Transactions of the Korean Nuclear Society Virtual Spring Meeting
July 9-10, 2020

Pulsed Beam Current Measurement System using Current Integrator and Counter at Proton Irradiation Facility

Gwang-il Jung *, Sang-Pil Yoon, Han-Sung Kim
Korea Multi-Purpose Accelerator Complex, Korea Atomic Energy Research Institute, 181 Miraero, Gyeoncheon, Gyeongju 38180
**Corresponding author: jkii0607@kaeri.re.kr*

1. Introduction

KOMAC (Korea Multi-purpose Accelerator Complex) has operated 100-MeV proton linear accelerator since 2013. A beam current measurement system at proton irradiation facility is required to assure beam quality for irradiation. Generally, electrometer (Keithley, 6517B) has been used to measure the charges of proton beam from faraday cup. Despite of its high duty of measuring continuous wave beam current, it has a dead time while it discharges capacitors for pulsed beam. Therefore, Current integrator (ORTEC, Model 439) is selected to measure charges of pulsed beam which has no duty cycle limits. To reproduce the digitized output pulse from current integrator to charge data, counter (ORTEC, Model 928) is used. In this paper, we will describe the configuration and test results of pulsed beam current measurement.

2. Methods and Results

The overall configuration of pulsed beam current measurement system is described in Fig. 1. It consists of a faraday cup, current integrator, counter, pulse delay generator and timing system.

2.1 Current Integrator and Counter

Current integrator is used to measure charge from the faraday cup. An input charge is digitized by producing an output pulse for specific values. There is three different selection of charge (10^{-10}, 10^{-8}, or 10^{-6} Coulomb) required to produce an output pulse. A 75 μF capacitor which acts as a storage element is installed in parallel at the input of the current integrator for the measurement of charge up to 750 nC. A resistor R_{in} = 100 Ω in series is added to avoid saturation [1,2]. The digitized output pulses are counted by counter. It uses an internal clock or external trigger to measure data acquisition time making it possible convert charge to current or dose rate. Brief specifications of current integrator and counter are described at Table 1, 2. Fig. 2 shows installed current integrator and counter [1,3].

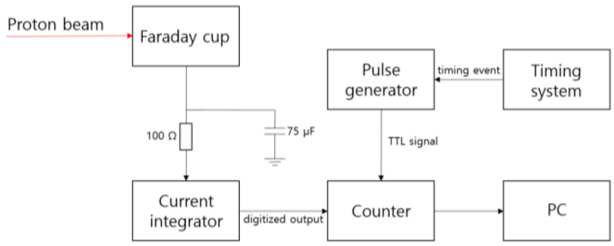

Fig. 1. The configuration of beam current measurement. system.

Table 1. Specification of ORTEC 439 digital current integrator.

	Specification
Input leakage current	1×10^{-12} A
Digitized reproducibility	0.01%
Maximum input charge	750 nC

Table 2. Specification of ORTEC 928 counter.

	Specification
Maximum counting rate	200 MHz
Count capacity	32 bits
Pulse pair resolution	7 ns

Fig. 2. Installed current integrator, storage element, and counter.

2.2 Test Conditions

The pulsed beam current measurement test is conducted at the TR103 of which flux is about 10^{10}~10^{11} #/(cm^2 · pulse), beam pulse width is 100 μ sec, and repetition rate is 1Hz, 2Hz, 5Hz, and 10Hz. On the selection of charge required to produce an output pulse of current integrator, 10^{-10} Coulomb is selected under 1Hz and 2Hz beam condition. On the other hand, 10^{-8}

Coulomb is selected under 5Hz, and 10Hz because of the occurrence of overload.

2.3 Accumulated Charge Measurement

The accumulated charge data using the current integrator and electrometer under repetition rate of 1Hz, 2Hz, 5Hz, and 10Hz is described in Fig. 3 and Table 3. During the beam irradiation of 100 pulses, except for 1Hz, the measurement using current integrator shows better linearity and consistency compared to electrometer. The current integrator shows high performance in the pulsed beam with a high repetition rate.

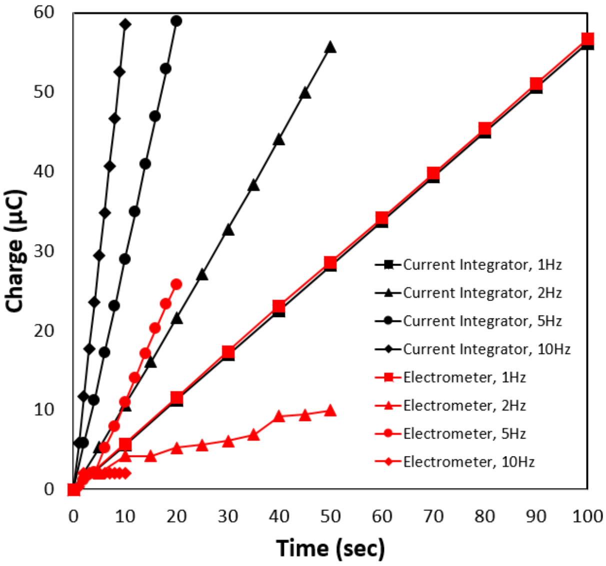

Fig. 3. Linearity of charge accumulation using current integrator and electrometer under 1Hz, 2Hz, 5Hz, and 10Hz

Table 3. Accumulated charge (μC) from current integrator and electrometer under 1Hz, 2Hz, 5Hz, and 10Hz.

	1Hz	2Hz	5Hz	10Hz
Current integrator	56.14	55.79	55.88	58.55
Electrometer	56.69	9.98	25.78	2.08

2.4 Pulse to Pulse Charge Measurement

Fig. 4 shows a timing between the TTL signal from beam extraction and charge collection from faraday cup on oscilloscope. The TTL signals sent to input of counter enable it to reset and restarts at the same time. The counter counts digitized pulsed from current integrator and makes output of charge per pulse data continuously every time the pulsed beam enters. The acquired charge per pulse data from measurement system applied this method is shown in Fig. 5 where average charge per pulse is 0.67 μC/pulse which can be converted to beam current.

Fig. 4. A timing between the TTL signal from beam extraction (blue) and charge collection from faraday cup (red) on oscilloscope

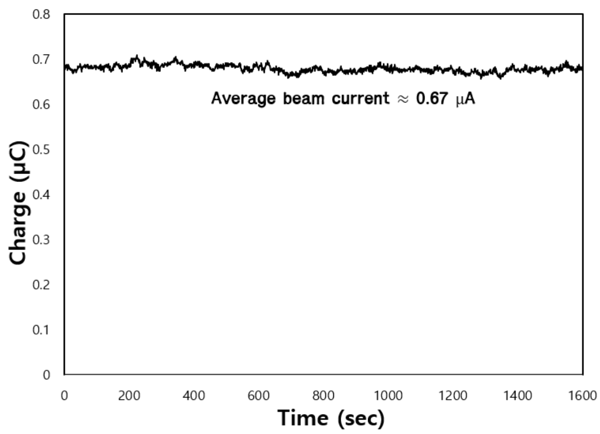

Fig. 5. The acquired charge per pulse data for 1600 sec under beam repetition rate of 1Hz.

3. Conclusions

The pulsed beam current measurement system including current integrator, counter, pulse delay generator and timing system is installed. The pulsed beam current measurement test with new established system is conducted. The results show consistent accumulated charge for the same pulse number under changes of beam repetition rate compared to electrometer. Also, the charge per pulse data can be acquired using external trigger to measure average beam current. It is expected to be introduced in pulsed beam current measurement and contribute to the improvement of beam quality assurance.

REFERENCES

[1] Advanced Measurement Technology, Inc. Model 439 Digital Current Integrator Operating Manual, 2008.

[2] A. Schuller, J. Illemann, F. Renner, C. makowski and R.-P. Kapsch, Traceable Charge Measurement of the Pulses of a 27 MeV Electron Beam from a Linear Accelerator, Journal of Instrumentation, Volume 12, March 2017.

[3] Advanced Measurement Technology, Inc. EASY-NIM 928 Suite High performance, Multi-function Nuclear Multichannel Buffer/Counter/Timer/Rate Meter Hardware Manual, 2014.