## CONTENTS

Acknow	edgement	c
Abstract	in Thai	d
Abstract	in English	f
List of T	ables	k
List of F	igures	1
	bbreviations	0
	ER 1 Introduction	1
1.1		1
1.2	Rationale of the Study	4
1.3	Objectives of the Study	6
1.4	Scopes of the Study	6
1.5	Benefit of Study	6
1.6	Literature Reviews	6
CHAPT	ER 2 Principle and Theory	9
2.1	Power distribution System	9
	2.1.1 Loop Primary Distribution System	9
2.2	Fault in distribution system	10
	2.2.1 Three-phase Fault	12
	2.2.2 Single phase to ground fault	18
2.3	Protection in the Distribution System	20
	2.3.1 A fault occurrence in the electrical distribution system	20
	2.3.2 Components of the protection system	21
	2.3.3 Protection zone	21

	2.3.4 Case in	scope the protection zone	24
2.4	Overcurrent p	protection devices in the power distribution system	26
	2.4.1 Overcur	rrent relays	26
2.5	Contingency	Analysis	31
	2.5.1 Charact	eristics of Contingency analysis	31
	2.5.2 Outage	electricity problems	33
CHAPTEI	R 3 The Analys	is Process of Wide Area Protection	36
3.1	The analysis	process of WAP	36
	3.1.1 Start the	e process analysis in step 1	38
	3.1.2 Data co	llection of the system in step 2	38
	3.1.2.1	Data used in the analysis on the electrical system	38
	3.1.2.2	General data of EDL grid 1	41
	3.1.2.3	General data of EDL grid 2	43
	3.1.2.4	General data of EDL grid 3	46
	3.1.2.5	General data of Sisaket substation	50
	3.1.2.6	General data of Sokpakluang substation	51
	3.1.2.7	General data of Thatluang substation	53
	3.1.2.8	General data of Dongnasok substation	54
	3.1.2.9	Data of Substation in the loop network in 22 kV	56
	3.1.3 The sys	tem is analyzed by passing a script of DPL in step 3	63
	3.1.3.1	Part of the analysis tools to write DPL Script	63
	3.1.3.2	Part of the information display	64
	3.1.4 The pro	cessing analysis in step 4	65
	3.1.5 The mo	del will be analyzed fault again under 2 criteria in step 5	67
	3.1.5.1	The contingency analysis	68
	3.1.5.2	The coordination of overcurrent relay	72
	3.1.6 The che	ecking system in step 6, 7, and 8	74
CHAPTEI	R 4 The Study I	Results	75
4.1	Analysis Syst	em Results	75
	4.1.1 Results	of conditional contingency analysis	75
	4.1.1.1	Analysis system before improvement the network	76

	4.1.1.2	Contingency analysis after improvement the network	77
4.2	Result Protect	tion Zones	79
	4.2.1 The coc	ordination time in the case 3 phase fault	79
	4.2.1.1	The protection in zone 1	79
	4.2.1.2	The protection in zone 2	81
	4.2.1.3	The protection in zone 3 and zone 9	83
	4.2.1.4	The protection in zone 4	86
	4.2.1.5	The protection in zone 5	88
	4.2.1.6	The protection in zone 6	90
	4.2.1.7	The protection in zone 7	92
	4.2.1.8	The protection in zone 8	95
	4.2.1 The coc	ordination time in the case single phase to ground fault.	99
	4.2.1.1	The protection in zone 1	99
	4.2.1.2	The protection in zone 2	101
	4.2.1.3	The protection in zone 3 and zone 9	103
	4.2.1.4	The protection in zone 4	105
	4.2.1.5	The protection in zone 5	107
	4.2.1.6	The protection in zone 6	110
	4.2.1.7	The protection in zone 7	112
	4.2.1.8	The protection in zone 8	114
CHAPTER	R 5 Conclusion	s and Recommendation	119
5.1	Conclusions		119
5.2	Recommenda	tion	120
REFEREN	ICES		121
PUBLICA	TION		123
APPENDIX A		124	
APPENDIX B 1		170	
CURRICULUM VITAE		179	

## LIST OF TABLES

Table 1.1 The summary statistic of power outage [1] will be studied the scope system	3
Table 2.1 Inverse-Time OC Relays [9] characteristics	27
Table 2.2 <i>a</i> , <i>b</i> , <i>c</i> are constants [11] of the selected curve characteristics	28
Table 3.1 Technical data of transformer of EDL grid 1	42
Table 3.2 Technical data of transformer of EDL grid 2	45
Table 3.3 Technical data of transformer of EDL grid 3	48
Table 3.4 The existing data of lines that connect with seven substations	57
Table 3.5 The existing data into seven substations	57
Table 3.6 Data of lines, connection point relay, and protection devices	58
Table 3.7 The existing data of power flow load in the feeders	59
Table 3.8 Result analysis before improvement the system	68
Table 3.9 Result analysis after improvement the system	71
Table 4.1 Result of analysis before improvement the system	76
Table 4.2 Result of analysis after improvement the system	78
Table 4.3 Summarizing of coordination time in the case 3 phase fault	97
Table 4.4 Summarizing of coordination time in the case single phase to ground fault 1	117

## LIST OF FIGURES

Figure 1.1	The loop distribution system in Vientiane capital	2
Figure 1.2	Scope of study	3
Figure 1.3	The concepts of study	5
Figure 2.1	The structure of loop Electrical distribution systems	10
Figure 2.2	The symmetrical components of sequence (a), (b), and (c)	13
Figure 2.3	Three-phase fault occurrence	16
Figure 2.4	Circuit symmetrical component of sequence in three-phase fault	16
Figure 2.5	Single phase to ground fault occurrence (phase a)	18
Figure 2.6	Circuit symmetrical component of sequence in single phase to ground	
	fault (phase a)	20
Figure 2.7	Protection zone of parallel network in the single-end-fed system	22
Figure 2.8	Scope protection in direction the clockwise loop and	
	the counter-clockwise loop	23
Figure 2.9	Criteria of coordination in the clockwise loop	23
Figure 2.10	Criteria of coordination in the counter-clockwise loop	24
Figure 2.11	Case occur fault in distance from F1 to H1	24
Figure 2.12	2 Case occur fault in distance from F2 to H1	25
Figure 2.13	Case occur fault in distance from F3 to H2	25
Figure 2.14	Case occur in distance from F4 to H2	25
Figure 2.15	Case occur fault in F <sub>BUS</sub>	26
Figure 2.16	5 Characteristics of graph operate of the type relays	29
Figure 2.17	The graph shows the time dial setting of relays	30
Figure 2.18	3 Contingency definition by used PowerFactory 15.1	32
Figure 2.19	O Contingency analysis by used PowerFactory 15.1	33
Figure 2.20	Flowing of current in parallel network	33
Figure 2.21	Flowing current max in the network line 2 (CBs A open)	34

Figure 2.22 Flowing current max in the network line 2 (CBs B open)	34
Figure 2.23 Flowing current max in the network line 1 (CBs D open)	35
Figure 2.24 Flowing current max in the network line 1 (CBs C open)	35
Figure 3.1 Determines characteristics of local area protection and wide	
	36
1	30 37
	39
	40
	40 43
Figure 3.6 Single line diagram EDL grid 2 is connected with Phonethong substation	
Figure 3.7 Single line diagram EDL grid 3 is connected with Naxaythong substation	
	51
	53
	54
Figure 3.11 Single line diagram of Dongnasok substation	56
Figure 3.12 Single line diagram of defining protection zone in the seven substations	62
Figure 3.13 The modeling with DIgSILENT PowerFactory	63
Figure 3.14 The structure of the DPL	64
Figure 3.15 Contingency analysis in the conditional (N-1) export in Microsoft Excel	65
Figure 3.16 Operating time, which show in Window result of program	65
Figure 3.17 DPL command of CA in conditional (N-1)	66
Figure 3.18 Program text of CA by DPL function	66
Figure 3.19 DPL command of setting OC relay	67
Figure 3.20 Setting OC relay by program text	67
Figure 3.21 DPL command of the coordination overcurrent relay	72
Figure 3.22 The coordination of OC relay R31 and R10	73
Figure 3.23 The coordination of OC relay R9 and R32	74
Figure 4.1 Single line diagram of the distribution system	75
Figure 4.2 New single line diagram, after improvement of the distribution system	77
Figure 4.3 Overloading of contingency analysis (CA) before and after improvement	
the network	79

Figure 4.4 The coordination time of OC relay R1 and R4	80
Figure 4.5 The coordination time of OC relay R3 and R2	81
Figure 4.6 The coordination time of OC relay R5 and R8	82
Figure 4.7 The coordination time of OC relay R7 and R6	83
Figure 4.8 The coordination time of OC relay R11 and R13	85
Figure 4.9 The coordination time of OC relay R14 and R12	86
Figure 4.10 The coordination time of OC relay R31 and R10	87
Figure 4.11 The coordination time of OC relay R9 and R32	88
Figure 4.12 The coordination time of OC relay R15 and R18	89
Figure 4.13 The coordination time of OC relay R17 and R16	90
Figure 4.14 The coordination time of OC relay R21 and R24	91
Figure 4.15 The coordination time of OC relay R23 and R22	92
Figure 4.16 The coordination time of OC relay R27 and R30	94
Figure 4.17 The coordination time of OC relay R29 and R28	95
Figure 4.18 The coordination time of OC relay R19 and R26	96
Figure 4.19 The coordination time of OC relay R25 and R20	97
Figure 4.20 The coordination time of OC relay R1 and R4	100
Figure 4.21 The coordination time of OC relay R3 and R2	101
Figure 4.22 The coordination time of OC relay R5 and R8	102
Figure 4.23 The coordination time of OC relay R7 and R6	103
Figure 4.24 The coordination time of OC relay R11 and R13	104
Figure 4.25 The coordination time of OC relay R14 and R12	105
Figure 4.26 The coordination time of OC relay R31 and R10	106
Figure 4.27 The coordination time of OC relay R9 and R32	107
Figure 4.28 The coordination time of OC relay R15 and R18	109
Figure 4.29 The coordination time of OC relay R17 and R16	110
Figure 4.30 The coordination time of OC relay R21 and R24	111
Figure 4.31 The coordination time of OC relay R23 and R22	112
Figure 4.32 The coordination time of OC relay R27 and R30	113
Figure 4.33 The coordination time of OC relay R29 and R28	114
Figure 4.34 The coordination time of OC relay R19 and R26	115
Figure 4.35 The coordination time of OC relay R19 and R26	116

## LIST OF ABBREVIATIONS

А	Appear
AC	Alternating Current
ACSR	Aluminum Conductor Steel Reinforced
CA	Contingency Analysis
СТ	Current Transformer
CB	Circuit Breaker
CS	Current Setting
CTR	Current Transformer Ratio
CTI	Coordinating Time Interval
DC	Direct Current
DPL	DIgSILENT Programming Language
EDL	Electricité Du Laos
EGAT	Electricity Generating Authority of Thailand
MW	Mega Watt
MSH	Maximum Segment Hoch
OC	Over-Current
OLF	Over-Load factor
SAC	Space Aerial Cable
TD	Time Dial
TDS	Time Dial Setting
TCC	Time Current Curve
ТОР	Time-Overcurrent Plot
VT	Voltage Transformer
V	Volt
WAD	Wide Area Protection

WAP Wide Area Protection