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A new type of rack for the clamp ammeter (

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***Abstract* – In order to improve the calibration ability of the clamp ammeter, realize the simultaneous measurement of single-phase, three-phase and multiple clamp ammeters, and provide technical support for realizing more efficient real-time monitoring of power, this paper analyzed the measurement methods and problems of the clamp ammeters, and studied the measurement principle of the clamp ammeters, then designed a new type of rack for the clamp ammeter. The measurement has been proved that the rack for the clamp ammeter is accurate and efficient.**

***Keywords* – clamp ammeter , measurement, hanging rack, real-time monitoring**

I. INTRODUCTION

The clamp ammeter is a kind of instrument that measures the current value by surrounding a current-carrying conductor by a magnetic circuit which can be opened and closed. It has the characteristics of non-contact measurement and simple operation, and is mainly used in electrical monitoring and measurement of scientific research departments in various industrial fields such as power, transportation, elevators, energy, and so on. In this paper, after considering the influence of the simultaneous measurement of multiple current clamps and the position of the wire through the center on the measurement results of the clamp meter, a new hanging rack is designed, which greatly improves the measurement ability to the clamp ammeter.

II. WORKING PRINCIPLE OF THE CLAMP AMMETER

The clamp ammeter is composed of an ammeter and a current transformer. The iron core of the current transformer can be opened when the wrench of the current clamp is tightened. The wire through which the measured current passes can pass through the open gap of the iron core without cutting off. When the wrench is released, the iron core is closed[1,2]. The tested circuit wire passing through the iron core becomes the primary coil of the current transformer, and the current passing through induces the current in the secondary coil, so that the ammeter connected to the secondary coil can measure the current in the tested wire.

III. INFLUENCE OF MEASUREMENT ACCURACY OF CLAMP AMMETER

The eccentricity and inclination of the current-carrying conductor can lead to uneven magnetic flux distribution along the cross-section of the transformer coil and unequal magnetic permeability along the circumference of the core, thus affecting the measurement accuracy of the clamp ammeter [3] .

The measured wire should be adjusted to the geometric center of the clamp as much as possible. If the measured wire deviates too much from the center, the magnetic induction strength produced by the clamp ammeter core will change significantly, which will directly affect the accuracy of the measurement. Generally, the measurement errors caused by improper positioning of the measured wire in the clamp can reach 2% to 5%.

According to Ampere's Law, the magnetic induction strength around an infinitely long cylinder conductor perpendicular to the plane of the current transformer coil's geometric center [4] is

$$B = \mu_0 I / 2\pi r \tag{1}$$

In formula, μ_0 is the vacuum permeability, I is the current of the conductor, and r is the radius of the center circle of the current transformer coil.

The magnetic flux on the coil cross section S is given by:

$$\Phi = \mathrm{B}S_{\perp} = \mu_0 S_{\perp} I / 2\pi r \tag{2}$$

In formula, $S_{\perp}$ is the projected area of the cross section of the coil perpendicular to the direction of the magnetic field. which is not necessarily the entire area of the coil, but the effective perpendicular area located in the magnetic field portion.

When B is not perpendicular to S:

$$\Phi = BS_{\perp} = BScos\theta \tag{3}$$

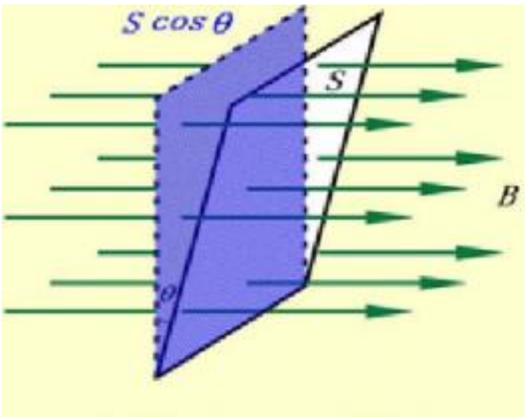

Fig. 1.The plane is not perpendicular to the direction of the magnetic field

As can be seen from the above formulas, the magnitude of the magnetic flux was related to the central circle radius of the current transformer coil and the effective perpendicular area of the coil in the magnetic field portion. Therefore, to ensure measurement accuracy when using a clamp meter, the measured wire should be perpendicular to the clamp.

IV. DESIGN OF A CLAMP AMMETER HANGING RACK

A. Key lssues

Realized simultaneous measurement of single-phase, three-phase and multiple clamp ammeters.

Adjusted and fixed the position of the clamp ammeter, so that the wire just passed through the geometric center of the clamp mouth and was perpendiculared to the clamp mouth.

B. Design ideas

For small mouth clamp ammeters: if only a single current line can pass throug, select directly clamped.

For large mouth clamp ammeters: The adjustable insulation rods are designed to adjust the position of the clamp ammeter up and down; the sliding insulation clasps are added on the insulation rod to fix the clamp ammeter.

C. Structural composition

The clamp ammeter hanging rack is composed of three adjustable insulating rods, three 100A copper rods, three 10A copper rods, six insulation clasps, two insulation plates, an aluminum alloy bracket, screws, and gaskets, as shown in Figure 2.

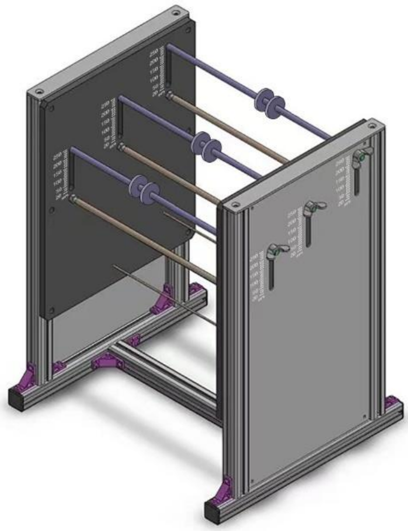

Fig. 2. Image of a rack for the clamp ammeter.

The three 100A and three 10A copper rods were fixed on the insulating plates at both ends respectively with screws.One end of the 100A and 10A current wires was fixed on the 100A and 10A copper rods with screws and gaskets, and the other end was led out from the bottom to be connected to the current source.

The two insulating plates were fixed and supported by the aluminum alloy bracket, and the outer sides were also fastened by the aluminum alloy panels, which were solid and beautiful. The insulating rods were fixed on the outer aluminum alloy panels with screw caps, to facilitate the adjustment of the current clamp position up and down during the test, the insulation clasps were used to hold the clamp ammeter, so that the wire just passed through the geometric center of the clamp mouth. In addition, the adjustment of the insulation rods were marked with scale, which can realize accurate adjustment according to the radius of the clamp ammeter.

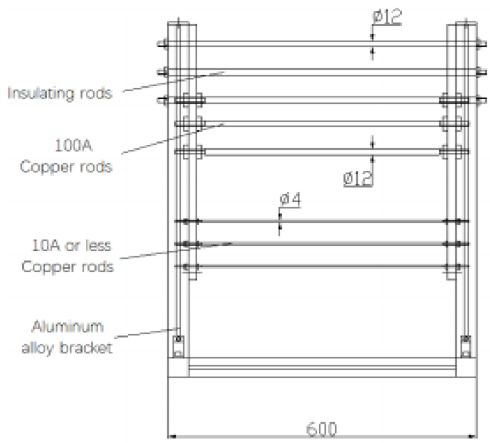

Fig. 3. Frontal structure diagram of the rack for clamp ammeter.

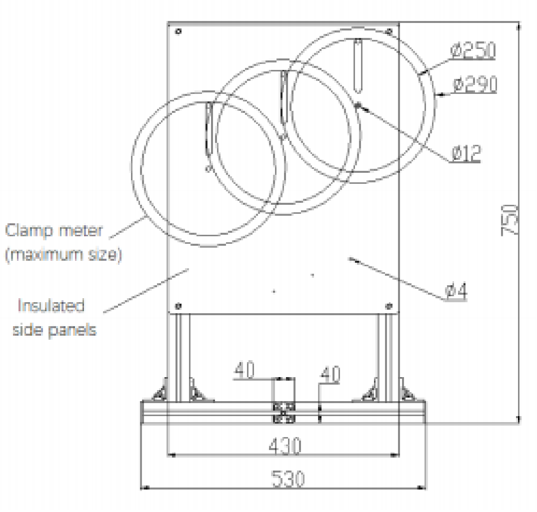

Fig. 4. Side structure diagram of the rack for clamp ammeter.

D. Method of application

For 10A and below small clamp ammeters, clamp them directly onto the 10A copper rods, and test them by 10A and below current. When hanging small current clamp ammeters, it should not be too compact to prevent interference.

For more than 10A large clamp ammeters, the clamp mouth is generally larger. To hang them, both 100A copper rods and insulating rods should be completely threaded into the clamp mouth. The clamp ammeter were secured with insulation clasps. By adjusting the position of the insulating rod, ensure that the 100A copper rod can be passed through the geometric center of the large clamp ammeters and be perpendiculared to the clamp mouth.Then, test it by passing current. When hanging large clamp ammeters, it should also not be too compact to prevent interference.

V. MEASUREMENT VERIFICATION

A. Calibration basis

JJF 1075-2015 "Calibration Specification for Clamp Ammeters"[5].

B. Environmental conditions

Ambient temperature: (20±2)℃; Relative humidity: (55±3)% .

C. Measurement standards

Three-phase energy meter inspection device, model: NST-3500, current range: 3×(0.01～100)A.

Three-phase standard energy meter, model: RD41-233, current range: 3×(0.005～100)A.

D. Tested object

Clamp type power meter, current range: ACI (0～100)A, accuracy: ±0.3%rdg.

Clamp type energy meter on-site calibration device, current range: ACI (0～5)A, accuracy: ±0.2%rdg.

E. Measurement method

The standard meter comparison method was adopted, the three-phase standard energy meter was connected to the current circuit of the rack for clamp ammeter, and clamp ammeter was measured by using the hanging rack and current wire respectively. By comparing with the current value of the three-phase standard energy meter, the measurement accuracy of the two methods was determined.

F. Measurement Results

Under the same conditions, measurements were taken at the specified current point after preheating. Restart the current before each measurement, and independently repeat each measurement for 10 times to obtain the data.

Table 1. Current standard value

The output value of the three-phase energy meter inspection device	Displayed value of the Three-phase standard energy meter		
	Phase A	Phase B	Phase C
5A	4.99992A	4.99994A	4.99995A
50A	49.9989A	49.9991A	49.9986A

Table 2. Measurement results of the rack for the clamp power meter

Number of measurements	Current 50A		
	Phase A	Phase B	Phase C
1	49.995A	49.994A	49.996A
2	49.994A	49.993A	49.997A
3	49.995A	49.994A	49.996A
4	49.994A	49.995A	49.996A
5	49.995A	49.994A	49.995A
6	49.995A	49.996A	49.997A
7	49.996A	49.994A	49.996A
8	49.995A	49.995A	49.997A
9	49.996A	49.994A	49.998A
10	49.995A	49.994A	49.996A
y	49.9950A	49.9943A	49.9964A

$s(y_i)=\sqrt{\frac{\sum_{i=1}^{n}(y_i-\bar{y})^2}{n-1}}$	0.0007A	0.0008A	0.0008A
Note: Adjust the insulating rods so that the 100A copper rods passes exactly through the geometric center of the jaws.			

Table 3. Measurement results of the rack for the clamp energy meter on-site calibration device

Number of measurements	Current 5A		
	Phase A	Phase B	Phase C
1	4.9995A	4.9996A	4.9996A
2	4.9994A	4.9991A	4.9991A
3	4.9997A	4.9995A	5.0001A
4	4.9997A	4.9999A	4.9995A
5	4.9993A	4.9995A	4.9999A
6	4.9995A	4.9995A	4.9995A
7	4.9991A	4.9992A	4.9992A
8	4.9995A	4.9995A	4.9995A
9	4.9997A	4.9998A	5.0002A
10	4.9993A	4.9999A	4.9992A
y	4.99947A	4.99955A	4.99958A
$s(y_i)=\sqrt{\frac{\sum_{i=1}^{n}(y_i-\bar{y})^2}{n-1}}$	0.0002A	0.0003A	0.0004A
Note: Hang the clamp ammeters directly on the 10A copper rods.			

Table 4. Measurement results of the clamp power meter using current line

Number of measurements	Current 50A		
	Phase A	Phase B	Phase C
1	49.997A	50.002A	49.991A
2	49.991A	49.992A	49.994A
3	49.995A	49.994A	49.996A
4	49.989A	49.988A	49.987A
5	49.995A	49.992A	49.995A
6	49.990A	49.994A	49.989A
7	49.996A	49.988A	49.993A
8	49.992A	49.995A	49.991A
9	49.996A	49.987A	49.990A
10	49.988A	49.992A	49.994A
y	49.9929A	49.9924A	49.9920A
$s(y_i)=\sqrt{\frac{\sum_{i=1}^{n}(y_i-\bar{y})^2}{n-1}}$	0.0033A	0.0024A	0.0029A
Note: Hang the clamp ammeters directly on the current lines.			

Table 5. Measurement results of the clamp energy meter on-site calibration device using current line

Number of measurements	Current 5A		
	Phase A	Phase B	Phase C
1	4.9994A	4.9991A	4.9992A
2	4.9993A	4.9992A	4.9995A
3	4.9994A	4.9996A	5.0002A
4	4.9998A	4.9997A	4.9987A
5	4.9989A	4.9996A	4.9991A
6	4.9995A	4.9986A	4.9996A
7	4.9997A	4.9996A	5.0001A
8	4.9995A	4.9987A	4.9989A
9	4.9989A	4.9985A	5.0001A
10	4.9987A	4.9989A	4.9997A
y	4.99931A	4.99915A	4.99951A
$s(y_i)=\sqrt{\frac{\sum_{i=1}^{n}(y_i-\bar{y})^2}{n-1}}$	0.0004A	0.0005A	0.0005A
Note: Hang the clamp ammeters directly on the current lines.			

G. Result evaluation

Table 6. Summary of measurement results with small clamp ammeters

5A / Phase	Phase A	Phase B	Phase C
The difference from the standard value and the rack measurements	-0.00045A	-0.00039A	-0.00037A
Standard deviation value of the rack measurements $S_1(y_i)$	0.0002A	0.0003A	0.0004A
The difference from the standard value and the current line measurements	-0.00061A	-0.00079A	-0.00044A
Standard deviation of the current line measurements $S_2(y_i)$	0.0004A	0.0005A	0.0005A

Table 7. Summary of measurement results with large clamp ammeters

50A / Phase	Phase A	Phase B	Phase C
The difference from the standard value and the rack measurements	-0.0039A	-0.0048A	-0.0022A
Standard deviation value of the rack measurements $S_1(y_i)$	0.0007A	0.0008A	0.0008A
The difference from the standard value and the current line measurements	-0.0060A	-0.0067A	-0.0066A
Standard deviation of the current line measurements $S_2(y_i)$	0.0033A	0.0044A	0.0029A

The evaluation of the measurement results using the hanging rack was based on the the average y and standard deviation $s(y_i)$. The closer the average value is to the standard value y, the higher the measurement accuracy is. The Smaller standard deviations $s(y_i)$ indicate better measurement repeatability and higher measurement reliability. From the above measurement results, it can be seen that the values obtained using the rack for the clamp ammeter are both accurate and reliable, thus it proves the measurement ability of the rack for clamp ammeters.

VI. CONCLUSION

Through studying the measurement principle of the clamp ammeter, analyzing the measurement methods and existing issues of the clamp ammeter, a new type of rack for the clamp ammeter was designed. The new type of rack for the clamp ammeter could not only achieve simultaneous measurement of single-phase and three-phase clamp ammeters, but also fixed the position of the large clamp ammeter by adjusting the insulation rod accurately up and down and moving the insulation clasps left and right, so as to the 100A copper rods could pass through the center of the clamp mouth and be perpendicular to the plane. This hanging rack reduced interference while achieving accurate measurement, significantly improved the measurement capability of the clamp ammeter.

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