METERING TECHNOLOGY INNOVATION IN POWER DISTRIBUTION SECTOR

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INTRODUCTION

With the proliferation of electrically powered devices and systems, there is an increasing need to accurately and precisely measure and monitor the quantity and quality of the electrical power supplying these devices and systems. It is important to describe the metering technologies and techniques currently in use with best meter installations practices.

METERING TECHNOLOGIES

An electric meter or energy meter is a device that measures the amount of electrical energy supplied to customers of an electric supply company. Electricity providers must install and maintain meters at all customer locations, at the provider's expense, to ensure proper measurement and billing of electric service. Utilities record the values measured by these meters to generate an invoice for the electricity. At present, energy meters based on electromagnetic technology and static meters are being used in the Indian distribution network. Single phase meters are being used for most of the domestic and some commercial consumers, whereas 3 phase meters are being used for industrial, agricultural and large commercial consumers.

Energy meters typically consist of an energy measurement apparatus for measuring energy consumption and a gauge that is visible outside the meter for showing the amount of electrical quantities including the energy consumed. Electricity meters track among other things, the amount of energy consumed, typically measured in kilowatt-hours (kWh), at each customer's facility.

The available technology options are mentioned below;

1. **Electromechanical meters (Ferraris wheel meters);**
2. **Hybrid meters;**
3. **Static (electronic) meters;**
4. **Demand meters;**
5. **Multiple tariff (variable rate) meters/Time of Usage (TOU) meters;**
6. **Prepaid meters;**
7. **Automatic Meter Reading (AMR) and Remote Meter Reading (RMR).**

i) Electromechanical Meters

Electromechanical energy meters are based on the FerrarisPrinciple. The working of these meters is explained in Box 13.2.

In 1885, Galileo Ferraris discovered that when a solid disc is placed in an out-of-phase AC magnetic field, it rotates at a rate proportional to the flow of electrical energy in the coils that generated the field. This discovery, made over a century ago, is the principle on which the great majority of electromechanical energy meters still operate today.

The principle is simple: a solid disc is mounted on jeweled bearings and allowed to rotate freely in a sealed container. AC flowing through the coils in the meter, sets up an alternating magnetic field, which is proportional to the amount of power flowing through the meter. As the armature rotates in the magnetic field, a counter detects the number of revolutions made by the disk.

The meters have a revolving metallic disc mounted on jewel bearings/magnetic suspension bearings. The display is cyclometer or mechanical counters and accuracy is typically 1% or 2% (class 1.0 or 2.0). They cater to limited tariffs applicable mainly to 1-phase or 3- phase direct connected segment (whole current meters).

The electromechanical induction meter operates by counting the revolutions of the disc, which rotates at a speed proportional to the power consumed. The number of revolutions is, thus, proportional to the energy usage. The metallic disc is acted upon by three magnetic fields, one proportional to the voltage, another to the current and a third constant field supplied by a permanent magnet. One of the varying fields induces currents in the metallic disc, which are then acted upon by the other varying field to produce a torque. This results in the torque being proportional to the product of the current and voltage, i.e., power. As the metallic disc rotates through the permanent magnetic field, eddy currents are again produced which dissipate energy (since the disc has some resistance) and act to slow the rotation. This drag is proportional to the rotation speed. The equilibrium between the applied torque and the drag results in a speed proportional to the power. The rotating disc in this type of meter is, in fact, an electric motor of a type called a reluctance motor or eddy current motor. It consumes a small amount of power, typically around 2 W.

Fig. Electromechanical Energy Meter

ii) *Hybrid Meters*

These meters have electronic measurement circuits but display is through impulse counters/stepper motors. Accuracy is typically class 1.0 or 2.0 and generally these meters cater to limited tariffs applicable mainly to single phase or 3-phase direct connected segment.

iii) *Static (Electronic) Energy Meters*

Electronic energy meters are replacing traditional electromechanical meters in many residential, commercial and industrial applications because of the versatility and low-cost afforded by electronic meter designs. The measurement circuits are electronic with LED (Light Emitting Diode)/LCD (Liquid Crystal Display) display and their accuracy is typically class 0.2, 0.5, 1.0. They cater to multiple tariffs for all segments CT-VT (Current Transformer – Voltage Transformer) operated, CT operated, 1-phase or 3-phase Direct connected segment. These meters measure and record active, reactive and apparent demand/energy. The static energy meters are microprocessor based and have non-volatile memory to record and store data. The electronic meter in its basic form has a power supply, a metering engine, a processing and communication engine, i.e., a microcontroller, other add-on modules such as Real Time Clock (RTC), LCD display, communication ports/modules, etc. **These meters are extremely difficult to tamper with and if somebody does attempt to tamper them, they will send alarm signals and record the information**. The programmability of microprocessor has become a useful tool for incorporating different features like Tamper data, Import-Export, Time-of day metering, load pattern analysis, etc. They can be made SCADA

(Supervisory Control and Data Acquisition) systems compatible. They can have communication ports to support AMR/RMR on various communication platforms as well as for downloading of data.

Fig. Electronic Meter

iv) *Demand Meters*

Demand meters measure volt-amperes (in kVA), which combine both reactive (reflected) and actual (consumed) power. In its simplest form, a demand meter has a gauge whose pointer moves a marker. When the gauge falls back, friction keeps the marker in place. When a demand meter is read, its marker is reset, usually with a magnet from outside the sealed meter enclosure. Computerized demand meters usually find the fifteen-minute interval in the month with maximum demand (MD). Often they also record a month worth of fifteen-minute averages. Some demand meters measure the temperature of a conductor, or simulate the heating of the conductor, in order to track "running" demand. Running demand meters usually log the times when a maximum demand is exceeded, or they log the times when the meter enters a different tariff rate.

Electricity cannot be stored, so electricity retailers need to arrange the necessary generators to meet the maximum demand. New generators are long-term capital investments, so demand also directly affects the retailers' and power-providers' accounting, and need for long-term debt. In particular, when interest rates are high, generating companies are reluctant to install new capacity, and want customers to reduce demand, so the retailers use meters to detect and surcharge high demand.

v) *Multiple Tariff (Variable Rate) Meters/TOU Meters*

Time of use metering facilitates load control and planning on the part of utilities. This is effectively achieved using a concept called Time of Usage (TOU) metering. This involves dividing the day, month and year into tariff slots and with higher rates at peak load periods and low tariff rates at off-peak load periods. Electric utilities may charge customers different tariffs at different times of the day with the help of this type of metering. This is because there is generally a surplus of electrical generation capacity at times of low demand, such as during the night. Such multiple tariffs can be made applicable only by time of use (TOU) meters, which incorporate or are connected to a time switch and which have multiple registers.

Domestic variable-rate meters normally permit only one (uniform) or two tariffs (“peak” and “off-peak”) and in such installations a simple electromechanical time switch may be used. Large commercial and industrial premises may use electronic meters which record power usage in blocks of half an hour or less. This is because most electricity grids have demand surges throughout the day and the power company may wish to give incentives to large customers to reduce demand at these times. Some multiple tariff meters use different tariffs for different amounts of demand. These are usually industrial meters.

The multiple tariff rates may also be dependent of frequency, also known as availability based tariff (ABT), deployed in grid substations and interutility transfer points for bulk transfer of energy. This is based on the premise that the system frequency is inversely proportional to the current load. This also causes self-regulation because the rates are higher when the system frequency is low, eventually bringing down the demand. ABT compliant meters also known as Special Energy

Meters (SEMs) record and store data on electrical quantities in blocks of 15 minute period, which are downloaded for billing purposes at the time of meter reading.

vi) *Prepaid Meters*

Prepaid metering is a system whereby consumers purchase electricity through a smart card. The amount paid together with other information is encoded in the smart card. In order to transfer the credit, the consumer inserts the card in the meter. The meter reads the data and when the paid for energy has been used up, the consumer gets the card reloaded/ reprogrammed. The system has the capability of programming with multiple rates, time of use tariffs, etc.

Fig. Prepaid Meter

The use of prepaid meters results in almost total elimination of non payment and delayed payment and enables transfer of reliable, accurate and up to date consumption and billing data according to tariff policy in use. This information can be utilized by the utility for demand forecasting and for controlling peak demands. It also means substantial reduction in staff for meter reading, bill serving, bill complaints and bad debts, etc.

Full meter programmability allows maximum flexibility in changing tariffs.

Consumer can also decide in advance the affordable level of expenditure, which helps him and the utility in elimination of disputes regarding inaccurate bills.

vii) *Automatic Meter Reading (AMR) and Remote Meter Reading (RMR)*

Automatic Meter Reading (AMR) and Remote Meter Reading (RMR) describe various systems that allow meters to be checked without the need to send a meter reader out. This can be effectively achieved using off-site metering, that is an electronic meter is placed at the junction point where all the connections originate, inaccessible to the end-user and it relays the readings via the AMR technology to the utility. Remote metering enables online metering of energy consumption. It is particularly useful for high value consumers where accuracy of billing and delays in time taken for meter reading are important. Monitoring of consumption patterns to detect theft/ tampering of meters is possible with these types of meters. The remote metering unit may be the RTU (Receiving Transmitting Unit), which receives the pulses generated by the electronic meters and is connected to the Central PC (Personal Computer) Station through a communication system which could be PLC (Programmable Logic Control), public switched telephone network, radio, etc.

METERING TECHNIQUES

The techniques of metering can be classified depending upon the voltage at which consumers are fed as:

- **LT (Low Tension) Metering, and**
- **HT (High Tension) Metering.**

<u>LT Metering</u>

The following types of meters are commonly used for LT consumers:

Whole Current Meters

i) Single phase meters

ii) 3-phase 4 wire meters

iii) 3-phase 3 wire meters

CT Operated Meters

iv) 3-phase 4 wire meters with CT and MD

v) 3-phase 3 wire meters with CT and MD

These can briefly describe below;

i) Single phase meters

Single phase meters are generally rated for 240 V AC supply; the current ratings are 5/10, 10/20, 2.5/10 or 5/20 A and are for direct connection to the mains. They start registration with small load of about 6 W and record up to 4800 W.

The main feature of a single-phase meter (electromechanical induction type) is its simplicity, compactness and robust design. It comprises a potential coil and a current coil. The potential coil is fitted on the middle limb of an E shaped electro-magnet and connected across the supply mains. Similarly, the current coil consisting of a few turns of heavy gauge copper wire is wound on two limbs of a U shaped electro-magnet. The two fluxes, produced by the voltage (pressure or potential) coil and current coil, set up a mechanical torque on the non-magnetic aluminium disc (which is located between the 2 coils) causing it to rotate.

A brake magnet of C shaped alloy steel is provided to control the movement or rotation of the disc set up by two fluxes. The disc rotates through the narrow air gap of the C shaped magnet and eddy currents are set up, which interact with the field and exert braking effect.

ii) 3-phase 4 wire meters

3-phase 4 wire meters (10/20, 20/50 A) are used for agricultural and industrial consumers. For loads up to 50 A, the meters are directly connected to the supply. For greater loads, it is preferable to provide CTs. They are rated for 415 V.

In a 3-phase 4 wire meter, 3 pairs of coils of each type, i.e., potential coil and current coil are provided for each of the three phases. Each of the 3 elements (coil pairs) of the meter produces equal torque, i.e., one-third of the total torque under all conditions of varying power factor.

iii) 3-phase 3 wire meter

A 3-phase 3 wire meter has 2 elements of each type instead of 3 elements as in the case of 3-phase 4 wire meter. The basic principle of operation is the same as that for 4 wire meter. The torque produced by 2 elements is equal to each other when power factor (P.F.) is unity. At other power factors, the torques produced by the 2 individual elements are not equal and are of varying proportion. B phase element produces more torque at lagging power factors, while the R phase element produces more torque at leading power factor. This particular feature can be made use of to find out the P.F. of the load current of the consumer for the purpose of checking at site. Power factors less than 0.5 are indicated by the reverse running of the meter with only the R element in operation.

Usually, 3-phase 3 wire meters are not used in recording consumption of LT power consumers for the simple reason that the lighting load has to be properly connected on one of the phases R or B. Otherwise, if it is connected on the Y phase, where no current coil is provided, the energy consumption would not get recorded.

iv) 3-phase 4 wire meters with CT and MD

If load is generally more than 50 A, CT operated meters should be used. It is to be noted that **CTs should be properly selected for accurate recording.** Usually rating of CTs should fall within 50 to 80 percent of the maximum load current of the consumer. For two part tariff, meters having recording arrangement for maximum demand in kVA are to be provided. The maximum demand (MD) indicators are additional mechanism attached to the meters to record the rate of consumption over a fixed period (usually half an hour) each time and then get reset with the help of a time switch. A pointer indicating the highest ever rate of consumption thus recorded by the MD indicator is left behind, which has to be manually reset while taking down the reading every month.

v) 3-phase 3 wire meter with CT and MD

It is exactly like 3-phase 4 wire meter and works on the same principle. It is also used in the same way and under the same circumstances as a 3-phase 4 wire meter – the only difference being that it is connected through CTs rather than being directly connected to consumer.

<u>HT Metering</u>

The following types of meters are commonly used for HT consumers:

- **Trivector Meter,**
- **Bivector Meter, and**
- **Summation Meters.**

i) **Trivector Meter**

A well planned tariff covering an electricity service takes into account both the energy consumed, maximum demand and recording of power factor. Tariff of this kind comprises:

i) charge on energy consumed in kWh;

ii) charge on maximum demand in kVA; and

iii) charge on account of power factor, if it is below the specific limit (these charges are not required where energy charge is on kVAh basis)

A trivector meter is designed to record active, reactive and apparent energy along with MD indicators on all. The trivector meter is a compact unit. It replaces the set of instruments, which must otherwise be installed and has the advantage of yielding full and more accurate data.

The trivector meter consists of three different recording elements, namely, kWh, kVAh and kVARh. The recording principle of kWh and kVARh element is the same as described in 3-phase meters whereas kVAh element records mechanically with the differential gearing arrangement. The meter is very reliable, robust and practically free of any adjustment even for a long period of service.

If the P.F. of the installation is leading, then kVARh element of the trivector has a tendency to record in reverse direction. But this is checked by providing a back stopper in kVARh element and if the power factor is leading, it records at unity power factor.

ii) **Bivector Meter**

As it is clear from the name given ‘Bivector’, it records kWh and kVAh consumption along with maximum demand on both or on any one as required. The working principle of kWh element is as usually described. But the kVAh element is an independent unit and the recording of kVAh is made proportional to the arithmetic sum of kVAh in the three phases. The principle of kVAh meter is that line currents are rectified to DC current and this DC current is fed to the control winding of a transducer. The kVAh element always records in forward direction irrespective of PF lagging or leading. Thus, it gives the average PF of the installation.

In the case of bivector, if the PF is a leading one, kVAh element records in forward direction and the average PF is always shown as lagging one. Over compensation does not help as it would record more kVARh, thereby the power factor if calculated would be very low. The consumers’ PF so arrived is less than the prescribed limit, and he is liable for penalty for low P.F. In this respect bivector meters may be of importance but results in penalizing the consumer, if compensation is not varied with varying loads in 24 hours of the day.

iii) **Summation Meters**

Summation meters are another special type of meters, which are used for recording the total consumption of a consumer fed at more than one point. The main purpose for connecting a summation meter is to facilitate the correct recording of the Simultaneous Maximum Demand, since adding up of the MDs recorded by the individual meters, arithmetically may not be correct because of the possible diversity in their periods, even though the total unit consumption can be worked out arithmetically. There are a number of methods for summing up the consumptions through one meter, some of which are as indicated below:

- Paralleling of the CT leads on the secondary side before connecting them to the meter current coil.
- Providing for each phase, one intermediate CT, known as summation CT, with a number of primary windings for connections to the secondaries of individual CTs and only one secondary winding to feed the meter current coil.
- Use of multiple current coils in the same meter for direct connections to the individual CTs, the measuring elements being common to all for the same phase.
- Having independent elements for all CTs mounted on a common shaft of the same meter so that the shaft gets the total torque and records total consumption thereby.
- Separate elements to measure the consumption independently as in the preceding method but having separate driving shafts connected to a common one through differential gears to record the total consumption
- Separate meters, each fitted with an electrical impulse transmitting device, to record the consumption at various points independently and pass on the impulses simultaneously to a common meter which then records the total consumption.

INSTALLATION OF METERS AND VERIFICATION OF CONNECTIONS

Meter must be properly installed as per the connection diagram. The points that must be kept in view while meters are installed are given below;

a) Position of meter should be such that reading is easily visible.

b) Mounting of meter should be on solid wall or DP structure or on panel board.

c) Vertical mounting of meters should be ensured. The utility engineer should use a plumb bob and mark a vertical line prior to installation. He could also use a spirit level and put on the top of the meter after hanging on the screw hole. Alternatively, he should put spirit level on the edge of the terminal block to ensure vertical mounting.

d) For HT metering equipment, CTs should be right on the incoming side before the point of isolation.

e) The meter box should be sealed.

f) The meter recording should be checked at site.

The following should also be ensured:

a) Appropriate crimping device should be used for crimping the lugs. Thimbles should be of appropriate configuration (pin type, fork type etc.) to match with the terminal block for low current connection. For high current terminations, crimping should be used with cable crimping tools and

b) multiple point crimping should be done for the lugs used for higher current ratings.

c) If the terminal block is of MS cage clamp type, there is no need to use any lugs and the copper cables can be directly terminated at the clamp.

d) The recommended tightening torque must be exerted on the screw to ensure proper tightening of the terminations. It is recommended to use proper tools, equipment for this purpose.

e) Usage of lugs as per the recommendation of manufacturer and ensuring proper crimping will protect the joints from failures.

f) For high current terminations, tensile test and shock test should be performed after crimping the lugs.

g) Where aluminium cable termination is to be done on copper bus bars or brass studs, bimetallic type of lugs should be used.

h) Some meters have lower terminal pitch. Because of this, cables foul with each other while installation. Proper cable size according to the meter rating should be defined.

i) Aluminium conductor cables should be replaced by copper cables for the whole current meters.

j) For indoor meters, the wiring should be done such that the cables enter the meter box from the bottom or rear side. This not only is aesthetic, but also prevents the service cable from tampers, etc.

SEALING POINTS

The meter seal should be tamper proof. The consumer should be briefed about seals. The sealing of all metering systems should be done at various points (as applicable) to avoid tampering. There should be at least one seal at all points mentioned below (wherever applicable):

a) CT Secondary Boxes (in addition to locking arrangement)

b) PT Secondary Box (in addition to the locking arrangement)

c) Meter Cabinet

d) Meter Test Block

e) Meter Terminal Cover

f) Meter Cover

g) Panel doors where CT and PT secondary circuits are terminated or where possibility for shorting or breaking exists and fuses/links are provided.

h) PT selector relay box where automatic change-over of potential supply to meter from one PT to another is provided

i) CT Primary Links and Top Covers

j) MD Reset Push Button

k) Boxes/Cabinets containing terminals for remote transmission of metered data via communication channels, junction boxes in the system and boxes wherein interface devices are mounted.

l) Meter reading port.

Seals are necessary to guard against the tampering of connections and internal parts of a meter. Tampering of seals will give consumers access to the relevant part of a meter installation where s/he can manipulate the unit to record less energy leading to commercial loss. A seal is placed to detect unauthorized entry to the meter internals. The effectiveness of the seal depends on the type of seal (whether it is tamper proof or not, whether a duplicate can be obtained or not, etc.), and the procedures used in tracking the seals.

CONCLUSION

The energy meter is the cash register of the utility. Energy meters form a vital instrument of revenue realization for the Supply Utilities. Based on the meter reading, the utilities submit their bills to their consumers for realization. Inaccurate/faulty recording may become catastrophic both to consumers and utilities. Thus, a need to ensure a high degree of performance and reliability from the meters has become important. There are many technologies available for energy meters from electromechanical meters to hybrid meters with stepper counter motor and completely electronic meter. The meters are tested and calibrated to ensure proper working and that the accuracy is to be maintained within permissible limits under IE Rules. Testing of meters can be carried out at site or in the laboratory. The meter has to be installed properly before commissioning.

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