Protection Audit of 220/132/66 kV Substation

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SUMMARY

In the power system world, protection is an insurance policy which is an investment against damage from potential faults and its main objective is to avoid the unwanted/uninterrupted tripping of generators & system connected with transmission lines so as to avoid any blackout. On July 30th & 31st 2012, India has experienced severe power outage which led the Central Electricity Authority (CEA) of India to instruct regional / central / state utilities to carry out protection audits regularly by third party independent agencies.
Protection Audit is mainly concerned with the checking of adequacy & robustness of protection setting & schemes and it is necessary to carry out this audit to ensure the continuity of service. The audit process can be methodically conducted by finding the inadequacy, fitness, inappropriate application of individual elements (all types of protective relays and their settings, Current Transformer (CT), Potential Transformer (PT), Capacitive Voltage Transformer (CVT), DC power supply, Event recorders/loggers, Power Line Carrier Communication (PLCC), Optic fiber links and testing and maintenance records of all relays, circuit breakers, etc.), application of individual elements associated with equipment and transmission line protection, identifying obsolete protection related equipment and checking adequacy and appropriateness of protection settings and schemes.
This paper describes the protection system adopted in one of the existing substations of a utility. ERDA has carried out short circuit calculations, protection scheme verification with respect to protection philosophy, relay setting verification and have given recommendations for improvement, wherever required. For this work, power system E-TAP package was used to simulate and verify the settings. This paper also describes the protection normally required according to standard operating procedures mentioned in CBIP / CEA guidelines for substations and compares them with actual protection provided in the substation.

KEYWORDS

Protection audit, Event recorders/loggers, Power line carrier communication (PLCC), Optic fiber links, CBIP / CEA guidelines

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I INTRODUCTION

Modern power systems are having more generators, transformers and a large inter connected network in the system. High degree of reliability is required for the better operation of this system. System can be protected from damage under abnormal conditions caused by faults, if trustworthy protective devices such as relays and circuit breakers are optimally installed.

The main role of protective device and protection scheme is to isolate the faulty section from the healthy system without any delay and it is required to be selective and sensitive so that the faults are quickly identified and cleared. In a well-designed system, the protection system may operate very uncommonly and protective relays are rarely required to go into operation. However, these relays should maintain their integrity under normal system operating conditions and be ready for fault detection and isolation whenever required. Therefore to assess the healthiness of the protection system, the relays are also required to be tested periodically.

II SIGNIFICANCE OF PROTECTION AUDIT

The protection audit is a method to identify the shortfall, fitness, improper application of individual elements associated with equipment and transmission line protection. It is an activity to identify and weed out obsolete protection related equipment. Protection audit is necessary for the safety of high cost equipment used in substation as well as to maintain optimum degree of continuity of supply on the grid. This leads to reduced amount of loss of equipment, loss of power, fire hazard and loss of life. The aim of the audit is to review the protection philosophy by carrying out evaluation of relay coordination and protection settings; checking healthiness of DC system, communication link with respect to protection system, time synchronization units, disturbance recorders, event loggers, verifying protection testing & maintenance records of relays, circuit breakers and identifying & weeding out older protection system technology.

III PROCEDURE ADOPTED FOR AUDIT OF SUBSTATION

The audited substation system comprises of 220 kV network having 10 feeders (Station A-1 to 10); 132 kV Network with 10 feeders (Stations B-1 to 10) and 66 kV network of 6 feeders (Station C-1 to 6). It is also having one transformer connected between 220 & 132 kV voltage level (100 MVA) and two transformers connected between 132 kV and 66 kV voltage level (50 MVA each). All related data for conducting study in ETAP is collected including load data, transformer name plate data, relay settings, existing line /cable data, etc.

A. Load flow Study:

As part of protection audit, first of all load flow study of the system as per Fig. 1 was carried out.

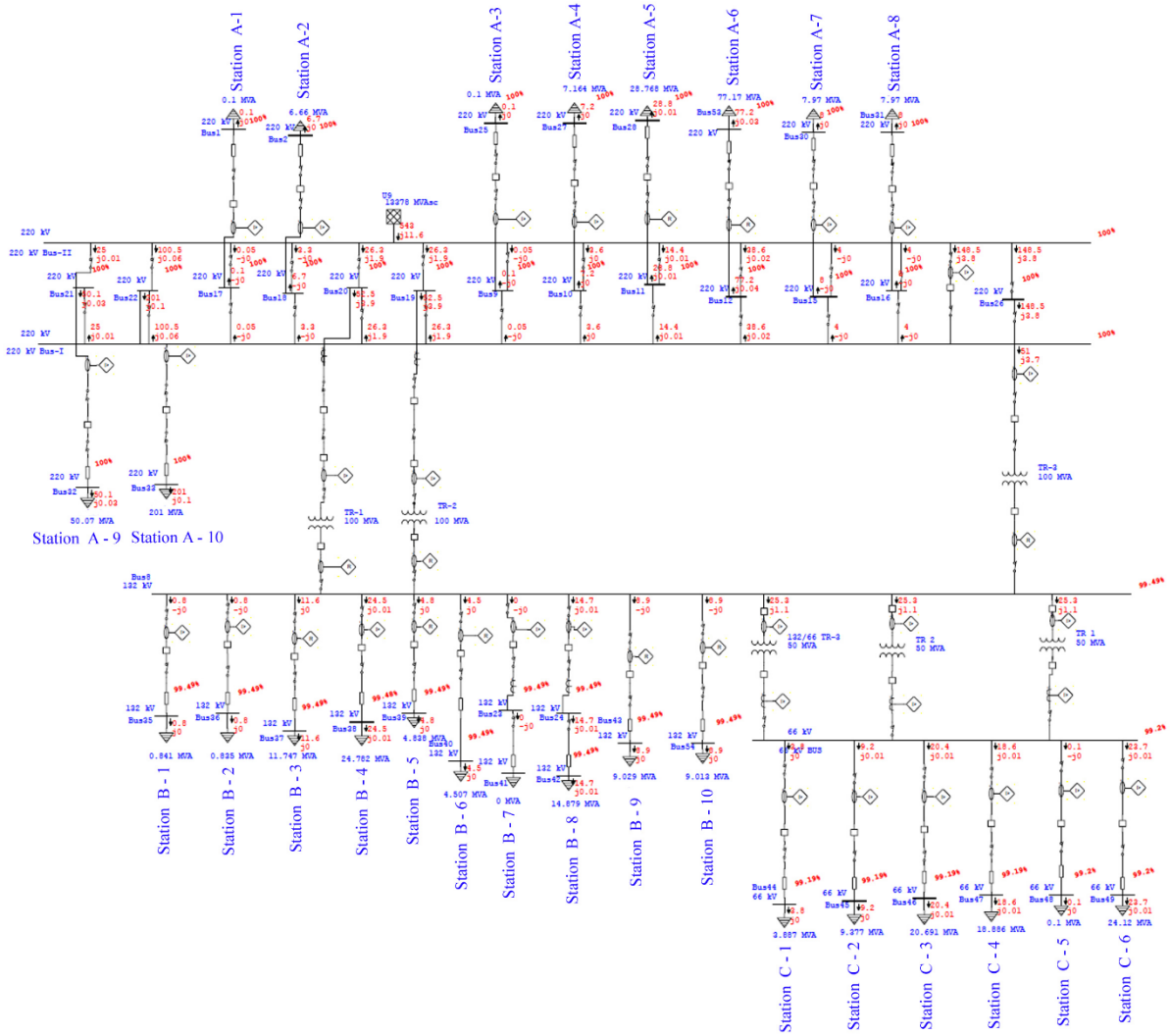

Fig. 1. Single Line Diagram of 220/132/66 kV Substation system

The summary of the analysis is presented in Table 1.

Table 1: Summary of Total Generation, Loading & Demand

	MW	**MVAr**	**MVA**	**% PF**
Source (Swing Buses)	543.012	11.635	543.135	99.98 Lagging
Total Demand	543.012	11.635	543.135	99.98 Lagging
Total Static Load	542.432	0.227	542.432	100.00 Lagging
Apparent Losses	0.580	11.408		

Table 1 shows the total demand & generation of system along with MW & MVAR flow. The analysis indicated that none of the transformers were overloaded.

B. Short Circuit Study:

Based on load flow study, short-circuit study was conducted as per single line diagram given in Fig.-2 and analysis report as per Table 2.

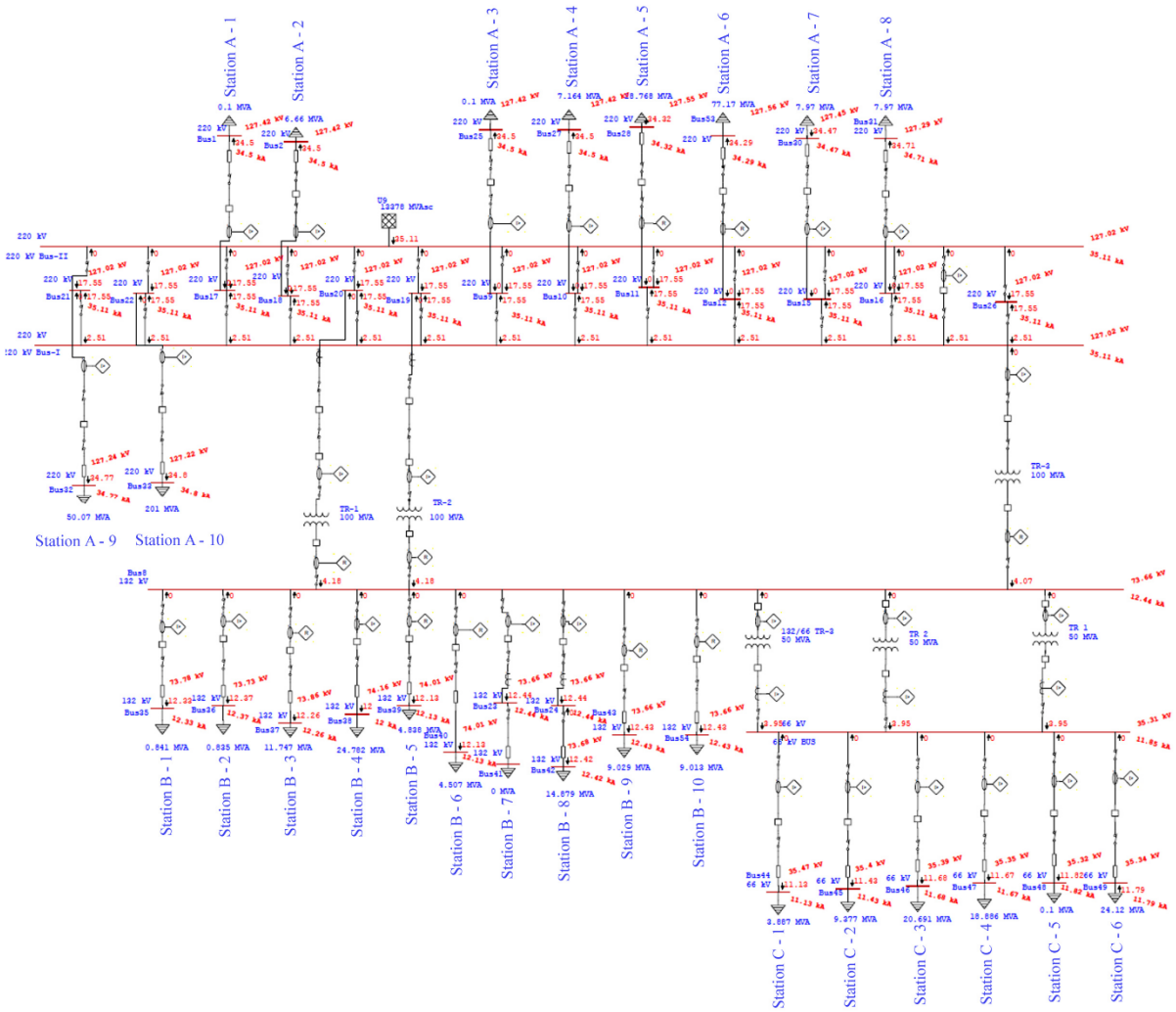

Fig. 2. Single Line Diagram for short-circuit study of 220/132/66 kV Substation system

Table 2: Short-circuit Study Summary report

Bus		3 Phase fault (kA)			Line to Ground fault (kA)			
ID	kV	I"k	ip	Ik	I"k	ip	Ib	Ik
66 kV BUS	66.000	10.129	26.695	10.129	11.853	31.236	11.853	11.853
220 kV Bus-I	220.000	35.109	92.525	35.109	35.109	92.525	35.109	35.109
220 kV Bus-II	220.000	35.109	92.525	35.109	35.109	92.525	35.109	35.109
132 kV BUS	132.000	11.567	30.426	11.567	12.329	32.429	12.329	12.329

Bus	Line to Line fault (kA)				Line to Line to Ground fault (kA)			
ID	I"k	ip	Ib	Ik	I"k	ip	Ib	Ik
66 kV BUS	8.772	23.119	8.772	8.772	11.311	29.810	11.31	11.311
220 kV Bus-I	30.405	80.129	30.405	30.405	35.109	92.525	35.109	35.109
220 kV Bus-II	30.405	80.129	30.405	30.405	35.109	92.525	35.109	35.109
132 kV BUS	10.018	26.350	10.018	10.018	12.005	31.576	12.00	12.005

The results of the analytical study enable calculation of the fault level of each and every bus in system for 3-phase, L-L L-G, L-L-G faults.

C. Relay Co-ordination Study:

After conducting load and short-circuit study, relay co-ordination study was carried out to check the appropriateness of relay settings with respect to existing relay settings for 3-phase fault condition on station A-8 feeder. Sequence of operation was observed for proper co-ordination. Sequence of operation shows that as soon as fault is created on station A-8, its breaker no. CB-11 gets operated as a primary protection and as a backup bus bar protection, CB-52 operates. Single line diagram, sequence of operation, report and graph are as shown below, in Fig. 3 to 5 and Table 3.

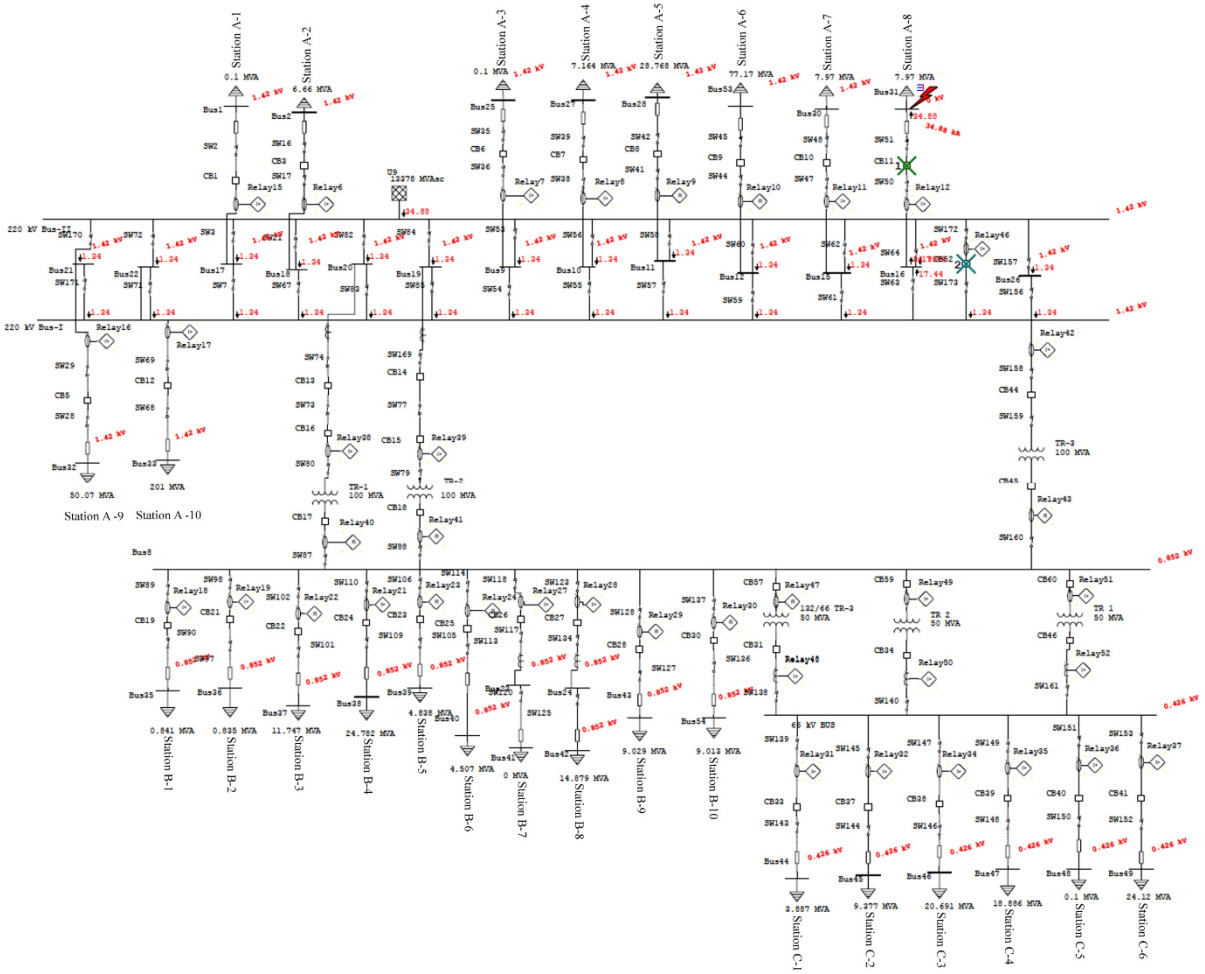

Fig. 3. Single Line Diagram for Relay coordination study of 220/132/66 kV Substation system

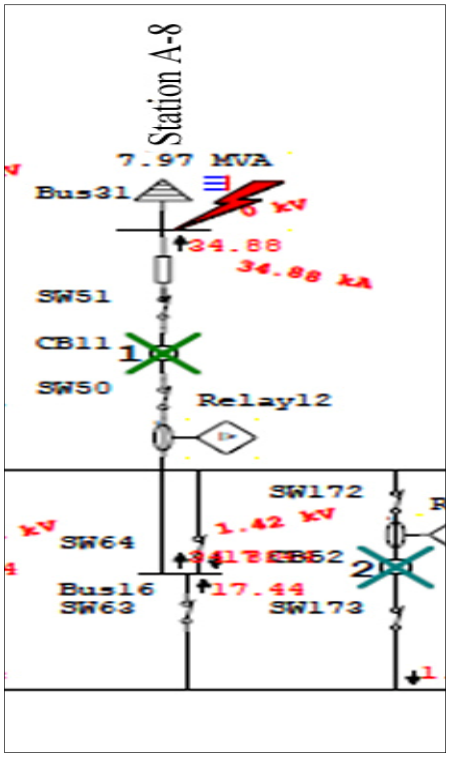

Fig. 4. Single line detailed diagram of fault condition at station A-8

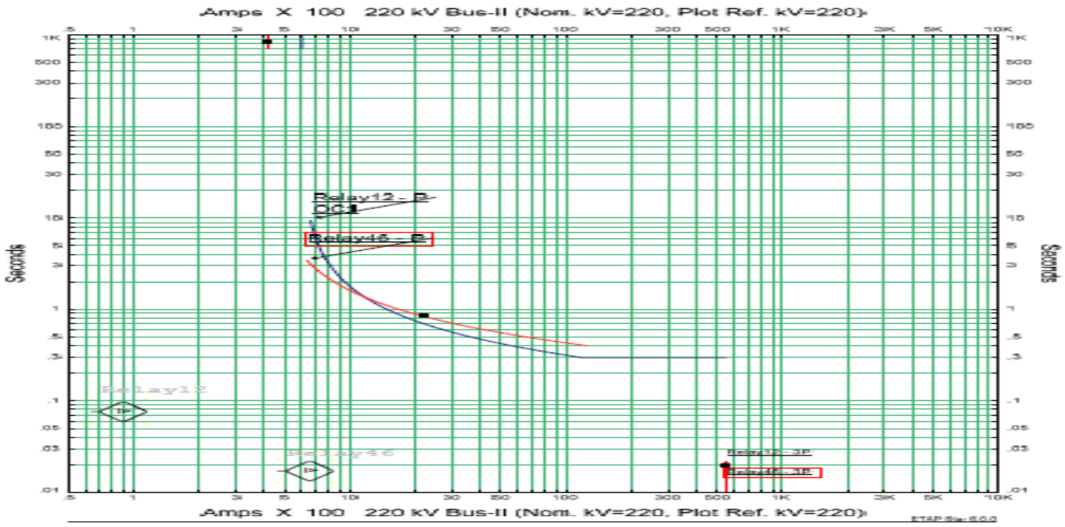

Fig. 5. Relay Operation graph during fault

TABLE 3 Sequence of Operation Event Summary Report in ETAP

Symmetrical 3-Phase Fault at Bus31				
Time (mS)	**ID**	**If (kA)**	**T1 (mS)**	**Condition**
295	Relay12	34.884	295	Phase - OC1 - 51
305	CB11		10.0	Tripped by Relay12 Phase - OC1 - 51
1191	Relay46	1.342	1191	Phase - OC1 - 51
1201	CB52		10.0	Tripped by Relay46 Phase - OC1 - 51

D. Review of Protection Schemes as per CEA/CBIP Guidelines:

After checking appropriateness of relay setting, following protection scheme of system was reviewed as per CEA guidelines.

i) Transmission Line Protection
ii) Transformer Protection
iii) Transmission Line Protection
iv) Disturbance Recorder (DR) and Event logger (EL) Protection
v) Circuit Breaker Protection
vi) Communication System Protection
vii) Station DC Supply System Protection

IV CONCLUSIONS

Protection audit of 220/132/66kV substation is carried out as per CEA/CBIP guideline. Short time breaking capacity of CB found adequate based on short circuit analysis study. Relay Co-ordination of protection system is also verified. Based on the sequence of operation of various relays, it is observed that PMS and TSM of few relay needs to be modified as below:

a) 66 kV line (Substation C-1 to 6): TSM: 0.07
b) 132 kV side Transformer No. 1, 2 & 3, 50 MVA: PSM:0.74, TSM:0.55
c) 66 kV side Transformer No. 1, 2 & 3, 50 MVA: PSM:0.8, TSM:0.07

During review of protection scheme, which includes physical verification of transmission line, transformer, circuit breaker, event logger and disturbance recorder protection; we found that for 220 kV Line, Main-II distance Protection / directional protection / phase segregated line differential protection should be adopted to strengthen 220/132/66 kV Substation system.

Also, protection audit needs to be carried out again under following circumstances:

(1) Whenever configuration of network is altered

(2) Fault level of feed bus changes

(3) Change in circuit breaker timings (opening /closing) due to change of CB type

(4) Change in relay characteristics or type of mode of operation.

Periodical testing through accredited laboratory should also be carried out for checking healthiness of DC system, PLCC, TSU, C.B.s and relay. Periodic condition monitoring of relays also helps to maintain healthiness of protection system.

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