Progress in the art of Demand Metering

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The art of electrical measurements has made rapid advancement during past half century. As the use of electrical energy became more wide spread and industry moved into the more remote sections of the country; reliable and exact metering of electric current has approached perfection.

A modern watt hour meter is a miniature electric motor-generator set of highly refined characteristics, which measures energy. Power is easier of measurement because it does not involve the time component; energy being power times time. We have, therefore, elected to treat power or demand measurements rather than energy.

It was early noted, that the energy supplied to any current consuming device was attended by heating of the conductor supplying the current. The greater the current the greater the heat. In direct current this would be in accordance with the fomula $W=I^2R$, in altering current circuits $W=EI\cos\theta$. This principal was applied in one of the first demand meters with which we had experience. It was known as the "Wright Demand Indicator" and was a maximum - ampere demand meter. It consisted of two glass tubes filled with air and connected by a U tube filled with colored concentrated sulphuric acid. A calibrated tube was tapped off at the top of one branch of the U tube. Around the bulb at the top of the other branch of the U tube was a heater unit which carried the current flowing to the electrical device. This resulted in the heating of the air in the bulb, the acid was pushed upward in the other arm of the U tube and ran over into the calibrated tube which was scaled in amperes.

The meter or rather demand was reset to zero, after reading, by tilting the meter so as to drain the acid from the index tube back into the U tube. Lagging was obtained by capillary constrictions in the tube. Altho this method of metering had a low degree of accurracy, as compared with present, it was quite widely applied early in 1900's.
Our first contact with an electrical rate based on kilo volt ampere demand was in the year 1913. The company, with whom we were connected as operating engineer, delivered much of their energy to a group of lead mines along the Idaho, Washington State line. Our rate department brought out a new rate based on K.V.A. demand and energy in KWH. As we recall the rate called for $3.00 per K.V.A. of demand plus 0.5 cts. per K.W.H. At that time the meter manufactures did

not produce a meter that would measure K.V.A. as a unit for demand billing.
In fact little was known of killo volt ampere metering. A time period of 5 minutes had been given as the demand period. That is it was to be a block interval demand.
As stated no block type demand meters were available especially for K.V.A. demand.

Our solution, though considered crude today, proved satisfactory to both the customer and our rate department.

Instantaneous graphic voltmeters and ammeters were installed on each customer. The graphs gave a very satisfactory record of the daily load in amperes and the corresponding voltage. Our problem was to determine the highest possible 5 minutes demand in amperes recorded during the entire month. The demand in amperes, as well as the simultaneous voltage had to be multiplied by the ratio of transformation of both current and voltage.
The billing demand in K.V.A. was then determined by multiplying the recorded voltage and current by the square root of three.
Energy was recorded by an integrating watt hr. meter which was connected on the same instrument transformers as the graphic meters. This meter altho considered highly accurate, lacked many of the refinements found in present day meters.

We are inclined to believe that this rate was ahead of its time. Today our solution would be considered very crude and void of accuracy. Paragraph the inclusion of both KW and KVA demands in the rate structure forced the meter manufactures to develop demand meters as well as energy meters. Today there are many kinds of demand meters available. Mostly for the recording of K.W. demands but K.V.A. demands are becoming quite universally used for billing and there are several excellent K.V.A. demand meters on the market. They all pocess a high degree of accuracy and require a minimum of maintenance. We will not attempt to mention all types but rather some of the more common types in use.

We quote the requirements of the "Code for Electricity meters". "A maximum demand of an installation or system is the greatest of all demands which have occurred during the period. It is determined by measurement over a prescribed time interval. In accordance with specifications a demand may be measred by an instrument with a time lag or an instrument integrating the load over the prescribed time interval, or the load may be determined from a sufficient number of readings of an indicating instrument, taken over the time interval."

Demand interval is defined as, "The length of time over which the demand is measured. For example in a 15 min demand, the demand interval is 15 mins."

A survey made a few years ago showed 15 minutes as most common interval with 30 and 60 minute intervals next in order.

There are 3 principal types of demand meter I - Recording, II - Integrated, III - Lagged demand meters. We will skip the Recording type as it was covered quite thoroughly in our description of the mine metering above. The integrated demand meter is generally a device used in conjunction with the watt hr. meter so that a periodic record is made of the K.W.H. consumed during the demand interval.

In brief it is a mechanical counter and recorder of the number of revolutions made by the watt hr. meter disc.

One of the more generally employed types has a two or three point contact device mounted on the rear of the integrating watt hour meter register. The contacts are motivated by an N point cam which is usually mounted on the shaft of the 1st wheel in the register mechanism. These contacts are permanently wired to an electro magnet in the recorder. The plunger of this magnet advances a large wheel which carries numbers, by means of a dog and ratchet.

At the end of the predetermined time period the synchronous timer energizes an electro magnet which pulls a printing platen, and recording apermanent record of the number of contacts and the exact time they occured. Simultaneously a spring restores the large wheel to the zero position ready to repeat the operation. The number of contacts when multiplied by the constant which is determined by the primary value of disc revolutions, the number of points on the cam and the location of cam on the register, give a true value of the KW demand for the particular time period in use.

Other manufactures accomplish the same result in a different manner, and are able to mount the demand chart and mechanism in the same case as the intergrating watt hr. meter.

The lagged demand meters function on the basis of requiring a certain time interval for the indication to reach a point corresponding to the value of the load. The indication lags behind the actual value of the load in much the same way that the rising temperature of the supply apparatus lags behind the load imposed upon it.

This class of instrument differs from the other class in that the record begins when the load begins and not at some fixed clock time.

There are two forms of this class. In the first the rate at which the pointer moves over the scale is proportional to the load at each instant. It, therefore, moves up-scale at constant speed under constant load. The lagging is mechanical.

In the second form the speed of motion of the pointer dimnishes even with constant load, toward the end of the deflection integral. Theoretically, it would require infinate time to reach the ultimate deflection. This is compensated for by defining the time period as that required for the instrument to indicate 90 percent of the full scale value of a steady load, thrown on the system suddenly without previous loading. The lagging is thermal.

Both forms of demand meters are employed in the States. But since our experience has been largely with the second form we will attempt to outline details of that form.

It is usually a thermal meter and the lagging is accomplished by thermal storage. It is radically different from the other meters in that the deflection of the demand pointer is derived from the differential action of opposed bimetallic springs which are heated by currents in resistors inserted in an ingeniously arranged circuit. The difference in deflecting torque of the opposed springs is proportional to the load watts. Heat developed in the resistors is applied to the springs through the medium of masses of metal which absorb and store the heat and thus introduce the desired demand interval.

The secondary of a small transformer circulated through the two heaters in series a current ie proportional to the voltage E. load current IL flows in opposite directions through the two halves of this secondary. At any instant it is in same direction as ie in one heater and opposite to ie in the other heater. Thus in R1 the heating effect at P.F. cos θ is.

$$I_1^2 R_1 = \left\{ i_e^2 + 2\tfrac{1}{2}L\, i_e \cos.\theta + \left(\tfrac{1}{2}L\right)^2 \right\} R_1$$

$I_n R_2$ # the heating effect is

$$I_2^2 R_2 = \left\{ i_e^2 + 2\tfrac{1}{2}L\, i_e \cos.(180^\circ - \theta) + \left(\tfrac{1}{2}L\right)^2 \right\} R_2$$

$$= \left\{ i_e^2 - 2\tfrac{I_L}{2}\, i_e \cos.\theta + \left(\tfrac{I_L}{2}\right)^2 \right\} R_2$$

$$D = KR\,(I_1^2 - I_2^2) \qquad D = KR(4\tfrac{I_L}{2} i_e \cos.\theta$$

$$D = K(2)(i_e R)\, I_L \cos.\theta \qquad D = K'E\, I_L \cos.\theta$$

R^1 & R^2 being equal the deflection D is proportional to the difference in heating developed in the two resistors.

The deflection, without heat storage, is thus proportional to the load in watts.

These meters are made to absorb and store the heat that establishes the desired demand interval. Most instruments with which we are familiar give a 90 percent deflection in 15 minute a 99 percent deflection in 30 minute and therefore might be described as having a 15 or 30 min demand interval.

Most of these instruments are of the indicating type and the method used to record the highest demand is of interest. The meter employs two pointers. One is called the pusher arm the other is a pivoted pointer with mechanical friction so that it will remain at the highest point to which it has been pushed by the pusher arm. The pusher arm advances up scale so long as the load on the system exceeds the KW demand on the scale. When the pointer & pusher arm reach the position of maximum load they will hold until load drops off when the pusher arm will remain at the point of maximum demand. Thus we have a permanent record of the maximum demand until such time asit is manually reset by an operator by means of reset device from outside the enclosure.

We had intended to describe what we consider a very satisfactory unit type K.V.A. watt hour demand meter but we have all ready exceeded our alloted space so will defer farther effort.

Doscose D. HART 氏 略歷
Denison 大学에서 理学士 (Mass Institute of Technology) 卒業
五年間華盛頓水力電気会社에奉職 運転技術에従事
三十二年間 中央이리노이스電燈会社 (Central Illinoisyight Co.) 試驗部主宰 (主로 計器.変圧器.継電器及一般試驗取扱)