Single-Circuit and Double-Circuit Regulating Apparatus for Gas Discharge Element

Stefan Barudov[1],Rositsa Dimitrova[2], Milena Ivanova[3]

Abstract **–Most purposefully, the usage of electrical discharge is related to its development in a specific, artificially created medium – a discharge element.Due to the specifics of the discharge elements, they are connected as a load to the power supply grid by regulating apparatuses.The work is dedicated to a comparative study between single-circuit and double-circuit regulating apparatuses for control of a direct current discharge with respect to the stability of the discharge current and the power parameters of the regulating apparatuses.**

Keywords **– DC discharge, single-circuit regulating apparatus, double-circuit regulating apparatus**

I. Introduction

The single-circuit regulating apparatus (SCRA) consists of an uncontrollable rectifier (a dc voltage source with magnitude $U^*_{D\max}$ – Fig.1), which supplies a regulating element (RE) connected in series with a compensation stabilizer (CS) and a discharge element (DE). $U = U^*_{D\max}$ - U'_D provides stabilization of the discharge current at a change of the amplitude of the input supply voltage.

The double-circuit regulating apparatus (DCRA) consists of a controllable rectifier which controls the voltage over the regulating element of the compensation stabilizer.

Most often, in operating mode the controllable rectifier realizes the law U_{RE}=const or switches on a regulator of the input supply voltage, which limits the fluctuation of the amplitude of the input supply voltage.

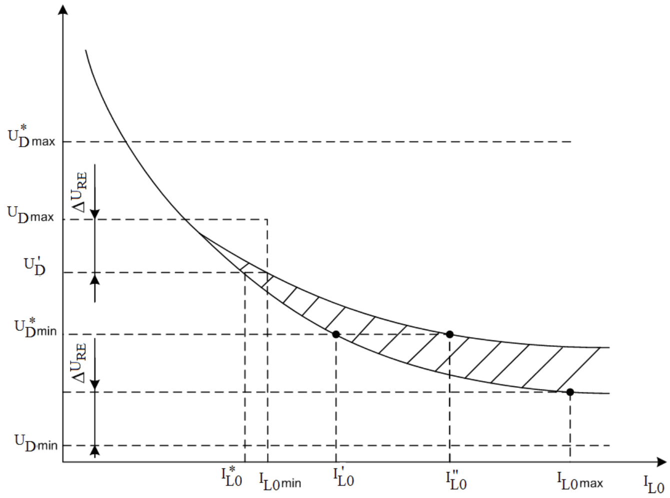

Fig.1. Single-circuit and double-circuit regulating apparatus

The mutual involvement of the input and output parameters, the influence of the destabilizing factors and the control modes can be traced in Fig.2.

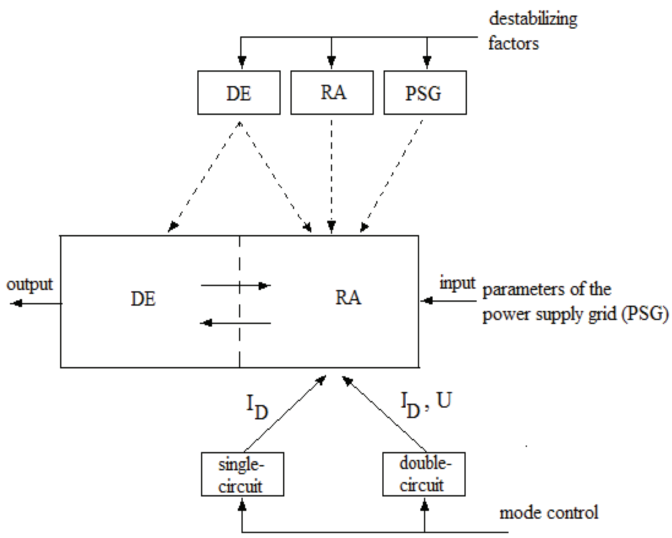

Fig.2. System "regulating apparatus (RA) -discharge element (DE)" – input/output parameters, destabilizing factors, control modes

The purpose of the present work is conducting of comparative analysis with regard to the current stabilization coefficientof the load (discharge current) and dissipated power by the regulating element and efficiency coefficient.

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II. Analysis

In Figs.3 and 4 are shown the block diagrams of a SCRA and a DCRA, where:

- DCVS is a DC voltage source which supplies regulating elements connected in series with the RE of the CS and the DE. DCSV also includes sections for providing of the starting mode.
- DE is a discharge element.
- U_m and ΔU_m - the amplitude value and its change of the input supply voltage.
- U_{S0} and ΔU_{S0} - the constant component and its change of the output voltage of DCVS. $U_{S0} = U_{RE} + U_{DE}$, where U_{RE} is the voltage applied over the regulating element and U_{DE} – over the discharge element.
- I_{L0} and ΔI_{L0} – value of the constant component of the discharge current and its change.
- R_{LS} and ΔR_{LS} – static resistance of the load (DE) and its change.

The analysis is performed with the following assumptions:

1. For the specified structures of RA destabilizing factors are the quantities U_m and R_{LS}, and the stabilizing quantity is I_{L0}.
2. DC1RA realizes the law ΔU_{S0}=const, and DC2RA – ΔU_{RE}=const.
3. The coefficient of stabilization K_{ST} can be defined by Eq. (1):

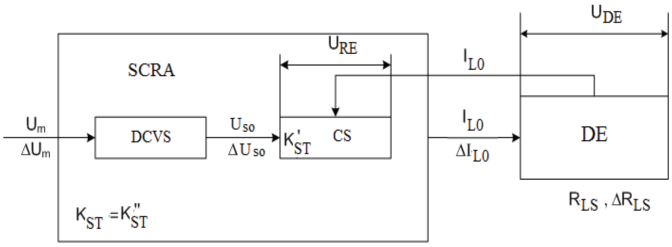

Fig.3 Block diagram of SCRA

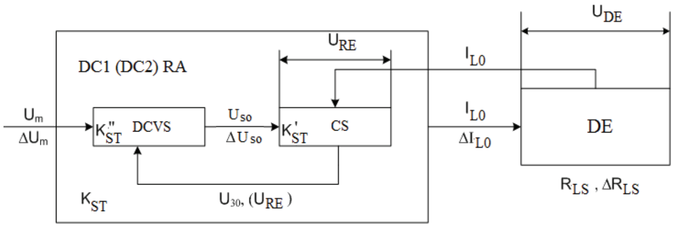

Fig.4 Block diagram of DCRA

$$K_{ST} = \frac{\Delta x}{x}.\frac{y}{\Delta y} \tag{1}$$

In the pointed expression x is a destabilizing factor and y is the stabilized quantity.

For the examined RA can be defined a stabilization coefficient with regard to the voltage K_{STU} and a coefficient with regard to the resistance K_{STR}, defined at different cases as follows:

- For SCRA:

$$K_{STU} = \frac{\Delta U_m}{U_m}.\frac{I_{LO}}{\Delta I_{LO}} = \frac{\Delta U_{S0}}{U_{S0}}.\frac{I_{LO}}{\Delta I_{L0}} \tag{2}$$

- For DC1RA:

$$K'_{STU} = \frac{\Delta U_{30}}{U_{30}}.\frac{I_{L0}}{\Delta I_{L0}}$$
$$K''_{STU} = \frac{\Delta U_m}{U_m}.\frac{U_{S0}}{\Delta U_{S0}} \qquad K_{STU} = K'_{STU}.K''_{STU} \tag{3}$$
$$K_{STU} = \frac{\Delta U_m}{U_m}.\frac{I_{L0}}{\Delta I_{L0}}$$

- For DC2RA:

$$K'_{STU} = \frac{\Delta U_{S0}}{U_{S0}}.\frac{I_{L0}}{\Delta I_{L0}} \qquad K_{STU} = K'_{STU}.K''_{STU}.A$$
$$K''_{STU} = \frac{\Delta U_m}{U_m}.\frac{U_{RE}}{\Delta U_{RE}} \qquad A = \frac{\Delta U_{RE}}{U_{RE}}.\frac{U_{S0}}{\Delta U_{S0}} \tag{4}$$
$$K_{STU} = \frac{\Delta U_m}{U_m}.\frac{I_{L0}}{\Delta I_{L0}}$$

For the three considered RA - $K_{STR} = \frac{\Delta R_{LS}}{R_{LS}}.\frac{I_{LO}}{\Delta I_{LO}}$.

From Eq.(2), Eq.(3) and Eq.(4) it follows that DCRA provides significantly higher K_{STU} than SCRA. The character of the feedback in the controllable rectifier which influences over K''_{STU} leads to a different magnitude of $K_{STU}$for the two types of DCRA. For them $U_{S0} = U_{RE} + I_{L0}R_{LS}$. Assuming that U_{RE}, I_{L0} and R_{LS} are independent variables, for ΔU_{30} is valid Eq.(5):

$$\Delta U_{S0} = \Delta U_{RE} + \Delta I_{L0}R_{LS} + \Delta R_{LS}I_{L0} \tag{5}$$

After transforming Eq.(4) and Eq.(5) for DC2RA, K_{STU} can be defined by Eq.(6).

$$K_{STU} = K'_{STU}.K''_{STU}.\frac{U_{S0}}{U_{RE}}\left(\frac{\Delta I_{L0}}{\Delta U_{RE}}R_{LS} + \frac{\Delta R_{LS}}{\Delta U_{RE}}I_{L0} + 1\right)^{-1} \tag{6}$$

From Eq.(6) and Eq.(7) it follows that with respect to K_{STU} the choice of DC1RA is advisable since the inequality (Eq.(7)) is always in force:

$$\frac{U_{S0}}{U_{RE}}\left(\frac{\Delta I_{L0}}{\Delta U_{RE}}R_{LS}+\frac{\Delta R_{LS}}{\Delta U_{RE}}I_{L0}+1\right)^{-1}=A<1 \qquad (7)$$

For typical values of I_{L0}, ΔI_{LO}, U_{RE}, ΔU_{RE} and R_{LS} – A=0,2÷0,4.

Hence:

$$K_{STR-SCRA}=K_{STR-DC1RA}=K_{STR-DC2RA}$$
$$K_{STU-SCRA}<K_{STU-DC2RA}=K_{STU-DC1RA}$$

In Figs.5 and 6 are presented respectively $P_{RE}=P_{RE}(I_{L0})$ and $P_{DE}=P_{DE}(I_{L0})$; $\eta=\eta(I_{L0})$ for:

- Curve 1 – DC2RA, controllable rectifier (U_{RE}=600 V);
- Curve 2 – DC2RA, step AC regulator which limits the change of U_{RE} - 600÷2000 V;
- Curve 3 – DC1RA – step AC regulator which limits; $\Delta U_{S0}/U_{S0}$ in the range up to 5%;
- Curve 4 – SCRA;
- Curve 5 – $P_{DE}=P_{DE}(I_{L0})$;

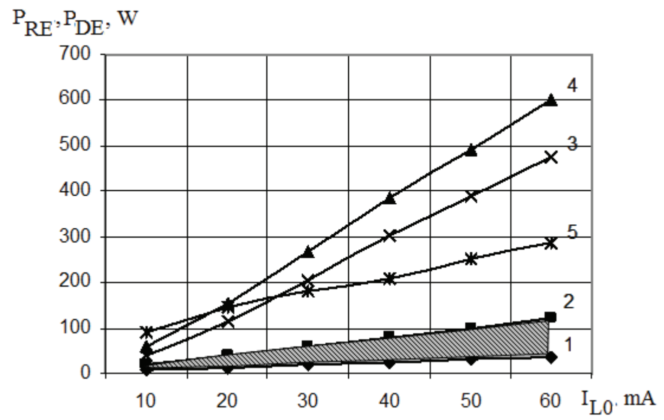

Fig.5.

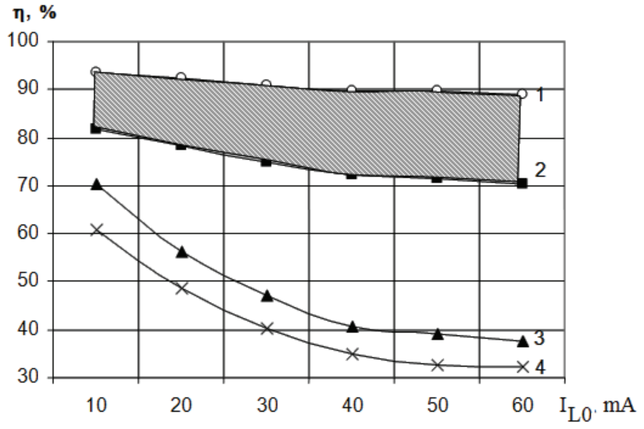

Fig.6.

III. Conclusion

The DCRA for discharge elements with comparison to the SCRA provides increased stabilization coefficient of the discharge current only with respect to the change of the input supply voltage. This coefficient quantitatively depends on the character of the feedback of the controllable rectifier.

The choice of DC1RA and DC2RAis a matter of compromise. DC1RA ensures a higher stabilization coefficient of the discharge current related to the change of the input supply voltage but a lower efficiency coefficient and higher dissipated power of the regulating element and vice versa.

The realization of the second control circuit with a controllable rectifier or a step AC regulator also is a question of compromise. The controllable rectifier gives a better efficiency coefficient and lower dissipated power of the regulating element, yet worse power factor and higher level of electromagnetic interference and vice versa.

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