

Contents

Contents	v
List of Tables.....	xiv
List of Figures.....	xv
Foreword	xvi
About this Guide	1
Aim	1
Scope.....	2
Why this Guide is Important	2
Revised Second Edition 2007	3
Revised Third Edition, 2013.....	3
Revised Fourth Edition, 2024.....	3
Relationship between EEMUA 191 and EEMUA 201	3
Acknowledgements.....	4
Quick overview	4
1 Introduction.....	8
1.1 What is an alarm?	8
1.2 What is an alarm system?	8
1.3 Why is alarm design important?.....	9
1.4 Key design principles.....	10
1.5 Practical and organizational issues	12
1.5.1 General approach – PDCA.....	12
1.5.2 Resources required	13
1.5.3 Alarm philosophy	13
1.5.4 Project lifecycle	13
1.5.5 Alarm system lifecycle (IEC 62682).....	14
1.5.6 Alarm database	16
1.5.7 Operator response to alarms.....	16
1.5.8 Fostering a culture of improvement.....	17
1.6 Using this guide.....	17
1.7 Supporting documents.....	18

2 Principles of alarm system design.....	19
2.1 Design goals and objectives.....	19
2.1.1 Human / user centred design.....	19
2.1.2 The role of the operator	20
2.1.3 The type of process	21
2.1.4 Designing for operability.....	23
2.2 Alarm system design.....	24
2.2.1 Hierarchy of risk control	24
2.2.2 Alarm system hardware and software	24
2.2.3 Designing individual alarms	26
2.2.4 When is it appropriate to provide an alarm?.....	26
2.3 Similar, non-alarm functions.....	27
2.3.1 Alerts	27
2.3.2 Events	28
2.3.3 Prompts.....	28
2.3.4 Non-alarms	29
2.4 Alarm classification	29
2.5 Highly Managed Alarm (HMA)	30
2.5.1 Types of HMA	30
2.5.2 Protective layer alarms.....	31
2.5.3 HMA management	32
2.6 Summary of alarms, alerts, events and prompts.....	33
2.7 Risk management.....	33
2.7.1 The need to identify and control risks	33
2.7.2 Risk reduction using alarms	34
2.7.3 Taking credit for alarms	35
2.7.4 Operator response times.....	36
2.7.5 Alarm systems contribute to controlling risks.....	37
3 Practical considerations for alarm design	38
3.1 Generation of alarms.....	38
3.1.1 Types of alarm.....	38
3.1.2 First-up alarms	39
3.1.3 The selection of alarm settings	40
3.1.4 Alarm settings by recipe	42
3.2 Field derivation of alarms	43
3.2.1 Challenges with switch type sensors	44
3.2.2 Measurement of actuator position	45
3.2.3 Location of sensors.....	45
3.2.4 Analogue sensor range	45
3.2.5 Reliability.....	46

3.3	Alarm processing hardware	46
3.3.1	BPCS processing of alarms.....	46
3.3.2	High integrity alarm systems.....	47
3.3.3	Combined BPCS and safety systems.....	47
3.3.4	Dedicated alarm systems	47
3.3.5	Reliability issues	48
3.3.6	Functionality.....	49
3.3.7	Environmental requirements.....	49
3.3.8	Validation of measurements	50
3.3.9	Signal transmission	50
3.4	Alarm design for unoccupied and remote control rooms	51
3.4.1	Getting information to remote operations.....	51
3.4.2	Alarm management in geographically distributed plant.....	52
3.4.3	The role of field personnel in handling alarms	53
3.4.4	Telemetry issues	54
3.4.5	Getting information to remote resources.....	55
3.5	Alarm identification	56
3.5.1	Alarm Tag numbers	56
3.5.2	Alarm messages.....	56
4	Implementing an alarm management system.....	57
4.1	Corporate and local arrangements.....	57
4.1.1	Corporate considerations.....	57
4.1.2	Local requirements and considerations	58
4.1.3	Corporate and local documents required	58
4.2	Alarm systems management organization	59
4.2.1	Leadership	59
4.2.2	Coordination.....	59
4.2.3	Alarm steering committee.....	60
4.3	Competence	60
4.3.1	Operator competence	60
4.3.2	Supervisors	61
4.3.3	Control and instrument technicians	61
4.3.4	Plant managers	61
4.3.5	Alarm coordinators	62
4.3.6	Human factors engineers.....	62
4.3.7	Non-technical skills	62
4.4	Alarm philosophy document	62
4.4.1	Requirements for different stages of a plant lifecycle	62
4.4.2	Mandatory requirements	63
4.4.3	Additional content	63
4.5	Testing of alarms	64

4.6	Operating with degraded systems	64
4.7	Determining how well alarms are managed.....	65
5	Alarm communication and HMI Design	66
5.1	Human factors	66
5.1.1	Human factors theory in relation to alarms.....	66
5.1.2	Human factors in practice.....	67
5.2	Display options.....	68
5.2.1	Alarm annunciator panels.....	69
5.2.2	Alarm list displays	70
5.2.3	Graphically embedded alarm objects.....	71
5.3	Making sure alarms are noticed.....	72
5.3.1	Audible indications.....	72
5.3.2	Visual indications	73
5.3.3	Alarm priority markers.....	73
5.4	Alerts, events and prompts	73
5.5	Design of alarm lists.....	74
5.5.1	Alarm states.....	74
5.5.2	Content of alarm entry	75
5.5.3	Positioning of new alarms on the list	76
5.5.4	Alarm acceptance.....	77
5.5.5	Movement through the list.....	77
5.5.6	Display filtering	77
5.5.7	On screen alarm response definitions	78
5.6	Displaying HMAs	78
5.7	Shelved and suppressed alarms	78
5.8	The full alarm list.....	79
6	Practical considerations for alarm system management	80
6.1	Maximising usefulness of alarms	80
6.1.1	Prioritisation.....	81
6.1.2	Special consideration for distributed plant.....	82
6.1.3	Minimising unnecessary and nuisance alarms	83
6.1.4	Avoiding alarm floods.....	84
6.1.5	Logical processing of alarms	84
6.1.6	Alarms generated by phase logic or procedure (batch process)	85
6.2	Grouping alarms.....	86
6.3	Alarm suppression.....	86
6.3.1	Bulk suppression.....	87
6.3.2	Logical suppression.....	87
6.3.3	Implementation of suppression.....	88
6.3.3.1	Specific example of bulk alarm suppression – condition equation	90
6.3.3.2	Specific examples of logical suppression.....	90
6.3.4	Authorisation and control	91

6.4	Avoiding repeating alarms	91
6.4.1	Why repeating alarms occur	91
6.4.2	Engineering of signals to minimise noise	92
6.4.3	Filtering	92
6.4.4	Transient suppression	93
6.4.5	Deadband	93
6.4.6	De-bounce timer	94
6.4.7	Counter	95
6.4.8	Single line annunciation	95
6.4.9	Logging of repeating alarms	96
6.4.10	Threshold setting	96
6.5	Alarm shelving	97
6.5.1	Circumstances when shelving is allowable	97
6.5.2	Release ('One-shot' shelving)	98
6.5.3	Alarms from equipment under test	98
6.6	Automatic alarm load shedding	99
6.7	Improving alarms and alarm systems	99
6.7.1	Improving individual alarms (bad actors)	100
6.7.2	Rationalisation to ensure the alarm system is properly configured	100
6.7.3	System replacement	102
6.7.4	General guidance for improving alarms	102
7	Performance monitoring and improvement	104
7.1	Introduction	104
7.2	Measuring what is important	105
7.3	Metrics applied during design	105
7.3.1	Metrics for HMAs	106
7.3.2	Priorities of alarms configured	106
7.3.3	Avoiding standing alarms	106
7.3.4	Performance data generation	107
7.4	Optimizing human Performance Influencing Factors (PIF)	107
7.4.1	Workload and time availability during steady state operation	107
7.4.2	Workload and time availability for non-routine and abnormal operations	107
7.4.3	Clarity of information provided by alarms	107
7.4.4	Benchmark for standing alarms	109
7.4.5	Key Performance Indicators (KPI)	109
7.4.6	Operations reporting and feedback	111
7.4.7	Alarm analysis tools	111
7.4.8	Summary of performance metrics	112
7.4.9	Alarm systems states (robust, stable, reactive, overloaded)	112
7.5	Alarm system audits	119

8 Management of change and projects 120

8.1 Management of change	120
8.1.1 Minor changes.....	121
8.1.2 Significant changes	121
8.1.3 Major projects.....	122
8.1.4 Implementing changes.....	122
8.1.5 Deleting alarms.....	122
8.2 Business case and justifying investment	123
8.2.1 Process improvements.....	123
8.2.2 Standardisation and consistency.....	125
8.2.3 Improved operator performance.....	125
8.2.4 Easier training.....	125
8.2.5 Improved security and resilience.....	125
8.2.6 The cost of alarm performance.....	125

Appendix 1 – The costs of poor alarm performance 126

A1.1 Accident summaries.....	126
A1.1.1 Milford Haven refinery.....	126
A1.1.2 Longford gas explosion.....	126
A1.1.3 BP Texas City refinery	126
A1.1.4 Buncefield Oil storage depot.....	127
A1.1.5 Enbridge Incorporated pipeline rupture	127
A1.1.6 Columbia gas pipeline rupture	127
A1.1.7 Pryor Trust well blowout.....	128
A1.1.8 BP-Husky.....	128
A1.2 Costs of poor alarm system performance	128
A1.2.1 HSE alarm survey	128
A1.2.2 Abnormal Situation Management (ASM) consortium	129
A1.2.3 Refinery study.....	129

Appendix 2 – Human Factors Integration Plan (HFIP) for alarms 130

A2.1 Purpose of a HFIP	130
A2.2 Project lifecycle.....	130
A2.3 Suggested content for an alarms HFIP.....	130
A2.4 HFIP introduction	131
A2.5 Concept>Select phase	131
A2.5.1 Users and requirements	131
A2.5.2 Constraints	131
A2.5.3 Learning from experience	132
A2.5.4 Responsibilities for alarm management	132
A2.5.5 Ensuring end user involvement.....	133
A2.5.6 Draft alarm philosophy	134
A2.5.7 Basis of design.....	131

A2.6 Define phase	134
A2.6.1 Review output from Concept>Select phase	135
A2.6.2 Modes of operation	135
A2.6.3 Layers of protection	135
A2.6.4 Logical processing	135
A2.6.5 Staffing philosophy	135
A2.6.6 Human Machine Interface (HMI) design philosophy.....	136
A2.6.7 Remote and repeater systems.....	136
A2.6.8 Working environment considerations	136
A2.6.9 Training requirements and facilities	136
A2.6.10 User preference	136
A2.6.11 Conceptual design.....	137
A2.6.12 Responsibilities for human factors integration	137
A2.6.13 Basis of design.....	137
A2.7 Develop/Execute phase.....	137
A2.7.1 Review output from Define phase	138
A2.7.2 Staffing levels and team working	138
A2.7.3 Creating the final alarm database.....	138
A2.7.4 HMI design.....	139
A2.7.5 Plans for commissioning and operation.....	139
A2.7.6 Project close-out.....	139
A2.8 Operate phase.....	140

Appendix 3 – Prioritisation methods 141

A3.1 Potential severity of consequence	141
A3.2 Time to consequence	141
A3.3 Priority distribution of alarms	142
A3.4 Example methods for setting of priority	142
A3.4.1 Method 1 - Priority matrix evaluation.....	142
A3.4.2 Method 2 - Consequence based prioritisation.....	144
A3.4.3 Method 3 - Taking maximum consequence.....	144

Appendix 4 – Example alarm philosophy 147

A4.1 Purpose	147
A4.2 Definitions	147
A4.3 Roles and responsibilities.....	147
A4.4 Alarm design principles	148
A4.5 Prioritisation methods and metrics.....	148
A4.6 Alarm class definition.....	148
A4.7 Criteria for identifying Highly Managed Alarms (HMAs)	149
A4.8 Rationalization criteria to assess alarms.....	150
A4.9 Alarm documentation	150

A4.10 Alarm design guidance	150
A4.11 Human Machine Interface (HMI) design principles.....	150
A4.12 New or changed system implementation	151
A4.13 Alarm response procedure.....	151
A4.14 Training for operators, managers, designers etc.....	152
A4.15 Alarm system maintenance and testing	152
A4.16 Alarm system performance monitoring.....	152
A4.17 Management of Change (MOC).....	153
A4.18 Alarm system audit.....	153
A4.19 Coverage of non-alarms	153
Appendix 5 – Alarm rationalization procedure	154
A5.1 Introduction.....	154
A5.2 Purpose of alarm rationalization.....	154
A5.3 Scope of the study.....	154
A5.4 Establish the team.....	155
A5.5 Collect alarm data	155
A5.6 Review the alarm philosophy vs requirements.....	155
A5.7 Conduct rationalization sessions.....	155
A5.8 Document rationalization findings:	156
A5.9 Identify recommended actions.....	156
A5.10 Suggested terms of reference for a rationalization study.....	157
Appendix 6 – Usefulness questionnaire	158
A6.1 Introduction.....	158
A6.2 How many alarms are useful?	159
Appendix 7 – Operator questionnaire	161
A7.1 Introduction.....	161
Appendix 8 – Alarm Review Checklists	169
A8.1 Alarm threshold setting	169
A8.2 Checklist for a good alarm	169
A8.3 Alarm configuration information	170
A8.4 HAZOP checklist.....	171
A8.5 Alarm sensor design	172
Appendix 9 – Example alarm suppression hazard study.....	173
A9.1 Introduction.....	173
A9.2 Example	173
A9.2.1 Familiarization.....	174
A9.2.2 Review of operating modes.....	174
A9.2.3 Review of alarms to be suppressed	174

A9.2.4 Reporting	175
A9.2.5 Follow-up.....	175
Appendix 10 – Specification checklist - small system	176
A10.1 Where dedicated alarm systems are used.....	176
A10.2 Input handling.....	176
A10.3 Alarm processing.....	176
A10.4 Alarm display/output.....	177
A10.5 Environmental.....	177
Appendix 11 – Specification checklist - large system	178
A11.1 Grading of requirements.....	178
A11.2 Input handling.....	178
A11.3 Processing of Alarms	179
A11.4 Display of Alarms	180
A11.5 Logging of Alarms.....	181
A11.6 Engineering of Alarm systems.....	182
Appendix 12 – Intelligent fault detection	183
A12.1 Pattern recognition	183
A12.2 Neural networks	184
A12.3 Fuzzy logic.....	185
A12.4 Knowledge-based reasoning.....	186
A12.5 Model-based reasoning.....	187
A12.6 Overview of intelligent fault detection methods.....	187
Appendix 13 – Glossary and abbreviations	189
Appendix 14 – References.....	195
Appendix 15 – Bibliography	198
EEMUA Publication: feedback Form.....	200
EEMUA Learning Courses	201
EEMUA Publications Catalogue	203

List of Tables

Table 1 Characteristics of a good alarm.....	12
Table 2 Alarm management lifecycle stages (IEC 62682 vs EEMUA 191).....	15
Table 3 How system size affects design and management.....	25
Table 4 Document suggestions	58
Table 5 HMI requirements for support of operators	67
Table 6 Alarm display options	68
Table 7 Alarm suppression.....	88
Table 8 Example of bulk alarm suppression.....	90
Table 9 Table of filter time constants.....	92
Table 10 Table of default deadband settings.....	94
Table 11 Table of default de-bounce timer parameters.....	95
Table 12 Checklist to assist with setting thresholds	96
Table 13 Checklist for evaluating an alarm.....	101
Table 14 Effective techniques for improving alarm systems.....	103
Table 15 Priority distribution.....	106
Table 16 Long term average alarm rate.....	107
Table 17 Major process upset alarm.....	108
Table 18 Target maximum occurrence rates of alarms of different priorities.....	108
Table 19 Standing alarms.....	109
Table 20 Summary of possible alarm metrics per operator station.....	112
Table 21 Alarm system performance metrics.....	113
Table 22 Overloaded alarm state.....	115
Table 23 Reactive alarm state	116
Table 24 Stable alarm state.....	117
Table 25 Robust alarm state	118
Table 26 Hazard Index grouping for use with an alarm priority matrix.....	143
Table 27 Time to Consequence (TTC) grouping for use with an alarm priority matrix	143
Table 28 Alarm priority guide when using an alarm priority matrix.....	143
Table 29 Priority break points for alarms.....	144
Table 30 Rules for allocation of safety, environmental and financial priority.....	146
Table 31 Example of weighting of results of usefulness questionnaires	158
Table 32 Proportion of useful alarms	160
Table 33 Alarm pattern array	184

List of Figures

Figure 1 Relationship between Basic Process Control System (BPCS), Safety Instrumented System (SIS) and alarm displays.....	9
Figure 2 PDCA applied to alarm management.....	13
Figure 3 Alarm management activities at project stages.....	14
Figure 4 Lifecycle model (taken from IEC 62682).....	14
Figure 5 Operator response to an abnormal situation	21
Figure 6 Illustration of how alarm settings can vary for batch and continuous processes.....	22
Figure 7 Identifying Alerts, Alarms and Prompts.....	29
Figure 8 Components of an HMA.....	31
Figure 9 Flowchart guide to decide selection of alarms, alerts, prompts and HMAs.....	33
Figure 10 Layer of Protection model of risk management.....	34
Figure 11 Engineered and human controls for managing risks depending on operational status.....	36
Figure 12 An effective and ineffective alarm system.....	40
Figure 13 The setting of a high alarm with an absolute setpoint.....	41
Figure 14 Example of a separate set of alarm thresholds.....	43
Figure 15 Geographically distributed processes	54
Figure 16 Example of a virtual annunciator panel.....	70
Figure 17 Alarm state transition diagram for static alarm list display.....	75
Figure 18 Example of a flowchart for allocating two levels of prioritisation	82
Figure 19 Typical approach to assigning alarms for batch processes (based on the IEC 61512/ISA S88 Batch Standard model)	85
Figure 20 Alarm suppression implementation.....	89
Figure 21 Repeating alarms generated by noise on a process signal	91
Figure 22 Transfer function of deadband.....	93
Figure 23 The elimination of repeating alarms using deadband.....	93
Figure 24 Alarm system performance	113
Figure 25 Typical plot of Key Performance Indicator.....	124
Figure 26 Productivity histogram.....	124
Figure 27 Alarm priority matrix.....	142
Figure 28 Prioritisation using maximum of individual priorities	145
Figure 29 Plant system with redundant equipment.....	183
Figure 30 A simple neural network.....	185
Figure 31 A graphical rule definition.....	186