Protection of Grid Connected Hydro Power Generating Units – Practical Insight with Reference to some Case Studies

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ABSTRACT
The paper attempts to present a unified approach to the vast field of protections for hydro power generating sets. Typically, there are a number of agencies involved in the formation of protection logics viz the main turbine-generator manufacturer, the protection relay supply company, the customer (Electricity boards or private producers) and may be a consultant also. The integration of views of these agencies is a task in itself. The typical inter-tripping logic diagram given in the paper fulfils this requirement to a great extent. Also, some case studies of actual fault incidents at hydro power stations have been included.

Keywords: Inter-tripping diagram, fault detection and action devices, categorization of faults, master tripping relays, generator circuit breaker (GCB), generator field breaker (GFB), penstock gate, main inlet valve, electro-mechanical and micro-processor based relays.

I INTRODUCTION

It is well known fact that availability factor of generating units for Power Generation in Power Stations is of paramount concern of all stake holders. It is also known that in spite of advanced manufacturing technologies together with good erection techniques at sites, faults do occur in the Generators and connected Transformer, Bus duct, Feeder Lines etc. up to switchyard for various reasons. In addition to these so called internal faults of the unit, there are faults originating in the grid system which affect the normal operation of the units connected to it. Obviously, faults need to be detected and acted upon quickly to avoid major damages and in-turn minimize the downtimeand cost. Hence, proper protections have to be provided for the twin objectives of timely detection and isolation of the unit in case of external system faults and stopping it on internal faults to prevent aggravation of damage.

II FAULTS CATEGORIZATION AND DETECTION

(a) **Categorization of Faults-** There are various ways of categorization. One broad way of it is location based that is internal or external as already clarified above. Internal, faults can be categorized either as hydro mechanical or electrical in nature which again can be either normal type where one can wait for a little while or emergency type requiring immediate action for stopping of the turbine after detection and that too by two stopping devices namely motorized limiter mechanism of governor and ESV (Emergency Slide Valve) both acting in parallel and independently.

(b) **Detection Devices/Circuits-** Normally, fault detection is done at two stages. In the first, only annunciation is given out for warning and in the second when fault level reaches the threshold, tripping is initiated with annunciation. List of fault types and their detection devices as well as corresponding action taking devices are given in Table-1.

Table 1
Faults and their Detectionand action devices

S. No	Fault Type	Detection Devices	Action Devices	Remarks	Abbreviations used
1.	Over Temperatur	DTT/Thermostat/ RTD	Motorized limiter of Governor for Normal Stopping of Unit	For Generator Bearings, Main Transformer etc.	DTT = Dial type thermometer
2.	Low Pressure	Pressure Switch	ESV + motorized limiter for stopping of the unit	For OPU Accumulator oil Pressure for Governor	ESV- Emergency Slide Valve OPU = Oil Pressure Unit
3.	Low level	Level Switch	ESV + motorized limiter for stopping of the unit	For OPU Accumulator oil Level	
4.	Over Speed	Centrifugal Force Operated Switch and		Additionally MIV/PS gate also	MIV = Main Inlet valve

		Speed Relays		close	PS = Penstock
5.	Over Voltage	PT	GCB	For generator Stator WDG and other voltage based faults	GCB = Generator circuit breaker WDG = Winding
6.	Over Current	CT	ESV + motorized limiter for Stopping of the Unit	For Differential Protections (and other current based Protections)	CT = Current transformer
7.	Fire	Fire/Smoke detectors	Motorized limiter of Governor for Normal Stopping of the Unit	For Generator Barrel Fire	

III INTER TRIPPING DIAGRAM

A Generally accepted Inter Tripping Diagram which shows classification of various faults into popularly known class A, class B and class C categories, is shown in Figure 1 which is quite self explanatory.

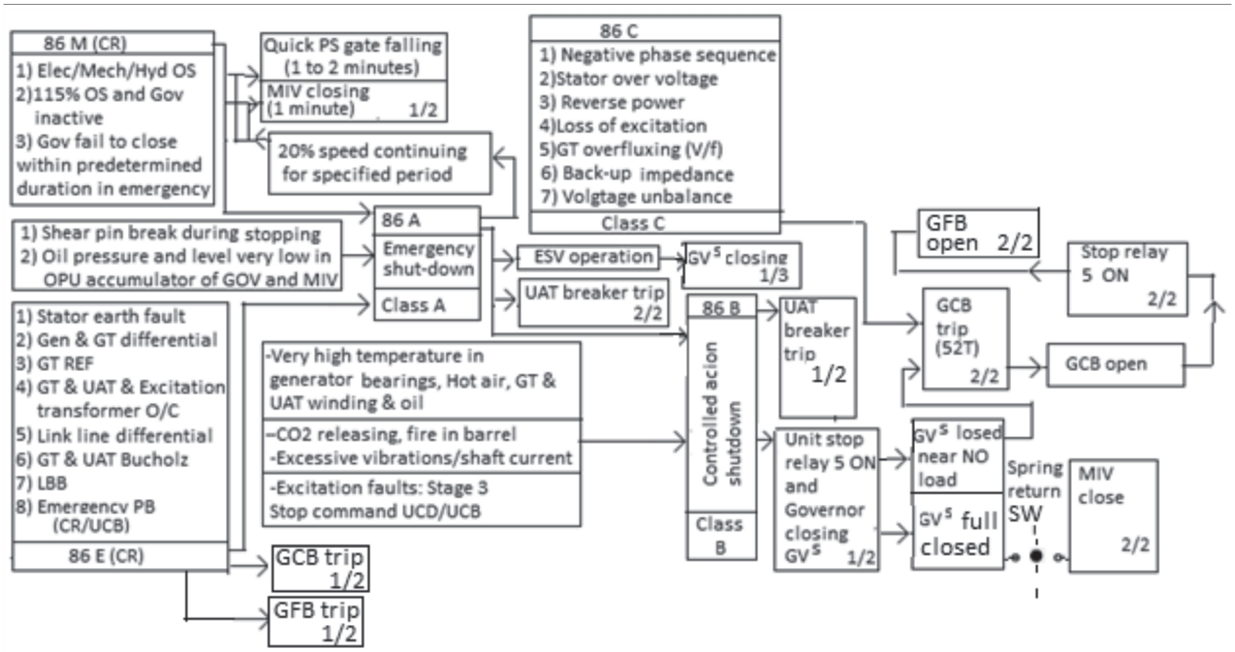

Fig.1 Inter-tripping diagram

(a) Class C Faults (Acting Through Master Trip Relay 86C) - These require only the isolation of the unit from the grid by opening of GCB. This is a load throw condition in which unit continues to run on NO load excited under auto governing and excitation, with UAT remaining charged to continue power supply for power house load as in normal operation.

(b) Class B Faults (Acting Through Master Trip Relay 86B)

These are non urgent types where some time is available to follow the normal sequence of stopping as shown in Figure 1 and elaborated below.

(i) Stop relay 5 of unit automation scheme is energized for start of GV^S closing through motorized limiter mechanism of governor.

(ii) At near no load position of GA as sensed by a master switch, operated by its movement for closing, GCB is tripped followed by tripping of GFB. Here, almost no over speed occurs.

(iii) After GV^sfull close (FC), MIV may be closed from its control switch if desired, which will be happening in still water.

(c) Class a Faults (Acting Through Master Trip Relay 86A): These are the severest type, requiring immediate action for stopping not only from motorized limiter but also from ESV acting at same time independently. GCB and GFB too open out immediately resulting in over speed like it happens in load throw, while stopping is in progress. Over speeds being more critical, back up of MIV OR penstock gate closing is additionally provided which would close in flowing water of turbine which may be noted.

IV CASE STUDIES FROM FIELD

(a) Differential Protection Maloperation-In Figure 2, normal CT connections are shown for differential protection of generator. When there is no short in the protected zone between CT1 and CT2, then $i_1 = i_2$. Therefore no current flows through differential relay DR for operation as shown in Figure 2.

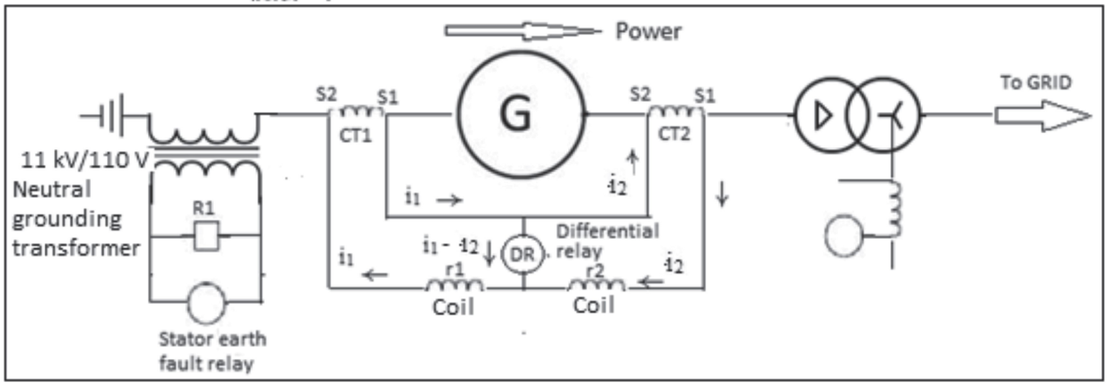

Fig. 2CT connections for differential protection of generator with correct polarities

In one of the hydro power projects, during complex testing for commissioning of the unit, differential relay operated as soon as stator current was raised for plotting SCC of the generator. On investigation, CT2 polarity was found reversed as shown in Figure 3. Due to this, instead of difference of i_1& i_2 currents, their sum was passing through the relay causing its operation to trip the unit.

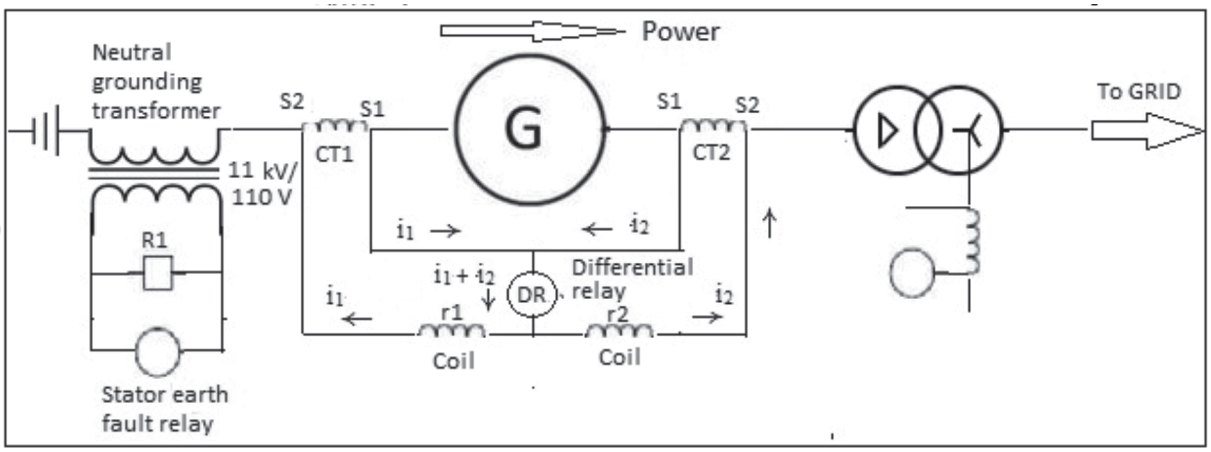

Fig. 3 CT connections for differential protection of generator (with incorrect CT2 polarity)

(b) Stator E/F operation - In one 12 MW generating unit, statorearth fault protection operated when grid voltage increased. The setting of the relay connected across the secondary of 11 kV/110 V. Distribution transformer of the generator neutral grounding system as shown in Figures 2 and 3 was 7.5 V. The IR (Insulation resistance) measurements provided no clue. Therefore, it was decided to draw a plot between stator voltage and spill voltage across the relay as given below in Table 2

Table 2
Stator voltage v/s spill voltage of stator earth fault relay

Stator Voltage (kV)	9.5	11	11.5	NB: Relay setting of 7.5V is for fundamental frequency voltage only whereas volt meter of spill voltage measures other frequency voltages also
Spill Voltage (V)	7.3	9.3	10.5	
Relay Operation	No	No	Yes	

To reduce spill voltage, XLPE cables connecting generator and main transformer were cleaned thoroughly up to 2 m on either side of generator terminals and main transformer which resulted in 2V decrease in spill voltage which solved the problem. Important conclusion to be drawn here is that generator terminal insulators seal off frame and inter connecting cables or bus duct to main transformer etc. must be kept clean to avoid such maloperations which may prove costly from the resulting down time.

V CONCLUSION

The subject of protections is very exhaustive. Given their role of 'silent sentinels' against various faults which may occur at any time during the operation of generating units this paper underline their importance and need for the plant engineers to ensure that they are always in ready state for action. Starting from electro-mechanical protection relays in the beginning, now-a-days, it is the time for microprocessor based relays- also known as numerical relays which use software based protection algorithm for detection of various electrical faults and housed just in a unit, requiring only CT/PT inputs from the field. One a disadvantage of these systems is also worth mentioning. With these sophisticated system the site engineers normally not get it to understand of underlying principles of fault detection as in the case of basic electromechanical protection relays.