EXPERIMENTAL SET-UP FOR MULTIPLICATION COEFFICIENT FLUCTUATION STUDY vs. ACCELERATOR PARAMETER DEVIATIONS on the JINR PULSED ACCELERATOR DRIVEN NEUTRON SOURCE *

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Abstract

The conception of an electron beam-driven subcritical molten salt safety reactor (MSR) was presented at the International Conference on Accelerator-Driven Transmutation Technologies and Application (ADTT) [1]. The essence of the concept is the use of the MSR cascade system to reduce the driving power. The cascade reactor could allow diminishing of the beam power down to a value where the electron accelerator could be used. The question is how much the neutron multiplication coefficient may be used in the ultimate safety reactor design. The Joint Institute for Nuclear Research (Dubna) has a facility, which could be named as a prototype of the future accelerator driven subcritical reactor. It is the IBR-30 pulse reactor driven by the S-band electron linac (LUE-40). Here the neutron multiplication coefficient of ≈ 200 (the same as the value of subcriticality $k_{eff} = 0.995$) from the coupled facilities allows an integral yield of 0.5×10^{15} neutrons per second at a pulse width of 4 microseconds. These facilities form the JINR experimental set-up for the study on multiplication coefficient fluctuations vs. deviation of accelerator driven parameters, as well as for the steady state and transient regimes. The experimental set-up for these studies and the first results will be presented.

I. INTRODUCTION

The Accelerator-Driven Energy Production is a modern conception of the next generation of nuclear safety power plant development. The main idea of this conception is the development of a type of reactor that does not produce nuclear wastes. For complete freedom from a nuclear accident, the reactor should work in the deep subcritical regime. It is for this reason that an external neutron source is needed. The subcriticality value k_{eff} is a function of reactor design and thus determines the power required from the neutron source.

It is clear that the beam power will increase when the requirements of safety dictate. The problem of beam power reduction is a major problem in the Accelerator-Driven Energy Production for nuclear safety power plant development. As a possible solution this problem the cascade reactor conception was presented at the conference on ADTT [1] . The essence of the conception is an use of the MSR cascade system which can allow diminishing of k_{eff} at every cascade step. For the first time it was shown that the present proton accelerators, like the PSI [2] cyclotron or Los Alamos linac [3] , could be used for the pilot experiments. But

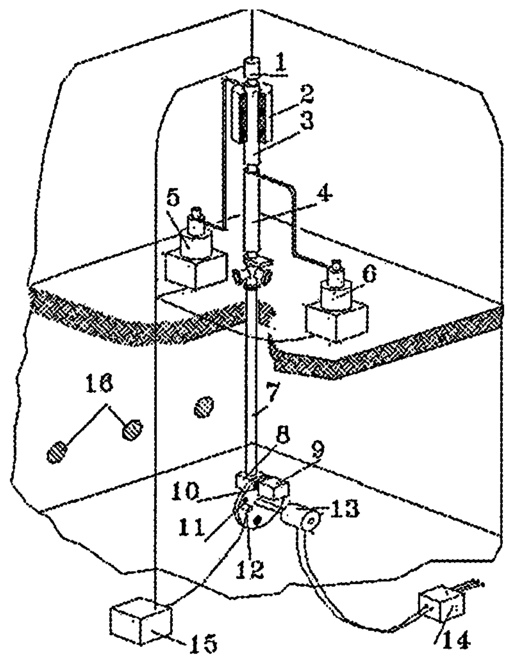

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Figure 1. Layout of the linac-driven subcritical neutron pulse source: 1 - electron gun; 2 - solenoid; 3, 4 - traveling wave sections; 5, 6 - klystrons; 7 - beam line; 8 - $e - \gamma - n$ converter and 1st half of plutonium core; 9 - 2nd half of fuel elements; 10 - wheel with two fuel shells; 11 - permanent magnet; 12 - coil; 13 - motor; 14 - motor power supply; 15 - trigger system and 16 - neutron beam channels.

lifetime linac problems, beam loss problems, total efficiency and reliability, and other practical things urged to do the next step. The cascade MSR, as example, could allow diminishing of the beam power down to such value where the electron accelerator system could be used.

On the other hand the total multiplication coefficient should be a large enough to reduce the beam power also. In this case the accelerator-driven reactor should have have a minimal power fluctuation in the subcritical assembly during all times of operation. Next would like to discuss which factors could be influenced by the subcriticality coefficient fluctuation.

II. LAYOUT OF THE FACILITY

A schematic layout of the JINR facility is shown in fig. 1.

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Electron linac is situated in a vertical plane and consists of two S-band sections (3, 4) which are fed by two Russian KIU-12 klystrons (5, 6). After acceleration in the traveling wave section, the electron beam passes downstairs through the transport line (7) downstairs in the hard concrete box. Here the multiplying target system is located. Neutron beam lines (16) are placed outside the concrete box in a horizontal plane encircling 180^o degrees to the side of the electron beam line.

The target system consist of two parts. The first one is an $e - \gamma - n$ converter. The second one is a splitting into two separate volumes containing subcritical plutonium fuel elements (8, 9). There is rotating a wheel (10) with two fuel element shells. This wheel has a special electrical drive (13). There is a permanent magnet shell (11) on the wheel and a stator coil (12). These elements (11, 12) form a trigger (15) for accelerator pulse systems.

Typical values for the repetition rate are 100 Hz and 50 Hz.

III. PRELIMINARY STUDY RESULTS

IBR-30 is a pulsed subcritical facility. Here the multiplication coefficient can be periodically changed from low level ≈ 16 up to a nominal value ≈ 200. Therefore, there could be a possibility to study the real fluctuations of k_{eff} for different levels of multiplication coefficients. On the other hand, it should be taken into account that IBR-30 contains a wheel with a shell of fuel mass. This system can give a contribution to the neutron fluctuation as well. What could be the sources of neutron fluctuation? Because of the pulse source, there could be two kinds of fluctuation. The first one is short range fluctuations (SRF). Time interval of SRF is several times the pulse duration. The second is long rage fluctuations (LRF). The time scale of LRF is several times the repetition rate.

Neutron detector (fission chamber) records a signal which has a small periodical deviation during the all time the facility is being run. A typical value of the fluctuation in a nominal regime is about 4-6% and it is shown in fig. 2. This value is much more (up to 12%) for the transient regime.

The new diagnostic elements were installed in the control room in order to determine what the reason was for such periodical deviations. The general linac signals were collected for on-line pulse to pulse analysis. A linac mathematical model was made up to study the processes more correctly.

A. Linac Related RF Properties and Transient Beam Loading Problem of LUE-40

The average energy sag per one mA is $\approx 43 keV/mA$. The first section has a buncher part 54 cm long and constant impedance structure as the regular part 400 cm long. The length of the second section is 314 cm. The filling time for both sections is $\approx 650 ns$. In fig. 3 the output energy of the two sections and a summary RF-efficiency vs. beam current are shown. This is the steady state regime. Any transient regime shall take that into account.

The typical range of the beam current is 0.3-0.5 A. The time duration of the beam current is $\approx 1.8 \mu s$ (i.e., $t_f \approx 1/3$ of t_{beam} and t_f is the filling rf - power).

In fig. 4 the experimental transient beam loading of the first rf-section is shown in arbitrary units. In practice the beam injection

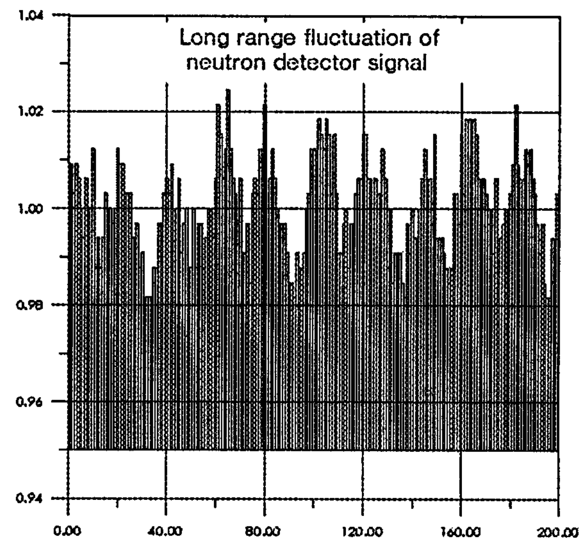

Figure 2. Long range neutron fluctuation vs repetition rate cycles.

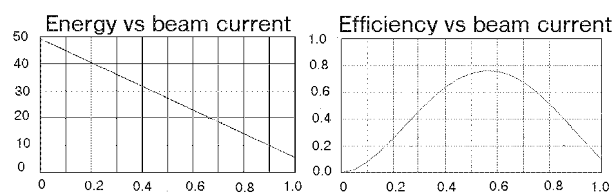

Figure 3. Output LUE-40 energy and rf-efficiency vs beam current.

starts before the end of the filling time in order to reduce the energy sag. The deviation of the output rf-signal during the pulse is $\approx 20 - 30\%$. The computer simulation of the rf-power sag for a beam injection at $t = t_f$ is shown in fig. 4 (3). To set the main parameters of the linac, the experimental results of relative power sag and filling time were used.

There are a several fluctuation sources. IBR-30 contains a mechanical system which consists of a DC power electromotor with a wheel. The motor generator feeds from an AC network. The rotational speed of the wheel can changed by the operator and tuned to be close to 100 Hz. On the other hand all power supplies of the linac systems feed from the 50 Hz AC network. The first fluctuation source is the beat frequency between the rotational speed of the wheel and network frequency. This is a long range fluctuation.

In our studies there was a possibility of simultaneously picking up several signals according to the phase of the network frequency (rf-system, beam current, amplitude of neutron detector signal etc.). Fluctuations of the neutron detector signal correlates with the phase of the AC network power is shown in fig. 5. Approximately $9,000$ events are shown in this plot and there is only a $\pm 4\%$ fluctuation of the neutron signal. This picture shows that 2% do not correlate with the phase of the network.

Above data were received when IBR-30 was running with 50

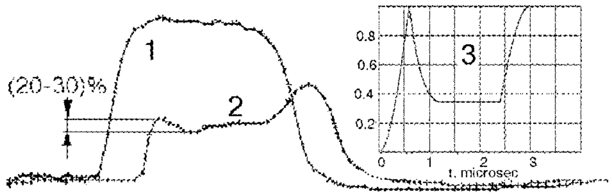

Figure 4. Transient beam loading in first section: 1 - P_{in} input rf-power; 2 - P_{out} output rf-power; 3 - computer simulation of the power sag for a beam injection at $t = t_f$.

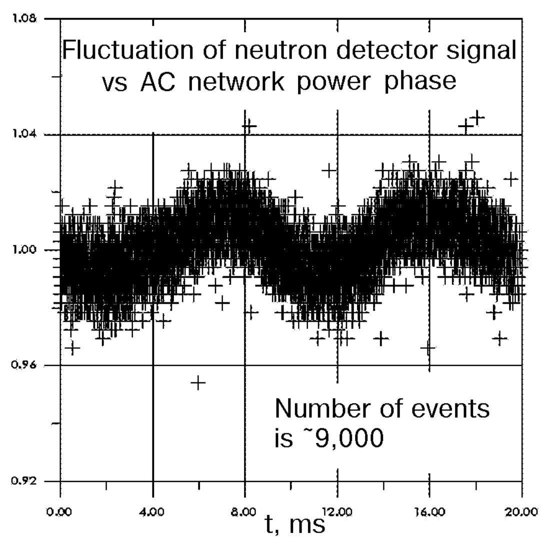

Figure 5. Fluctuation of neutron amplitude signal vs phase of network power.

Hz repetition rates. There was only short time to record a runaway (to get a nominal regime) regime of IBR-30 with 100 Hz repetition rate. It can be seen in fig. 6 when the velocity of wheel was equal the AC frequency of the network power and there was a period when phases almost did not change (region). In this regime the LRF of beam power and neutron signal were less than 1%.

IV. CONCLUSION

The first preliminary results for multiplication coefficient fluctuation study vs. accelerator parameter deviation on the JINR accelerator driven neutron source were carried out.

The experimental fluctuation of thermoneutron detector signal was correlated with the fluctuation of the beam power. The major source of the neutron signal fluctuation is the absence of the equiphase conditions the wheel rotation velocity and the network frequency.

The study should be continued with the signal of the fast neutron detector. The on-line experiments should be done in stable phase regime.

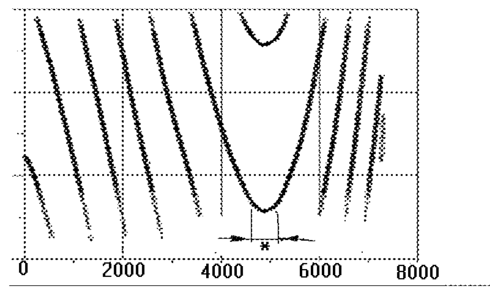

Figure 6. AC phase of network power supply vs number of cycles of IBR-30.

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