Application of design methods for precision energy supply systems in the educational process using information technology

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Abstract. Teaching electrical engineering disciplines in technical universities involves the use of information technology in modeling processes in electrical circuits and in organizing the educational process. The main problem of the existing automated training systems for technical universities is their low didactic efficiency. This paper presents the application of a training system that takes into account the psycho-factors of the participants in the educational process and the personal characteristics of students. The initial data for the operation of the automated system is information about the fundamental pedagogical concepts and information reflecting the personal characteristics of the participants in the educational process. The color design of the means of visual display of information blocks on monitors is tuned in accordance with the user's psychotype. The proposed automated training system contains a set of training electronic devices with interchangeable functional units, which, based on the results of testing academic training and testing personal characteristics, are offered to students for design and stage-by-stage modeling. The paper shows the design of a precision DC voltage stabilization system. This study proposes technical solutions that implement the principles of the combined use of negative and positive feedback circuits. In the proposed technical implementation of the device, a method is proposed for fully compensating for the instability of the stabilizer output voltage when the load current changes from zero to the nominal value.

1 Introduction

The study of electrical disciplines in technical universities is not complete without the use of new information technologies. Information technologies are used not only in modeling processes in electrical circuits, but also in automating the learning process itself using information training systems. When building informational training systems, a negative trend is to automate only the subject area of the studied technical discipline. With this approach, the system does not take into account modern pedagogical concepts and teaching methods, and therefore such software and hardware teaching tools have low didactic effectiveness. This paper presents a variant of the application of new information technologies in the educational process using automated information training systems that take into account not only academic training, but also the psycho-factors of the participants in the educational process [1, 2]. The identified psychofactors are used to implement a student-centered approach in teaching, and at the same time, psychofactors are new additional components of the system analysis of pedagogical situations.

Software and hardware learning tools are inherently information systems for monitoring, analyzing and managing the educational process. The database of information systems contain information resources for both students and teachers.

A feature of the proposed educational information system is the ability to quickly adjust the forms of presentation of educational material in accordance with the identified personal characteristics of the student.

In this paper, we consider a variant of designing a powerful precision system of stabilized power supply using virtual models of training devices that are part of the training system.

The functioning of the training system is shown on the example of the use of a precision DC voltage stabilizer included in its training virtual training device, made according to the author's patent KG 2029 [3].

Stage-by-stage calculation of the ratings of the electronic components of the stabilizer is given by us in [4], therefore, we will consider only the functioning of the system and the main features of technical solutions.

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The relevance of designing powerful precision power supply systems is as follows.

The increase in the functional complexity of new electronic devices for monitoring power supply systems during their creation implies an increase in the requirements for the quality and stability of stabilized power sources. Conducting experimental scientific work in the design of devices for monitoring and controlling power supply processes increases the requirements for stability and accuracy of the supply voltage parameters by dozens of times.

Industrially produced DC voltage stabilization systems, in terms of their characteristics, are quite consistent with the requirements of standard devices during their operation, but when designing such devices, developers need precision power supply systems.

Modern industrially produced stabilized power systems have an instability coefficient of at least 1%, but during the experimental development of new systems, sometimes the required stabilization accuracy can exceed 0.01%.

Due to the high requirements for the weight and size indicators of the power supply system, when creating electronic devices, pulsed power supply systems are mainly used. But if the designed power supply system has high requirements for the stability of the output voltage, for ripples, for radiated interference, linear stabilized power systems are widely used [5].

In addition to being used in precision power supply systems, linear DC voltage stabilization systems are now widely used in the construction of two-stage DC power supply systems [6]. In such systems, linear regulators with a low voltage drop (LDO - low dropout) at the output stage are used as the second stage [7]. But industrially produced integrated LDO stabilizers are produced for small load currents up to 5 A and for scientific research have a low stabilization coefficient of the order of 1%. In this regard, there is a need to design both precision reference voltage sources and powerful stabilized power supply systems..

2 Experimental research and results

In the process of designing an automated learning system, a synergistic approach was used to formalize educational components.

When formalized, the automated educational environment is a synergistic ergatic model "student - electronic educational tools". Memory is chosen as the "order parameter" of a self-organizing ergatic system. The description of the ergatic model with memory can be described by the following equation [8].

$$\frac{dY_T(t)}{dt} + X_T Y_T(t - \tau_T) = P_T$$

where: Y_T (t) – parameter of the state of the training system;

X_T – parameter coefficient of knowledge perception;

t – time;

τ_T – delay parameter;

P_T – portion of knowledge.

When automating the components of the educational process, the functioning algorithms of the proposed learning system reflect modern theories and concepts of learning. The educational system in its composition contains a module for psycho-diagnostics of the qualities of the participants in the educational process.

The automated training system considered in this paper includes virtual models of real electronic devices used as training devices.

The training system and all training electronic devices are protected by invention patents. Each training device has a main base part and a set of duplicate functional modules of varying complexity.

The educational information system, in accordance with the preliminary testing of the student's academic preparation and his personal characteristics, corrects the complexity of the designed device presented for study and provides him with modules of the appropriate complexity for designing.

The visual display system of the educational system, in accordance with the student's psychotype, adjusts the color representation of information blocks on the monitor screen, since choleric, sanguine and melancholic people react differently to the color display on the monitor screen.

In this case, the student is tasked with calculating the parameters of the components of a precision linear stabilization system with an output voltage of 12 V, 50 A with an instability coefficient for load current no worse than 0.001%.

To create a power supply system with a stabilization accuracy of 0.001% when the load current changes from zero to the nominal value, a precision reference voltage source is required [9, 10, 11]. Integrated reference voltage modules cannot provide such accuracy. In the proposed technical solution, the reference voltage source is made according to the scheme of two back-to-back current stabilizers (see Fig. 1).

The main precision zener diode D2 is powered by a back-to-back current regulator on the transistor VT2. In turn, the reference zener diode of the current stabilizer on the transistor VT2 is powered by the current stabilizer on the transistor VT1. Therefore, when supplying the reference zener diode D2 with a stable current, the internal resistance of the main reference zener diode has practically no effect on the value of the output reference voltage.

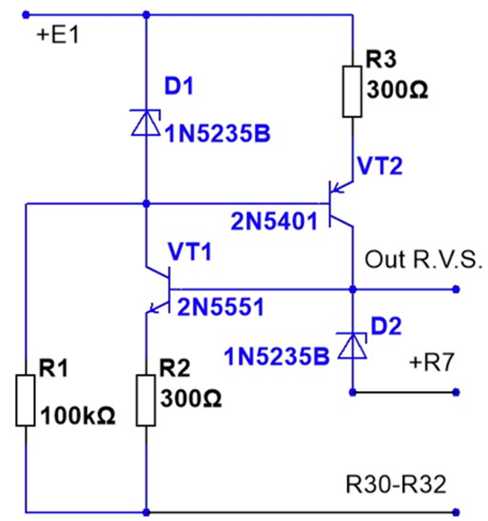

Fig. 1. Reference voltage source

To achieve the stability of the output DC voltage of the stabilizer, as a rule, the gain of the mismatch amplifier of the error signal is increased. But a significant increase in the gain of the error signal mismatch amplifier leads the power supply system to parasitic generation.

In this circuit solution, in order to significantly increase the stabilization factor with changes in the load current, in addition to circuits with negative feedback, circuits with positive feedback are used. To do this, a current sensor is inserted between the negative terminal of the main reference zener diode and the common wire of the voltage stabilizer - a low-resistance resistance R7, through which the load current passes (see Fig. 4). In this technical solution, at a load current of 50 A, the resistance value of the current sensor R7 is 0.01 mOhm. When the load current flows through the current sensor R7, a voltage drop is created on it, which is added to the reference voltage and is fed to the input of the mismatch amplifier (see Fig. 2).

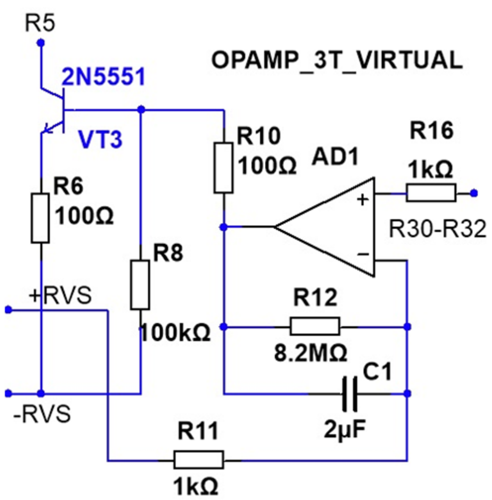

Fig. 2. Error amplifier

When debugging the stabilizer, by adjusting the resistance of the current sensor R7, you can completely compensate for the change in the output voltage of the stabilizer when the load current changes from zero to the nominal value.

The mismatch amplifier of the error signal in this technical solution is made on the operational amplifier AD1 and the matching transistor VT3.

The gain of the mismatch amplifier is set by resistors R10 and R12. The error signal from the output voltage divider is applied to the non-inverting input of the operational amplifier AD1, and the reference voltage is applied to the inverting input AD1. The mismatch signal isolated by the operational amplifier is compared with the reference voltage and the corrective signal is fed from the collector of the transistor VT3 through the resistor R5 to the base of the pre-terminal stage VT4 (see Fig. 2 and Fig. 3).

The final control stage is made according to the scheme of a composite stage with current-equalizing emitter resistors (see Fig. 3). At a load current of 50 A, the composite cascade includes 5 2SC5200 transistors.

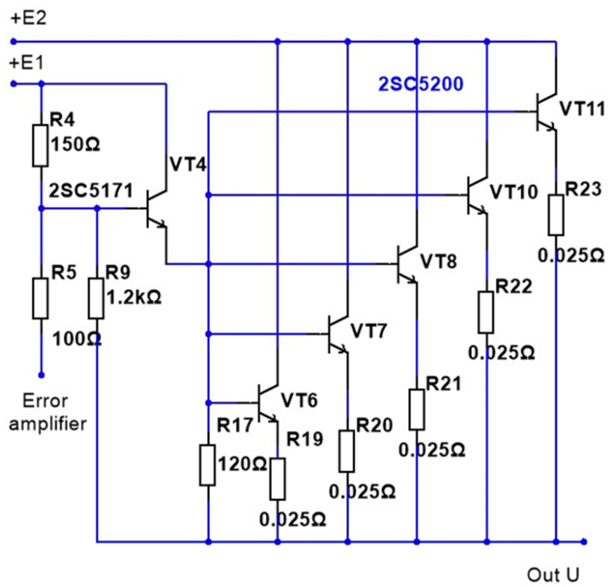

Fig. 3. Output control stage

In order to reduce losses on equalizing emitter resistances, their nominal value is reduced to 0.025 Ohm. At a load current of 50 A, a current of 10 A will flow through each transistor. At a current of 10 A, the voltage drop across the equalizing resistors will be 0.25 V, which is a quarter of the opening operating voltage at the bases of the transistors of the composite cascade. Such a voltage drop is quite sufficient for accurate equalization of the currents of the composite output control stage [12].

In order to reduce losses during power dissipation in the composite control stage, an additional low-voltage voltage boost source E1 is introduced into the circuit, which is connected in series with the main power source E2 (see Fig. 4).

The final output control stage is powered by the main power supply E2, while the reference voltage source and the final stage are powered by the sum of the two voltages of the sources E1 and E2. Such a circuit solution allows you to open the transistors of the output composite stage to saturation and increase the stabilization range with a decrease in the input supply voltage.

On fig. 4 shows a general block diagram of a precision DC voltage regulator.

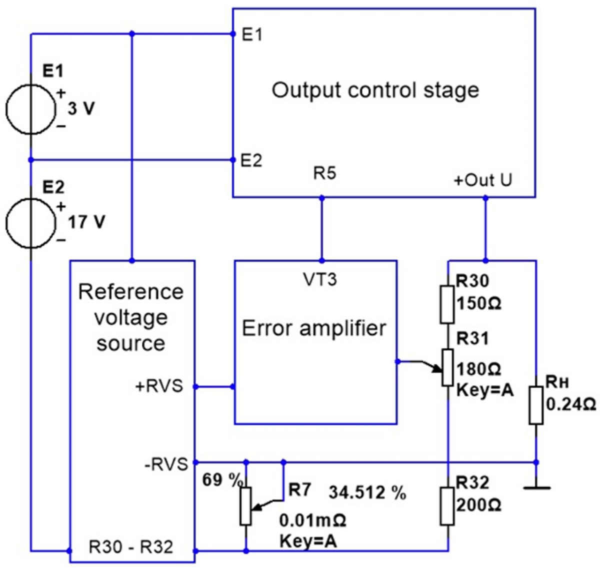

Fig. 4. Precision voltage regulator

If a student is offered to design a voltage regulator for 12 V and 8 A with a stability of 1%, then the student does not need to use a precision reference voltage source on two counter-connected current stabilizers. In this case, it will be sufficient to use a parametric stabilizer circuit on a single precision zener diode as a reference voltage source (see Fig. 5 b).

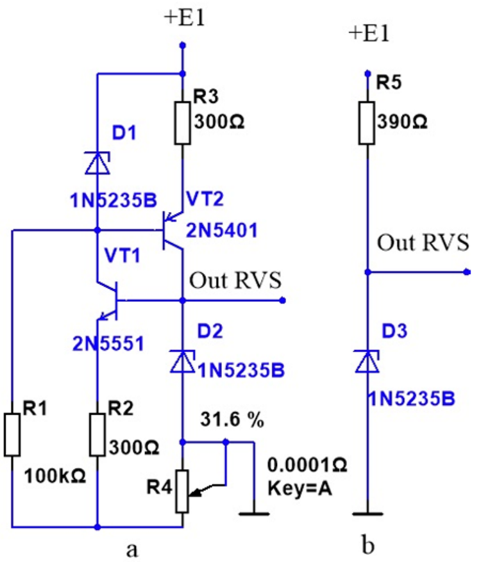

Fig. 5. Precision reference voltage source (a) and simple reference voltage source (b)

When designing a stabilizer for 12 V and 8 A as an output control stage at a load current of 8 A, a composite stage is not required. In this case, a cascade on one 2SC5200 transistor will be enough (see Fig. 6a), and in the case of a load current of 0.2 A, there will be no need for a pre-terminal cascade and one 2SC5171 transistor will be enough as a final control cascade (see Fig. 6 b).

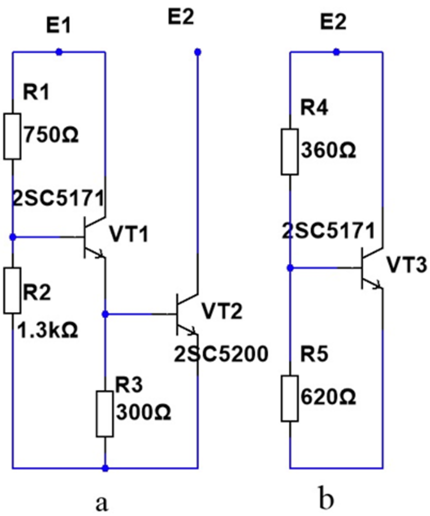

Fig. 6. Output control stage 8 A (a) and output control stage 0.2 A (a)

3 Conclusion

1. The use of negative and positive feedback circuits in the design of stabilized power supply systems makes it possible to fully compensate for the dependence of the stabilizer output voltage on changes in load current.
2. The designed information training systems in their functioning algorithms must contain the fundamental concepts and teaching methods, as well as modules for psychodiagnostics of participants in the educational process.
3. The identified psychofactors of participants in the educational process can be used as new elements of system analysis in solving pedagogical situations.
4. When formalizing the educational components of automated systems, synergistic ergatic models are the most effective.
5. In order to increase the effectiveness of the presentation of educational material, the means of visual display of information blocks on monitors, teaching systems must have the function of color alignment with the student's personal characteristics.

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