Particle Accelerator: Nigeria Experience at the CERD Laboratory

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Introduction

The Particle Accelerator Facility at the Centre for Energy Research and Development (CERD), Obafemi Awolowo University, Ile-Ife, Nigeria, was commissioned on 28 September 2008, for Ion Beam experiments with one beam line. The facility was acquired through the support of the Federal Government of Nigeria and the International Atomic Energy Agency Technical Cooperation (IAEA TC) Project NIR 1010. The machine Model is NEC 5SDH 1.7MV Pelletron Accelerator manufactured by National Electrostatics Corporation (NEC), Middleton, WI, USA. In 2016 we upgraded the facility with the addition of a second beam line equipped with NEC RC43 end-station.
Brief overview of facility

The CERD Ion Beam Analysis (IBA) facility is centered on a NEC 5SDH 1.7 MV Pelletron Accelerator, equipped with a RF charge exchange ion source. The ion source is equipped to provide proton and helium beams.

The accelerator has provision for five beam lines but we are presently maintaining two beam lines, one equipped with a general purpose End Station for four different types of techniques, namely, Particle Induced X-ray Emission (PIXE), Rutherford Backscattering (RBS), Elastic Recoil Detection Analysis (ERDA), and Particle Induced Gamma-ray Emission (PIGE); and the other equipped with NEC RC 43 End station also equipped with the 4 techniques, and much more grazing can be carried out on thin samples for material studies.
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Range</th>
</tr>
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<tbody>
<tr>
<td>Terminal voltage</td>
<td>0.3 – 1.7 MV</td>
</tr>
<tr>
<td>Proton (H⁺) beam energy</td>
<td>0.6 – 3.4 MeV</td>
</tr>
<tr>
<td>⁴He⁺ beam energy</td>
<td>0.6 – 3.4 MeV</td>
</tr>
<tr>
<td>⁴He²⁺ beam energy</td>
<td>0.9 – 5.1 MeV</td>
</tr>
<tr>
<td>Proton beam current</td>
<td>100 – 200 nA</td>
</tr>
<tr>
<td>⁴He⁺ beam current</td>
<td>200 – 500 nA</td>
</tr>
<tr>
<td>⁴He²⁺ beam current</td>
<td>200 – 500 nA</td>
</tr>
<tr>
<td>Beam spot size</td>
<td>Variable ~ 1 mm, 2 mm, 4 mm and 8 mm</td>
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Areas of Application

Our fields of application are wide and diverse, cutting across many disciplines. These include:

• Mineralogy and geological samples analysis,
• Agriculture—analysis of soil and plants (leaves, fruits and seeds)
• Biomedical/Biological samples analysis,
• Environmental pollution studies and Air quality monitoring,
• Materials Science and Thin films studies
• Archaeological and Cultural heritage studies
Operation and Maintenance

• Since its commissioning, we have ran more than 6,500 samples, doing more than 3,200 hours of accelerator time.

• Presently we have a team of two Research scientists and two technologists that are involved in the day to day operation of the machine and another technologist that handles all electronic issues with the machine.

• Running the 1.7 MV accelerator in the last 13 years has not been without challenges. We have gone through a number of them but with each challenge, we came back stronger and having more ownership of the machine. As NEC stated in “Instruction Manual No. 2AT051510 for the Operation and Service of 5SDH PELLETRON ACCELERATOR,” the 5SDH has been designed to be a reliable, low-maintenance machine. There is no schedule for periodic tank opening and servicing. The philosophy is: “If it isn’t broken then don’t try to fix it.” This has been our experience.

• Each time we have had an issue, we do the trouble shooting and try to resolve the problem. We always contacted the NEC Support Team to report problems and seek their support. The NEC Support Team always responded promptly, guiding us to solve the problems.
Challenges

- **Our major challenge has to do with power supply.** Power surges damage some sensitive electronic components. We had a particularly bad one in 2011/2012 that took us almost 20 months to overcome. We did overcome and are still running strong.

- Another area of challenge is **the lack of fast internet services.** With a fast internet service, the manufacturers of the accelerator, (NEC), can link up with our machine if we give them access. They can operate the machine from their base in the USA, be able to observe the difficulties we have and advise on solution but we do not enjoy this service because of poor internet network.

- Another challenge I would like to mention is **the problem of getting spare parts.** The accelerator is a specialized machine. Most of its parts can only be obtained from the manufacturer and the procurement of these spare parts/consumables is not easy at all for us in Nigeria of today.

- **Linked to spare parts challenges is the funding challenges** which can be very frustrating.
Keys to successful operation and Maintenance of Particle Accelerator.

• There are some keys to note for a successful Operation and Maintenance of the accelerator:

• Every operator of the machine must take time to carefully read and understand the Instructional Manuals supplied by the manufacturer. For our accelerator, every operator must be very familiar with these three:
  • Instruction Manual No. 2JT002110 for RF CHARGE EXCHANGE ION SOURCE.
  • Instruction Manual No. 2AT051510 for 5SDH PELLETRON ACCELERATOR.
  • AccelNET Control System User Manual No. 2RT025400.

• The first, No. 2JT002110 is very important for the proper running and maintenance of the Ion source. The second, No. 2AT051510 is very important for the proper running and servicing of the 5SDH Pelletron Accelerator. While the third, No. 2RT025400 gives one an understanding of AccelNET, the software package for the control of electrostatic particle accelerator systems.

• Another important key is that every operator must strictly follow the manuals instructions in everything that must be done – No shortcuts!!

• The third important key is proper Documentation. The operators must keep good records (Daily logs) of the machine operation, - machine working parameters, any issues that came up each day, etc.
Examples of the technical challenges we have had:

In the next few slides we will be presenting some, (3) examples of the technical challenges we had and how we handled them and in so doing we can see the progress we have made over the years.
On Tuesday, February 09, 2010 while running the accelerator for a 2.5 MeV proton (PIXE) experiments, the accelerator suddenly stopped. We did not know why, no power shutdown. We did some trouble-shooting and were able to localize the problem to the Charging Chain. The Chain had stopped and will not come on when switched ON. We also observed that the MCP1 (Motor Circuit Protector 1) in the ACPC (AC POWER CENTER) cabinet goes to TRIP position. When we reset and tried to switch ON the Chain, the MCP1 tripped again.
(a) As we could not continue without expert assistance, we sent a report to NEC.

(b) NEC Team responded on February 10 asking us to do some tests, which we did and reported back to NEC team (we had about 10 email exchanges).

(c) We had to open the tank on February 16, 2010 and following NEC advice/suggestion we increased the Overload setting on MCP1, did the connection for running the Charging Chain in air and everything went well.

(d) We coupled back the machine and the problem was resolved.

(e) February 21, 2010, we reported back to NEC that the problem has been solved and that the Accelerator is up and running.
WE reported to NEC Support Team the following on

Tue, Feb 9, 2010 at 2:04 PM

Problem with our 1.7 MV Pelletron at CERD

(1) The accelerator suddenly stopped while in normal (2.5MeV proton) operation.

(2) We localized the problem to the charging chain. The chain will not come on when switch on.

(3) We also observed that the MCP1 in the ACPC cabinet goes to TRIP position. When we reset and try to switch on the chain, the MCP1 trips.

Please advise.

The response from NEC Support Team

Date: Tuesday, February 9, 2010
Subject: Chain Motor Control

• Thank you for your e-mail. Repeated tripping of the MPC (motor circuit protector) indicates that either the motor or another component in the circuit has a fault.

• To confirm, first disconnect the chain motor plug at the local junction box and test the motor control again. If it is OK (does not trip), then the problem is with the load or the associated wiring. With the power disconnected of course, check for a motor fault both phase to phase and phase to ground using an ohmmeter. Each motor winding has a few Ohms of resistance but should not be zero. There are also spark protection components in the tank head motor feedthru box. Check here also for a possible fault. Refer to feedthru 2BA059750 on the documentation CD for details.
This was the major problem we had that took about twenty (20) months to resolve. On Wednesday, February 16, 2011 we observed that the Turbo pumps at both L.E. and H.E. of the accelerator were $10^{-4}$ ($10^{-5}$) levels as against ~ $10^{-8}$ that we normally should have. Under these conditions we could not start the accelerator.

We requested for and received an International Atomic Energy Agency (IAEA) Expert Mission to assist us.

The Expert was able to confirm that our pumps were working well but ion gauges needed to be replaced. We ordered for and replaced the faulty ion gauges.

- The power surges knocked off:
  a) ion gauges for vacuum measurement.
  b) the control computer,
  c) the control system interface module,
After the Expert Mission, the CERD team, comprising Professors E. I. Obiajunwa, D. A. Pelemo, G. A. Osinkolu and Mr. Adegoke Borisade (Engr.) set out to work on the accelerator, in collaboration with NEC (through the exchange of information via the internet. We exchanged at least 30 emails).

• Summary of actions:

• We ordered and received replacement Ion gauges from NEC, for vacuum measurements. These were installed and we were able to resolve the vacuum problem.

• When attempts to repair the malfunctioning Control computer failed, we ordered and received a new Control computer from NEC. With the assistance of Mr. Aladesanmi of the OAU Computer Centre, we were able to configure the computer and upload the accelerator control software, AccelNET.

• With the Control computer now functioning, we were able to diagnose the failure of communication between the Control computer and the accelerator. We were finally able to localize the problem to the Control System Interface (CSI) module. The CERD team was able to identify the faulty components in the CSI module and effected the necessary repairs.

• Continuous pumping down of the accelerator 24/7 for three weeks was carried out to eliminate water vapor from the accelerator tubes and to regain the accelerator maximum voltage of 1.7 MV.

With the above steps taken the Accelerator was restored to normal functioning, at the level of the standards set at its delivery.
Zero readings for Charging Chain current, (CH TX-1), LE and HE column (COL TN-1, COL TX-1) charges respectively, when accelerator was powered and charging voltages applied. This was a problem we observed on March 18, 2019, after we have had one of those bad power surges that damaged the UPS that powered the Accelerator.

- We did some trouble shooting to locate the problem. When we were not making any progress, we sent an e-mail to NEC support Team, stating the problem and what we have done and asking for their assistance.
• Issues with our Accelerator: PC Motherboard not energized, UPS damaged by Mains power supply problem and zero readings on LE, HE and Charging chain Currents

We forwarded the following note to the NEC Support Team on Wed, May 8, 2019

• Previously (as we reported in January) IDC5 OPT022 for channel 0 CH TX1 PWR SR on PCs Motherboard 4(MB4) was not energized with +24V (Refer to 2 HA071370 of process control station, Nigeria High Energy – Assembly). It was tentatively resolved by disconnecting CH TX-1 PWR SR signal cable that failed to supply the +24V and the IDC5 OPT022 for channel 0 was now powered from the +24V obtained from channel 1 through 4.7k resistor and it solved the problem and CH TX – PWR SR can now be powered.

• We subsequently had mains power supply problem that damaged the UPS that powered the accelerator system. When the accelerator system was later powered, zero readings were obtained for charging chain current, (CH TX – 1 CR), LE and HE column currents.

• We did some troubleshooting to verify that the tank high voltage power supply is in a good condition and accepts commands from the console via CPS TX – 1 VC with correct feedback from CPS TX1 VR.
Using Keithley 263 calibrator/source we injected currents of few micro amps to Pins 1 and 6, Pins 4 and 9 of cable J 13 HE current feed THRU and obtained some readings for charging chain current (CHTX-1 CR), HE column current respectively. Similarly, using LE current feed – THRU cable J14, readings were obtained for LE column currents on the console. From these tests we are of the opinion that the voltage charging controller unit and the Process Control Station 2, PC-02 are working correctly to process the injected currents and that the accelerator tank is not supplying the necessary currents; charging chain current and other LE & HE column currents.

The accelerator tank was opened and we implemented the procedures for running the chain in the open air. We changed the Current Contact Drive Assembly 2DA037330 and verified it made a good contact with the side plate connected to HE current Feed THRU J13 (please ref to voltage charging controller Schematic 2HS066660. Also we changed the carbon brush assembly 3AB010101. Still zero readings are obtained on the console for charging chain current. The chain is verified to be running in the air and a high voltage probe showed that a high voltage preset from the console reaches the inductor.

Please advise.

Thanks and best regards.

Professor E. I. Obiajunwa,
The next day we received the following response from NEC Support Team:

- SUBJECT: Issues with our Accelerator
- DATE: May 8, 2019

You did a very thorough job of trouble shooting the problem, which made my job more difficult. What else should you check? Finally, I figured out your problem. Your chain motor is running backwards and your terminal is charging negative.

The GVM is not sensitive to polarity. It will read the same for positive and negative voltages, but the chain and column current reads will always read zero if the polarity is reversed. The chain should be going out on top from the ground end.

If you switch any two phases of an AC induction motor, the motor will run the reverse direction. When you had the UPS repaired/replaced, the phases were not hooked up in the original order. Simply reverse any two phases as they come into the ACPC. Be sure to turn off the building power going to the ACPC first.

I will send another email tomorrow with some troubleshooting help for the chain status read.

Regards,

NEC Support Team
SOLUTION

• We quickly followed the NEC Support Team suggestion

• noting that the CHAIN MOTOR was indeed running backward, and

• when we reversed the phases everything started working well.

• The problem was solved!!
• NEC Support Team was notified of the solution to the problem.
SERVICES PROVIDED ACROSS THE COUNTRY

We wish to state that this facility has been rendering services nation-wide to the Nigerian scientific community. Our records show that we have received samples from more than 32 Universities and Institutions from 20 states in Nigeria.

A good number of these are for post-graduate (Masters, Ph.Ds and Fellowship of West Africa College of Surgeons [FWACS]) projects/thesis.
SERVICES PROVIDED IN OAU.

In our own University, Obafemi Awolowo University (OAU) we have done more than 1,200 samples for (67) Students and Lecturers in (15) different Departments.

The staff of CERD using this facility have produced more than 12 MSc and 7 PhDs in various Departments of the University. Surely this facility has contributed significantly in the training and development of the nation’s scientific human resources.
THANK YOU AND THANK YOU