

The Design Project of the Pulse Generator Based on an Inductive Storage and a Combination of Vacuum Interrupter and Plasma Opening Switch

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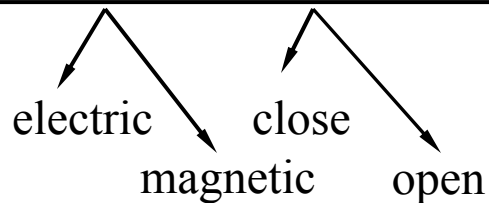


1. Introduction

Pulsed Power Application

- lasers
- impulse radiation sources
- particle acceleration
- controlled fusion
- intense microwave sources
- high power radar
- geophysical researches

Simplify of drivers structure



multisteps opening switch ←

Table No.1

	Electric field	Magnetic field
density of energy	100 kJ/m ³ Marx bank under: 1MV - 10kJ/m ³ ---//--- 2MV - 5kJ/m ³	10-30 MJ/m ³
cost	0.8-0.25 \$/J	~0.01\$/J
energy transfer to the load by	closed switch	opening switch
time accumulation	second -millisecond	second -millisecond
times relation	10 ⁷ ÷ 10 ⁸	~10 ÷ 2 0

Demands made on switches

- maximum value of cut-off current
- maximum value of voltage capability
- thermal stability of contact system
- current flowing - current breaking time relation



2. Problems and classification of opening switches

Classification of opening switches

Table N.2

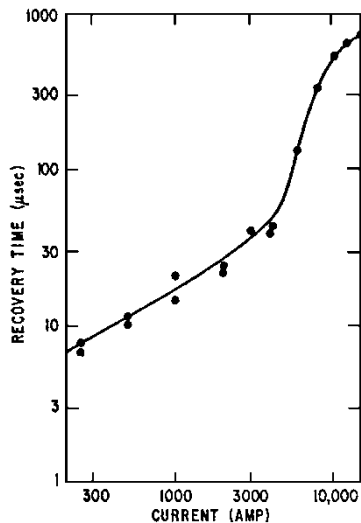
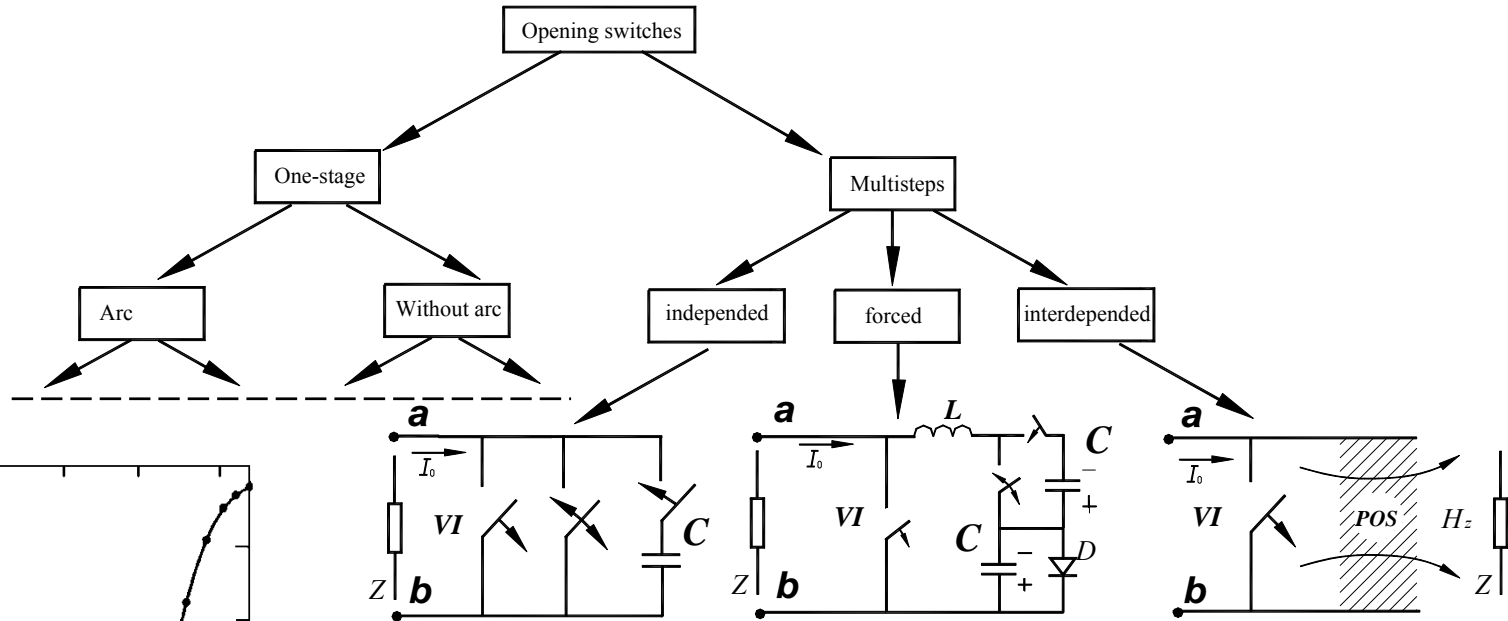


Fig.1

$$W = \frac{U \cdot I \cdot t}{4}$$

Find G., Croll J.J., Goody C.P., Tuohy R.J.

// IEEE Trans. Power Appar. Syst., PAS-101, p.775, 1982



3. Elements of generator based on combined opening switches

“Forced” two steps breaker

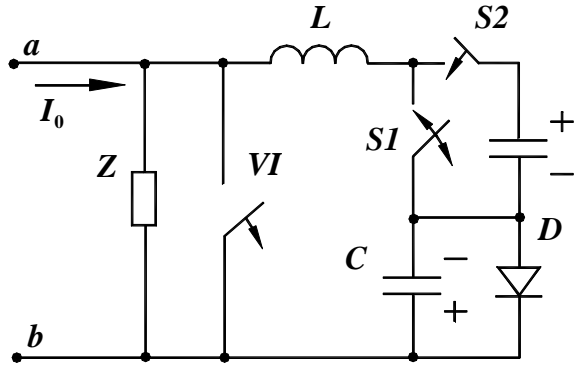


Fig.2 The scheme of breaker

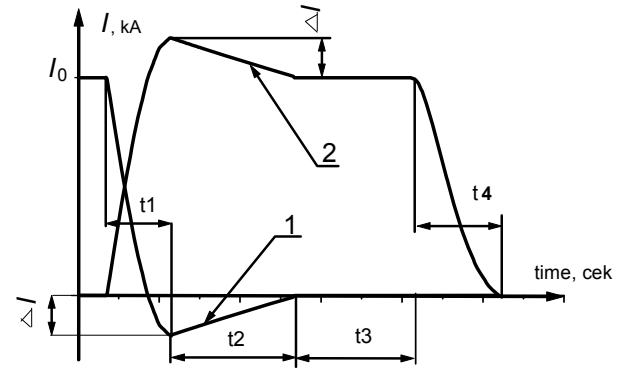


Fig.3 Current distribution

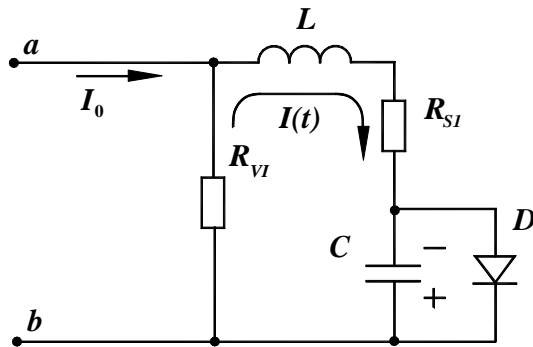


Fig.4

$$R_{VI} (I(t) - I_0) + L \frac{dI}{dt} + IR_{S1} = U - \frac{1}{C} \int Idt$$

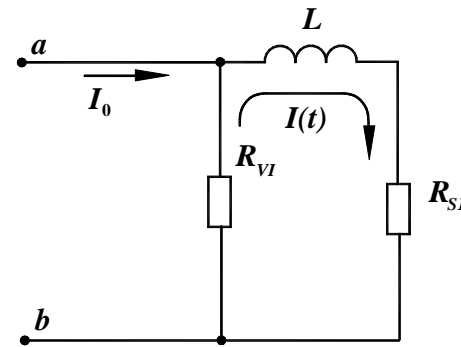
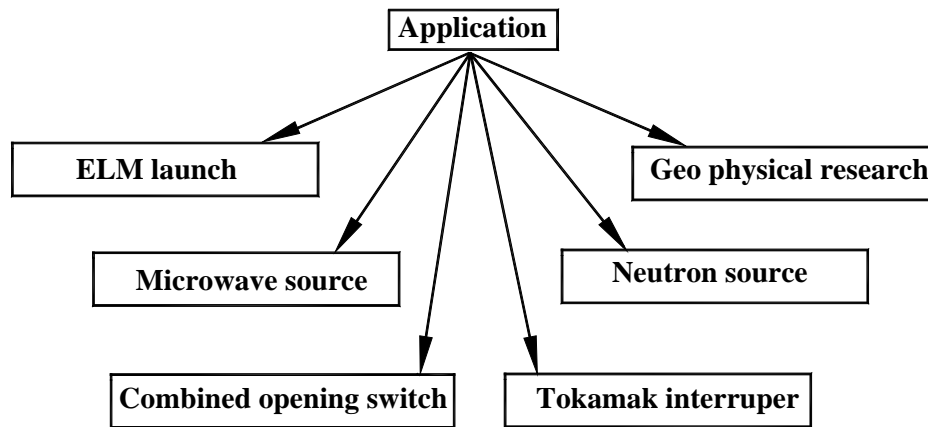


Fig.5

$$L \frac{dI}{dt} + I(t) (R_{VI} + R_{S1}) = 0$$



vacuum devices

possibility of work in repetitive pulse mode.

gap strength under the conditions of magnetic insulation has the maximum value;

- the condition of vacuum, VI recovered ($P_{min}=10^{-4}$ mm.Hg), POS works reliably ($5 \cdot 10^{-4}$ mm.Hg);

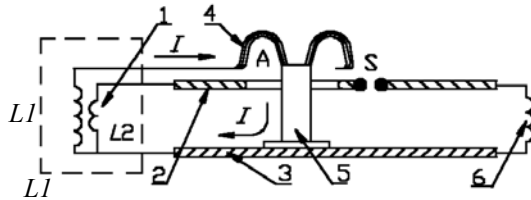
Action of COS

- energy accumulating
- arc
- current zero and its break
- plasma opening switch and magnetic insulation



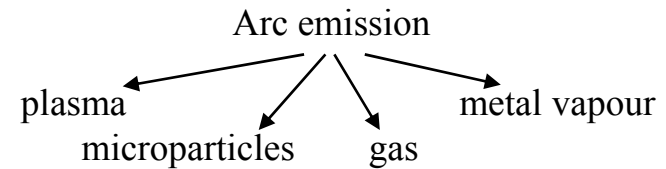
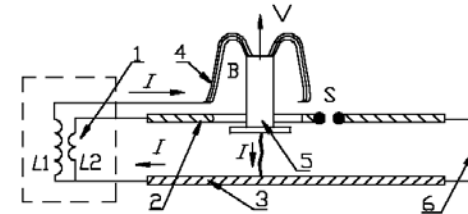
“Interrelation” two steps breaker:

Stage 1

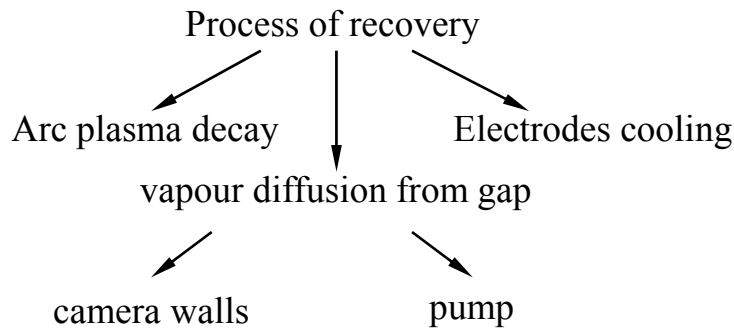
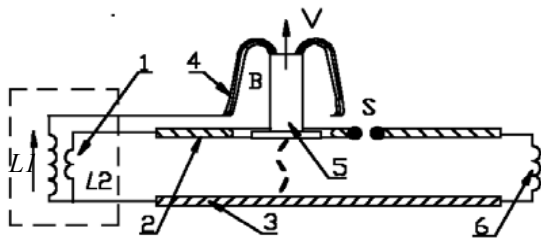


Inductive storage of transformer type- (1),
 anode- (2), cathode- (3), flexible buses- (4),
 mobile electrode- (5), closed switch- (S),
 load- (6)

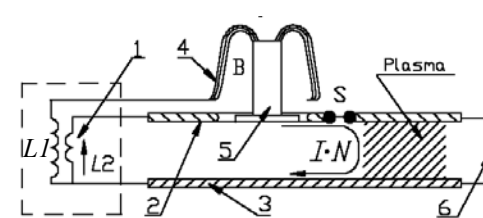
Stage 2



Stage 3



Stage 4

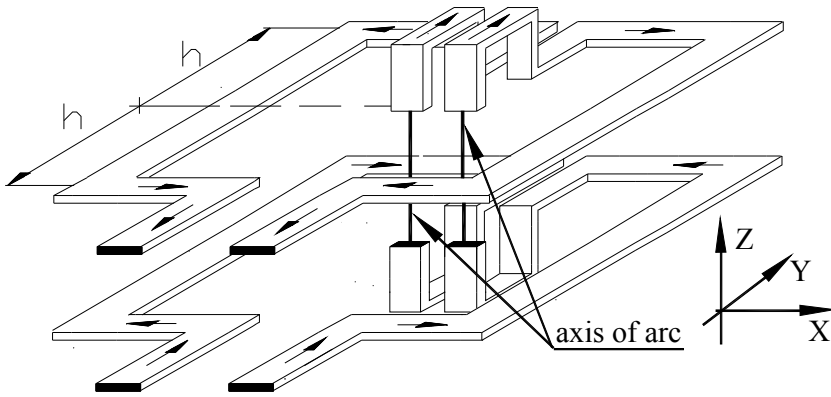


plasma opening switch

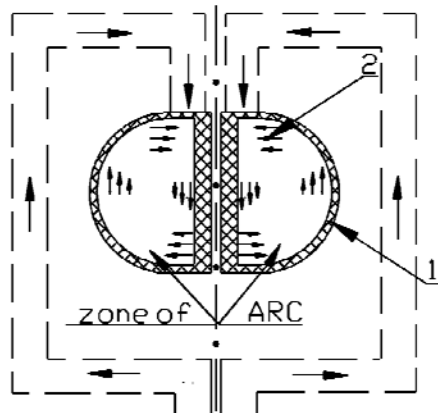
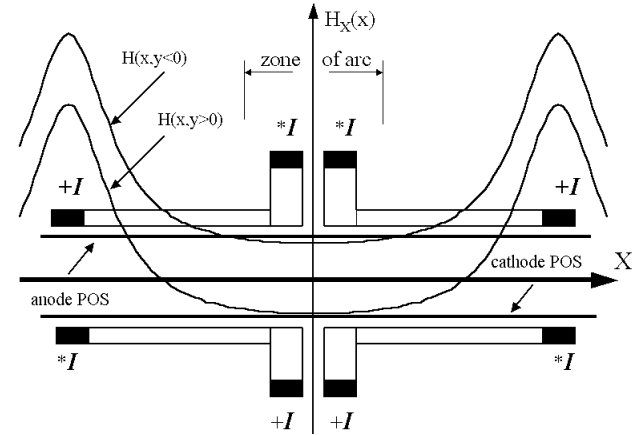
$$U_{\text{COS}}[\text{MV}] = 3.6 \cdot (U_{\text{VPG}}[\text{MV}])^{4/7}$$



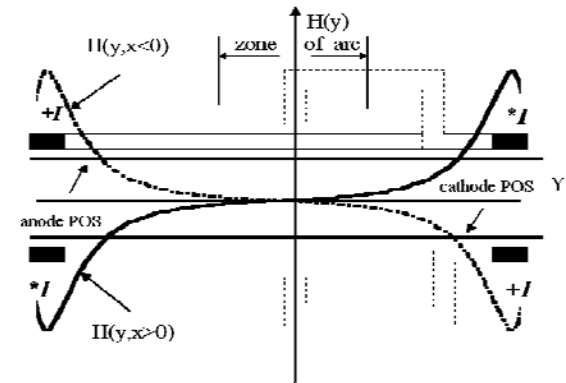
Construction of ARC stability



Geometry of bus-bars

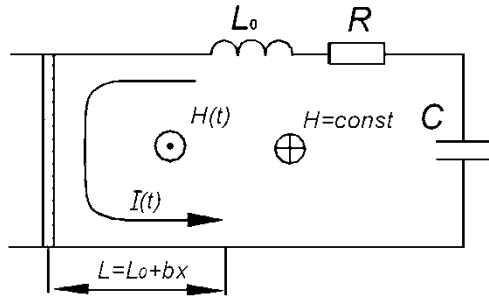


Cross-sectional view of cathode in x-y plane

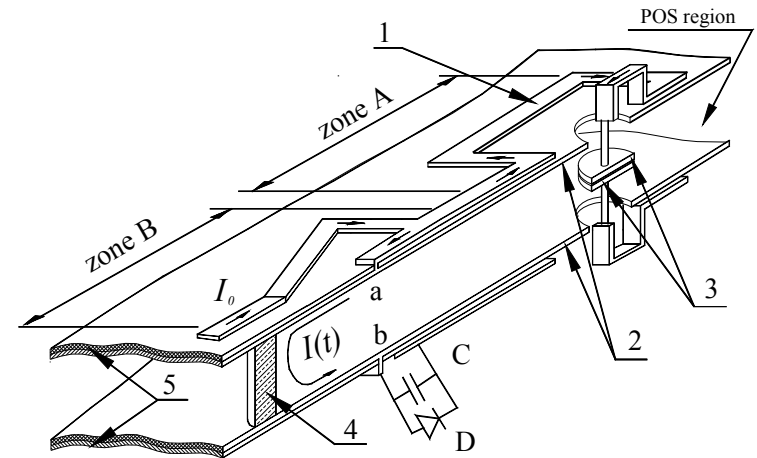




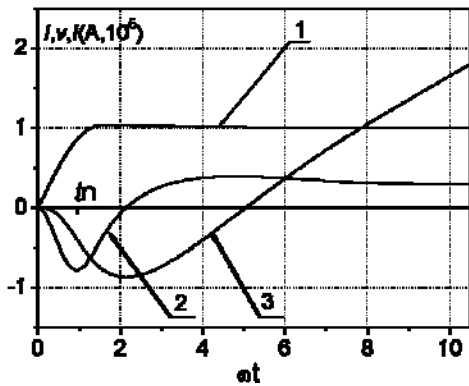
Adapted construction of COS



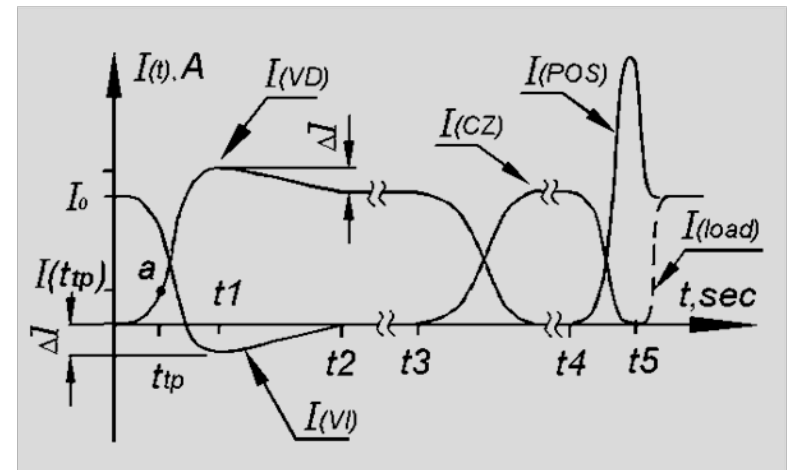
The electrical scheme of discharge movement process



General view of modification COS



Current , - velocity, - and are coordinate - time relation.



Combined opening switch currents - time relation



Correlation of first ad second turns

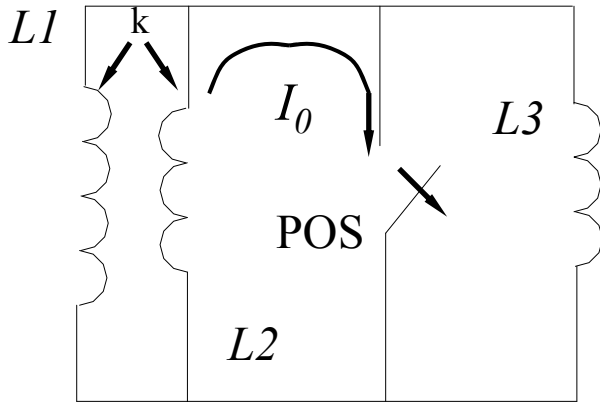


Fig.8. The scheme of energy output.

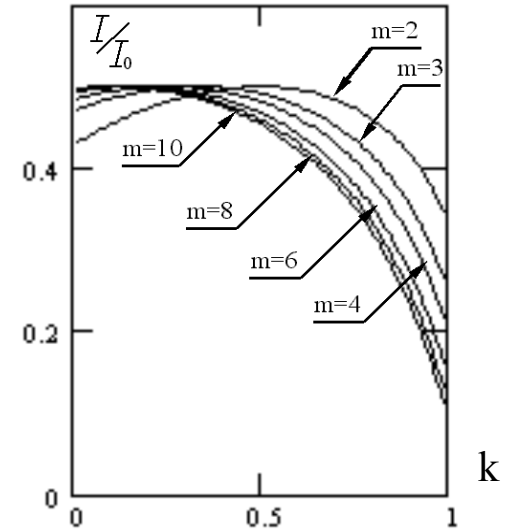
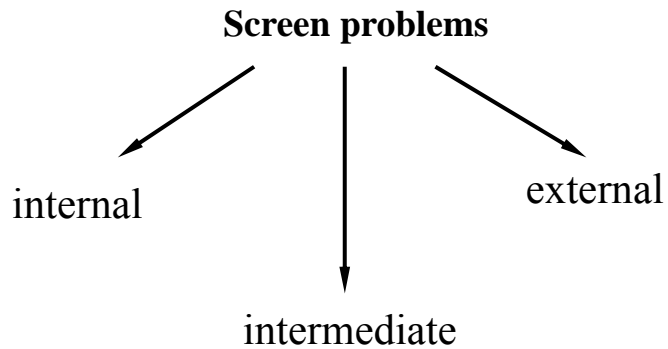


Fig.9 The load current - k dependence for various m

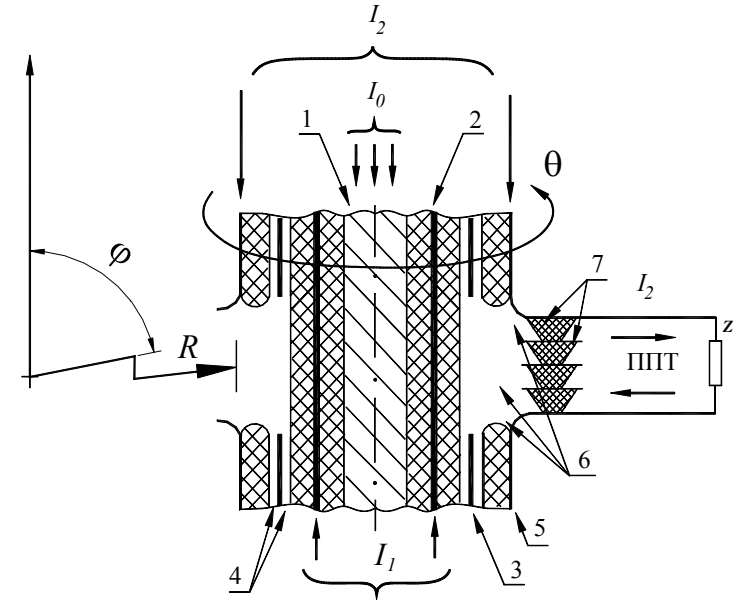
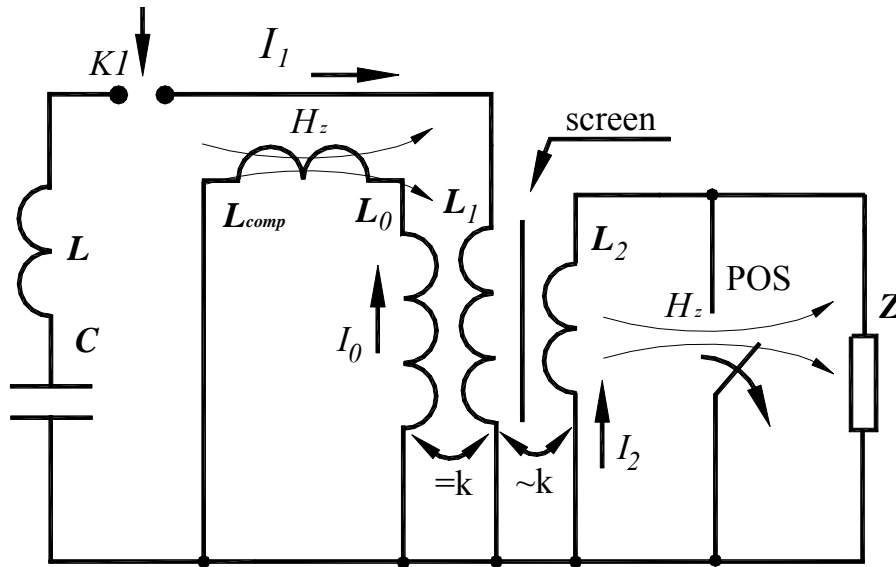


$$m = \sqrt{\frac{L1}{L2}} \quad \text{under } L2=L3$$

$$\left(\frac{I}{I_0} \right)_{\max} \approx 0.5 \quad \text{under } k \approx \frac{1}{m}$$



Generators without first opening switches.

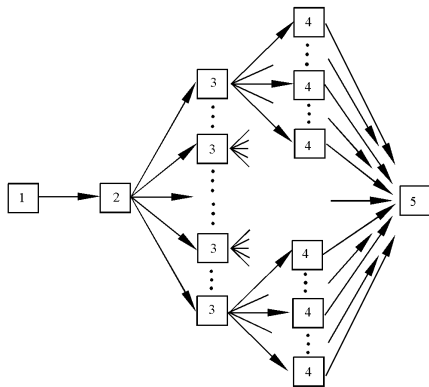
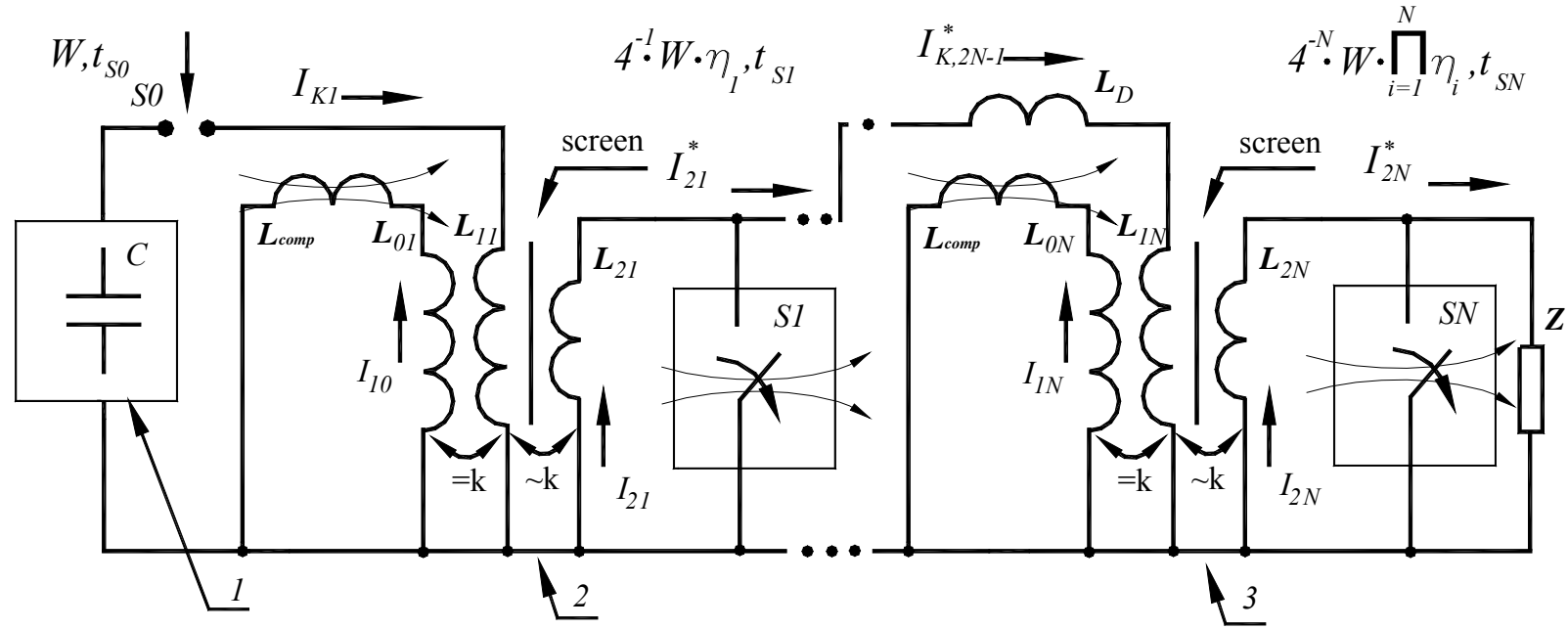


$$\eta = \frac{W_L + W_{L_0} + W_{\text{ПНТ}}}{W_C}$$

$$H_Z \geq (2-3) \max \{ H_\phi, H_c \}$$

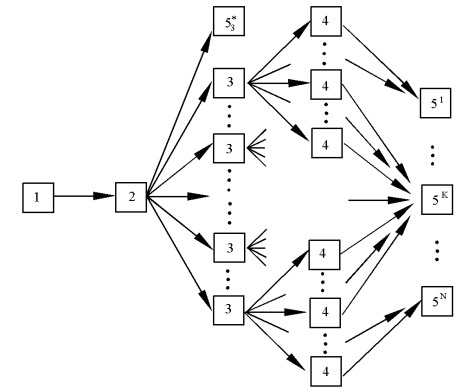


Generators with chain multiplication



- 1 - start storage, W, t_{SO}
- 2 - amplifier No. 1, $W_1 = 4^{-1} W \cdot \eta_1, t_{S1}$
- 3 - amplifier No. N, $W_N = 4^{-N} W \cdot \eta_1, t_{SN}$

$$t_{SO} > t_{S1} > \dots > t_{SN}$$



Three-stage circuit of pulse power branching and combining in the load

Three-stage circuit of pulse power branching and combining at different loads



Conclusion

The complex solution offered to consideration allows to provide:

- the maximum electrical strength of vacuum gap;
- steady arc burning;
- to decrease vacuum gap recovery time down to $\sim 100 \div 120 \mu\text{s}$;
- energy storage time– energy transfer to the load time relation attain $10^6 \div 10^7$, under power $10^{11} \div 10^{12}$ W and higher.



-experimental verified of this proposition

Tank's for attention!