MONITORING THE CONSISTENCY OF THE DYNALYSER OUTPUT VIA DIGITAL DISPLAY UNIT AND CALCULATED PRACTICAL PEAK VOLTAGE

Wan Hazlinda Ismail, Muhammad Jamal Md Isa, Abd Aziz Mhd Ramli and Shahrul Azlan Azizan
Malaysian Nuclear Agency
Bangi, 43000 KAJANG, MALAYSIA

Abstract

This study was carried out to ensure the adequacy and accuracy of the Dynalyser Digital Display unit for measuring the true kVp from the invasive kVp meter unit during calibration of non-invasive kVp meters. An invasive high voltage divider (dynalyser) coupled to the x-ray system measures the true kilovoltage supplied to the x-ray tube. The kVp output measured was displayed via its digital display unit while its waveform was acquired using a calibrated oscilloscope. The waveform was used to calculate the Practical Peak Voltage (PPV) using the International Standard method adapted from IEC 61676 and treated as the true kVp value. The kVp output was measured at 9 points ranging between 40kV-120kV with interval steps of 10kV and monitored every day. The test result was evaluated for variation of output, intrinsic error and limit of variation in compliance with the IEC standard. Results showed that kVp output measured by the display unit everyday is consistent with variations of not more than ±0.45kV, intrinsic error of not more than ±0.009kV and limits of variation of less than 1% which comply with the IEC standard requirement. The kVp output via digital display unit has a total uncertainty of not more than 2.8 kV (k=2) while the PPV output via oscilloscope has total uncertainty of not more than 0.75kV (k=2). As a conclusion, the dynalyser digital display unit complies with standard requirement and can be used to measure the true kVp output during the calibration of non-invasive kVp meters.

Abstrak

Kajian ini dijalankan untuk memastikan kesesuaian and kejituan unit paparan digital dynalyser yang digunakan untuk mengukur nilai sebenar kVp semasa menjalankan tentukuran meter kVp 'non-invasive'. Sebuah pembagi voltan tinggi invasive telah disambungkan ke sistem sinar-x untuk mengukur nilai voltan sebenar yang dibekalkan ke tiub sinar-x. Bacaan voltan dipapar pada unit paparan dynalyser manakala waveform voltan diperolehi melalui sebuah osiloskop yang telah dikalibrasi. Daripada waveform yang diperolehi nilai PPV dapat dikira mengikut protokol yang telah ditetapkan di dalam standard antarabangsa IEC 61676. Output kVp telah diukur pada 9 titik iaitu di anatara 40kVp hingga 120kVp dengan peningkatan selaan 10kV. Hasil kajian dinilai daripada beberapa aspek iaitu variasi output, intrinsic error dan had variasi sejajar dengan standard IEC. Keputusan kajian menunjukkan unit paparan dynalyser adalah stabil dan mempunyai varasi kurang daripada ±0.45kV, intrinsic error kurang daripada ±0.009kV dan had varasi kurang daripada 1%. Didapati juga ketakpastian pengukuran output kV melalui unit paparan adalah tidak lebih dari 2.8kV (k=2) manakala bagi pengukuran melalui osiloskop pula adalah tidak melebihi 0.75kV (k=2). Sebagai kesimpulan, unit paparan digital dynalyser memenuhi keperluan standard dan boleh digunakan untuk mengukur kVp sebenar semasa tentukuran meter kVp non-invasive.

Keywords/Kata kunci: Practical peak voltage, Dynalyser, Oscilloscope, invasive kVp meter, non-invasive kVp meter.

INTRODUCTION

The measurement of the peak potential voltage (kVp) of an x-ray system is considered one of a decisive routine in the quality assurance program (QAP) worldwide. Since the kVp applied to the x-ray system have a large influence on the patient dose and image quality, it is vital to make precise measurement of the kVp during this routine to assure the system is functioning accordingly. To achieve this, a well calibrated instrument for measuring kVp output is desirable (Ramirez-Jimenez, 2004).

The kVp of x-ray system can be measured using two different methods which are the invasive method and non-invasive method. Both methods have their advantages and disadvantages. The invasive methods measure the kVp of the x-ray system within the system itself incorporating a high voltage (HV) divider into the system and monitoring through its display unit or an oscilloscope. This method offers high precision in measurement but is expensive and impractical to use on site in the QAP due to the bulky size of the high voltage divider and complex procedure. One requires a lot of experience and expertise to proceed with this method. However, this is the method of choice employed in a standard calibration laboratory where the kVp measured is used as the reference kVp (http://pintassilgo2.ipen.br/biblioteca/2008/events/13392.pdf).

The non-invasive method on the other hand, is more portable and practical to be used in practice since handling a non-invasive instrument is a straight forward procedure. The non-invasive method is basically just placing the radiation detector or sensor in the x-ray beam and measurement can be taken directly. However, the non-invasive methods have its disadvantage due to the instrument limitation and give larger uncertainties than the invasive instruments. Therefore, it is crucial to periodically calibrate the non-invasive kVp measuring instruments (http://pintassilgo2.ipen.br/biblioteca/2008/events/13392.pdf).

In Malaysia, the Medical Physics Laboratory at the Malaysian Nuclear Agency is responsible to carry out the calibration for non-invasive kVp meters used in diagnostic radiology. The calibration method used is by comparing the reading of two non-invasive kVp meters which are simultaneously placed in the x-ray beam. One of the kVp meters is the reference standard while the other is compared and corrected to the reference. The reference kVp meter is calibrated by an International Calibration Laboratory for verification of output accuracy. However, in recent years, the laboratory has established a standard method that employs an invasive kVp meter as the reference against which the non-invasive kVp meters are compared in accordance with the guideline of International Standard IEC 61676. The standards recommended that the kV value should be standardised to a value known as the practical peak voltage (PPV). The PPV is applicable to any waveform since it is an equivalent voltage value related to an ideal x-ray generator that provides a constant voltage and the same film contrast (Ramirez-Jimenez F J et al, 2004). The PPV is expressed as in equation 1.

$$\hat{U} = \frac{\sum_{i=1}^{n} p(U_i).\, w((U_i)U_i}{\sum_{i=1}^{n} p(U_i).\, w(U_i)} \quad \text{(eq. 1)}$$

Where $p(U_i)$ is the probability distribution of any voltage U_i incidence in the range from $[U_i-(\Delta U/2)]$ to $[U_i+(\Delta U/2)]$; and $w(U_i)$ is a weighting function obtained theoretically for the related voltage range. For this study, the voltage range is 40 kV to 120 kV for diagnostic general application. Therefore, the weighting factor in this study is determine in equation 2 (IEC 61676, 2009)

$$W(U_i) = d.\, U_i^4 + e.U_i^3 + f.\, U_i^2 + g.U_i + h \quad \text{(eq. 2)}$$

Where
d = + 4 310 644 E -10
e = -1 662 009 E -07
f = +2 308 190 E -05
g = +1 030 820 E -05
h = -1 747 153 E -02

In this paper, studies were carried out to (1) monitor the consistency of the x-ray output using the invasive method and (2) comparing the digital display unit output of the HV divider to the practical peak voltage (PPV) calculated. The purpose of this study is to assure the adequacy and accuracy of x-ray system and the dynalyser digital display unit (DDU) output for use in calibration of non-invasive kVp meter in diagnostic radiology except for mammography beam quality.

The DDU output value obtained was compared to the PPV value calculated from the oscilloscope waveform and both data was evaluated in accordance with IEC 61676 for voltage waveform and frequency of diagnostic since it does not involve the other parameters. In this standard it is recommended that the measured value should agree with the true value with its limits of variation, L, (for constant potential) measured under standard test conditions, shall not exceed 2%. The minimum intrinsic error for this parameter was not stated. However the intrinsic error can be calculated using equation 3.

(eq.3)

Where U_{meas} is the kVp measured via DDU and U_{true} is the PPV voltage calculated from the dynalyser waveform (IEC 61676, 2009).

MATERIALS AND METHOD

In this work an invasive kVp meter, Radcal Dynalyzer III A, High Voltage unit connected to x-ray machine, Bennett Programmable High Frequency Quartz Accuracy Model HFQ 6000 SE Model: HFQ 6000 with nominal filtration: 3.5 mmAl was used to measure the true kilovoltage supplied to the x-ray tube. The measured value is displayed via its digital display unit while the voltage waveform was measured using a calibrated digital oscilloscope Yokogawa model 7015 10. Both the kVp output and waveform were simultaneously measured. The PPV value was calculated from the waveform obtained using Microsoft excels.

The Radcal Dynlyzer III A, high voltage unit has a frequency response of 100 kHz and D.C. voltage division ratio of 10 000:1 ± 1% accuracy. Whilst its display unit has the ability to measure voltage from anode to cathode ranging from 20kV to 150kV ±(0.75kV + 0.5% of reading). The output was assumed to display the PPV value. In addition, the DDU unit test voltage was consistently monitored, since the value was found to degrade after a period of time which affected the x-ray output value of the DDU. The test voltage was initially set at 10.15V.

The digital oscilloscope output on the other hand was used as the reference value or true value. It was calibrated at a national standard laboratory, SIME-SIRIM TECHNOLOGIES SDN BHD with uncertainty of ± 0.002V (k=2) for function 1V/div. The system has a vertical axis of D.C accuracy ± (2.5% of 8 div + 1LSB).

The kVp of the x-ray system was measured at 9 points ranging from 40kV – 120 kV with interval steps of 10 kV and monitored every day as shown in table 2. The room condition during measurement was noted as shown in table 1.

Temperature (°C)	19-24.5
Humidity (RH%)	41-80
Pressure (mbar)	1003-1008

RESULTS AND DISCUSSION

The results shown in table 2 are the average kVp measured daily for one and half month. The test voltage monitored was in the range of 10.15-10.03 V. Throughout this period, the DDU output showed a slight decrease in kVp measurement by a factor of not more than -0.043. Figure 1 shows the trend of kV measurement from the DDU during this period which did not show any significant decrease in kVp measurement. Table 1 shows the results of the kVp average measurement monitored in one month.

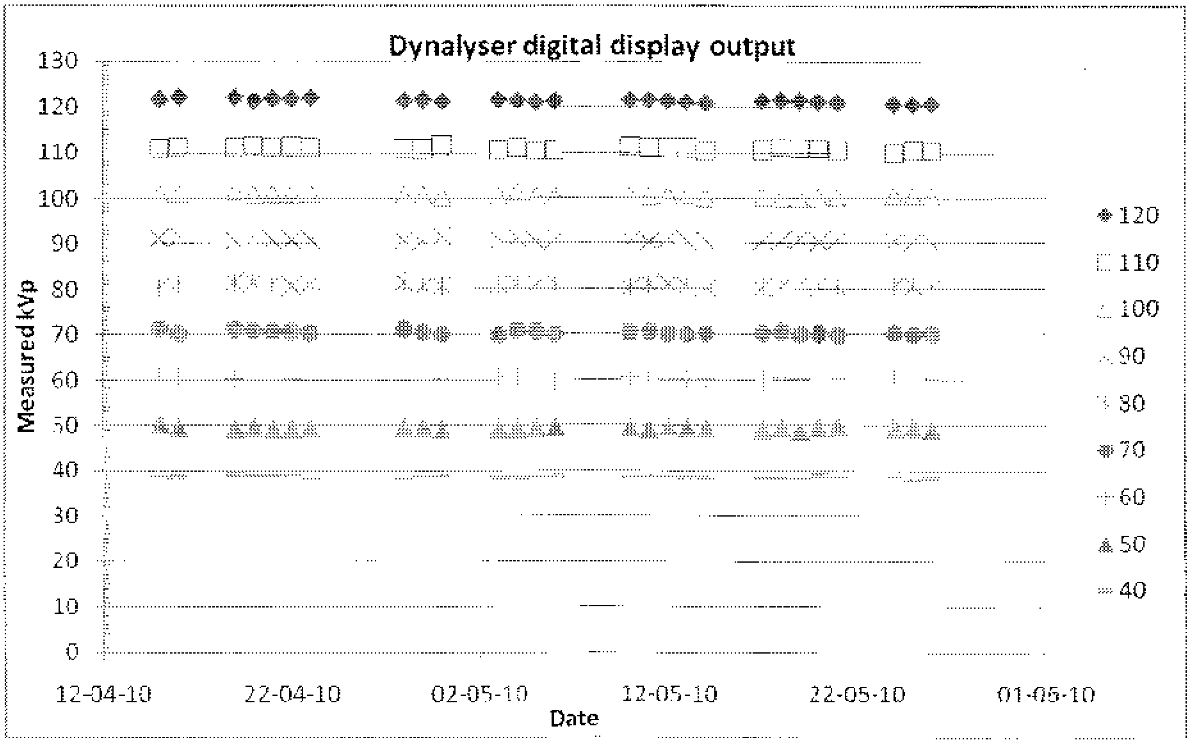

Figure 1: The DDU output trend of the kVp measurement daily for April – May 2010.

From table 2 it shows that the variation of the DDU output is not more than ±0.45 kV while the PPV calculated have a variation of not more than ±0.37 kV. This shows that the PPV calculated from the oscilloscope waveform is more consistent than the DDU output. Considering the PPV as the reference, the limits of variation for DDU calculated is not more than 0.87% which is within the specified value in the standards (2%). The intrinsic error, E, for the DDU calculated is not more than 0.009kV.

Table 2: Average values of the kVp measurements and its standard deviation.

System kVp (Dial kVp)	kVp		Intrinsic error, E (kV)	Limit of variation (%)
	DDU	PPV		
120	121.38±0.41	121.29±0.32	0.001	0.08
110	110.95±0.42	111.02±0.37	0.001	0.06
100	100.62±0.44	100.74±0.33	0.001	0.12
90	90.82±0.39	90.92±0.35	0.001	0.12
80	80.82±0.39	81.10±0.35	0.003	0.34
70	70.42±0.45	70.63±0.31	0.003	0.30
60	60.36±0.35	60.67±0.31	0.005	0.51
50	49.53±0.30	49.75±0.30	0.004	0.44
40	38.56±0.25	38.90±0.30	0.009	0.87

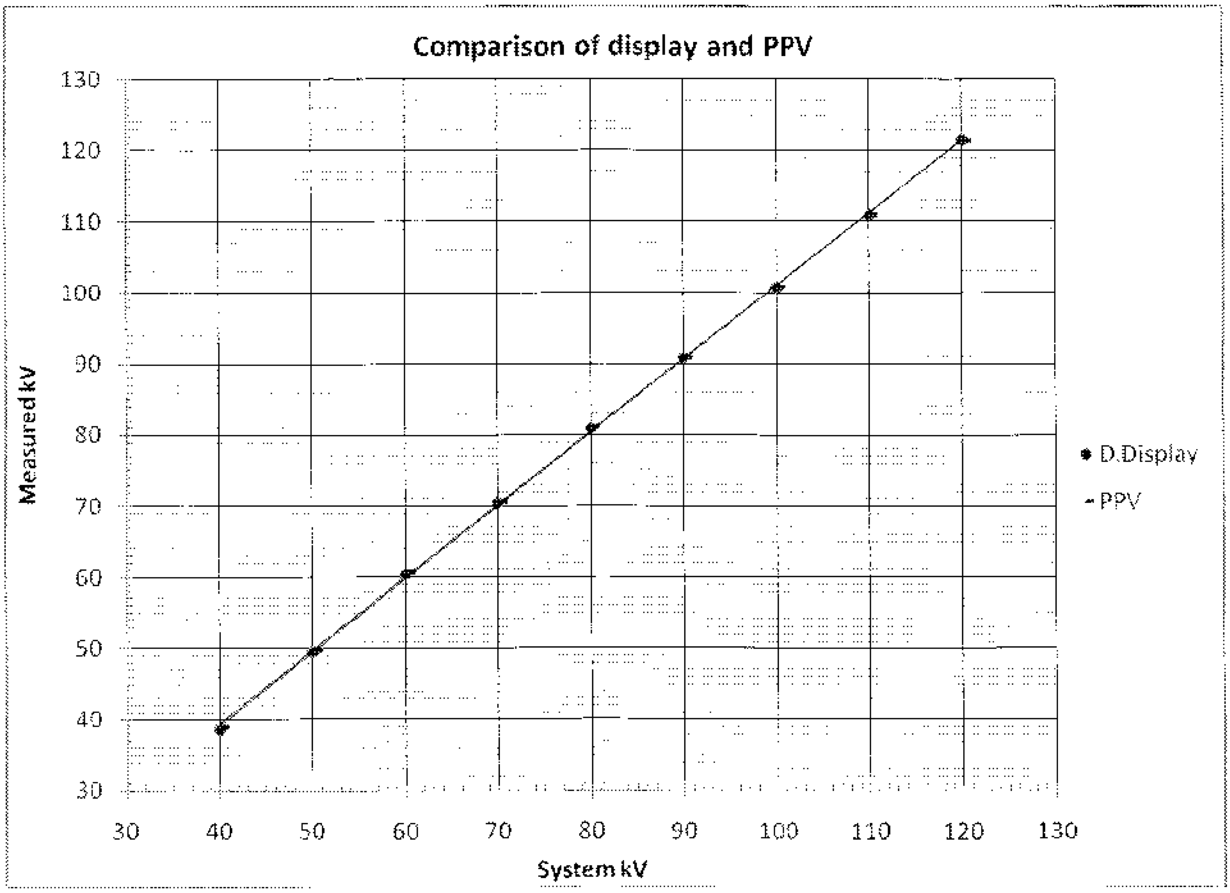

Figure 2: The relationship of average kVp measured of the PPV calculated of the oscilloscope and DDU output.

From figure 2, the DDU output and the PPV value shows good agreement with one another. There is a slight difference at low kV (< 40 kV) of not more than 0.9%, which is considered insignificant as these low values of kV are never used in the calibration of non-invasive kVp meters in this calibration laboratory.

From the results, the uncertainty for measurement of kVp via DDU and oscilloscope was estimated. Taking into consideration the measurement of variation and system error of the DDU as well as the oscilloscope calibration uncertainties, it was found that the DDU have a larger uncertainty compared to the oscilloscope. The kVp output via DDU has total uncertainty of not more than 2.8kV (k=2) which is approximately 6%. Whereas measurement via the oscilloscope estimates total uncertainty of not more than 0.75kV (k=2) which is about 1.7%.

CONCLUSION

This study is only a preliminary study and more data are required (for a whole year) before the findings can be really considered conclusive. However, from the results obtained, it can be considered that the DDU unit complies with the requirements as specified in IEC 616976 standard in terms of the limits of variation and therefore can be be used for true kVp measurement.

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