Light & Engineering
Vol. 26, No. 3, pp. 150–154, 2018

Svetotekhnika
No. 3, 2018, pp. 56–59

PULSE IGNITION DEVICES WITH NEW CIRCUIT SOLUTIONS

Alexander M. Mayorov and Michael I. Mayorov

Ogarev Mordovia State University, Saransk
E-mails: allexx1383@mail.ru; mayorovmi@mail.ru

ABSTRACT

The most of three-lead domestic pulse ignition devices (PID) do not provide parameters of high-voltage pulses determined by the lamp operation manuals. New circuit solutions are presented, which meet the requirements to HP sodium lamps used in street illumination and greenhouse irradiation. It is proposed to separate two functions of the three-lead PID pulse transformers: generation of high-voltage pulses and transmission of the lamp full current. To generate high-voltage pulses, transformers with a big turn number of thin wire should be used. And to transmit lamp full current, high-frequency throttles with a low resistance should be applied. A version of calculating parameters of a high-frequency throttle and oscillograms of pulses generated by the PID are given.

Keywords: discharge lamp, pulse ignition device, high-voltage pulse

It is known that production volume of ballasts, especially for high pressure sodium lamps (HPSL) and metal halogen lamp (MHL) are still big and such situation will remain for a long time [1].

For ignition of HP discharge lamps in circuits with electromagnetic ballast, it is necessary that the PID generates pulses with certain voltage amplitude and duration. So for some types of such lamps, pulse parameters specified in the Table are necessary.

Parameters of pulses generated by a PID are determined by the PID electronic circuit features, and the pulse transformer parameters, such as transformation coefficient, inductance of primary and secondary windings, as well as saturation current.

Domestic enterprises only manufacture PIDs providing high-voltage pulse parameters corresponding to the given in the Table with a parallel ignition circuit (the pulse oscillogram is given in Fig. 1, curve *1*).

Such PIDs have two leads and are connected in parallel to the lamp switched to the circuit in series with the ballast throttle, which is a ballast element limiting lamp current. Lamp current in this circuit does not flow through the PID, which causes its simplicity, low cost and universality. A disadvantage of such PID is that high-voltage pulses influence not only the lamp but also the ballast throttle, as well as the connecting wires between the throttle and the lamp. This reduces ballast reliability, causes a necessity to strengthen insulation of the ballast

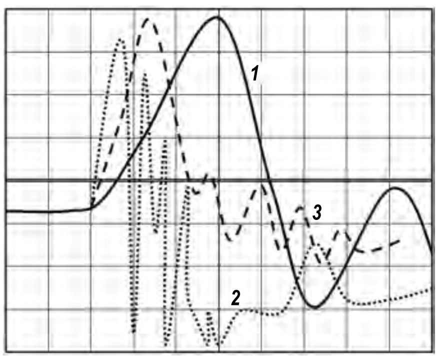

Fig. 1. Oscillogram of pulses generated by different type PIDs:
1 – PID-T 70–1000 PID (two-lead); *2* – 400/220V-012 PID; *3* – *Z 1000 S* PID;
(1000 V/div 1 μs /div; 0 is one square lower than the screen middle)

throttle and leads to a dependence of the PID output pulse parameters on the input wire length and on the ballast throttle structure [2].

Fig. 1 also shows oscillograms of the pulses generated by a sequential ignition PID (curves *2* and *3*). One can see from these oscillograms that such PIDs do not provide high-voltage pulse parameters according to the Table. So pulse duration at a level of 3 kV generated by PID400/220V-012 is 0.5 µs, and by PID *Z 1000 S* it is equal to *1* µs. Application of these PIDs causes a necessity of pre-term replacement of operable lamps, which are not ignited because of insufficient pulse duration. Sequential ignition PIDs have three leads, two of which are connected in series with the lamp [2]. Sequential ignition PIDs have certain power losses, big size and mass (as pulse transformer secondary winding should be designed for the lamp current passing through it). However, such PIDs are most widespread as they do not require strengthening insulation of the ballast throttles.

PID circuits without a pulse transformer are known, because functions of the latter are performed using a ballast throttle with a drop wire [2]. On the one hand this allows obtaining a big amplitude voltage wide pulses and reducing PID size, mass and cost. Such PID circuits are widely used abroad, for example in the *ZRM 2300C201* PID and in *ZRM 4000B101* (see also article [3]). But they require presence of special ballast throttles with drop wires and strengthened insulation.

It is also known a circuit of serial-parallel three-lead PIDs [4], which were produced in large quantities since eighties, for example, 250–400ДНаТ/220 PID. The throttle voltage when generating ignition pulses by these PIDs did not exceed 2000 V, which did not require special ballast's throttles with strengthened insulation. But by mass-dimensional factors, these devices did not differ much from sequential ignition PIDs. Therefore, the problem of creating an effective and cheap three-lead PID for HP discharge lamps of a big power is topical until now. It can be solved by a little addition, which turns a two-lead PID into three-lead eliminating defects of two-lead PIDs [5]. It is proposed to separate two functions of three-lead PID pulse transformers: generation of high-voltage pulses and transmission of a lamp full current by means of two separate inductors. An apparent complication of the structure allows generating pulses with characteristics selected in advance using a pulse transformer with

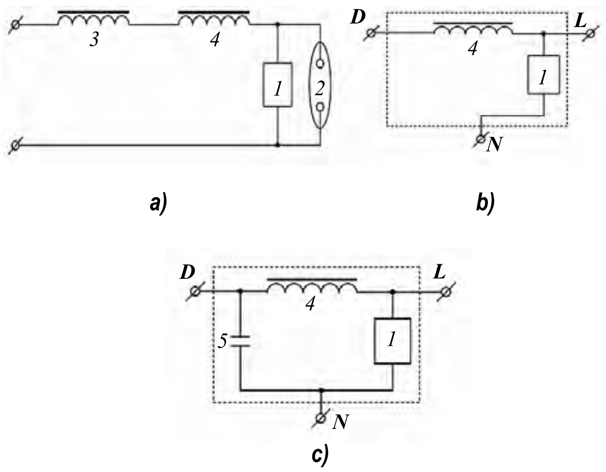

Fig. 2. PID circuit versions [5]

a large number of thin wire's turns. And to pass the lamp full current, one should use a high-frequency throttle with a small resistance protecting the throttle ballast against a breakdown. This separation is especially effective for PIDs designed for big currents and big pulse durations.

Fig. 2 *a* shows a circuit ballast with PID. This circuit contains two-lead PID1, connected in parallel with discharge lamp *2* switched to the circuit in series with ballast throttle *3* and with high-frequency throttle *4* complementary added in order to protect ballast throttle *3* against breakdown by the PID high-voltage pulses. PID1 and high-frequency throttle *4* can be placed in the same case with three leads (Fig. 2, *b*.)

The ballast within a PID operates as follows. When switching on, PID1 generates high-voltage pulses mainly with 3–5 kV amplitude. These pulses create a conducting channel in the interelectrode gap of lamp *2*. In this channel, high-current discharge plasma is formed then. The discharge is supplied through ballast throttle *3* and high-frequency throttle *4* from a power-line. Throttle *4* limits pulse voltage affecting ballast throttle *3* during pulse generation to maximum permissible for this ballast throttle 3 (usually it is 2 kV. After lamp *2* is ignited, it shunts PID1 charge circuit, in consequence of which it is automatically switched off. In the event lamp *2* is not ignited or it is just absent, PID1 continues pulse generation. In some cases, this PID is equipped with a disconnection unit stopping pulse generation within several minutes, if lamp *2* is not ignited. This time depends on type and power of the lamp and is equal to (1–2) min for HPSLs and (10–15) min for MHLs [2]).

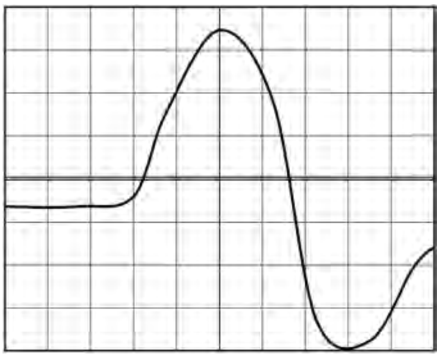

Fig. 3. Oscillogram of a pulse generated by PID #1 with a high-frequency throttle based on the ETD44 core. (1000 V/div; 1 µs /div; 0 is one square lower than the screen middle)

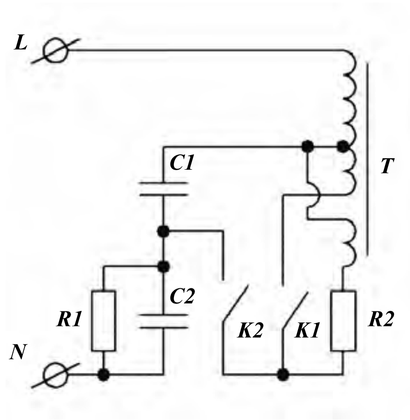

Fig. 4. Electric circuit od two-lead PID applied in PID#3

Not only the high-frequency throttle, but also an own ballast throttle capacity takes part in the limitation of pulse voltage influencing the ballast throttle during pulse generation. However in some cases, in order to limit the pulse voltage influencing the ballast throttle, one should add a varistor or an additional capacitor *5* (mainly up to 2000 pF) as it is shown in Fig. 2, *c*.

For rectangular shape high-voltage pulses generated using a closed magnet conductor pulse transformer, pulse duration by amplitude product is limited by size and by maximum achievable magnetic induction B_{max} of the pulse transformer core.

According to it, high-frequency throttle parameters are mainly selected by means of the following expression:

$$\Delta B \cdot S \cdot w \geq 0{,}5 \cdot \int_{t_1}^{t_2} \varepsilon(t)\,dt, \qquad (1)$$

where ΔB is the change of magnetic induction in the high-frequency throttle during PID pulse action maximum possible in this circuit; $\varepsilon(t)$ is the function describing voltage dependence on time of the pulses generated by the PID; integral is the pulse "area" (for example, in V·s dimension); $(t_2 - t_1)$ is the pulse duration; S is the cross-section area of the high-frequency throttle magnet conductor; w is the turn number of the high-frequency throttle winding.

The 0.5 coefficient forward of the integral means that a part of the high-voltage pulse generated by the two-lead PID (Fig. 2, *a*) only, "falls" on the high-frequency throttle, and the other part is applied to the ballast throttle. When calculating, one should watch that this part do not exceed a maximum permissible voltage for this ballast throttle.

In the PID (PID #1) version according to Fig. 2, *b*, the high-frequency throttle was made based on the *ETD44* ferrite core (S = 173 mm^2) without a gap of material #87 with μ = 1650 relative magnetic permeability. With ignition pulse "area" of 4000 V·2 µs and ΔB = 0.4 T, according to (1), w > 58. An oscillogram of the pulse generated by this PID version is shown in Fig. 3. As two-lead PID1 (Fig. 2, *b*) of the ИЗУ-Т 70–1000 type is applied, which pulse oscillogram is shown in Fig. 1.

It follows from the presented data that pulse parameters meet requirements of the operation manual given in the Table. And ballast throttle pulse amplitude does not exceed 2000 V.

In comparison with high-voltage pulses generated by the *Z1000S* PID (Fig. 1), in which the ferrite *ETD44* core without a gap made of material #87 is also used, the pulse duration in the proposed PID version is twice more, and at a level of 3 kV it exceeds 2 µs.

In accordance with (1), pulse "area" depends on ΔB. In order to minimise size and mass of the high-frequency throttle, it is expedient to use magnetic conductors of a material with a high maximum achievable magnetic induction B_{max} [6]. For ferrites, B_{max} does not exceed 0.5 T, and for amorphous metal alloys based on iron it reaches 1.5 *T*. It means that size of a magnetic conductor made of amorphous metal alloys based on iron in comparison with a magnetic conductor made of ferrite can be reduced up to three times. And in doing so, identical parameters of high-voltage pulses are achieved. A reduction of magnetic conductor size will allow reducing resistance of the pulse transformer due to a decrease of the winding wire length, which will lead to a decrease of losses at the pulse transformer winding and to saving copper wire.

Table

HPSL(ДНаТ) Power, W	Pulse amplitude, V		Pulse duration at the 0.5 level, μs, no less	Pulse energy, J, no less
	no less than	no more than		
600	4000	5000	2.0	0.002
1000				

In another PID version (PID #2), according to Fig. 2(*b),* the high-frequency throttle was made on the basis of a ring magnetic conductor AMET 5B32·20·10 with S = 90 mm^2, which material had B > 1.2 T at magnetic field strength of 5 A/m and μ > 50,000 at 0.1 A/m. With w = 45 and in case of application as two-lead PID1 (Fig. 2, *b*) of PID-T 70–1000 type, an oscillogram of the pulses generated by this PID version coincides with the presented in Fig. 3. Mass of the high-frequency throttle does not exceed 50 g, and its active resistance is equal to 0.03 Ohm.

A reduction of high-frequency throttle magnetic conductor size at the same high-voltage pulse parameters is achievable in case, if its magnetic reversal is made not from zero to B_{max} (as it is implemented in PID #1 and PID #2) but from – B_{max} to B_{max} (or from B_{max} to – B_{max}) thereby twice amplifying ΔB [7]. In accordance with (1), it will allow reducing S twice having saved pulse former "area".

These solutions were implemented in PID #3, in which two-lead PID1 (Fig. 2, *b*) were performed according to Fig. 4. In this case, operating capacitor *C1* charged via current-limiting element *R1-C2* was connected using a switching element in parallel to the pulse transformer *T* primary winding.

The switching element consisted of two keys *K1* and *K2* connected in series. General point of the keys connected to each other via a current-limiting resistor *R2* is switched to the end-point of an additional primary winding, which beginning is joined with the primary end-point. Key *K1* is connected to the beginning of the primary winding, and key *K2* – to the operating capacitor and to the current-limiting element. Key *K1* is switched on in (0.1–10) µs (in the event of PID #3 – in 2 µs (Fig. 5)) after key *K2* is switched on [7]. Key *K2* is only switched on, if the working capacitor is charged to a necessary level. Power part of keys *K1* and *K2* is made based on triacs connected to the correspondent control circuits. It is proposed in patent [7] to use a saturable throttle as *K1* key. Due to the circuit solution according to Fig. 4, two-lead PID1 (Fig. 2) generates a bipolar pulse, which first magnetises high-frequency throttle 4 (Fig. 2) into one polarity (for example, to – B $_{max}$), and then, when polarity changing, the basic high-voltage pulse is generated. In doing so, the high-frequency throttle is re-magnetised from $-B_{max}$ to B_{max} and reliably protects the ballast throttle from breakdowns maintaining its voltage at a level less than 2000 V when generating an ignition pulse of up to 5 kV amplitude.

Fig. 5 (curve *1*) shows an oscillogram of the pulses generated by PID #3 intended to ignite HPSLs according to the Table with use of the foregoing circuit solutions [5, 7, 8]. It is seen that pulse parameters meet the Table requirements: the pulse duration at the 0.5 level is more than 2 µs. With that, high-frequency throttle *4* (Fig. 2) consists of two throttles connected in parallel; ETD29 ferrite cores of material #87 are used without a gap, and pulse transformer *T* (Fig. 4) has mass of 20 g. Due to a little material consumption s, this provides a high economic efficiency of this PID. Foreign PIDs with similar parameters, *ZRM 12ES/B* for example, have

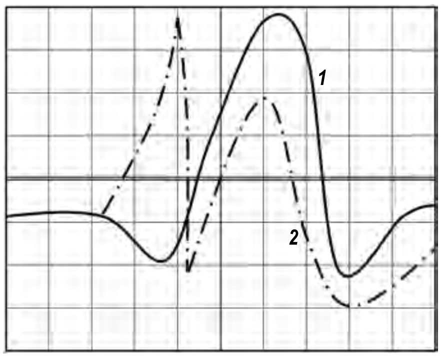

Fig. 5. Oscillogram of a pulse generated by PID #3 with a high-frequency throttle based on the ETD29 core with connected (1) and disconnected (2) additional primary winding. (1000 V/div; 1 µs /div; 0 is one square lower than the screen middle)

twice greater mass, and their cost is significantly more.

Fig 5 also shows an oscillogram of a pulse generated by PID #3 (curve 2) with disconnected additional primary winding of the two-lead PID (Fig. 4). It is seen that pulse duration at the 0.5 level in this case is less than 1 μs.

PIDs with pulse parameters meeting the Table requirements were developed to be introduced into production together with Kadoshkinsky Electrotechnical Factory JSC being a part of BL GROUP International Lighting Corporation.

REFERENCES

1. Klykov Mikhail E. and Agafonova Tatyana A. LED drivers and Discharge lamps control gears: present state and future development// Light & Engineering, @017, V25, #4, pp.32–40.

2. Reference book on lighting engineering / Edited by Yu.B. Ayzenberg.The 3rd revised edition, Moscow: Znak, 2006, 972 p.

3. Rajat Mandal, Santosh Upadhyay, Saswati Mazumdar, Asit Kumar Sur, Chetan M. Sankhla, and Susanta Bhaumik " Igniter Issues with High Intensity Discharge Llighting Applications"// Light & Engineering, 2012, V.20, #4, pp. 90–96.

4. Reference book on lighting engineering / Editerd by Yu.B. Ayzenberg, Moscow: Energoatomizdat,1983, 472 p.

5. Mayorov M. I, Mayorov A.M. A ballast with pulse ignition device / Patent #167448 of the RF, 2017.

6. Mayorov M. I, Mayorov A.M., Goryunov V.A. A device for ignition of gas-discharge lamps/ Patent #103436 of the RF, 2011.

7. Mayorov M. I, Mayorov A.M., Goryunov V.A. A device for ignition of gas-discharge lamps/ Patent #2567739 of the RF, 2015.

8. Mayzenberg S.I., Polyakov A.G. An airfield searchlight / Patent of the USSR #739307, 1980.

Alexander M. Mayorov,
Ph.D., graduated from Physical Faculty of the Ogarev MSU in 2005. At present, he is an Associate Professor of the Structure and Technology Informatics Chair of the Ogarev MSU

Michael I. Mayorov,
Dr. of Technical Science, Associate Professor, graduated from Physical Faculty of the Ogarev MSU in 1970. At present, he is a Professor of the Structure and Technology Informatics Chair of the same university