Importance of in-circuit reliability of Energy Meters

Electricity meters are ubiquitous in today’s world and considering the importance of electricity they measure, it is absolutely necessary that they do not fail. Unlike electro-mechanical meters, a well designed and manufactured electronic meter generally does not wear out per se. But in reality the percentage that fail exceeds 10% per year. Often, the root cause of poor reliability of meters can be traced back to its poor design or design with little or no head-room, compromise on component selection and lack of controlled manufacturing processes. The commonly used procurement criterion of ‘compliance to metering standards’ which prescribes only the minimum requirements does not help in meter selection.

- Rajesh Nimare

Concerns with energy meter

- Overload with each premature failed meter
  - Cost of dispute
- Replacing out of turn defective meter
- Staff for meter defective call
- Engineering and management time
- Customer move to other DB

Focus on in-circuit reliability
This document explains the impact of poor in-circuit reliability of meters on customers and the utility, it explains the fundamentals of reliability and concludes by helping the utility to develop their own check-list towards meter evaluation.

Customer first
As an electricity customer, did you think yourself lucky if your meter was defective and you were getting zero consumption or an average bill, think twice. There is a bright chance that you will be levied a bill in arrears to cover-up for the billing based on average consumption. This will be calculated based on the maximum consumption measured in the “window months” after the meter has been replaced. With consumption increasing steadily, the arrears could run into several tens of thousands of rupees. The duration for which this charge would be levied will depend on whether the new meter is installed after the “season boundary” and the time taken to change the meter. This leads to a possibility of real life disputes like, e.g., If you were away all the summer why should you pay the hefty arrears and who will pay for the arrears in case of changed tenancy.

Utility too suffers
On the flip side, the electricity distribution office in your locality whose primary job is to attend to outage calls and line maintenance, with its aging workforce and expanding customer base has very few or no resources for meter replacement. Replacing meters has a costly chain of back-office activities like investment in meters, storage of meters in standard, defined conditions, logistics, re-testing at expensive meter test laboratories, warranty returns and scrap management. At times, a meter defect like a blown neutral results in high voltage at the customer’s premises leading to burn-out of expensive white goods. The aggrieved customer can sue the utility and the already burdened utility engineers have to attend Court hearings; further worsening the situation. Considering the present, conservative, estimate of in-circuit meter failure of over 10% per year, the utility are lucky that you have thought of improving meter reliability.

Who loses?
What clearly emerges is that in-circuit failure of electricity meters is a societal loss; its magnitude is way higher than the cost of the meter for the electricity it would have traded. Would you buy a local “standard compliant” music system or something of repute like Sony when it is your money which is being spent? Surely you would not want to build an electricity infrastructure with unreliable meters which impact the wider society. The utilities too realise the menace associated with in-circuit failure of the meter and have tried to reduce their risk by a range of measures, e.g., demanding a prolonged warranty period (up to 10 years) to address the issue. These measures have not yielded the expected results. Limited testing facilities and technical specialists to establish the cause of the defect constrain the utilities in claiming under the warranty. Therefore the question arises: can the utilities predict the performance of meters? Yes, reliability engineering is all about that!
Need to focus

Poor performance of meters cause customers to lose trust in them and increase the liability a utility faces. For these reasons it is important the utilities create a knowledge base on the reliability of metering assets and use this knowledge for vendor evaluation and meter procurement.

Utilities world-wide have identified in-circuit reliability of meters as a key priority area (KPI) and have created dedicated laboratories for evaluating reliability, conducting failure analysis and running sampling plans for meter procurement, a competitive advantage. The plans are a well kept secret.

The following sections reviews the fundamentals of meter reliability, the vocabulary associated with it and its measurement. Understanding a meter's block diagram should be a good starting point.

The key components of an energy meter which determines its reliability are explained below:

Power supply: The power supply section comprises 35-40% of the total component count in a meter and its job is to provide the regulated, low voltage DC power needed to drive the meter electronics. Being exposed to the distribution network, the meter power supply has to endure over/ under voltage, sag/swell, transients, resonance, switching surges and lightening impulse. A meter reported "dead" usually has its roots in power supply failure which account for around 70% of all failures. Designers uses high dissipation resistors and voltage clamping devices such as pre-conditioners, however, because they are costly and do not directly add any value to compliance with "metering standard" (which defines the minimum criteria), this is often neglected. Therefore, the entire power supply design continues to be an area to examine while evaluating meter reliability. There are two types of power supply used in modern electronic meters, viz capacitor based linear power supply and Switch Mode Power Supply.

Capacitor based supplies uses a capacitor divider network to drop the input voltage (230V) to the usable value. An input capacitor, which experiences maximum stress, is the critical component in such power supplies and its rating (temperature, voltage) determines the reliability of such meters. Utilities during procurement should insist on the design analysis of each component under stress.

Switch Mode Power Supply (SMPS): is used for advanced meters which have higher power supply requirements. In such designs the supply voltage is rectified, filtered and then switched at high frequency (to minimise transformer size) to create the required low voltage which is further rectified and filtered for powering up the meter. As the power supply in the first stage is exposed to the electricity supply, its endurance against voltage variation, spikes, transients, dips, surges determines the reliability of energy meter.

Voltage Transducer: Often a simple resistive divider is used to step down the mains voltage to a measurable range. As the long term performance of the voltage divider depends upon the selection of resistor used, the utility should examine this component critically to ensure long term performance.

Current transducer: Modern meters either use a miniature current transformer or a shunt to step down the load current. As the entire load current flows through the transducer, the integrity of the current circuit is important; it is important to take into consideration its endurance during overload and a short circuit. Often, no power symbol in a meter is due to burning of the meter bus-bar. As the current transformer provides a natural isolation between the mains and measurement circuit, its insulation design should be examined for reliability. For designs using a shunt as the current transducer, the method of handling line surges, transient load caused by modern gadgets should be critical examined during design evaluation.

Display: In modern meters the display is invariably a Liquid Crystal (LCD), its performance depends upon its specifications like tolerance to humidity and temperature variation.

Real Time Clock (RTC): Needs a battery back-up to maintain the clock during transportation and power outages. Usually the battery used for clock backup is specified for performance during Off-power mode running to typically 2-4 years and the shelf-life of the battery which determines the product life. A utility should evaluate the design of RTC backup battery to ensure that the meter is going to perform for the committed duration. Derating the label mA-hr of the battery is essential as there is a native variation of -15% to its capacity owing to influence of ambient temperature.

Understanding meter performance: the 'bath tub curve'

Over many years, and across a wide variety of mechanical and electronic components and systems, people have calculated empirical population failure rates as units age over time and repeatedly obtained a graph such as the one shown below. Because of the shape of this failure rate curve, it has become widely known as the "Bath Tub" curve.

Typical to a discussion of reliability is the concept of the bathtub curve. Shown below, the curve can be broken up into three portions.

Zone I - Burn-In Period: The rapidly decreasing part of the curve, referred to as the burn-in period or infant
mortality stage, is characterised by failures due to inherent component weakness and manufacturing defects. This relates to the practical observations with new energy meters where there is a surge of complaints of meter failing within a few months of meter installation. After passage of time the failure rate drops. Given that this is predicted behavior, quality meter manufacturers follow "burn-in" processes where selected components and circuit cards go through a burn-in in the factory before they are integrated into the product. In essence, the infant mortality which is inevitable should be precipitated and created before the supplies to the utilities to prevent expensive in-Circuit failure. Utilities should include an evaluation of the manufacturing technique as a part of their tender evaluation programme.

Value conscious utilities realises the importance of the manufacturing process (which can not be measured by "metering standard compliance" alone), hence they run a dedicated "vendor manufacturing capability evaluation programme". A series of open ended questionnaires are sent to the prospective vendors. The qualification based on the written statement factory is followed by an inspection where the processes, facilities, quality of people, in-works quality test plan, in-circuit failure figures (past) are audited. Often these utilities seek the assistance of industry experts in the field of manufacturing, reliability and QC to frame the entire vendor evaluation program; such that the society gets the bang for their buck.

Zone II Useful Life Stage: This is characterised by a constant failure rate due to random failures. There are techniques available to predict the constant failure rate and utilities should demand from meter vendors their prediction model as a part of their procurement process. Before going for a large procurement, a utility should verify the performance on a small pilot quantity. There are third party specialist companies which provide such evaluation services, however considering continuity of business, it is important that the utility develop their own reliability assessment facility.

Zone III- Wear Out Period: This stage is characterised by an increasing failure rate because of meter aging and deterioration. Because modern electronic meters are largely made up of semiconductor devices that have no real short term wear out mechanism, the existence of a Zone III for electronic systems is sort of a gray area. Usually, this area refers to the failing of batteries and fading of LCD. For most electronic components, Zone III is relatively flat.

Reliability prediction modeling

There is a variety of reliability prediction modeling techniques. These can be classified into five main categories. Utilities should focus on the details of each technique and its application during reliability assessment.

- Similar Equipment Techniques. In order to estimate the level of reliability, the meter design is compared with similar equipment of known reliability.
- Similar Complexity Techniques. The reliability of a meter design is estimated by comparing its relative complexity with an item of similar complexity.
- Prediction by Function Techniques. Correlations between function and reliability are considered in order to obtain reliability prediction of a meter.
- Part Count Techniques. Reliability is estimated as a function of the number of parts involved, more the number of parts in the critical path, the lower the reliability. However, this principle is to be applied with caution as a design which uses more pre-conditioning components in the power supply makes the design stronger vis-a-vis a design without it.
- Stress Analysis Techniques. Failure rate is a function of individual part failure rates and takes into consideration part type, operational stress level, and derating characteristics of each part.

Accelerated life cycle test

A highly accelerated life test (HALT), is a stress test for assessing product reliability. It is commonly applied to electronic equipment and is performed to identify design weaknesses in equipment. Thus it greatly reduces the probability of in-service failures (i.e., it increases the product's reliability). Progressively more severe environmental stresses are applied building up to a level significantly beyond what the equipment will see in-service. By this
method weaknesses can be identified using a small number of samples (sometimes one or two but preferably at least five) in the shortest possible time and at least expense. The second function of HALT is that it characterises the equipment under test, and identifies the equipment’s safe operating limits and design margins. Data from HALT is therefore used as a basis for the design of an optimal “HASS” or “ESS” test, which is used to screen every piece of production equipment for latent manufacturing defects and defective components. HASS or “highly accelerated stress screening” is an extension of HALT, but is applied during production.

An environmental test chamber artificially replicates the conditions to which machinery, materials, devices or components might be exposed. It is also used to accelerate the effects of exposure to the environment, sometimes at conditions not actually expected.

These conditions may include:

- extreme temperatures
- sudden and extreme temperature variations
- moisture or relative humidity
- electrodynamic vibrations
- electromagnetic radiation
- salt spray
- rain
- weathering
- exposure to sun, causing UV degradation
- vacuum.

Manufactured samples, specimens, or components are placed inside the chamber and subjected to one or more of these environmental parameters to determine reliability or measure after-effects such as dry solder.

Conclusions: Importance of meter reliability

There are a number of reasons why the electricity meter reliability is an important attribute for the utility, including:

- Reputation: A utility’s reputation is very closely related to the reliability of their installations. The more reliable a meter is, the more likely the utility is to have a favourable reputation.
- Customer Satisfaction. While a reliable meter may not dramatically affect customer satisfaction in a positive manner, an unreliable meter will negatively affect customer satisfaction severely. Thus high reliability is a mandatory requirement for customer satisfaction.
- Warranty Costs. If a meter fails to perform its function within the warranty period, the replacement and repair costs will negatively affect profits, as well as gain unwanted negative attention. Introducing reliability analysis is an important step in taking corrective action, ultimately leading to a meter that is more reliable.
- Cost Analysis. A utility may evaluate reliability data and combine it with other cost information to arrive at the cost-effectiveness of their purchase. This life cycle cost analysis can prove that although the initial cost of purchase might be higher, the overall lifetime cost is lower than a competitor’s because their meter requires fewer repairs or less maintenance.
- Competitive Advantage. With competition in the utility business, utilities worldwide publish their predicted reliability numbers to help gain an advantage over their competition who either does not publish their numbers or has lower numbers.

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