THE DEVELOPMENT OF CT INTEGRATED ELECTRONIC METER

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ABSTRACT

This paper proposes a new design of current transformer integrated electronic watt-hour meter (CTIM) for 3-phase 4-wire power. The essential requirements of new meter were compact size, simple wiring scheme, and reduction of installation and maintenance costs. To meet those requirements, we developed a new type of clamp CT embeddable inside the meter and invented a simple wiring scheme like 'plug-and-screw' that does not require wiring at installation and any power failure during maintenance. As the results, the cost of materials and construction is reduced by 40% compared to that of the conventional meter with CTs external. Furthermore, either the possibility of power stealing or miss/wrong connection of metering cables is thoroughly eliminated. This meter also provides smart metering with AMR, 4-tariff measuring and 90-days memory. This newly developed CTIM was certified by the required domestic and international standards and will replace all the installed meters of KEPCO customers until 2015 subsequently.

INTRODUCTION

For decades, KEPCO (Korea Electric Power Corp.) has been using mechanical or electronic watt-hour meter with external CTs (current transformers) for customers consuming more than 120A of 3-phase 4-wire power at 220/380V 60Hz[7]. These external CTs cause problems in installing and maintaining those conventional meters, such as complex wiring, large panel size, customer's complaint about power failure during CT replacement, the possibility of electricity stealing, and even accuracy distortion.

Therefore, it is necessary to develop a new type of electronic watt-hour meter to solve these problems. The major contribution of the work is that we developed a device that branches voltage from power cable without stripping or cutting wires. Furthermore, we developed a dedicated clamp CT to detect current with the cable intact and installed without cutting the cable. Also CT should be integrated with and embedded in the digital meter to eliminate the wiring effort.

As the result, a new type of watt-hour meter for 3-phase power, called CTIM (CT integrated watt-hour meter), was successfully developed, which is certified by IEC 62053-21[2] and IEC62053-23[3]. This paper presents the detailed design of CTIM and some test results. Advantage and disadvantage of new CTIM compared with conventional meter are also summarized.

Problems statement

In case of CT rated watt-hour meter for 3-phase 4-wire power above 120A current, it is necessary to install 3 external CTs, as shown in Figure 1.

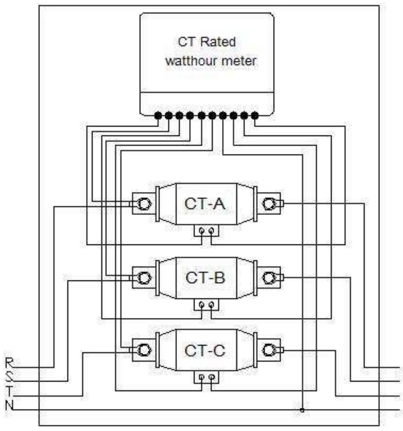


Figure 1. Schematic diagram of a conventional meter

This conventional external CT is responsible for both branching voltage and sensing current level. Due to the three external CTs, total 17 wires need to be connected between CTs and the meter. Inherently, those require big panel size and cost a lot of wiring labour which may cause miss or wrong connection by human error. Also it entails the worry of power stealing. Furthermore, when the replacement of a CT is required, it causes a power fail that makes the customers complain a lot. Usually, it is hard to make an agreement of end-users who use a common meter, for there are some cases that they may not be able to cut the power down even for a single moment. In summary, the problems of the conventional watt-hour meter can be summarized as follows:

- complex wiring – miss or wrong connection
- big panel size – for CTs and cables
- power stealing
- power fail during replacement - inconvenience

To solve these problems majorly caused by external CTs, we developed a totally new CT-integrated watt-hour meter (CTIM) that addresses the following major three requirements:

R1. No wiring work at installation and maintenance
R2. Compact form with CTs integrated inside meter

R3. No power fail during CT replacement

These requirements seem to be challenging, but, finally solved by our innovative design and ideas described below.

PROPOSED DESIGN OF CT INTEGRATED METER

A. Layout of CT integrated meter

To meet the three requirements in R1~R3 in the previous section, firstly we substitute the external CT by a clamp CT developed by our own, which is co-located with the terminal block of the meter case as shown in Figure 2. Unlike the conventional external CT, which necessarily requires cutting a power cable to replace it, a clamp CT does not require cutting any cable since it just surrounds the cable to sense the electro-magnetic radiation generated by current flow. The layout of the clamp CT used in this model is shown in Figure 3.

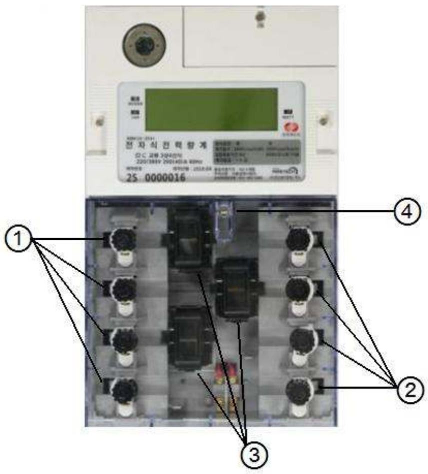


Figure 2. The CT integrated digital meter: ① voltage branch device(VBD) ②cable fixture ③ clamp CT ④ seal.

Figure 2 depicts the CT integrated watt-hour meter (CTIM) developed in this work. The upper half part is 'electronic meter' and the lower part is 'terminal block'. The essential contribution of our work resides in the terminal block. In this terminal block, there are four horizontal rows, and each row is designed to grip each wire of 3-phase 4-wire power. A row consists of 3 components: a voltage branch device(VBD)①, a cable fixture② and a clamp CT③. The lowest row does not have a clamp CT, because it is for the neutral wire. The seal④ locks the terminal block cover. In the back panel of the block, there are appropriate fixed connections to the meter.

The role of each component of a row is as follows. The VBD is designed to sense the voltage level of the power cable and deliver it to the electronic meter without cutting or stripping the cable. The clamp CT is specially devised to surround the power cable to detect the current level also without any wiring job. The cable fixture additionally grabs the power cable at the other side of the VBD.

B. Plug-and-lock clamp CT

To continuously supply power even during CT replacement, any cut on power cable is not permitted. To make this possible, we developed a new type of clamp CT as shown in Figure 3.

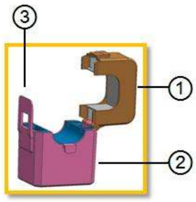


Figure 3. Diagram of clamp CT

The clamp CT is composed of an upper core①, a lower core including coil②, and a lock③. One can easily know that the power cable can be plugged and locked in the inner cylinder of core without any cable cut. We call it 'plug-and-lock' clamp CT. Thus, we can see that installing a power cable inside the clamp CT requires no wire cutting.

Note that, however, it does not provide a voltage terminal unlike the conventional external CT. Thus, we need to think other way to branch the voltage from the power cable. In the following subsections, we explain the detailed design of each component of the VBD.

C. Plug-and-screw voltage branch device(VBD)

The objective of the VBD developed here is to probe voltage from the power cable without stripping it. Figure 4 represents the schematic diagram of the VBD, which is a simple 'plug-and-screw' type device that fixes the cable and extracts voltage by screwing a branch bolt.

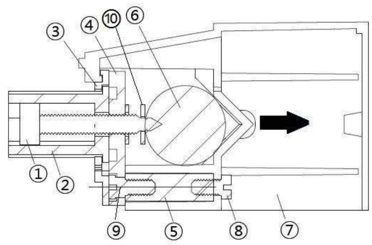


Figure 4. Plug-and-screw voltage branch device(VBD)

The path of voltage extraction is as follows: power cable ⑥ → branch bolt ① → brass support ④ → bolt ⑨ → brass terminal ⑤ → voltage terminal ⑧. A hidden wire is connected from the voltage terminal to the voltage input circuit of the digital meter in the upper part of CTIM.

The safety knob ② and the branch bolt ① are tightly coupled by hexagonal shapes that the branch bolt rotates along with the safety knob when the knob is turned. The tip of the branch bolt is so pointed that it can penetrate the sheath of the power cable as well as the core conducting wire. This VBD can be used up to ∅19mm power cables. To hatch the VBD to install a power cable into the VBD without wiring, we have to screw up the safety knob that is tightly jointed with the branch bolt.

Lock ③ assures not to move the knob once the cable is installed. Washer⑩ works as a stopper for the branch bolt to drill no more than 5mm depth of the cable.

Meanwhile, the design of the cable fixture is the same as that of the VBD except the tip of the fixture bolt is flat rather than sharp, just to press down the cable.

D. Rationale of the design

It can be claimed that the above layout and the design of components collectively meet the requirements R1, R2, and R3. Recalling that requirement R1, no wiring work at installation and maintenance, is collectively satisfied by the VBD, the clamp CT, and the cable fixture. It can be proved by the installation process.

The second requirement R2 is to embed CTs inside the meter. Recalling the layout of the terminal block in Figure 2, we can easily see that CTs are located in the terminal block and protected by the terminal block cover that is sealed. This satisfies requirement R2.

Finally, requirement R3 tells that there should be no power fail during installation and replacement. It can be proved by understanding the simple installation sequence of a cable; first, open VBD, cable fixture and clamp CT; then place the cable firmly in the right row; after then, screw the voltage branch bolt and the cable fixture bolt; finally, lock the clamp CT. That's very simple. Figure 5 shows the terminal block with power cables installed.

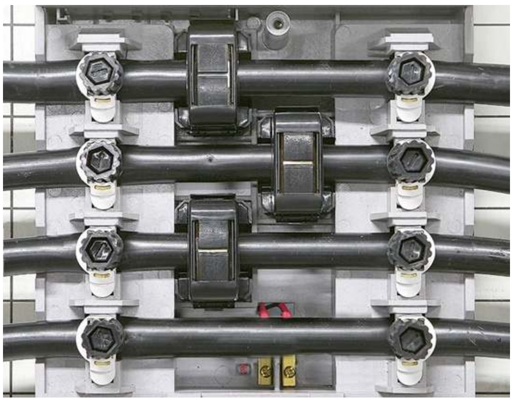


Figure 5. The terminal block with power cables installed

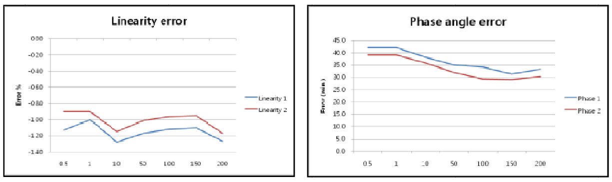
Understanding this job sequence, one can figure out that there is no need of cutting the cable. This means that a cable can be installed even while the electricity flows through the cable. This means that requirement R3, no power fail during replacement, is also satisfied.

Therefore, the need of wiring is completely eliminated for both installation and replacement with carefully designed devices in this work.

TEST RESULTS OF CTIM

A. Characteristics of clamp CT

Figure 6 depicts the measurement results of linearity error and phase angle error over the current level ranging from 0.5A to 200A. Due to the inherent characteristics of clamp CT, linearity error lies within from -0.9% to -1.3% steadily over the current range. The phase angle error measure in the same test condition, ranges from 29min to 42min. These errors can be easily calibrated in the meter to meet IEC62053-21 CL1.0 [2].



(a) Linearity error (b) Phase angle error

Figure 6.Chacteristics of clamp CT

B. Test results of CT-integrated meter

The most important factor is the test result of CT integrated watt-hour meter, CTIM. Sample CTIMs acquired the final certification of Korean standard KSC1214 [1], which is a combination of international standards IEC62053-21[2] and IEC62053-23[3], for 3-phase 220/380V 200(40)A CL1.0. Table 1 shows the test results of a sample CTIM compared to the corresponding specification of the international standard IEC62053-21[2] and IEC62053-23[3]. We have single phase 220V 200(40)A CL1.0 60Hz and 3-phase 4-wire 220/380V 200(40)A CL1.0 60Hz. The sample CTIM is 3-phase 4-wire 220/380V 200(40)A CL1.0 60Hz. The test equipment was EMH test bench of Swiss MTE Corp., 'MTE F3 30.20. CL0.05'.

Table 1.Accuracy test results of the CTIM*

Power	Test Point	Error Tested	IEC Std.
Active Power	Starting	1 #	1 #
	No Load	0 #	0 #
	0.05Ib PF1.0	-0.22%	±1.50%
	0.1Ib PF1.0	-0.19%	±1.00%
	0.1Ib PF0.5L	+0.33%	±1.50%
	0.1Ib PF0.8C	-0.31%	±1.50%
	0.2Ib PF0.5L	+0.24%	±1.00%
	0.2Ib PF0.8C	-0.32%	±1.00%
	Imax PF1.0	+0.12%	±1.00%
	Imax PF0.5L	-0.01%	±1.00%
	Imax PF0.8C	+0.12%	±1.00%
Reactive Power	0.05Ib QF1.0	-0.22%	±2.50%
	0.1Ib QF1.0	-0.18%	±2.00%
	0.1Ib QF0.5	-0.58%	±2.50%
	0.2Ib QF0.5	-0.56%	±2.00%
	0.2Ib QF0.25	-0.77%	±2.50%
	Imax QF1.0	+0.12%	±2.00%
	Imax QF0.5	+0.15%	±2.00%
	Imax QF0.25	+0.24%	±2.50%

* SPECIMEN: 3-phase 4-wire / 220/380V 200(40)A CL1.0 60Hz

As shown in the table 1, the errors of active power at each test point satisfies the permitted range of class 1.0 of IEC62053-21[2], and the errors of reactive power is within the range of class 2.0 of IEC62053-23[3].

Among many EMC tests, only three test results, fast transient burst test[5], surge immunity test[6] and test of immunity to electrostatic discharges[4], are presented in the paper for short of space.

First, the test equipment for fast transient burst test was FNS-AXII of NoiseKen Corp., Japan. Test was conducted at 220/380V, 40A, PF1. Table 2 shows the test results, which means that CTIM meet to IEC 61000-4-4[5] at test voltage : ±4.5kV, duration of the test : 60sec at each polarity..

Table 2.Fast transient burst test result

Test Voltage	Before the Test Error (1)	Test		Error Change (1) - (2)	
		Test Point	During the Test Error (2)	IEC Std.	Change value
+4.5kV	+0.12	P1,2,3,0	-0.03	Class 1.0 (4.0%)	-0.15
		Pulse Line	-0.06		-0.18
-4.5kV	+0.12	P1,2,3,0	+0.02	Class 1.0 (4.0%)	-0.10
		Pulse Line	-0.01		-0.13

Surge immunity test was executed with MIG1A153C and CDN2000-06-25 of EMC Partner AG Co., Swiss. Table 3 shows the test results, which tells that CTIM meet to IEC 61000-4-5[6] at test voltage : ±6kV, repetition rate : 30sec, number of tests : 6 positive and 6 negative.

Table 3.Surge immunity test results

Accumulation before the Test (1)	Test Point	Accumulation after the Test (2)	IEC Std.	Change value (1) – (2)
28.7kWh	P1-P0 P2-P0 P3-P0	28.7kWh	0.01kWh	0.00kWh

Finally, test of immunity to electrostatic discharges uses model ESS-2000 & TC815R of NoiseKen, Japan. The test results in Table 4 say that CTIM satisfies IEC 61000-4-2[4] at test voltage : ±15kV, number of discharge : 10.

Table 4.Test results of immunity to electrostatic discharges

Accumulation before the Test (1)	Test Point	Accumulation after the Test (2)	IEC Std.	Change value (1) – (2)
28.7kWh	LCD Cover	28.7kWh	0.01kWh	0.00kWh

REMARKS

Table 5 summarizes characteristics of CTIM compared with the conventional meter. Note that new CTIM innovatively simplifies the installation and replacement work and has very compact size. This greatly reduces the cost of installation and maintenance, which is best for providers like KEPCO.

Table 5.Comparisons between old and new meters

Comparison Item	Conventional Meter	CT integrated Meter
number of external CTs	1 CT for each phase installed outside meter	No external CT (clamp CTs inside)
power cut at replacement	Need power cut before installment	No power cut required
error factors	Meter and external CT	Meter only
cabling	Complex (17 wiring). Cable cut, stripping and connecting to 10 points	No wiring work
current terminals	6 for 3-phase	0
voltage terminals	4 terminals	eliminated by the voltage branch device

Therefore, KEPCO plans to install new CTIM for new customers and to replace all the conventional meters until 2015.

CONCLUSION

In summary, this paper presented the result of a work to develop new CTIM that eliminates the need of both wiring at installment and power fail at replacement. By replacing external type CT with dedicated clamp CT and inventing a VBD, all of which are integrated with the meter, the CTIM completely eliminates wiring job at installation and requires no power fail at maintenance. Also it is certified by Korean and international standards for single phase 220V 200(40)A CL1.0 and 3-phase 220/380V 200(40)A CL1.0. The installation procedure is so simple. Consequently, new CTIM innovatively overcomes the problems of the conventional meter.

Future works include development of high accuracy CTIM with class 0.5, and extension of current up to 300(10)A.

REFERENCES

[1] KS (Korea Standard) 1214, 2005, "Static meters for active energy (class 0.2, 0.5, 1 and 2) and Static meters for reactive energy (class 2 and 3)"

[2] IEC standard 62053-21, 2003-01, "Electricity metering equipment (a.c.) - Particular requirement Part21: Static meters for active energy (class 1 and 2)"

[3] IEC standard 62053-23, 2003-01, "Electricity metering equipment (a.c.)-Particular requirement-Part23: Static meters for reactive energy (class 2 and 3)"

[4] IEC standard 61000-4-2, 2001-04, "Electromagnetic compatibility-Part4-2: Testing and measurement techniques-Electrostatic discharge immunity test"

[5] IEC standard 61000-4-4, 2004-07, "Electromagnetic compatibility-Part4-4: Testing and measurement techniques-Electrical fast transient/burst immunity test"

[6] IEC standard 61000-4-5, 2005-11, "Electromagnetic compatibility-Part4-5: Testing and measurement techniques-Surge immunity test"

[7] KEPCO Standard, 2010, "Static meters for low voltage"