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Comparison Study of the Solar Radiation Effect on The Electricity Meter in Case of Operating and Non-operating Conditions

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Abstract_ **Climatic tests are one of the most important type tests that are carried out on electricity meters, Protection against solar radiation test is one of these climatic tests, that is carried out using solar simulators. In this work, the electricity meter has been tested by using a solar simulator developed at High Voltage Laboratory, Egyptian National Institute of Standards, NIS. The test is performed on an outdoor three-phase energy meter at two different cases operating conditions with different loads and non-operating conditions. Also, the accuracy of the electricity meter has been recorded and analyzed before exposure to solar radiation, during, and after the absence of solar radiation. The uncertainty budget of measurements has been evaluated to obtain the actual result of the test.**

Keywords— Electricity Meter; Solar Radiation; Uncertainty; Solar Simulator; Type Tests.

1. INTRODUCTION

Type tests are a set of tests that carry on an electricity meter to ensure that the characteristics of the energy meter are compatible with the requirements of the electricity meters' standard (IEC Standards). Solar radiation tests are carried on outdoor electrical energy meters to test their performance when exposed to solar radiation and ensure that the accuracy of the meter does not change during operation or failure in its insulation during exposure to sunlight. The level of protection and insulation of outdoor meters, which are installed outside, is increased because outdoor electricity meters are almost exposed to direct sunlight, this test is carried according to IEC62052-11, IEC60068-2-2:2010 [1-2]. The solar test was performed by using a solar simulator at the level of radiation specified by the standard and equal 1120 W/m^2 ± 10%. A solar simulator is an appliance that acts as sunlight through different types of light sources [3]. The output irradiance intensity of the solar simulator depends on many factors such as the number of lamps used, type of light source, the distance between lamp and test area, the distance between lamps [3]. Several research works have been done to build a solar simulator with reliable performance for use in tests and research works [4-5]. Light sources that are used to simulate sunlight are very many with different characteristics such as light-emitting diode lamp (LED), quartz tungsten halogen lamp, mercury xe-neon lamp, metal halide lamp, carbon arc lamp, etc. [6]. In 2018, Erkata Yandri used sixteen units of halogen lamps of 50W for each. The lamps were fixed on an aluminum frame with dimensions of 430 mm × 390 mm × 1000 mm. The distance between the light surface and the test area was 32 cm, giving the maximum non-uniformity of 9.7% [7]. In 2019, Bărar, Ana, et al. constructed a solar simulator by using 10 w of red led lamp and three 10 W LEDs with color temperatures 3000-3500K, 4000-4500K, and 6000-6500K [8]. In 2020, Al Mansur, Ahmed, et al. tested solar panels by using a solar simulator with dimensions (107 cm × 92 cm × 72 cm) and contains 4 units of halogen lamps with (0.5kW for each) [9]. In 2021, Hayakwong, Ekkawid, and Athipat Matarach. Designed solar simulator for laboratory research by using 12 units of tungsten halogen tube with a total capacity of power equal 12 kW and the output irradiance of the simulator be 0 to 900 W/m^2 [10].

Protection against solar test has been done on a three-phase electricity meter with accuracy class 2 and protective class II. the accuracy of the electricity meter has been measured during exposure to solar radiation at the operating condition and various electrical loads to know the effect of radiation on electricity meters' accuracy. Also, the energy meter was tested according to IEC standard at non-operating conditions then the meter's accuracy was tested before and after the test to analyze the effect of radiation in this case and compare the results between the two tested methods. The uncertainty budget of measurements has been evaluated and taken into consideration to obtain the actual result of the test.

2. CONSTRUCTED SOLAR SIMULATOR

In this paper, the solar test is carried out by using a solar simulator built by adding four units of quartz tungsten halogen lamps (QTH) with 250 W, 24 Vdc for each on the climatic chamber model (MKF-240). The lamps are supplied through four units of 24 V of dc power supply manufactured by (MEAN WELL) through wires coated with a thermal insulator to be protected from heat during the test. The spectrum irradiance of halogen lamps includes wavelengths from 280 nm to 2500 nm as illustrated in Fig.1, which are close to normal sunlight [11]. The lamps are placed at specific points on an aluminum plate inside the chamber. The solar power meter (pyranometer, model TM-207) used to measure the output radiation of lamps is connected to an external sensor via a wire with a length equal to 1.5 m. The

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pyranometer measures irradiance from zero to 2000 W/ m^2 with ±5% accuracy [12]. The climatic chamber that is used can control the environmental conditions from -40° C to 180° C and humidity from 45% to 95% RH [13]. The output irradiance of the designed simulator equals 1066 ± 15 W/m^2 at 26 cm distance from lamps to test area with non-uniformity 8.5% with test area sufficient to test one electricity meter. Figure 2 showed that the radiation distribution inside the chamber during the test.

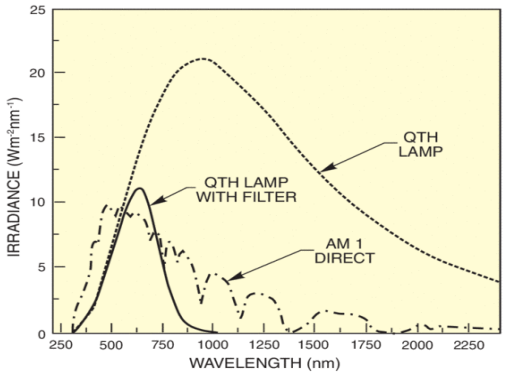

Fig. 1. QTH lamps Spectral irradiance [11]

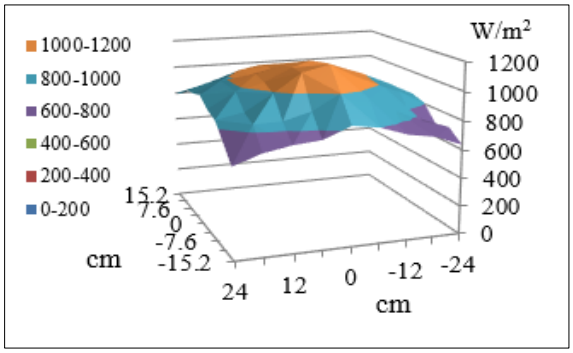

Fig. 2: Irradiance distribution at 26 cm, 1066 W/m^2 with 8.5% non-uniformity

3. SOLAR TEST PROCEDURE

According to IEC standard, protection against solar radiation test is performed on electricity meter for three consecutive days where the energy meter in non-operating condition and placed inside the climatic chamber and exposure to solar radiation with temperature 55° C for eight hours, and sixteen hours in darkness with temperature 23° C then the meters' accuracy has been recorded before and after the test. The energy meter was tested by the standard method in addition to method differ from standard method to study the solar effect on meter at normal operation. The energy meter has been supplied by its nominal voltage and variable balanced load current using comparator reference standard wattmeter and energy meter manufactured by ZERA, model (Com-303), in the lab. Meters' error has been measured and recorded to know the extent of radiation effect on meter under different loads. The electricity meter has been tested at the operating condition and 23°C before exposure to solar radiation as a reference condition. The electricity meter was placed inside the climatic chamber, and its accuracy has been measured at a value of radiation 1066 W/m^2 ±8.5% and ambient temperature 55°C. By considering the temperature generating from the climatic chamber in addition to the output temperature from the halogen lamps an external temperature sensor was placed inside the chamber over the test area to control the temperature through changing the adjustment of climatic temperature and noted that the ambient temperature inside the chamber reached to 55°C when the chamber temperature adjusted at 33° C. After that, the electricity meter accuracy was measured after reaching manually room temperature (23°C ± 2 °C), the meter has been tested to know if the effect of radiation will be continuous or electricity meter will back to its normal condition. Many readings have been taken for each value of the applied currents to acquire its average, then the data has been analyzed by excel program.

4. THE RESULTS

The electricity meters' accuracy has been measured by photo scanning head of comparator (com303-3). Table I illustrated the average of measurement accuracy meter at non-operating condition (standard method). First, at room condition 23°C in the absence of solar radiation. Second, after three days which meter exposure to radiation equals 1066 W/m^2, ambient temperature 55°C. Fig. 3,4,5 show the accuracy of the electricity meter under different loads for each case.

TABLE I ACCURACY TEST RESULT FOR THE ELECTRICITY METER

Applied Current (A)	P.F	Error % Before test	Error % After test	Error Deviation% (before standard test – standard test)
0.5	1	-0.8125	-0.5267	-0.2858
1		-0.5680	-0.4206	-0.1474
2		-0.6008	-0.3492	-0.2516
5		-0.2998	-0.2647	-0.0351
10		-0.3891	-0.2440	-0.1451
20		-0.3580	-0.1843	-0.1737
30		-0.3324	-0.1446	-0.1878
40		-0.3001	-0.1036	-0.1965
1	0.8 (Capacitive)	-0.2995	-0.3777	0.0782
2		-0.2430	-0.2258	-0.0172
5		-0.2401	-0.1254	-0.1147
10		-0.1007	-0.0589	-0.0418
20		-0.1039	-0.0047	-0.0992
30		-0.1105	0.0344	-0.1449
40		-0.0998	0.0672	-0.1670
1	0.5 (Inductive)	-0.8789	-0.5878	-0.2911
2		-0.8835	-0.5208	-0.3627
5		-0.8251	-0.4110	-0.4141
10		-0.6790	-0.3547	-0.3243
20		-0.6854	-0.3070	-0.3784
30		-0.6605	-0.2858	-0.3747
40		-0.6329	-0.2626	-0.3703

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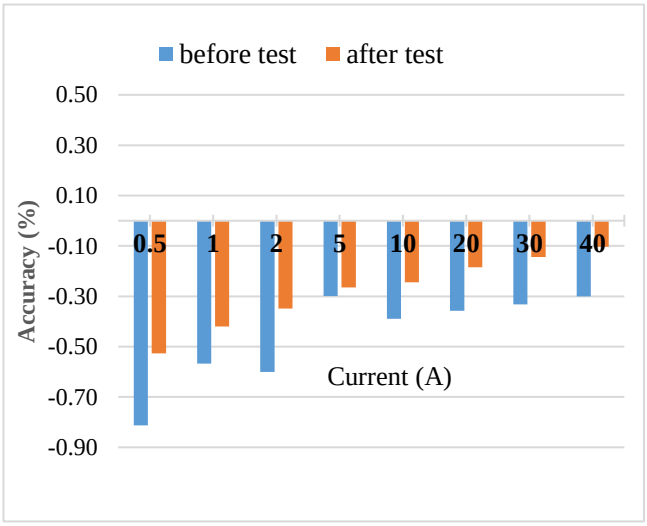

Fig.3: Meter standard test result, at pf=1

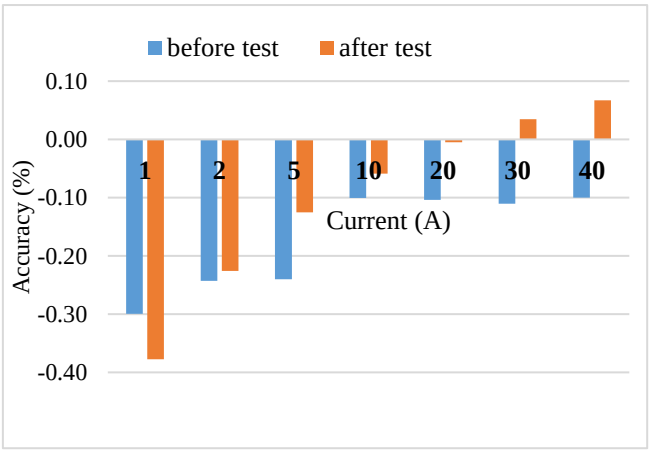

Fig.4: Meter standard test result, at pf=0.8C

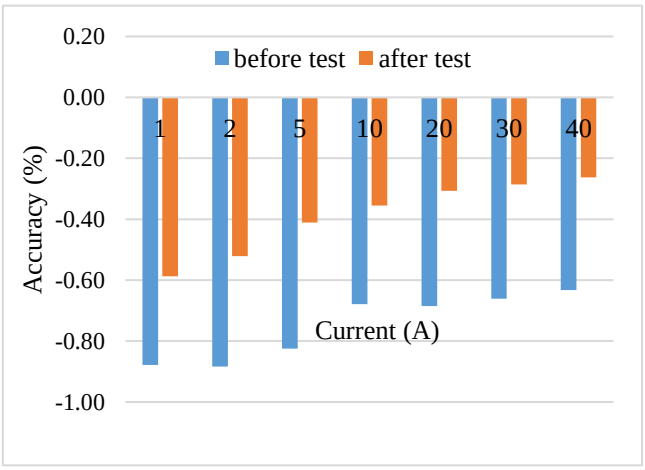

Fig.5: Meter standard test result, at pf=0.5L

After the standard test the electricity meter has been tested at the operating condition with the same environmental standard value then the accuracy measured before, during, and after exposure to solar radiation. Table II shows the accuracy results in three cases. Fig. 6,7,8 show the accuracy of the energy meter under different loads for each case.

TABLE II ACCURACY TEST RESULT FOR THE ELECTRICITY METER AT THREE CASES

Applied Current (A)	P.F	Error % at R=0 W/m² T=23°C	Error % at R=1066 W/m² T=55°C	Error % at R=0 W/m² T=23°C	Error Deviation% (without radiation – with radiation)
0.5	1	-0.9205	0.9727	-0.8125	-1.8932
1		-0.7760	1.6127	-0.5680	-2.3887
2		-0.6083	1.9817	-0.6008	-2.5900
5		-0.4876	2.0260	-0.2998	-2.5136
10		-0.4295	2.0127	-0.3891	-2.4422
20		-0.3630	2.0447	-0.3580	-2.4077
30		-0.3234	2.0763	-0.3324	-2.3997
40		-0.2924	2.0857	-0.3001	-2.3781
1	0.8 (Capacitive)	-0.0850	2.2340	-0.2995	-2.3190
2		-0.2590	1.9325	-0.2430	-2.1915
5		-0.2517	2.1155	-0.2401	-2.3672
10		-0.0643	2.2753	-0.1007	-2.3396
20		-0.0920	2.2537	-0.1039	-2.3457
30		-0.0927	2.0130	-0.1105	-2.1057
40		-0.0947	2.2610	-0.0998	-2.3557
1	0.5 (Inductive)	-0.9776	-1.5303	-0.8789	0.5527
2		-0.9985	-0.9773	-0.8835	-0.0212
5		-0.8570	1.7417	-0.8251	-2.5987
10		-0.7809	1.5857	-0.6790	-2.3666
20		-0.7165	1.8363	-0.6854	-2.5528
30		-0.6853	1.9040	-0.6605	-2.5893
40		-0.6597	2.0073	-0.6329	-2.6670

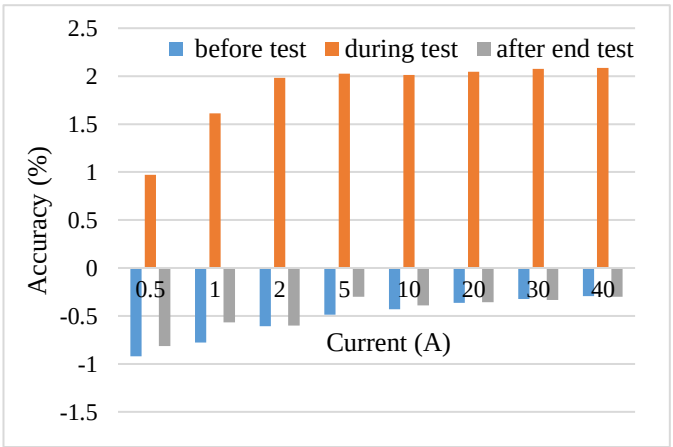

Fig.6: Meter test result, at pf=1

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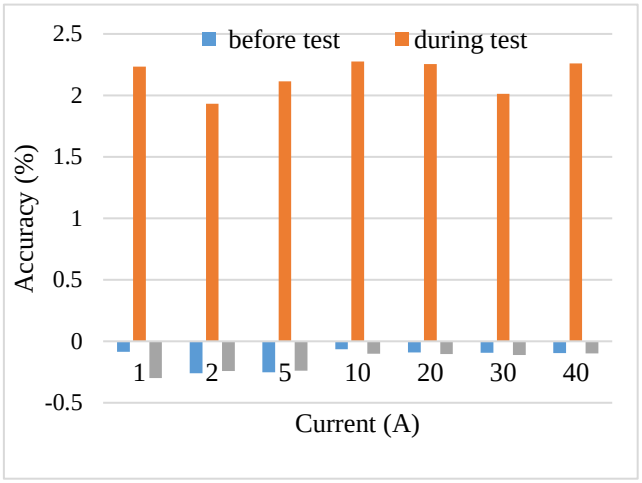

Fig.7: Meter test result, at pf=0.8C

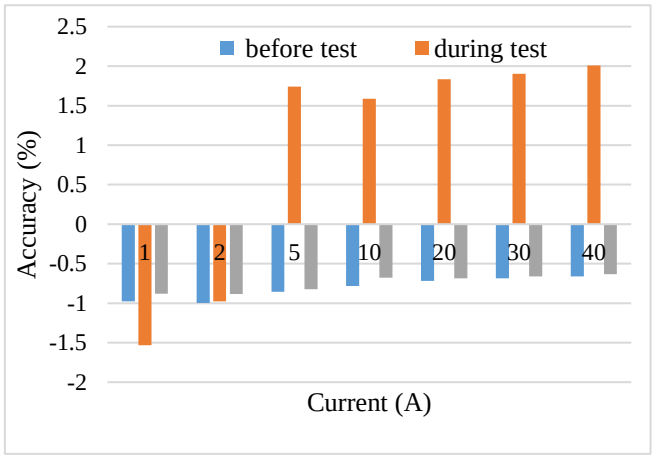

Fig.8: Meter test result, at pf=0.5L

5. CONCLUSION

Solar radiation has a visible transient effect on the accuracy of the electricity meter during radiation although there is no visible degradation on the outer surface or insulation of meters. This effect of solar radiation doesn't observe when electricity meter has been tested at non-operating condition because the solar effect was transient and disappear when the radiation disappear. The electricity meter returns to its normal operation after the exposure to radiation has been disappeared.

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