Enhancement of Reference Power Standard at SASO NMCC on AC power And revaluation of measurement uncertainty

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Abstract

The accuracy and reliability of Power Standards for AC power measurements are significant subjects in current times and for the future. The rapid increase in smart electricity meters in Saudi Arabia necessitates the development of an NMCC (National Metrology and Calibration Center) reference power standard to meet legal metrology and industrial requirements. This study explores advancements in reference power standards, specifically focusing on the development of more precise and stable AC power measurement systems for high-current applications. The results demonstrate a significant reduction in the estimated uncertainty, leading to more accurate calibration of power meters. In a parallel case study, a calibration method is applied to a commercial power meter to measure AC power across high current values ranging from 10 A to 120 A using Refernce CT. The calibration method involves comparing the reference AC power system with the commercial power meter. The term 'DSWM' (Digital Sampling Watt Meter) refers to the reference AC power system, which utilizes sampling techniques to collect various data with a Unit under Calibration (UUC). Homemade software under the environment of LabVIEW software is used to controlling, optimizing, handling the data, statistically calculation and finally for exporting the well gathering data in the form in digitized certificates. The paper explains the components of the DSWM, the measurement results for AC power are presented, considering active and reactive power, which may impact various aspects such as voltage, current, and phase measurements. The evaluation of uncertainty was 40 µW/V.A for active power and 40 µvar/V.A for reactive power. Finally, the paper mentions future work in its concluding section.

Keywords: NMCC, UUC, CT, DSWM.

1. Introduction

since the demand of smart electricity meter used In residential and Industry In Saudi Arabia , Saudi Electric Company Install more than 10 million electric meters in different region of Saudi Arabia [1].however, Legal metrology in SASO required to satisfy all the requirements of OIML R 46 standard [2] which the accuracy test is one of the main test on any smart electricity meter. National metrology Institute is responsible to maintain the traceability of any of the measurement instuermnt . Power meter is the master device of electricity meter which can measure Ac power. Power and energy lab has ability to calibrate Ac power interments in National Metrology and calibration center "NMCC" .This paper aims to improve primary level system in the lab. The modular method used to calibrate the ac power source or meter called DSWM" Digital sampling watt Meter. DSWM Is sampling technic using sampling multimeters DMM 3458A. Operating principle of the standard is based on the use of two sampling voltmeters synchronized to the power source, fig. 1. Sinusoidal voltage and current signals or with steady-state harmonics are generated by the phantom power source and applied to the relevant input terminals of the
voltage and current measurement units. Regulated voltages are then applied to the voltmeters for sampling with the help of triggering synchronized to the power source[3,5].

2. Measurement Setup

The operational principle of the standard relies on the utilization of two sampling voltmeters that are synchronized with the power source, as illustrated in figure 1 below. The phantom power source generates sinusoidal voltage and current signals, or signals with steady-state harmonics, which are subsequently directed to the appropriate input terminals of the voltage and current measurement units. Regulated voltages are then supplied to the voltmeters for sampling, facilitated by triggering that is synchronized with the power source. [3].

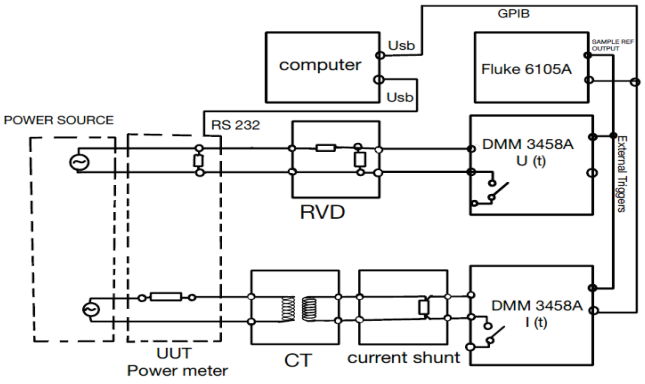

Fig.1 . the setup of AC power calibration

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The Components of modular measurement setups;

- Power source & phase locking :

The phantom power is the ac power system can deliver a sinusoidal voltage and current signal with different phase angle between them in period of cycle. It can generate active power and reactive power. The equation of ac power are [6]:

Active power

$$P = V * I * \cos(\varphi)$$

Reactive power

$$Q = V * I * \sin(\varphi)$$

Or other formal used based in power triangle :

$$(Q) = \sqrt{((S\text{^}2 - P\text{^}2))}$$

Where are

V. sinusoidal voltage signal

I. sinusoidal current signal

φ . The phase difference between voltage and current waveforms.

S .Apparent power which voltage multiply Current V.A.

6105A fluke used on this modular for phase locker that the external triggers of DMM connect to sample Ref OUTPUT of the fluke 6105A. The software controlled Phase-locking device.

- Voltage measurment unit:

Voltage measurment unit used a resisitive voltage divider which play the important role to cover input voltage from 30 V to 240V in 53 Hz and 60 Hz.the benfent of using resistive voltage divider to minmize the voltage input to 0.8V to get accurate measurermnet and achive the best uncertinty value.it is calibrated on Ratio & Phase displacmnet within less than 8 µV/V & µrad.

- Current measurment unit:

Current measurement unit is basically current shunt which cover current input from 62mA to 5A then convert the drop voltage as the output of the shunt. The output voltage is in the range of 1 V DCV to get the best accurate measurement and achieve the best uncertainty value.it is calibrated on Dc resistance value and AC-DC transfer value. For higher current value , the current transformer used to minimize the input current up (1A-4 kA) to reach 5A in secondary output of the current transformer.it is calibrated on CT ratio and Phase displacement.

- DMM & DSWM software :

DSWM is system using sampling technic which contents all unit list above and DMMs (keysight 3458A).Tow digital mulitmeters (DMMs) used to sample the voltage U(t) through a resistive voltage divider and current I(t) through current shunt with CT.

.Both DMMs connect together in external trigger siginal with 6105A to provide a simultaneous voltage signals for Ac power calculation. In addition, all devices are connect through GBIP connection to computer for communications and controlling, enquiring data from DMMs. Mr.Rado Labuh cover many sampling technic using by 3458A .the sampling mode use in our Lab is DC voltage (DCV) same as Tubitak UME & RISE “Research Institutes of Sweden “. User define many parameters figure 2 such as :

- Communication part by using NI MAX from NI.
- DMMs , voltage and current set depends on the range .
- Accrue measurement by:
  - A. Number of measurement :10 measurement
  - B. Number of sample :Repeat counting measurements (128)
  - C. Sampling period: time period per cycle (10)
  - D. Frequency : what is the main frequency used in measurement .(60 Hz or 50 Hz)

after quering and collect data , the software will reprsent the voltage and current wave with copmaring the waves to calculate the phase angle between them. Base on the main scentifc equation on active and reactive power [6],the software can calculate the Ac power in high accurate mode.

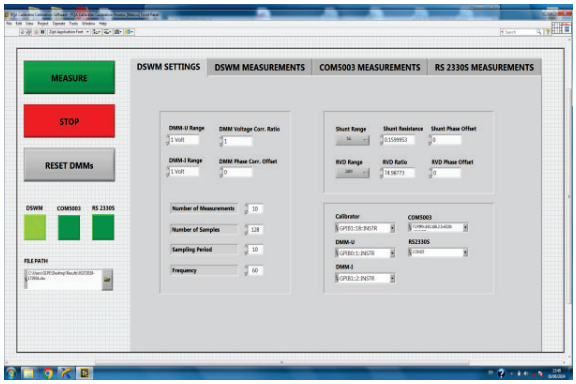


Fig.2 . configuration user and Front DSWM application

The values of data collection and calculation are represented in the software and store in Excel files immediately figure.3.

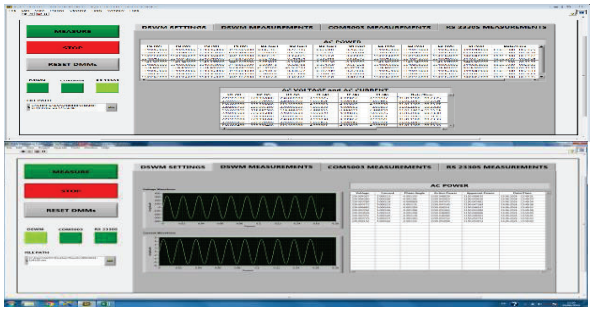


Fig.3 . Data present on DSWM system and UUT.

3. Measurement Result

Base on inquiring data from various devices and apply it on many different equation to calculate the ac power, the experimental of calibration was implemented on one of the most commercial AC power meter RS 2330s that has accuracy 100 µW/V.A for active power and 100 µvar/V.A for reactive power. The equation used to compare the ac power (active, reactive, apparent power) used is:

$$Relative\ error = \frac{measured\ power\ value - nominal\ power\ value}{apparent\ power\ value} \times 10^6$$

Where are:

measured power value:Ac power measure indicate from UUT

measured power value=Ac power value indicate DSWM

apparent power value: Ac power indicate from DSWM

So far the table result give indicate value of the relative error compare with primary AC power standard.

- Active power result at 230 V 60 Hz

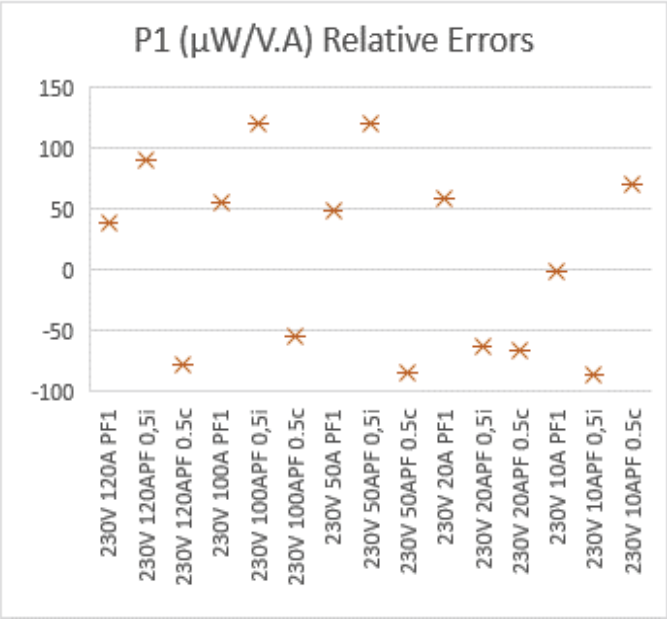
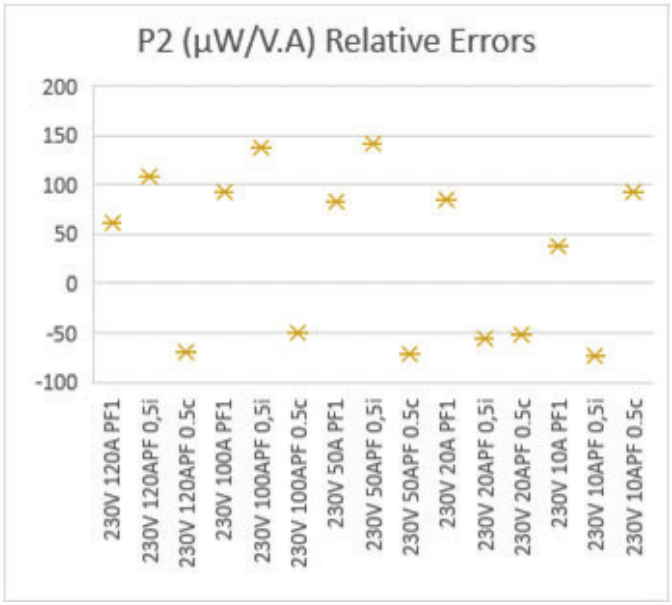


Fig 4: Active power in first phase at balanced system.

Fig 5: Active power in second phase at balanced system.



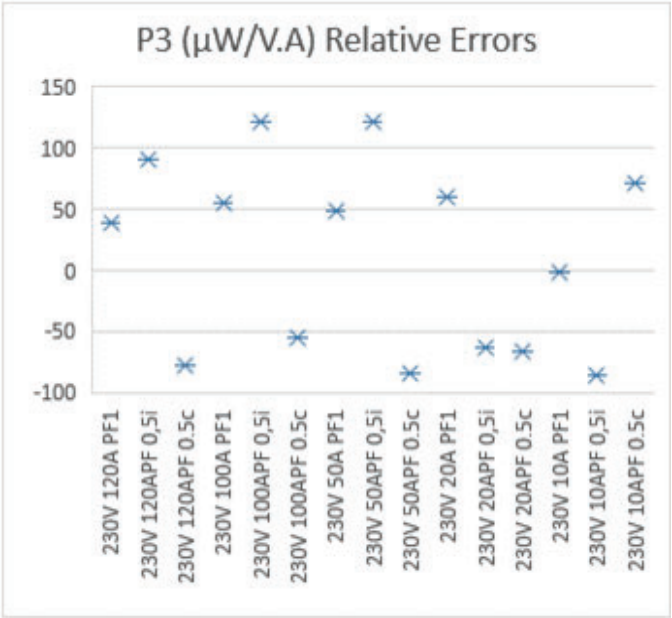
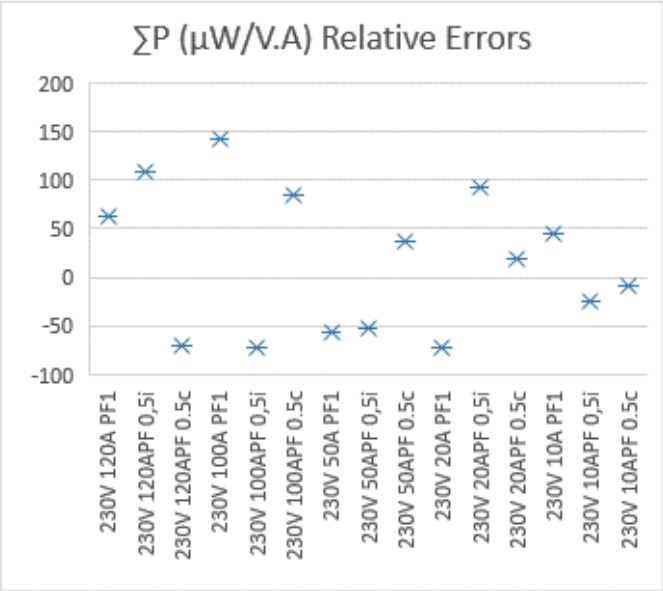


Fig 6: Active power in third phase at balanced system.

Fig 7: Total active power in three phase balanced system



Where are

P1. Active power in first phase at balanced system.

P2. Active power in Second phase at balanced system.

P3. Active power in Third phase at balanced system.

∑P.Total active power in three phase balanced system.

- Reactive power result at 230 V 60 Hz

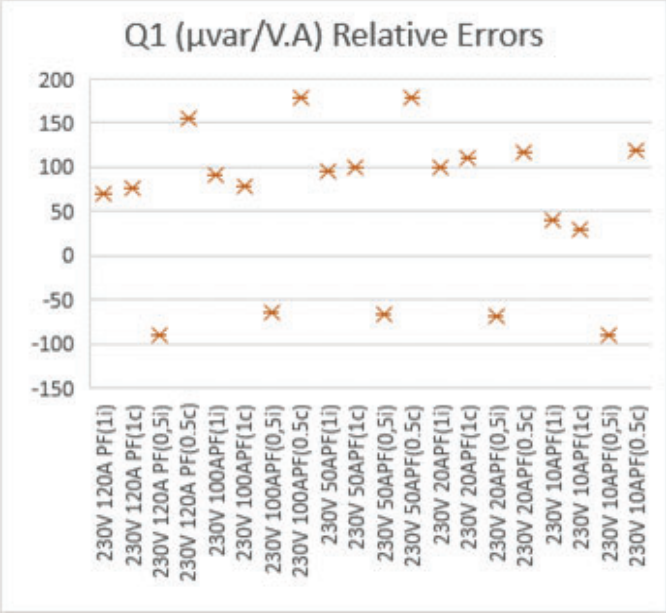
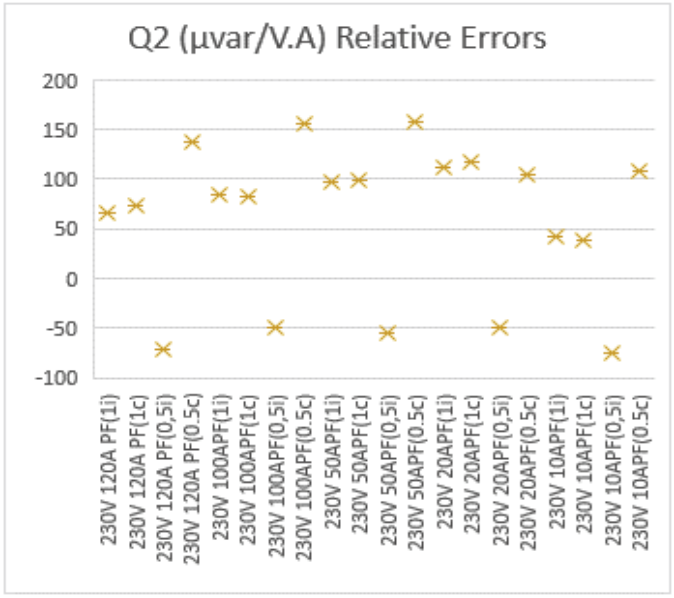


Fig 8: Reactive power in first phase at balanced system

Fig 9: Reactive power in second phase at balanced system



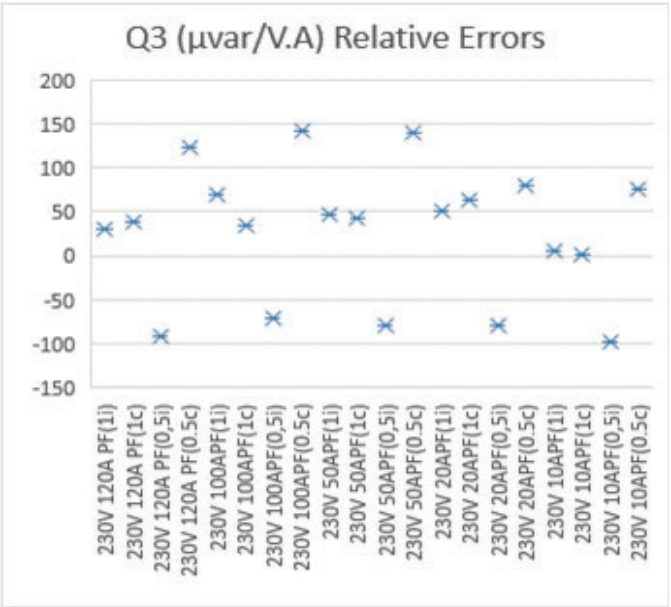
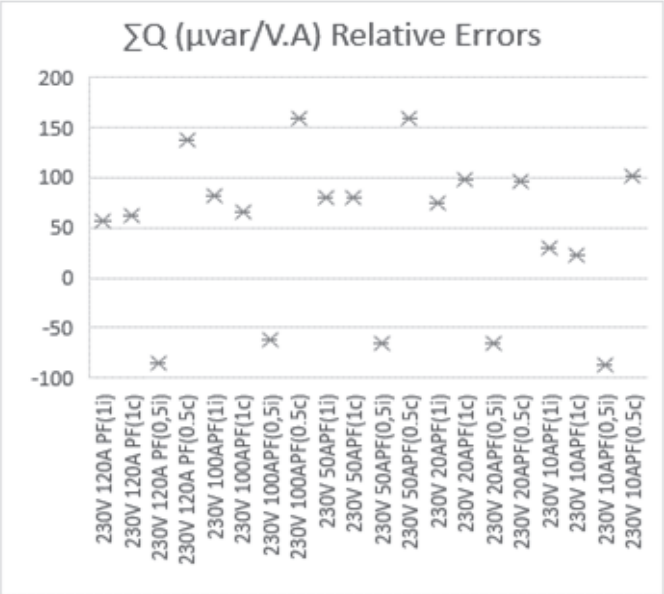


Fig 10: Reactive power in third phase at balanced system

Fig 11: Total Reactive power in three phase balanced system



Where are

Q1. Reactive power in first phase at balanced system.

Q2. Reactive power in Second phase at balanced system.

Q3. Reactive power in Third phase at balanced system.

∑Q.Total Reactive power in three phase balanced system.

4. Uncertainty Evaluation

The following sample tables below shows a typical Uncertainty budget used by Power and energy lab (SASO-NMCC) in the calculation of its uncertainty values. After using CT in current measurement, the achieve uncertainty value is 40 W/V.A & 40 var/V.A for more than 10 A. And, uncertainty budgets of both sides for 53 Hz and 60 Hz measurements are given in Table below.

Summary calculation of measurement uncertainty[4].

Uncertainty evaluation for active power P in W/V.A and reactive power Q in var/V.A					
Main uncertainty components	Type method of evaluation	Standard uncertainty value u(xi)	Probability distribution	Sensitivity coefficient	Uncertainty Contribution (µW/V.A) or (µW/V.A)
Voltage meas. (U)/U	Here specify the type A or B of all sub uncertainty components	Here specify the value of all sub uncertainty components	Normal	cos(φ) for active power sin(φ) for reactive power cos(φ)	Root square sum of all sub uncertainty components value and Sensitivity coefficient (in V/V)
Current meas. u(I)/I			Normal		Root square sum of all sub uncertainty components value and Sensitivity coefficient (in A/A)
Phase shift meas. u(φ)			Normal	1	Root square sum of all sub uncertainty components value and Sensitivity coefficient (in rad)
Meas. setup	Type B		Rectangular	1	-
Std. uncertainty	Type A	Std.s/number of measurement	Normal	1	-
The standard uncertainty for active power P in W/VA is the root square sum of the standard uncertainty of the three independent components of the Main uncertainty components.					
Expanded uncertainty for active power P in W/VA or reactive power Q var/VA in is equal to standard uncertainty multiplied by 2 which gives 95.45% coverage factor					

Fig 12: Typical Uncertainty budget used by Power and energy lab

5. Future Work

Current and voltage measurement units will be re-evaluated for better measurement uncertainties to get lower uncertainty for low current value. Maintain the Ac power measurement traceability to the national standards inside Saudi Arabia. In addition, AC power quality is one major activity inside the lab, which it will be focused next stage too.

6. Conclusion

An AC power measurement standard has been established at SASO NMCC. Performance of the system was tested with a key comparison and achieve CMC in KCDB data base with in 60 µW/V.A [7]. The reported results were found in good agreement with the estimated measurement uncertainties. Further research work is planned for improvement in the measurement uncertainties and this paper aim to minimize the uncertainty values to 40 µW/V.A.

1. The Saudi Electricity Company (SEC) has completed the installation and replacement of over 10 million smart electricity meters, within its most important project towards digital transformation. https://saudienergyconsulting.com/10-million-smart-meters-set-to-transform-saudi-grid/
2. Technical requirement for effective electric energy meter : https://taqyees.sa/en/regulations
3. Establishment of Reference Power Standard at SASO NMCC and GULFMET Bilateral Comparison
4. GUIDE FOR SAMPLING POWER AND POWER QUALITY MEASUREMENTS
5. The book \Sampling with 3458A - Understanding, Programming, Sampling and Signal Processing", authored by Rado Lapuh [7] covers the entire sampling capabilities of the 3458A that can be used in various practical applications.
6. IEEE Standard Definitions for the Measurement of Electric Power Quantities Under Sinusoidal, Nonsinusoidal, Balanced, or Unbalanced Conditions IEEE Std 1459TM-2010
7. https://www.bipm.org/kcdb/cmc/search?domain=PHYSICS&areaId=2&keywords=&specificPart.branch=-1&specificPart.service=-1&specificPart.subService=-1&specificPart.individualService=-1&_countries=1&countries=151&publicDateFrom=&publicDateTo=&unit=-1&minValue=&maxValue=&minUncertainty=&maxUncertainty=#comment-31920