Calculations have shown that in the presence of power shedding the reactivity depends strongly on the moment of shedding relative to the start of the reactor cycle, the stopping time of the reactor after power shedding, and the number of sheddings. It is shown that reactivity effects due to power shedding continue to act for 2 days after shedding, after which these effects can be neglected. The total change of the reactivity after power shedding can range from 0.12 to \(-0.05\%\Delta k/k\). A region of negative reactivity forms in most practical cases after power shedding. The depth of this region can reach \(-0.05\%\Delta k/k\), and the duration varies from several hours to several tens of hours. Knowledge of the reactivity after power shedding makes it possible to determine more accurately the consequences of different emergency situations and to predict the critical state of the reactor when the reactor is once again brought up to power.

It has been noted in the course of investigations of IBR-2 that power shedding during operation has a large effect on the character of the return to operational power. For comparison with, for example, power reactors the effect of power shedding on IBR-2 operation is not so critical, though the number of sheddings itself is limited, since it limits the service time of the reactor. We note that over the entire time of IBR-2 operation from 1984 to 2006 the average number of power sheddings over an individual reaction cycle (~250 h continuous operation at power followed by a two-week interruption) was 2.27.

A sharp power change, especially shedding, during which the neutron power decreases to almost zero in less than 1 sec, engenders a complex reactivity effect due to the feedback on power. The reactivity after power shedding in IBR-2 varies in a way so that when the reactor is restarted the state of criticality can differ from pre-shedding state.

Understanding IBR-2 dynamics in the presence of power shedding is important from the standpoint of nuclear safety and operation. In the first case it permits determining more accurately the consequence of different emergency situations and in the second case to predict the critical state when the reactor is brought back up to power.

**Modeling the Reactivity with Power Shedding.** It is known that the dynamics of feedback on power in IBR-2 is determined by three links: almost non-inertial with time constant 0.2–10 sec, reflecting the character of the feedback; inertial with positive and negative feedback with time constant 2.5 and 92 h, respectively [1]. The fast feedback is due to the thermomechanical and hydrodynamic processes occurring inside the core. Slow coupling is due to a change of the state of the structural elements from the immediate environment of the core with the power, for example, heating of stationary reflectors, thermal, and biological protection. The IBR-2 operating cycle consists of a repeating two-week period of operation at power followed by a two-week interruption.

The inertial nature of feedback on power can be neglected, since its time constants are much smaller than the time interval being analyzed. Each of the slow links (second and third) has two time constants – buildup and diminishment. The reactivity after power shedding was studied using the experimental data on the parameters of the feedback on power, which correspond to the IBR-2 operating period from 1987 to 2000 and are presented in Table 1 [2]. The average power level was assumed to be the nominal value 1.5 MW, and the time required to reach the nominal power level at startup corresponded to 2 h with the regular linear power increase.
The fact that the transfer constant of the most rapid link of feedback on power as compared with the slow links (second and third) depends on the energy production was taken into account in the calculations [2, 3]. A detailed description of the particulars of IBR-2 dynamics is presented in [4].

In the present case, it is sufficient to use an analytical expression to evaluate the reactivity of feedback. In the model of the dynamics of feedback on power, each $i$th inertial link is expressed as a differential equation

$$T_i \frac{d\rho_i(t)}{dt} + \rho_i(t) = k_i P(t),$$

where $T$ is a time constant; $i$ is the link number; $\rho$ is the reactivity (output signal); $k$ is the transfer constant; and, $P$ is the power (input signal). Two values are used for the time constant: $T_{b_i}, T_{d_i}$ for power buildup and diminishment, respectively.

The total power effect is a result of summing the output signals of each link. For this reason, the analytical solutions of the differential equation (1) can be examined for the following three characteristic cases:

- with linear power increase

$$\rho_i(t) = (\rho_{0i} + k_i P_0 T_{b_i} / \tau) \exp\left(-\frac{t-t_0}{T_{b_i}}\right) - \frac{k_i P_0 [T_{b_i} - (t-t_0)]}{\tau}, \quad t > t_0;$$

- with constant power

$$\rho_i = \rho_{0i} \exp\left(-\frac{t-t_0}{T_{b_i}}\right) + k_i P_0 \left[1 - \exp\left(-\frac{t-t_0}{T_{b_i}}\right)\right];$$

- with power shedding

$$\rho_i(t) = \rho_{0i} \exp\left(-\frac{t-t_0}{T_{b_i}}\right), \quad t > t_0,$$

where $\rho_0$ is the $i$th component of the reactivity at time $t_0$, $P_0$ is the nominal power, $t_0$ is the time of the event (onset of buildup, time at which constant power is reached or power is shed); $\tau$ is the time required to increase the power from 0 to the nominal level.

In the general case, each reactor cycle consists of a series of alternating power-buildup events, operation at power, shedding (once or several times), and lower the power. The $i$th component of the change of the power effect of the reactivity for a cycle with an arbitrary number of sheddings can be determined using expressions (2)–(4). The overall power effect can be calculated from the relation

$$\rho = \sum_{i=1}^{3} \rho_i(t).$$

### TABLE 1. Parameters of the Dynamic Model of IBR-2

| Link No. | Transfer constant $k$, %/MW | Time constant, h
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<thead>
<tr>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td></td>
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<tr>
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</tr>
<tr>
<td>2</td>
<td>0.119</td>
<td>2.54</td>
</tr>
<tr>
<td>3</td>
<td>-0.0657</td>
<td>92</td>
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