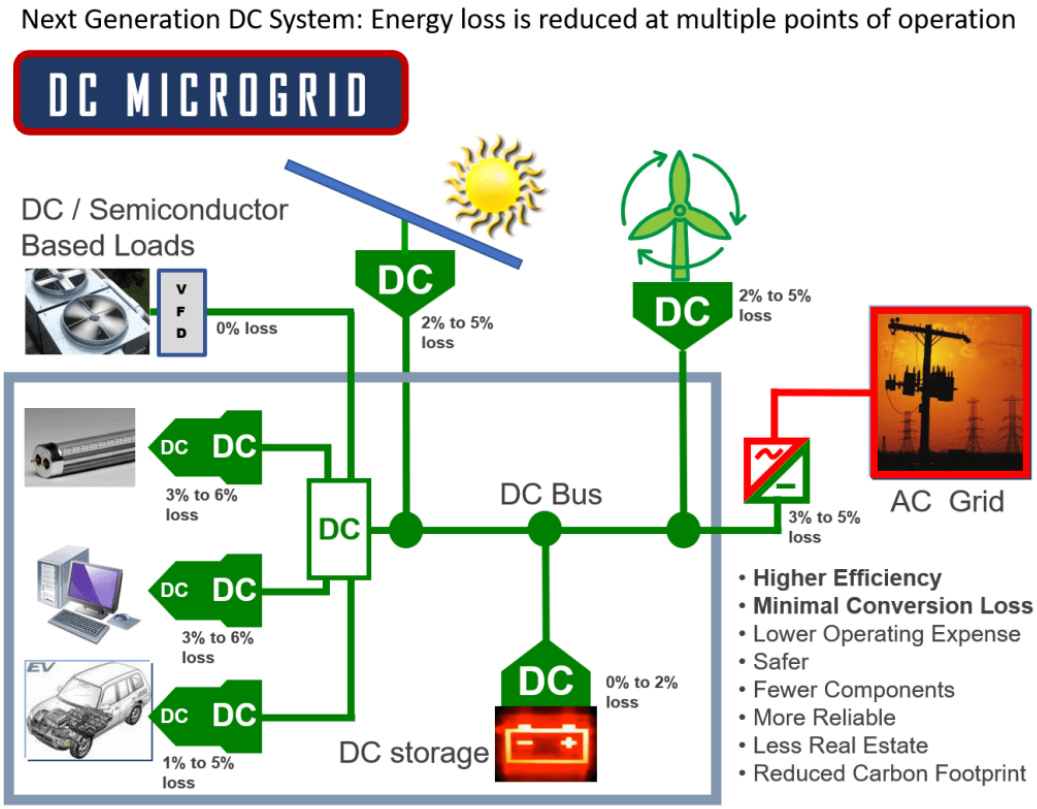
MICROGRIDS

- Any small business or even a home can become a Microgrid at this time given that virtually every appliance and tool can be powered by DC.
- Inverting the AC to DC one time and in an efficient manner at the demarcation point between the home/microgrid and the utility.
  - Inverting one time instead of for each piece of equipment can represent a 20% energy savings alone.

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 accurate and traceable DC metering

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:

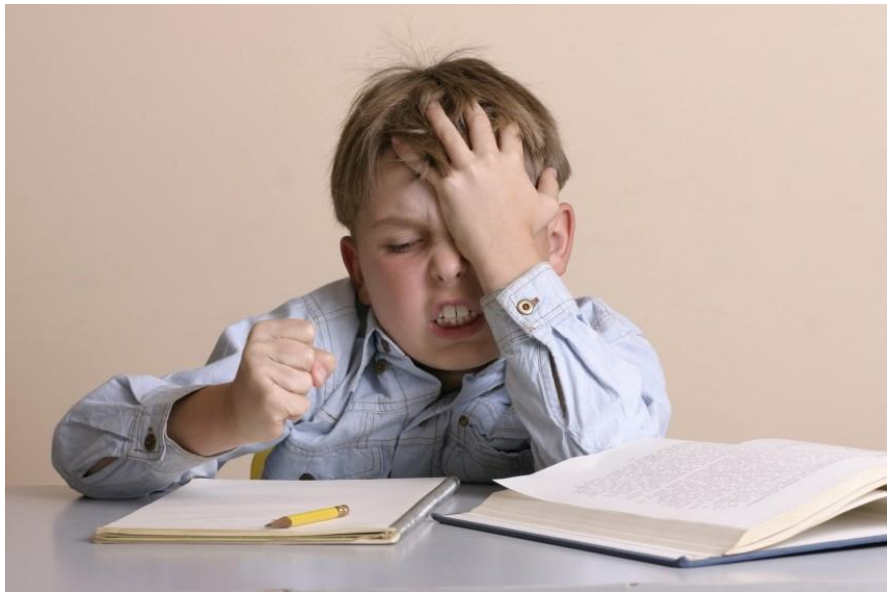
Voltage, current, time, simultaneity

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

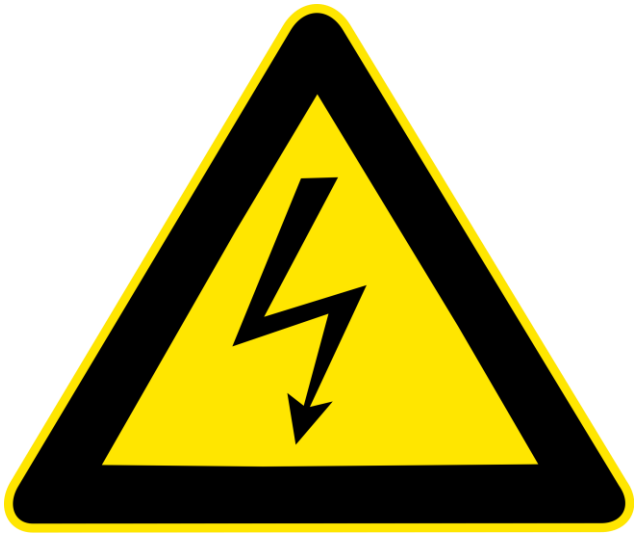
CHALLENGES

- Time Interval
  - Neither measurement nor accuracy is an issue
- Simultaneity
  - Modern sampling ADC's (Analog to Digital Converter) make true simultaneity easy
- So why is DC metering considered so difficult?



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 FFT's (Fast Fourier Transform's) 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
  - 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

So we have technology that may be viable for the field and may be able to provide the 0.5 to 1.0% accuracies that we might want from a DC meter. How do we do better than this for calibration and certification purposes?

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

ESTABLISHING TRACEABILITY

- Make and Validate
  - 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

- 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

ESTABLISHING TRACEABILITY

- Since there is no primary DC Energy Standard to provide Traceability we had to start from basic measurements, agree a methodology and qualify a primary standard.
- Working with NRC, NIST the Bureau of Weights and Measures and other interested agencies a methodology was developed and the first 17025 lab in the country has been accredited for DC energy measurement.

BASIC TOOLS

- As an industry we now have some of the basic tools in place
  - A DC metering standard, ANSI C12.32 has been published. This standard will be under constant revision as DC usage continues to expand and develop – but we have a starting point.
  - The ability to provide traceable calibrations for devices trying to meet this standard. We have many new players jumping in to the DC world who do not know anything about metering and have never considered metering as they develop new devices.
    - We saw this with the initial Electric Vehicle chargers. The manufacturers of these devices have pushed back hard against being required to comply with any sort of accuracy standard – in large part because the devices did not initially meet any revenue grade standard
    - The same has been true for other new areas such as street lights.

- Now we have the ability to at least provide answers and guidance to these manufacturers as they develop their equipment

AND THE WORK GOES ON

- Now that we have the basics and now that DC metering is recognized as a field that must be mastered by regulatory agencies - and by utilities working to comply with these regulations (as we have on the AC side of the world for 125 years), the industry is able to forge ahead.

MOVING AHEAD

- National Bureau of Weights and Standards adopted into law after nearly a decade of debate and push back the first regulations on DC fast chargers
- More and more DC meters are being developed as meters and not simply as embedded devices in DC devices
- Guidance is being given on how to better meter DC energy

Instead of the Wild West

Instead of operating in a vacuum equipment manufactures now have guidance on what will be needed from them.

Comments on DC Fast Charging Relevant Current Sensors- HB44 requires type certification at 1% for point of dispensing, indicating .5% or better sensor

The following slides describe cost, accuracy and physical size of hall, flux gate and shunt current sensors. Of consequence is location and physical constraints in EVSE dispensing systems for installing sensors. Relevance is meter/sensor complexity, that data output needs to be isolated from measured signal, along with dedicated power for hall sensor/meter.

AND EVOLVING

- As the market continues to evolve the metering requirements will continue to evolve.
- We now have the technology to run an entire household on DC. What are the implications of that?

The DC Home or Small Business

- All DC in the house
  - Kitchen
  - HVAC
  - Bathroom
  - Entertainment
  - Communication
    - Telecommunication
    - Internet for work
  - Car
  - Solar
  - Energy Storage

CLEAR ADVANTAGES

- Safety – class 2 touch safe wiring can be used throughout new construction or existing circuits can be used in existing homes, but converted to DC
- Lower distribution cost – especially for remote locations

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CLEAR ADVANTAGES

- Shorter potential outages as there is a back-up system
- Significantly Greater energy efficiency due to fewer and more efficient energy conversions
  - Within the house potentially no energy conversion – generate and store DC and then use DC. There may be nominal losses in the storage of the energy.

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What is the Utilities Role?

- Why not take on our traditional role?
  - Generation
  - Distribution
  - Metering
  - The technology for the coming century
- Why not provide the solar or another renewable and the storage as an optional part of the service.
- Build truly distributed generation
- Provide the AC back up and to smooth the demand as users grow in individual buildings

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AND HOW DO WE METER?

- For AC we have established a precedent where the utility delivers the apparent power and the customer is billed for the active power. The utility loses the difference created by the power factor.
- A meter with a bidirectional inverter included or immediately after the inverter would meter the DC used or in some small amount, generated.
- Regulators can determine if a factor can be added for the conversion losses as these can be determined and will be fixed, like transformer losses.

CONCLUSION

- DC Metering is here
- Today's technology can deliver cost effective DC metering with accuracies and environmental performance similar to AC meters.
- DC applications will evolve and the form factors for DC Metering will evolve.
  - Will we go with din rail mounted?
  - Embedded?
  - Return to our socket based meters for ease of installation and removal?
  - Some combination of the above?
  - None of the above?

CONCLUSION

Regardless of the answer, DC Metering is here today and is here to stay. DC will share the limelight with AC and will no longer be a relic of the past.

Edison is smiling today!!!!

Questions and Discussion

TESCO – The Eastern Specialty Company

Bristol, PA

215-228-0500

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