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Selective Coordination and its impact on Low-Voltage System Design & Arc Flash

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***Abstract:** This paper focuses on total selective coordination of low voltage systems for critical facilities and based on reliability requirements. Critical facilities which include Data Centres, Health Care Facilities & Emergency Systems. It also discussed the importance of achieving total selective coordination and the impact on network design and how it is related to arc flash incident energy. It also states the National Electric Code requirements for the implementation of selective coordination based on system reliability requirements. The difficulties in achieving selectivity from Grid side and an inhouse generation side and the reliability benefits on critical facilities are discussed.*

***Keywords:** Selectivity, Dynamic Impedance, ATS, Critical Facility, NEC, Coordination, TCC, bolted fault current, Electrode configuration, Arc flash.*

I. INTRODUCTION

The paper aims to analyses the protective devices for a low voltage system and achieving total selective coordination for life safety and critical circuits. To analyses the impact in a low voltage system design such as higher frame breakers, modern trip units and impact in Arc flash incident energy and to compare the results with the initial system design.

II. SELECTIVE COORDINATION

A. NEC Selectivity Requirements

National Electric code mandates selective coordination in article NEC 700 for Emergency Systems, NEC 620 for Elevators, NEC 645 for IT Equipment's, NEC 701 for LR Standby.

NEC 100 defines selectivity as follows: "Localization of an overcurrent condition to restrict outages to the circuit or equipment affected, accomplished by the choice of overcurrent protective devices and their ratings or settings" (NFPA 70, 2017).

NEC 700 uses "system(s) overcurrent devices shall be selectively coordinated with all supply side overcurrent protective devices." As per NEC, selective coordination exempted that the devices on transformer primary and secondary devices & series equipment's are not required to coordinate.

III. SELECTIVE COORDINATION IN A TYPICAL NETWORK

Selectivity analysis conducted in a typical network shown in Fig. 4. The data considered can be reference from the single line diagram shown below.

A. Operating regions of low voltage circuit breakers

The operating regions of a circuit breaker are

1. Long time
2. Short time
3. Instantaneous

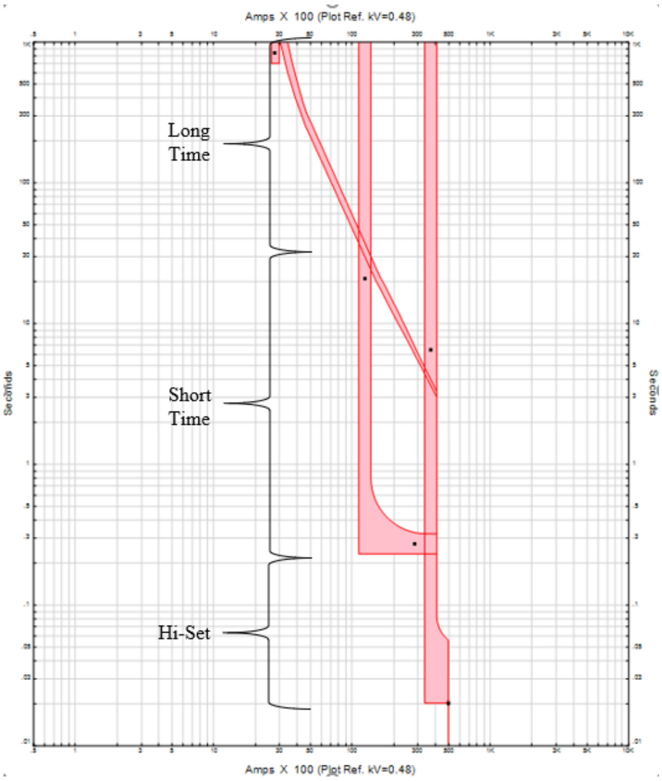

Fig. 1. Operating Regions of LVCB

The first step in the process of system protective device design is to determine the network model to perform short circuit analysis. At the same time, validate the network to meet the code requirements. The short circuit analysis calculates the actual short-circuit level at each node that needs to be evaluated. The breakers must be selected with proper voltage and continuous current rating. The WCR should be evaluated from short circuit study.

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IV. INITIAL SYSTEM DESIGN & COORDINATION CURVE

Low voltage network is shown in Fig. 2. Fault analysis is used to verify the suitability of the panelboards & switchboards. During normal operation, facility shown in Fig. 2 is operated via grid. For emergency, panels namely panel LS, & ES were operated via in-house generation.

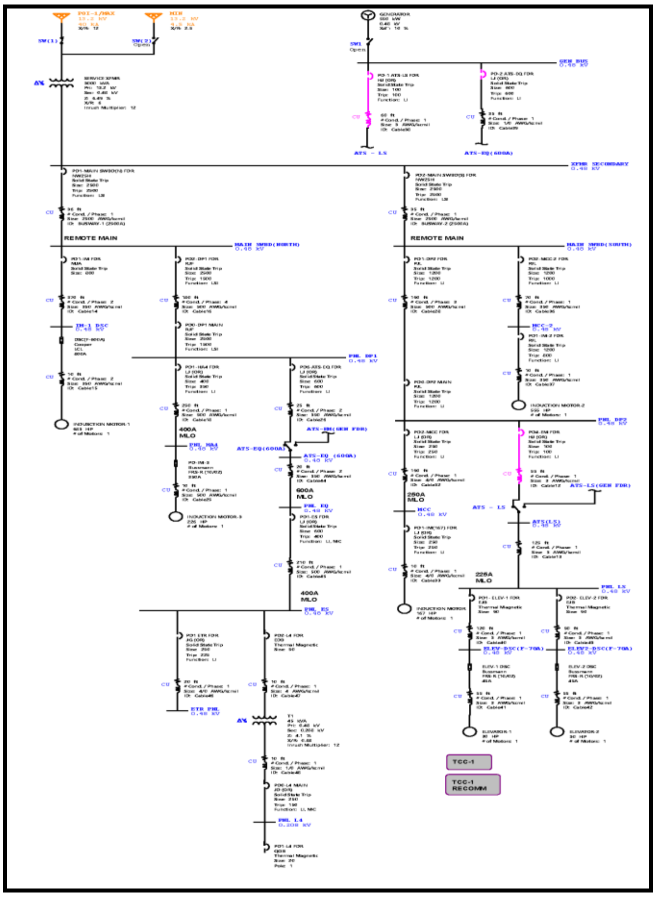

Fig. 2. System Design coordinated for 0.1seconds

A. Time Current Coordination Curve

TCC plotted for ATS-LS circuit is shown in Fig. 3 based on initial system design. PD4 and PD1 is overlapping in the transition band and instantaneous band. When fault happens in any of the feeder breakers of elevators the immediate upstream should trip without interrupting the other branches. So, these two breakers need to be changed to higher frame breaker with adjustable trip units to achieve total selective coordination. The Time current coordination curve shown in Fig. 3 does not account the dynamic impedance when breaker operated (peak let through current). In order to account for the dynamic impedances, breaker manufacturer test tables need to be referenced. The breakers are tested for factory X over R ratio.

V. IMPACT ON LV SYSTEM DESIGN AND ARC FLASH ANALYSIS

The total selective coordination can be achieved in a LV network if the actual fault level at the grid end is known because not all circuit breakers shown in the manufacturer test table will coordinate for complete range of fault currents. Further breaking down, selection of circuit breakers is also with respect to panelboard/switchboard or switchgear dimensions and the physical space constraints.

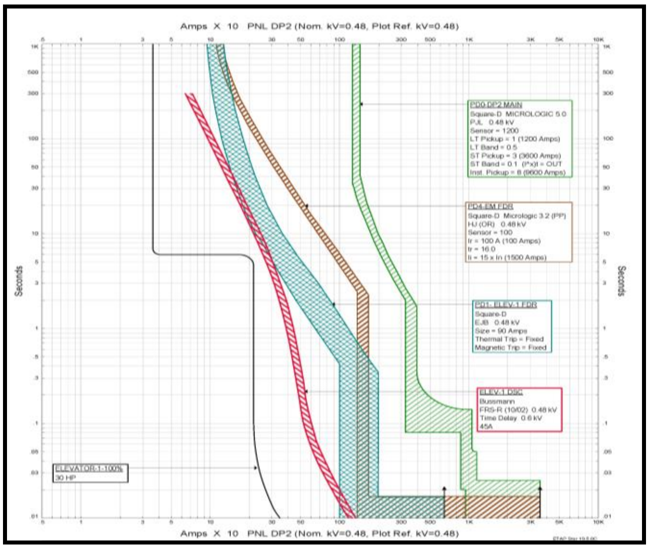

Fig. 3. Coordination Curves (0.1seconds)

To achieve total selective coordination in circuits, we must opt for near higher frame breaker which is having modern trip units - adjustable long time (LT), short time (ST) and instantaneous (INST) regions with variable time bands to offer complete flexibility for a range of currents and operating time. Improved coordination or selectivity can be achieved for circuits 225A rated or higher. Main lugs can also be used instead of main breakers if multiple levels of selectivity is required. At the same time, increasing the breaker size violates the code requirements of cable protection for the section. Breaker recommendations must be the last step after addressing all code violations. Upgrading the cable size increases the available fault current which in turn impacts the arcing current. The initial design considered as base model and the revised model considered for analysis for arc flash incident energy. Both the results were shown in Table-I. Multiple scenarios were considered for more conservative arc flash analysis. The electrode configurations were considered as VCB and VCBB for panelboards.

VI. SELECTIVELY COORDINATED SYSTEM DESIGN

The following design changes were implemented to achieve total selective coordination. 100A breaker feeding ATS-LS changed to 1200A frame with 250 ampere sensor and 100 ampere trip setting. To comply with NEC 240 the cable feeding ATS-LS changed to #1 AWG. The above recommended breaker change was obtained from the manufacturer test table.

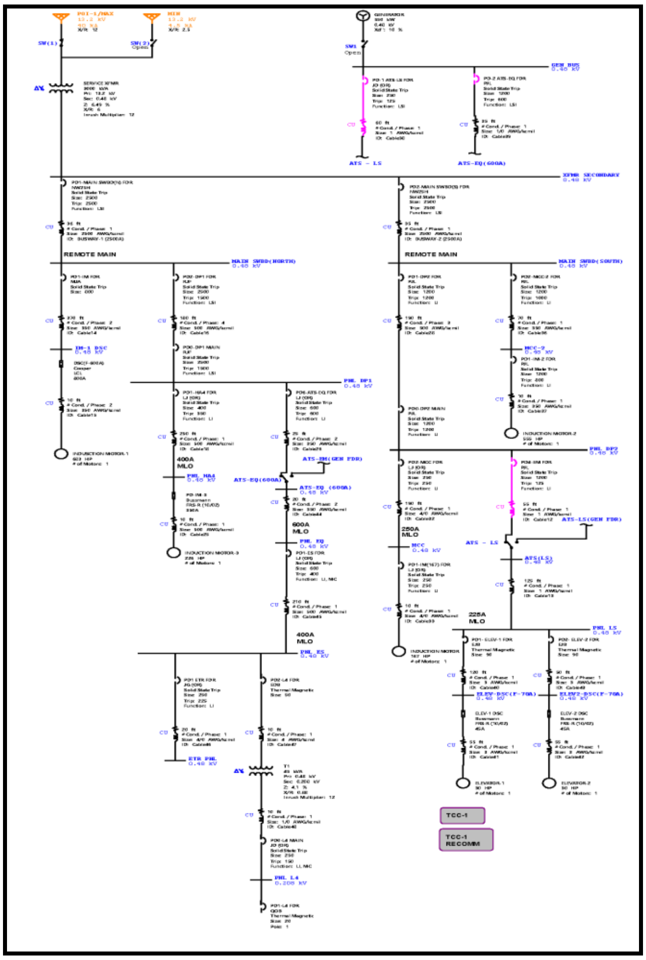

Fig. 4. System Design coordinated for 0.01seconds

VII. SELECTION OF CIRCUIT BREAKER

The selection of upstream circuit breaker depends on the following

- Largest branch circuit breaker
- Available fault level
- Selectivity current limit to which the recommended breaker needs to be coordinated
- Equipment dimensions.

The above recommended breaker is highlighted in the Fig. 4.

Upstream Circuit Breaker[2]			Downstream Circuit Breaker—Type / kAIR Maximum Level of Selective Coordination Shown in kA											
Max. Cont. Current Rating	kAIR[1]	Type[3]	ECB[4]	EDB[4]	EGB[4]	EJB[4]	FA	FH	FJ[4]	BD	BG	BJ	HD	HG
			14	18	35	65	18	25	65	18	35	65	18	35
		Mission Critical [5]	See Appendix A											
	18	JD	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
	18	JDU3250	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6
	18	JDWU[6]	See Appendix A–Mission Critical				2.6	2.6	8	10	10	10	8	8
	18	LDU3250	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6
	18	LDWU3250[6]	14	18	18	18	2.6	2.6	8	18	18	18	8	8
	35	JG	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
	35	JGU3250	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6
	35	JGWU[6]	See Appendix A–Mission Critical				2.6	2.6	8	10	10	10	8	8
	35	LGU3250	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6
	35	LGWU3250[6]	14	18	30	30	2.6	2.6	8	18	18	18	8	8
	35	PG	14	18	35	35	18	25	35	18	35	35	18	35

Fig. 5. Breaker Test Table [15]

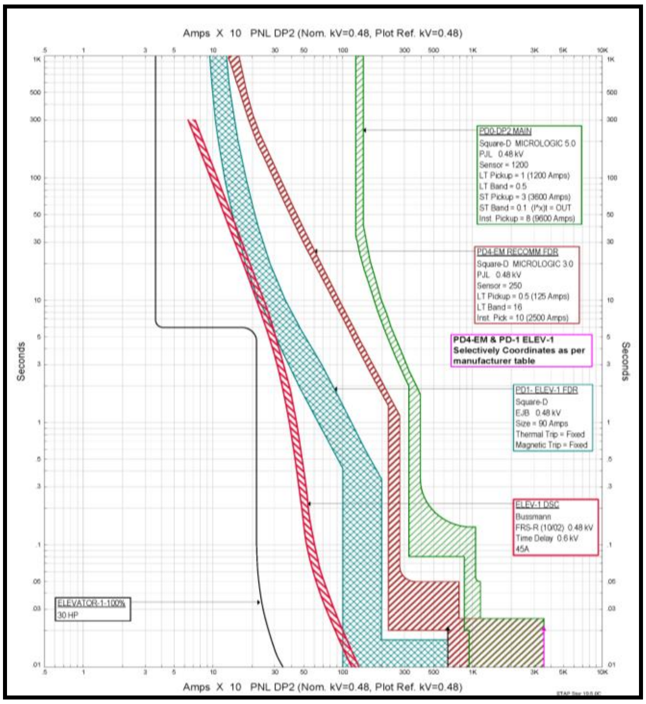

Fig. 6. Coordination Curves (0.01seconds)

VIII. ARC FLASH HAZARD ANALYSIS TABLE

The Arc flash analysis was performed using "IEEE 1584 - Guide for Performing Arc-Flash Hazard Calculations, 2018"[19]. Typical equipment dimensions were considered for the analysis. To account for complete range of fault currents, three scenarios were considered. High Case, Low Case, and a Generator Case. For high case and generator case, all motors were assumed to be turned on. For low case, all motors were assumed to be turned off.

A. Arc Flash Incident Energy

From the below Table-I, it is evident that the total incident energy in the base model and the model with total selective doesn't show significant impact.

Table-I: Incident Energy(cal/cm^2) Plots

Bus Description	kV	Initial Design	Total Selective Coordination
		Total Energy (cal/cm²)	Total Energy (cal/cm²)
ATS-LS (225A)	0.48	0.63	1.17
ATS-EQ (600A)	0.48	9.25	9.25
ELEV-DSC (F-70A)	0.48	0.12	0.15
ELEV2-DSC (F-70A)	0.48	0.16	0.21
ETR PNL	0.48	0.51	0.51
PNL EQ	0.48	9.19	9.19
PNL ES	0.48	3.63	3.63
PNL L4	0.208	3.35	3.35
PNL LS	0.48	0.21	0.92

B. Impact on Arcing Current for 0.1s & 0.01s coordination.

The arcing current values in kA are presented in the below Fig. 7. There is no significant impact on the values.

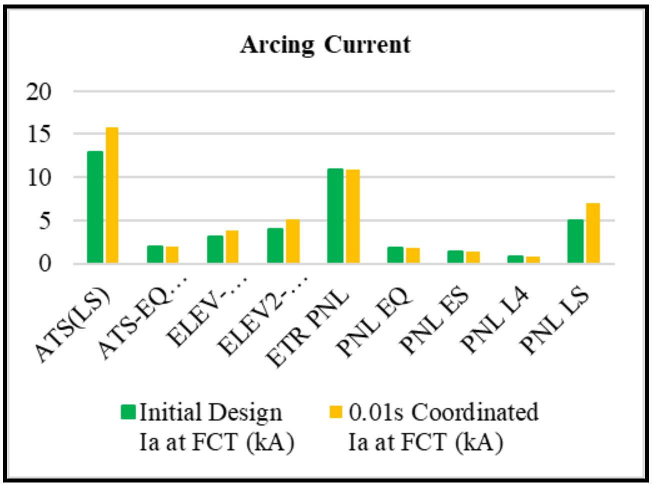

Fig. 7 Arcing Current plots

IX. CONCLUSION

The implementation of total selective coordination for a complete range of fault current might impact the system design but it may not impact the Arc Flash Incident Energy Levels in circuits less than or equal to 100A and the results are shown in Fig. 7. Future work needs to be carried out in a network with multiple levels of selective coordination requirements and it might impact the system design in a high rate and fault clearing time, when higher frame breakers are used.

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