Contents

AUTHOR'S FOREWORD v

NOTATION xiii

INTRODUCTION xvii

1. FUNDAMENTAL CONCEPTS OF THE THEORY OF RELIABILITY 1
   - 1.1 Reliability 1
   - 1.2 Failure 6
   - 1.3 Criteria of Reliability. Characteristics of Reliability 8
   - 1.4 Storageability 9
   - 1.5 Maintainability 11
   - 1.6 Service Life 13
   - 1.7 Redundancy 13
   - 1.8 Component of Reliability Calculation 14
   - 1.9 Standby Redundancy 15

2. QUANTITATIVE CHARACTERISTICS OF RELIABILITY 22
   - 2.1 General Comments 22
   - 2.2 Probability of Failure-Free Operation 24
   - 2.3 Failure Rate. Mean Failure Rate 27
   - 2.4 Intensity of Failures 35
   - 2.5 Mean Time of Failure-Free Operation. Mean Time Between Adjacent Failures 38
   - 2.6 Reliability Factors 47
   - 2.7 Coefficients Which Take into Account the Forced Down Time of Equipment 48
   - 2.8 The Rate of Preventive Maintenance 52
   - 2.9 Coefficients Which Characterize the Effect of Components on the Reliability of Equipment 53
   - 2.10 Coefficient of the Cost of Operation 63
   - 2.11 The Flows of Failures 64
   - 2.12 Laws of Distribution of the Time Intervals Between Failures 73

2.13 Quantitative Characteristics of Reliability for Different Laws of Distribution of the Times of Occurrence of Failures 74
2.14 Quantitative Characteristics of Reliability of Equipment for Different Purposes 96

3. RELIABILITY OF COMPONENTS 99
3.1 Quantitative Reliability Characteristics of Components 99
3.2 Effect of the Reliability of Components on the Reliability of an Automatic System 102
3.3 Types of Failures. Effect of Operating Conditions on the Quantitative Reliability Characteristics of Components 109

4. CALCULATION OF RELIABILITY FOR MAIN COUPLING OF COMPONENTS 130
4.1 General Comments 130
4.2 Calculation of Reliability for Sudden Failures 131
4.3 The Coefficient Method of Calculating Reliability 144
4.4 Taking into Account the Burn-in Period 153
4.5 Calculation of Reliability in the Case of Gradual Failures 154
4.6 Calculation of Reliability in the Presence of Gradual Failures According to Deviations of the Transfer Function 161
4.7 The Matrix Method of Calculating Reliability 164
4.8 Method of Calculation of Reliability Which Takes into Account Variation of the Parameters of Components 171
4.9 The Spectral Method of Calculation of Reliability 174

5. RELIABILITY ANALYSIS FOR CONSTANTLY CONNECTED STANDBYS 181
5.1 Fundamental Quantitative Reliability Characteristics for Constantly Connected Standbys 181
5.2 Reliability Coefficients in the Case of Constantly Connected Standbys 196
5.3 Gain in Reliability in the Case of Constantly Connected Standbys 204
5.4 Effects of Switching Devices on the Quality of Standby Redundancy with Constantly Connected Standbys 215
5.5 Probability of Failure-Free Operation and Failure Probability of a System in the Case of Standby Redundancy by Replacement 227
5.6 Fundamental Quantitative Characteristics in the Case of Exponential Law of Reliability and "Cold" Standbys 235
5.7 Fundamental Quantitative Characteristics in the Case of Exponential Law of Reliability and "Tepid" Standbys 243
5.8 Coefficients of Reliability in the Case of Standby Redundancy by Replacement 251
5.9 The Gain in Reliability in the Case of Standby Redundancy by Replacement 253

5.10 Effect of Switching Devices on the Quality of Standby Redundancy by Replacement 261

6. RELIABILITY ANALYSIS OF SYSTEMS IN THE CASE OF BY-COMPONENT (SEPARATE) STANDBY REDUNDANCY 269

6.1 Fundamental Quantitative Characteristics of Reliability in the Case of Constantly Connected Standbys 269
6.2 Gain in Reliability in the Case of Constantly Connected Standbys 287
6.3 Effect of Open Circuits and Short Circuits on the Quality of Standby Redundancy 295
6.4 Fundamental Quantitative Reliability Characteristics in the Case of By-Component Standby Redundancy by Replacement 309
6.5 Gain in Reliability in the Case of By-Component Standby Redundancy by Replacement 313
6.6 Effect of Switching Devices on the Quality on Standby Redundancy by Replacement 318

7. RELIABILITY ANALYSIS OF SYSTEMS IN THE CASE OF STANDBY REDUNDANCY WITH FRACTIONAL MULTIPLICITY 323

7.1 Quantitative Characteristics of Reliability in the Case of Constantly Connected Standbys 323
7.2 Gain in Reliability in the Case of Constantly Connected Standbys 330
7.3 Effect of Switching Devices on the Quality of Standby Redundancy with Fractional Multiplicity 334
7.4 Reliability Analysis in the Case of "Cold" Sliding Standbys 340
7.5 Gain in Reliability in the Case of "Cold" Sliding Standbys 349
7.6 Reliability Analysis of a System with Standby Redundancy and with Automatic Failure Locators 351
7.7 Combining General and Separate Standby Redundancy 359
7.8 Optimal Standby Redundancy 361
7.9 Application of "The Process of Pure Multiplication" for the Investigation of Standby Redundancy 366

8. METHODS OF INCREASING THE RELIABILITY OF COMPLEX SYSTEMS 373

8.1 Requirements Imposed on the Reliability of Complex Systems 373
8.2 Methods of Increasing the Reliability of Complex Systems 379
8.3 Standby Redundancy as a Means of Increasing Reliability 382
8.4 Decreasing the Failure Intensity of a System 387
8.5 Shortening of Time of Continuous Operation 397
8.6 Decreasing Mean Repair Time 399
8.7 Comparison of Different Methods of Increasing Reliability 400
8.8 Examples 409

APPENDIX 1. Tables of the Probability Integral and the Reduced Laplace Function 417

APPENDIX 2. Failure Intensity of Components 421

APPENDIX 3. Correction Coefficients for Failure Intensity of Components 438

APPENDIX 4. Table of the Gamma Function 445

APPENDIX 5. Table of the Exponential Function 446

REFERENCES 451

INDEX 457