PLANNING AND IMPLEMENTATION OF A TC PROJECT FOR ACQUISITION OF A NEW RESEARCH REACTOR FOR MULTIPURPOSE APPLICATIONS IN NIGERIA

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ABSTRACT

The **NI**geria **R**esearch **R**eactor**-1** (NIRR-1) was commissioned in 2004. NIRR-1 has been safely operated and deployed for training and education with Neutron Activation Analysis (NAA) as the principal area of research and utilization. However, due to the limitations of NIRR-1, a new research reactor with higher flux for multi-purpose applications is being planned. It is well known that a new research reactor project is a major undertaking requiring careful planning, preparation and investment in time, financial, and human resources. Consequently, the Nigeria Atomic Energy Commission (NAEC) has initiated a new research reactor project with the IAEA. This paper discusses the important policy and technical issues regarding the project including lessons learned on NIRR-1, which will facilitate the acquisition a new high capacity research reactor for multipurpose applications in Nigeria

1.0 Introduction

In 1964, Nigeria became a member of the International Atomic Energy Agency (IAEA), thus opening up an avenue for obtaining technical assistance in the nuclear field and also signaling the country's interest in joining the race for the peaceful, safe and secure uses of nuclear energy. The country's interest in peaceful applications of nuclear energy was reiterated in 1976 with the establishment of NAEC as a specialized agency of government to promote its implementation. However, it did not take-off properly as expected. This necessitated its activation in 2006. Hitherto, pockets of individuals and institutions have been utilizing nuclear technology in their research activities. A significant milestone was recorded in 2004 when the first nuclear research reactor was commissioned at the Centre for Energy Research and Training (CERT) [1]. CERT is one of the university-based nuclear research Centres under the aegis of NAEC. Other research institutes/centres affiliated to universities have installed modest nuclear research facilities which include neutron generators, isotopic neutron sources, X-ray fluorescence set ups, a gamma irradiation facility, a linear accelerator facility and ancillary facilities for neutron and gamma ray spectrometry. The acquisition of NIRR-1 began in 1996 when the IAEA approved the supply of a Miniature Neutron Source Reactor (MNSR) to the Government of Nigeria under a Project Supply Agreement (PSA) between China, Nigeria and the IAEA. The equipment and components of the 30 kW tank-in-pool nuclear research reactor called Nigeria Research Reactor-1 (NIRR-1) were installed between January to April 1999. Due to unforeseen circumstances, the fuel was not available for the subsequent commissioning of the reactor. However, on February 3rd 2004, NIRR-1 went critical for the first time, thus the first nuclear research reactor in Nigeria became operational. NIRR-1 is currently in its 9th year of operation and has been fully deployed for training and research in different fields of endeavour aimed at socio-economic development of the country. A detailed safety measures used routinely in NIRR-1 facility has been discussed in several publications [2 – 7]. In the African region, there are ten operating research reactors covering a wide power range of 30 kW to 22 MW in eight countries [8]. The South African research reactor, the SAFAR-1 is one of the five main producers of the radioisotope, Mo-99 in the world. Therefore, the acquisition of a high flux research reactor on the continent, which can complement this endeavour will facilitate commercially viable radioisotope production globally. This presentation focusses on the important policy and technical issues regarding planning and implementation of a new research reactor project in Nigeria. Furthermore, the lessons learned from a similar project leading to the commissioning of NIRR-1, which will facilitate the acquisition a new high research reactor for multipurpose applications are discussed.

2.0 Nigeria Research Reactor-1 (NIRR-1)

NIRR-1 is a Miniature Neutron Source Reactor (MNSR) designed by China Institute of Atomic Energy (CIAE). First criticality was achieved on 03 February 2004 and has been operated safely. It is specifically designed for use in neutron activation analysis (NAA) and limited radioisotope production. NIRR-1 has a tank-in-pool structural configuration and a nominal thermal power rating of 31 kW corresponding to a maximum neutron flux of 1 x 10^{12} $n/cm^2.s$.The current core of the reactor is a 230 x 230 mm square cylinder and fueled by U-Al_4 enriched to 90% in Al-alloy cladding. There is only one Control Rod in NIRR-1 serving as shim rod, regulation rod as well as safety rod. With a built-in clean cold core excess reactivity of 3.77 mk measured during the on-site zero-power and criticality experiments, the reactor can operate for a maximum of 4.5 hours at full power as result of in-built large negative temperature feedback effects. As part of the HEU to LEU conversion feasibility study, an MCNP model of NIRR-1 fueled with HEU has been developed and displayed in Figure 1 [7]. NIRR-1 is suitable for three of the 11 areas of applications of Research Reactors listed below [2 -7]:

I. Education and Training
II. Neutron Activation Analysis
III. Prompt Gamma Neutron Activation Analysis
IV. Radioisotope Production
V. Geochronology
VI. Transmutation Effects
VII. Neutron Imaging
VIII. Material Structure Studies
IX. Positron Source
X. Neutron Capture Therapy
XI. Testing of Instruments and Control Components
XII. Neutron Scattering Experiments

The reactor has been heavily deployed for NAA and for education and training with respect to reactor physics design using computer codes. The limitation of NIRR-1 with respect to low flux, especially for radioisotope production in medical applications has informed the current desire to acquire a higher power/flux research reactor for multi-purpose applications in Nigeria

3.0 The new research reactor project

NAEC has conceptualized a new research reactor project with the main aim of providing multipurpose applications for socio-economic development in the country. The project, NIR201002 entitled "*DESIGN AND DEVELOPMENT OF RESEARCH REACT0R FOR MULTIPLE APPLICATIONS*" has been submitted to the IAEA for reconciliation and final approval. In conceptualizing the project, the guidelines specified in the IAEA Nuclear Energy Series No.NP-T-5.1 entitled "Specific Considerations and Milestones for a Research Reactor Project" were followed [9]. Details regarding the important policy issues, the size, type, power level, and uses of the research reactor have been provided. The stakeholder support needed for the research reactor has been identified and were part of the team that formulated the project. Considering the limitations identified with areas of applications of NIRR-1 and lessons learned, the new research reactor capable of providing services in other areas listed above is to be considered. By applying the graded approach, the following factors are being used in arriving at the final choice. These are but not limited to reactor power; source term, including fission product inventory, which depends on the reactor power and operating regime; fuel enrichment; reactor utilization; site examination/selection; and proximity of population groups. These issues are to be formally addressed in the research reactor preliminary safety analysis report (PSAR). In the area of education and training, especially with regards to reactor physics design using computer codes, the project will provide opportunity for domestication of knowledge through the involvement of identified stakeholders in scientific visits and training fellowships as well as on-site interactions during expert missions. It is well known that research reactor with power greater than 2 MW is capable of delivering all the areas of applications listed in Section 2, therefore considerations will be given to vendors with track records of performance with regards to research reactors utilization and safety in this category of power.

4.0 Conclusion

Research reactors have played and will continue to play an important role in the development of peaceful applications of nuclear energy in the world. In many countries, they are acquired not only as a national 'prestige' but also as the foundation for education and training towards a robust and sustainable nuclear power programme (NPP). Many different designs of research reactor exist and they have a very high power density in a small core. Only very few still operate with HEU including NIRR-1, and are currently undergoing conversion to LEU. There has been no significant safety issues in research reactor facilities worldwide and security issues are not as strict as in NPP's. In Nigeria, the experience of successful operation of NIRR-1 spanning a period of approximately ten years has provided the impetus to conceptualize a new research reactor project with high power/flux for multipurpose applications. It is envisaged that the new reactor will provide capabilities for medical radioisotope production and other areas of applications which NIRR-1 has not been able to provide. Specific attention will be devoted to human resources development throughout the implementation of the project with aim of domesticating the technology with respect to design and construction.

5.0 References

[1] SAR, 2005, Final Safety Analysis Report of Nigeria Research Reactor-1. CERT Technical Report-CERT/NIRR-1/FSAR-01

[2] S.A. Jonah, G.I. Balogun, I.M. Umar, M.C. Mayaki, "Neutron spectrum parameters in irradiation channels of the Nigeria Research Reactor-1 (NIRR-1) for the *k0*-NAA standardization" *J. Radioanal. Nucl. Chem.*266, (2005), 83-88

[3] S.A. Jonah, I.M. Umar, G.I. Balogun, M.OA. Oladipo, D.J. Adeyemo "Standardization of NIRR-1 Irradiation and Counting Facilities for Instrumental Neutron Activation Analysis" Appld Rad. & Isotopes, 64, (2006), 818-822

[4] S.A. Jonah, G.I. Balogun, A.I. Obi, Y.A. Ahmed, B. Nkom, A.A. Mati, I. Yusuf "Operational experience and programmes for optimal utilization of the Nigeria Research Reactor-1" In Proceedings of International Conference on Research Reactors: Safe Management and Effective Utilization, 5 -9 November 2007, Sydney, Australia, IAEA-CN-156, IAEA, Vienna, Austria

[5] S.A. Jonah**,** V.Y. Ibrahim, E.H.K. Akaho "The determination of reactor neutron spectrum averaged cross-sections in miniature neutron source reactor facility" Appld Rad. & Isotopes 66, (2008), 1377 – 1380

[6] C.E. Mokobia, F.O. Ogundare, E.P. Inyang, F.A. Balogun**,** S.A. Jonah "Determination of the elemental constituents of a natural dolerite using NIRR-1" Appld Rad. & Isotopes 66, 12 (2008), 1916 – 1919

[7] S.A Jonah, J.R. Liaw, J.E. Matos, "Monte Carlo simulation of core physics parameters of the Nigeria Research Reactor-1(NIRR-1)" Annals of Nuclear Energy 34 (2007), 953-957

[8] IAEA Pamphlet on Research Reactors in Africa, (2011), IAEA, Vienna, Austria

[9] IAEA Nuclear Energy Series No.NP-T-5.1 "Specific Considerations and Milestones for a Research Reactor Project" IAEA, Vienna, Austria, 2012

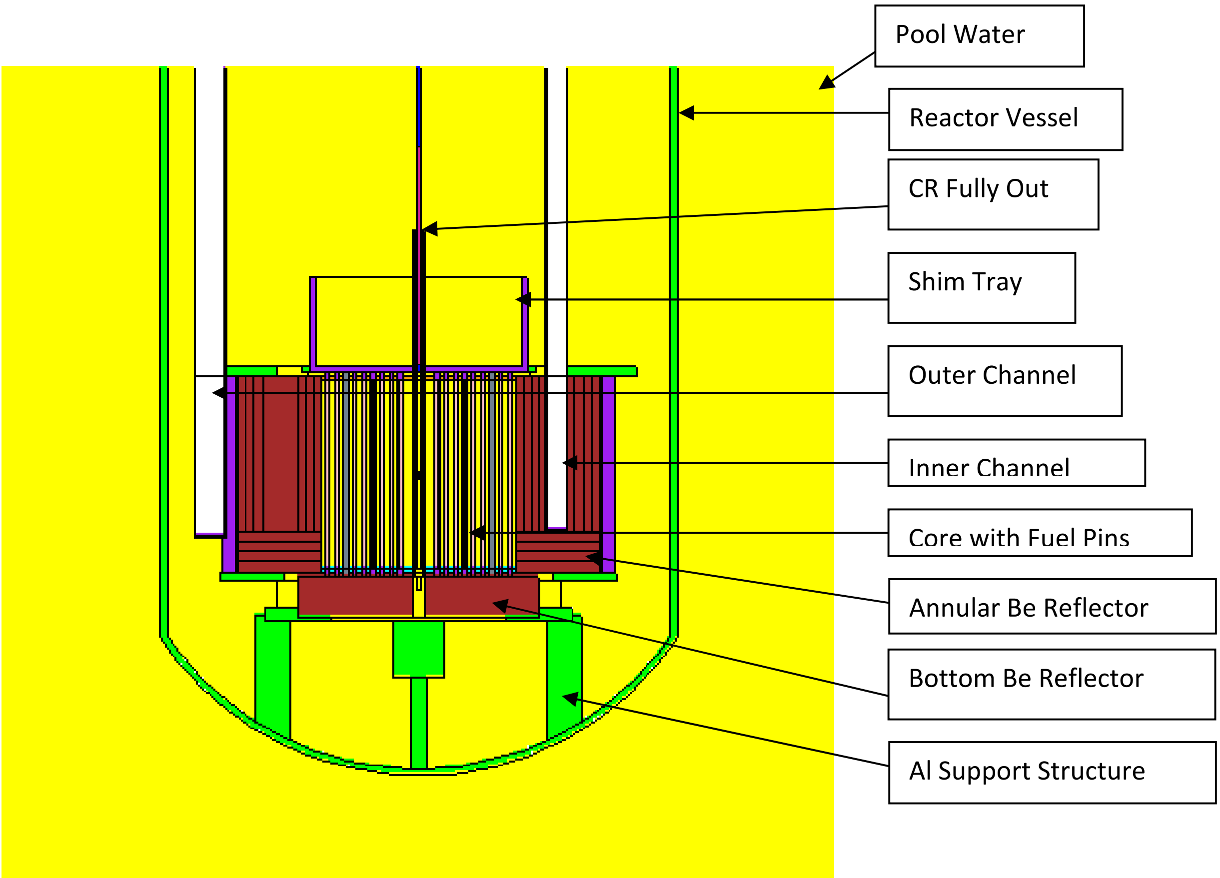

Fig. 1 An MCNP geometric representation of NIRR-1 with CR totally withdrawn