SAFE ATOMIC ENERGETICAL INSTALLATION WITH ION LINAC

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Abstract

The is discussed possibility of creation of transported 300 MW atomic energetical installation with under-critical reactor controlled by ion rf linac. Chain reaction is initiated by outer neutron source. Neutrons may be obtained from different targets which are irradiated by intensive beam of accelerated protons. Theoretical and experimental information about proposed accelerator scheme and different blocks are given.

1 INTRODUCTION

At present time the main problem of atomic energetics is safety of atomic energetical stationary and transported installation. Most destroying accidents are results of uncontrolled chain reactions. It take place if reactiveness of critical reactor is increased because some reasons and reactor is drivenaway by instantaneous neutrons. There are two ways to prove safety. Traditional way is multiple duplication of reactor's control and guard systems. It allows to lower a risk of wreck but not to exclude one. Second way is technical solution which permit to exclude the driving away of reactor by instantaneus neutrons. This way is based on using of uranium fission in under-critical reactor where chain reaction is initiated by outer neutron source of nigh intensity. Accelerator of charged particles may be used as such source. Intensive neutron flows may be obtained by irradiation of different targets with the beam of accelerated particles. Their energy is tens or hundreds MeV. Weights and sizes of such accelerators and energetical expenditure for their work give possibility to realize second principle already by this time.

2 REQUIREMENTS TO THE BEAM PARAMETERS

At the last time proposals to use accelerated as driver of under-critical reactor are discussed by many scientists. As rule there are considered schemes with big accelerators [1]. Their output beam power may be several megawatts or several tens of megawatts. Such powers are need for driving of reactors with thermal power in a few gigawatts. But there are proposals to lower the beam power. At the paper [2] is proposed to use booster in the center of a big reactor. Both of reactors are under-critical. The first one is under-critical because of small sizes and neutron surface leakage and the second one became its coefficient of multiply $k>1$. Using of booster allows to lower beam power to 5 MW for thermal power of station 2 . In these works cyclotrons are to use as drivers. Output energy of these accelerators is supposed from 0.4 to 1 GeV. Aspiration for big accelerator drivers is explained by wish to obtain sufficient energetical gain (30 and higher). For transported atomic installations main factor is safety. Their power way be several hundreds of megawatts. Therefore it may appears profitable that such energetical installations will be controlled by compact rf linac with about 500 kW power. In comparison cyclotron rf linac has few advantages:

- linac permit to obtain greater average current;
- linac beam quality is better;
- problem of the beam extraction is absent;
- radiative conditions are better.

Comparison of electron, proton and deuteron beams as producers of neutrons for different targets was made in the paper [3]. For produce the same quantity of neutrons power of the electron beam must be much more (approximately on order) then power of ion beams. On other efficiency of electron beam for energies more then 50 MeV just a little higher then proton beam one. Fabrication and exploitation of deuteron linac will be more expensive then proton linac. Therefore our choice is proton rf linac as driver. Let consider scheme of proton linac as energetical amplifier for reactor that works on high-enriched uranium 235. With energy's growth number of neutrons produced only accelerated particle on the total absorption's target are increased and trade-off final energy of accelerated particles against average beam current is determined by allowable accelerator's clearance and accelerating structure's acceptance which permits to pass required current without lost. For transported atomic station with thermal power 300MW maximal particle's energy 80-100 MeV will be good practice. Coefficients of deuteron-neutron and proton-neutron conversion for 100 MeV energy are 1.02 n/d 0.92 n/p accordingly. (It is mean uranium target). Total density of neutron flow which proves normal working of reactor must be about 10^{14} neutrons/sec sm^2. Average linac current 3-5 mA is according to this flow density.

3 KEY SYSTEMS OF ACCELERATOR AND WORKING MODE

Accelerator-driver must be compact enough to work with reactor inside the compartment of limited sizes. Therefore our choice of working frequency is 433

MHz. This choice proves relatively small sizes of accelerator if to use H-cavities which are working on H(TE) oscillation type. RFD is used as first stage of accelerator which is accelerating particles up to 2 me and permit to capture about 100% ions into acceleration. It is proposed to accelerate ions from 2 up to 50...100 MeV in drift-tube resonators but not Alvarez type. Instead of Alvarez here is proposed structure with crossed transversal holders (CTH) [4]. First of CTH-cavities accelerates ions from 2 up to 10 MeV and there is used alternating phase focusing (APF). Modification of CTH-structure which has focusing magnetic lenses inside some of drift tubes is used for acceleration from 10 up to 50...100 MeV. Pulsed mode must be used instead of CW-mode because scattered power inside cavity's walls will be too big to prove reliable thermal regime for CW-mode. If duty circle is 0.1 wall scattered power density will be 2 W/cm^2 and required cooling one may proves. Thus main parameters of accelerator are:

particles	protons
energy	80...100 MeV
pulse current	30...50 mA
average current	3...5 mA

It is expediently to build up RF system multisectioned accelerator as separate amplificating lines. Dividing of RF power is made on low level. As output amplifier of line may be used klystron or endotron type devices. There are endotron type "Kiwi" of output pulsed power 450 kW [4] and preamplifier of output power 2 kW at the Efremov Institute. Working frequency's diapason of endotron is (433 ±5) MHz. Using "Kiwi" construction as base it is possible to achieve following parameters of amplifier:

output pulse power	350-400 kW
average power	40 kW
pulse length	600 μsec
diapason of working frequencies	15 MHz

These parameters may be obtained by "Kiwi" modernization. Each of resonators is feeding by two of endotrons. Scheme of key blocks of accelerator-driver supposed dividing of the beam into seven ones before injection to reactor is given on fig.1.

4 RELIABILITY AND SOLIDITY OF CONSTRUCTION

It is possible to design and fabricate separate accelerator blocks of high reliability under transportation and exploitation. The Efremov Institute has experience of such designing and manufacturing. Such possibility is confirmed by American experiment in space [5].

5 PRELIMINARY RESEARCHES AND CONCLUSION

So long as technical solutions and their realization's possibilities depend on power of atomic station and purpose its using principal possibility to create driving accelerator for transported installation of thermal power 200-300 MW there is considered with regard limited weight, gabarites and special conditions of exploitation. The working out and creation of a new type safe reactor require 10-15 years, therefore it is interested to consider principal possibility to combine working at present transported atomic station with proton linac as demonstrative installation. In this connection transported station with reactor KH-3 of thermal power 300MW was considered. This station has following characteristics:

thermal power	...	300 MW
water pressure of primary coolant	...	15 MPa
temperature of primary coolant on the reactor input	...	280°C
the same on the output	...	320°C
productivity	...	500 T/hour
life time (for full power)	...	7500 hours
minimal under-critical depth	...	2%
maximal under-critical depth		
under samarium and cobalt poisoning	...	10%

Under these conditions required average current of accelerator-driver must be about 5 mA if proton energy is 100 MeV. These results show possibility to create safe atomic energetical installation with under-critical reactor and rf ion linac-driver. Wreks determined by noncontrolled chain reaction are excluded.

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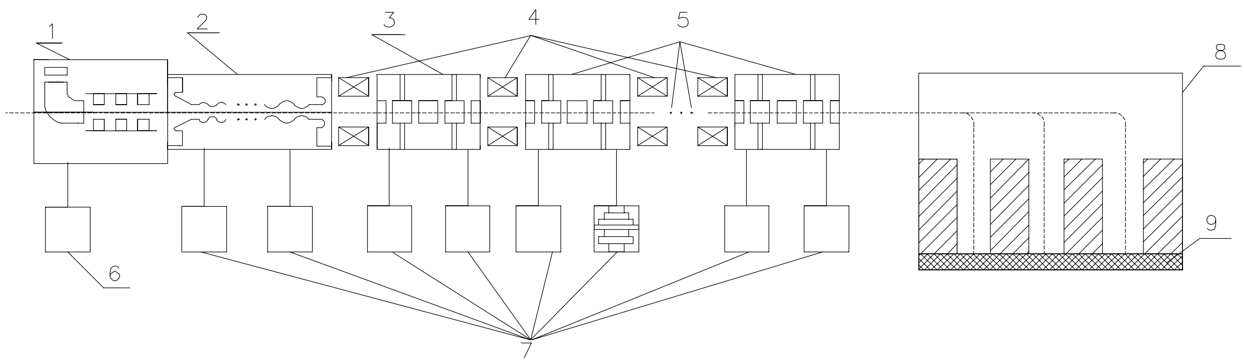

Fig 1. Key blocks of accelerator-driver:
1 - injection system; 2 - RFQ; 3 - cavity of APF; 4 - magnetic lenses; 5 - 10 cavities with drift-tubes; 6 - injector's feeding system; 7 - RF system; 8 - output pulsed magnetic system; 9 - targets.