Improvement of the regulation system for the electric drive of rolls rotation in the rolling mill

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Improvement of the regulation system for the electric drive of rolls rotation in the rolling mill

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Abstract. An improved dual-zone speed control system for the electric rotation of the rolls of a metallurgical plant using a dynamic current sensor has been developed. For example, the rolling engine of the mill "900" of the beam workshop was used. The use of an improved system will increase the productivity of the rolling mill.

1. Introduction

Present day in rolling production of metallurgical plants, widespread use has been found for automatic electric drives for rotating rolls (main drives) using the Controllable AC-DC converters using tyristors and typical systems of subordinate control [1]. The rolling engine has the following nominal parameters: frequency – 50 hz, power – 7100 kW, armature voltage – 900 V, armature current – 8100 A, speed – 80/120 rpm, exciting current – 360 A, overcurrent ratio (shutdown) – 2.75.

2. Development of an improved dual-zone speed control scheme

In a typical scheme, to change the speed to the main one, the armature current control loops with an IP-controller and speed with a P-controller are used. To control the speed of the electric motor above the main one, the flow and EMF control loops are used, where, accordingly, the P-regulator of flow and I-regulator of EMF are used. The current, speed, EMF and flow controllers (CR, SR, ER and FR) are tuned according to the modular optimum [2]. The advantage of this system is a standard, fairly simple (typical) method for calculating the parameters of the electric drive (regulators and sensors), the ease of setting up control loops, when the internal loop is first optimized and then the next in the structure, and the loops are set independently, it is quite simple to implement limitation of the main parameters of regulation.

Slave sequential regulation of coordinates allows you to provide almost any desired transfer function of the regulators on integrated operational amplifiers or in digital form [3, 4].

The disadvantages of typical systems of subordinate regulation are as follows. With a load surge, the output value of the speed controller is limited by the magnitude of the dynamic current reproduction error, which leads to underutilization of the electric motor power during acceleration under load and, accordingly, to a decrease in the productivity of the rolling stand. When working in the restriction zone at the input of the speed controller, a significant error accumulates, which, with a decrease in the static moment, decreases with some delay. At the same time, the drive becomes uncontrollable for a while. The disadvantages of the typical scheme can also be attributed to the engine EMF-dependent flow change for controlling the speed in the second zone. When working with large static moments, the motor voltage becomes limited, which leads to underutilization of the electric drive in terms of power, and at low static loads the motor is underused for anchor voltage.

To eliminate these drawbacks, an improved electric drive is proposed that contains a two-zone speed control system, where, unlike a typical system, an electric motor flow control independent of the EMF is implemented. The structural diagram of the improved automatic control system is shown in figure 1 and contains a dual-circuit system for controlling the EMF to the main speed of the electric motor and a dual-circuit system for regulating the flow above the main speed.

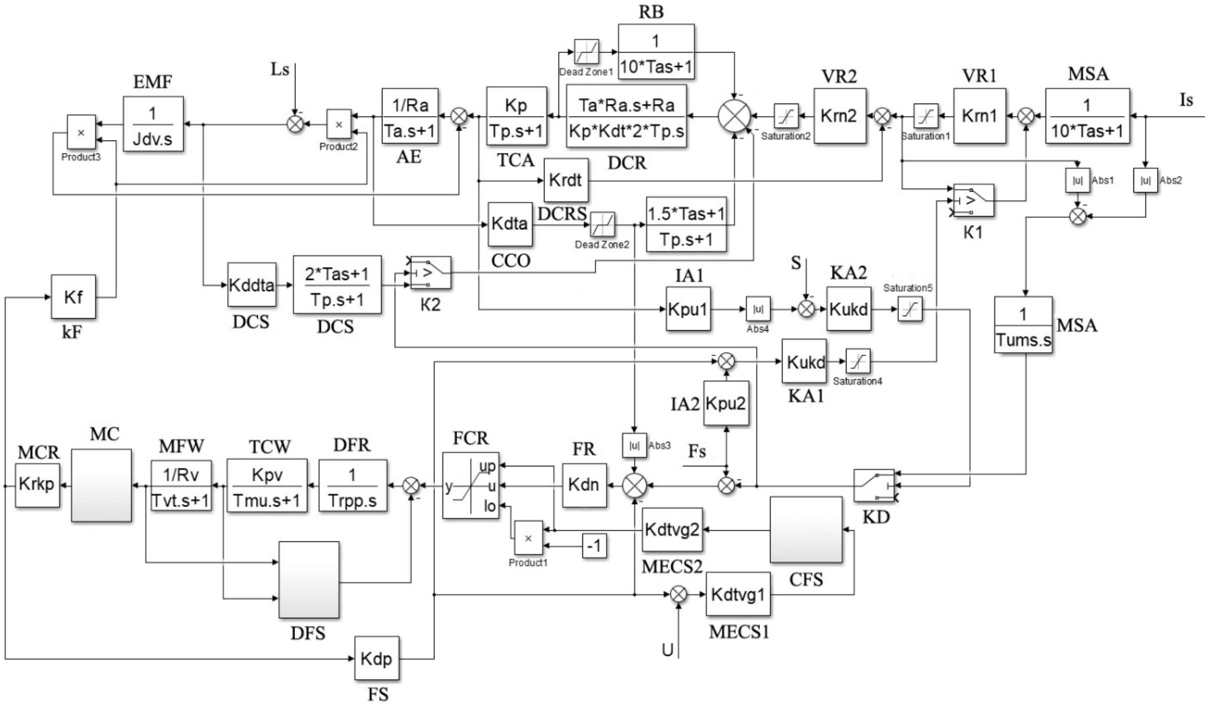

Figure 1. Structural diagram of an improved dual-zone automatic control system.

The EMF control system contains an internal dynamic current circuit consisting of a proportional-integral regulator DTR and a dynamic current sensor DCS, as well as an external EMF control circuit consisting of a proportional regulator VR2 and a sensor ES. The motor flow control system comprises an internal control loop of the derivative of the electric motor flow, consisting of a proportional controller DFR and a flow derivative sensor DFS, as well as an external flow circuit, consisting of a proportional RP flow controller and a DP flow sensor. To limit the maximum current, a current-limiting unit is introduced into the circuit, containing a current sensor for the motor armature CCO and a delay unit DZ2 with a current-limiting setting. In the area of operation of the electric drive below the main speed, the current limiting signal acts on the dynamic current controller, and in the area above the main speed, it affects the input of the flow controller FR. To maintain the constancy of the dynamic current in the control zone above the main speed, the driving signal to the flow is generated as a function of the cube of the flow. To this end, the FR limitation is performed in the FCRB block with an adjustable limiting voltage coming from the flow cube sensor CFS. To switch from the first to the second regulation zone and backward, electronic keys K1, K2, KD are used, which are controlled by comparison devices KA1 and KA2 [5, 6]. The derivative of the flow of the motor pF (1) is implemented in the sensor of the derivative of the flow DFS.

$$pF = U_f - I_f \cdot R_f \tag{1}$$

$U_f -$ the voltage across the motor excitation winding (ATS); $I_f -$ the current of the ATS; $R_f -$ the resistance of the winding.

The parameters of the regulators and sensors are set using known methods of tuning subordinate control systems [2]. A feature of tuning the derivative flow loop is the following simplification: since the change in the excitation current I_f occurs much slower than the voltage U_f due to the large inductance of the field winding, feedback on the excitation current in dynamic modes can be neglected. Thus, in practice, the contour of the derivative stream is tuned as the MFW voltage circuit to a modular optimum. Current limitation parameters were determined using the Matlab and Simulink software.

3. Analysis

To analyze the typical and the improved control systems, their modeling was performed using Matlab and Simulink. ACS models are shown in figure 2 and figure 3. The resulting transients are shown in figures 4 and 5.

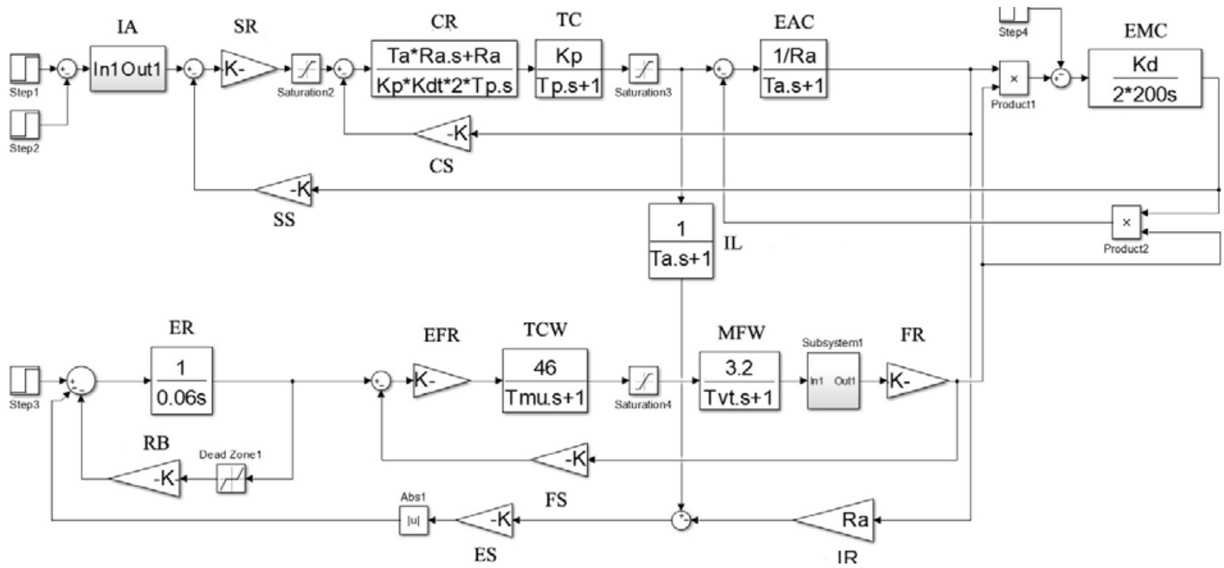

Figure 2. Mathematical model of a typical dual-zone automatic control system.

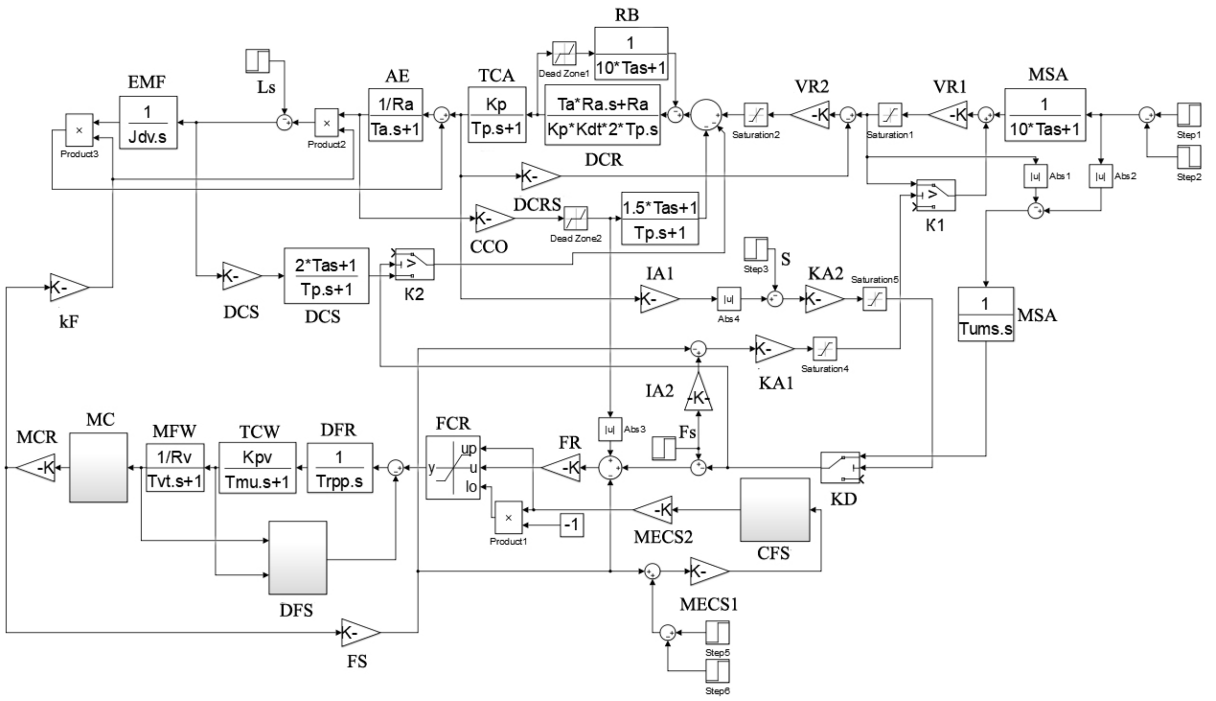

Figure 3. Mathematical model of an improved dual-zone automatic control system.

In a typical and improved electric drive system, in order to compare operating modes for different values of the static moment, the current limit setting was set to an armature current of 16 kA, and the acceleration speed of the electric drives at idle was also chosen to be the same - 4 rad / sec * sec.

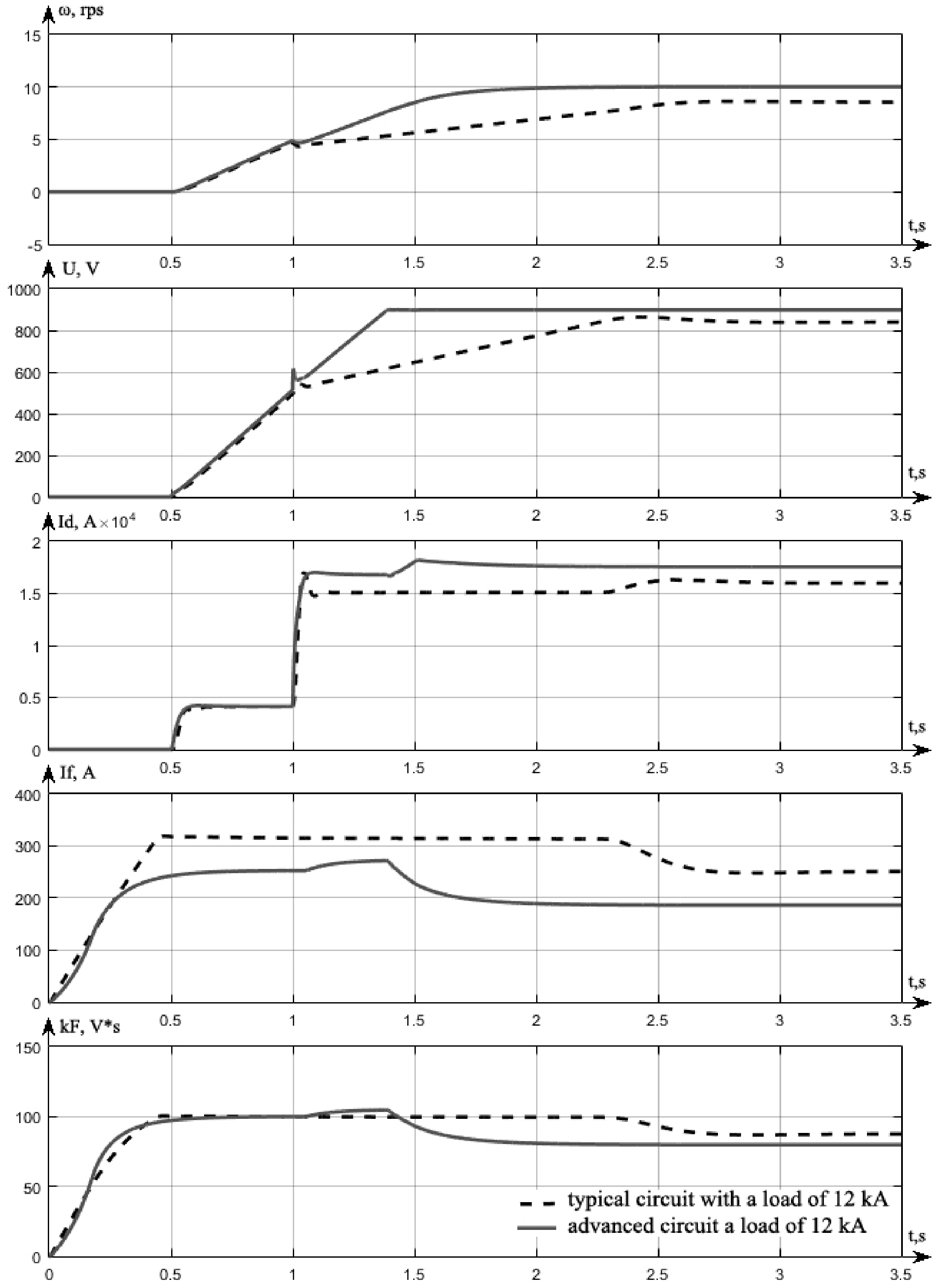

Figure 4. Transients obtained in the simulation of work under load.

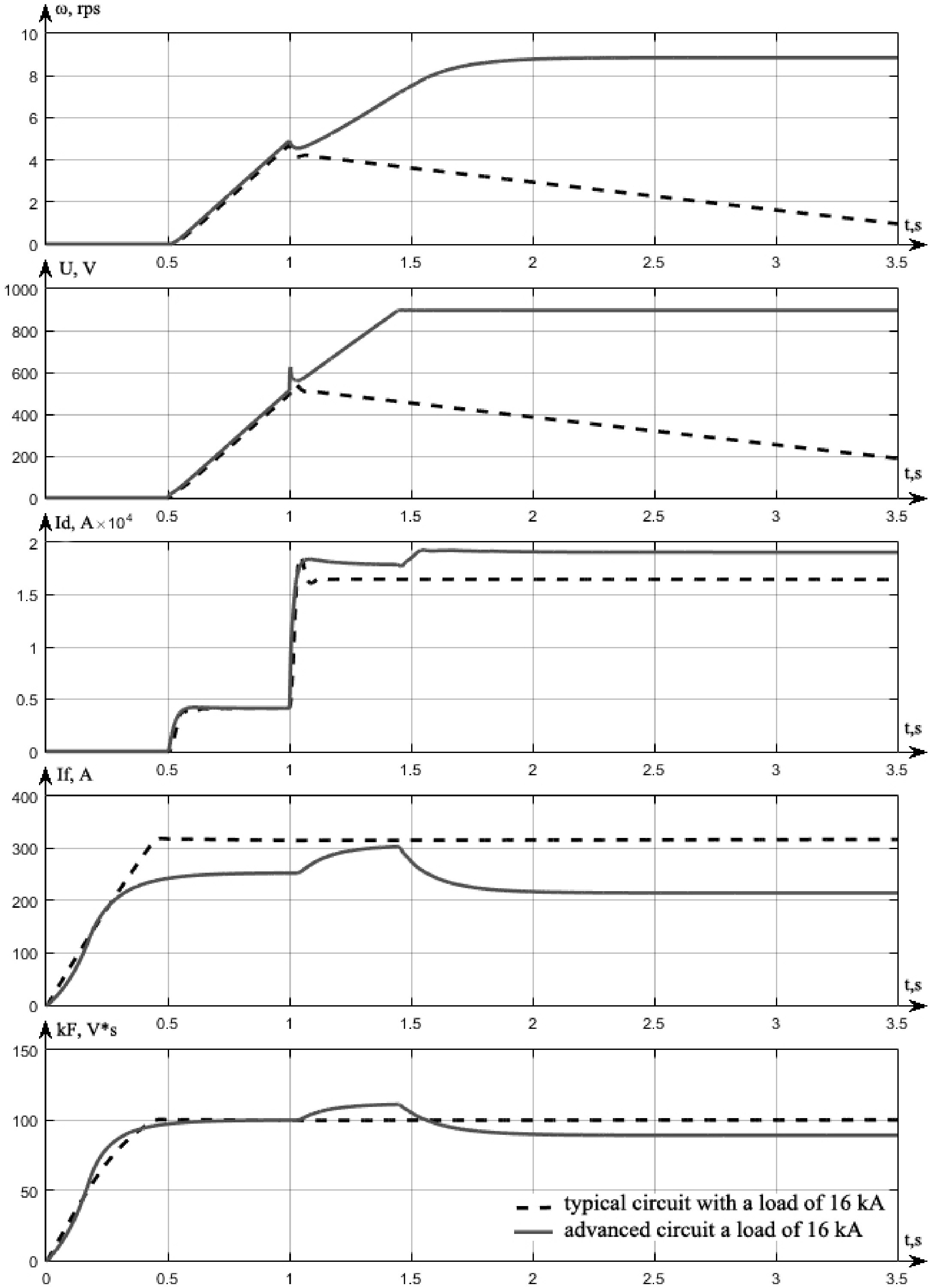

Figure 5. Transients obtained by modeling the operation of an electric drive with a maximum load.

4. Results and conclusions

From the analysis of transient waveforms shown in figure 4 it follows that at the moment of billet capture at a load current of 12 kA in a typical circuit, there is a decrease in the rate of increase in speed, which increases the acceleration time of the engine (the productivity of the mill decreases), while the rate of increase in the speed of the improved circuit does not change.

In figure 5 shows the parameters of electric drives with an increase in static load up to 16 kA. The rate of increase in speed in the improved dual-circuit design is reduced, since the armature current of the motor exceeds the current limit setting, while a typical dual-circuit system can no longer cope with such a load, as evidenced by the braking process until the motor stops and remains stationary under current, which may ultimately lead to an emergency.

Analysis of the operating modes of the electric drive with a typical and improved system of subordinate regulation revealed the following advantages of the improved system:

- In an improved control system during load surge, there is no drawdown of speed until the current limitation begins;
- High quality current limiting allows you to increase the maximum torque on the motor shaft;
- The motor of the improved system is fully used for anchor voltage.

The operating experience of the improved ACS in crimp and rail workshops of the Kuzmetkombinat showed the high quality of transients and reliable operation.

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