Experience of Rehabilitation & Commissioning of Excitation systems in Tata Power

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1. General
Tata Power is recognized as India’s largest private sector power utility, with a reputation for trustworthiness, built up over nearly nine decades.

The article here focuses on the issues faced in the area of design, integration with existing system and site engineering during rehabilitation of AVR. The article also brings out recommendation to the issues faced.

2. Need for Rehabilitation:
a) The existing excitation system was old & obsolete. Technical support from OEMs was not available. Maintaining of spares was difficult.
b) In Hydro Machines having indirect excitation systems, maintenance of Main exciter & associated systems was high on account of wear & tear of rotating parts.
c) Indirect Excitation having high time constant, the response of AVR was not matching system requirement. This was resulting in undesired tripping during system faults.
d) The existing AVR system was not compatible for plant automation.
e) The existing AVR system had limited limiter functions

3. Features Digital Excitation system
a) Numerical advantage – Digital AVR has fast response thereby contributing to system stability.
b) Control & Limiter functions are incorporated in software; there is no drifting in settings resulting in high reliability.
c) PID Controller with all soft adjustable setting resulting in high flexibility
d) Pre - programmed typical control logic inbuilt in software - e.g. Field breaker interlocking with GCB is taken care in software block.
e) Use of standard software library functions eliminates the need for separate hardware components like timers, relays etc.
f) Superimposed controller e.g. MVAR, Cos Phi regulators etc.
g) Monitoring & Protection Function
h) Display of online values, operating status, events & Alarms.
4. Rehabilitation / Commissioning Requirements:

Following are some of the important point that needs to be checked during Rehabilitation / commissioning & operation of Digital AVR.

A) Excitation source.

A1) Supply to Excitation Transformer

The excitation input supply requirement needs to be looked in detail during Engineering / Rehabilitation of AVR to ensure proper behavior of Excitation system. This aspect is more important for direct excitation system where the excitation supply is derived from source other than Generator.

The excitation source when derived form Auxiliary bus can experience voltage sag & swell during different operating condition such as starting of high capacity motors, capacitor switching, delayed fault clearance etc. This gets aggravated when the source impedance is high.

In one of the thermal plants the excitation system used to trip on AC over voltage protection. The Excitation system had an AC over voltage protection on the secondary of excitation transformer to protect thyristors from over voltage. The over voltage protection consisted of 3 phase diode rectifier, surge capacitance and a resistor as shown in the sketch below. The Excitation transformer voltage rating was 3.3 kV/ 490 V and was fed from 3.3 kV Unit bus.

It was observed that the diodes in the rectifier unit used to fail due to voltage spike. The diode failure resulted in blowing of the fuse and tripping of unit. The peak value of the voltage spike was around 2.5 kV. The voltage spikes were produced during start up of high capacity motor on the bus or any fault feed by the bus. The PIV ratings of diodes were 1600 V. These were replaced by putting two diodes in series having PIV rating of 1800 V each.
A2] Excitation transformer

The rating of Excitation transformer needs to be arrived by considering overheating of transformer due to harmonics and cooling arrangement. This is important in case of dry type transformer. Also a suitable shielding arrangement is required to avoid transmission of voltage surges from HV system into LV system. This is achieved by inserting a metallic screen between HV & LV winding and connecting it to ground.

In one of the hydro machine where excitation system was rehabilitated overheating of dry type excitation transformer was experienced. The overheating of Dry type Excitation Transformer was experienced even at partial loading. The temperatures were reaching as high as 140°C. This led to over-temperature alarm & Trip on few occasions. Transformer rating was adequate considering the field current requirement. The over-temperature was mainly due to inherent high level of harmonics generated by excitation system. The design of Excitation transformer was reviewed. The design review indicated excitation transformer rating needs to be 150 % to account for harmonics.

The enclosure size for the transformer was also increased to facilitate proper ventilation. New Transformers with higher ratings were installed & temperatures were found to be in the region 85°C for full load generation.

B] Integration of Excitation system during Rehabilitation.

Excitation system are as such well designed and are reliable, however it needs to be customized to take care of site requirements. Digital excitation system offers wide flexibility in terms of monitoring and protection functions which needs proper parameterization of the functions to be done.

Following are some of the integration issues experienced during rehabilitation of the excitation system.


For hydro Machines, having class B type insulation, drying out of insulation is carried out by short circuiting stator winding & applying field in a controlled manner. During short circuit test, input power to AVR is supplied using external source. This test requires various changes in AVR to be done like parameter setting, manual mode operation, blocking of field flashing & blocking of rotor earth fault etc. Above changes are required to be done manually. Wrong parameterization or missing any of the requirements could result into mal-operation of AVR.

It is felt that logic for short circuit test mode taking care of all the requirements is incorporated in AVR soft block and implemented in design stage itself.

B2] PLC Synchronization problem

The PLC in AVR requires the function called Phase lock loop to issue trigger pulses to thyristor in synchronism with the input supply. PLL is required to avoid wrong firing of thyristor. In one of the AVR, problem faced was AVR trip initiation on PLL Fault during Active Power load throw off test. The PLL circuit was unable to lock to change in Generator frequency (df/dt).

The setting adopted for PLL was 20 Hz/sec. This was the maximum possible setting. The application software of PLC was changed to accommodate higher setting. The setting was changed to 50 Hz/sec. Machine performed satisfactorily after adopting above change.
DC drives works satisfactorily with lower PLL setting. DC drives when used for AVR application should incorporate higher PLL setting.

**B3) Rotor over temp trip**
AVR utilizes rotor voltage & current for monitoring rotor temperature using a special software block that utilizes rotor details such as field winding resistance, brush voltage drop & ambient temperature etc. This feature requires accurate field data to calculate correct rotor temperature. The measurement could go wrong sometimes due to large drop in rotor brush, insufficient contact, slip-ring sparking & cable resistance at high temperature. AVR trip on rotor over-temperature was experienced as due to lot of variables & inaccurate field data. This feature was selected for alarm to avoid unwanted tripping.

**B4) PT supervision Scheme**
During start up of one of the hydro Machine, Generator tripped on over-voltage protection. The cause of high voltage was due loss of one phase PT voltage to AVR. The PTs are mounted on trolley & secondary voltage is taken through sliding contacts of trolley. Due to improper alignment of sliding contact, one phase to AVR was missing. This problem was solved by installing a voltage supervision relay which will detect loss of PT voltage & change over AVR to manual mode.
This monitoring can be inbuilt in AVR system by monitoring AVR input voltage with reference to PT voltage.

**B5) Excitation fault during System disturbance**
Synchronizing voltage -U syn signal is derived from the secondary winding (490 V) of excitation transformer. The signal U gen is derived from generator PT. When the U syn voltage become less than U gen by 30 % an instant trip is generated, sensing converter input supply problem.

During a system disturbance associated with voltage fluctuation the Generator voltage recovered immediately, however recovery of signal U syn was delayed due to system inertia. This resulted in tripping of AVR.

A delay of 100 m sec was then introduced in converter input supply monitoring circuit so as to prevent tripping of Unit during system disturbance.

**B6) Communication failure**
Excitation system of 150 MW Machine comprises of two individual panel called controller panel & Thyristor panel. The Controller panel houses AVR & is located in Control room while Thyristor panel is located on turbine floor. The fiber based communication cable (called arcnet cable) is used for carrying gate pulses to triggering circuit mounted in thyristor panel and also the analogue information. AVR witnessed tripping due to failure of arcnet cable.
C) Impact of AVR components
It has been observed that the reliability of AVR is largely affected due to failure /mal operation of associated components. Failure of components can be minimized by selection of good quality products. The AVR logic should be designed in such a way that mal operation of single component should not affect operation of AVR. This can be achieved using 2 out of 3 logic and use of redundancy. Few cases of component failure leading AVR tripping are as below

C1) Tripping Excitation system on Air flow monitoring
One of the Excitation systems uses a pair of external fans to ensure sufficient airflow in the thyristor cubicle for cooling. One fan is fed by Excitation supply while other is powered from station supply. One fan is adequate to cater the flow required & other remains in standby mode. The airflow is monitored by a flow switch, which turns on standby fan in case of insufficient flow and Loss of airflow for more than 10 seconds initiates AVR trip.
Machine tripped on “Air Flow failure” few times due to mal operation of flow switch. Mal-operation was mainly due to drifting of flow switch setting.
The problem was solved by providing additional air flow switch & adopting two out of two logic for tripping.

C2) Tripping due to High Cabinet Temperature
One of the Machines tripped on "Cabinet High Temperature" although temperature of thyristor cabinet observed to be normal. The tripping was attributed to mal-operation of temperature sensor. The problem was solved by providing additional Temperature sensor & adopting two out of two logic for tripping.

C3) Transducer Failure
Analog output of AVR is generally in 0-10 volts. The integration of AVR to SCADA/ DAS system necessitates converting this signal to a more acceptable form of 4-20 mA signals and also for signal isolation Transducers are used for this conversion and are mounted in excitation panel & experience variation in cabinet temperature & vibration.
In hydro excitation system, Failure rate of these signal transducers are high.
It is recommended to go for in-built signal conditioning card directly for interface or use transducers. This also saves Panel space & internal wiring.

D) Factory Inspection of AVR
Detailed AVR functions cannot be checked at site during commissioning due to limitation imposed by system condition and limitation of testing facility. This can lead deficiency remaining unnoticed till actual failure takes place.
Detailed inspection of AVR at factory should be undertaken to verify component ratings, logic and function checks. Limiters and response can be checked and tuned to the extent possible using Generator Simulator.
An example of AVR tripping due to improper rating of component is given below

D1) Tripping on Rotor over voltage Protection
The Digital AVR incorporates standard rotor over voltage protection often called as crow bar protection. The over voltage is sensed by break-over diode (BOD) circuit. This circuit then shorts generator field through discharge resistors. The selection of BOD rating is very important and may very depending upon system configuration. The most common setting is 800 Volts for the machine operating in parallel with grid or other machine.
One of the hydro Machine tripped on "Rotor over-voltage" while feeding the delayed fault. The reason of trip initiation was due to lower rating BOD in AVR.
The rotor over voltage protection should be tested during factory inspection as it is difficult to confirm over voltage setting at site.

E) Installation of AVR
It is recommended to install AVR in dust free well ventilated atmosphere. This will prevent failure of electronic components, contactor, limit switch etc.

In one of the hydro Generating station, the Excitation system panels were installed on the turbine floor. As AVR was installed in humid atmosphere, moisture along with dust got deposited on thyristor & electronic cards. This resulted in card failure.

5) Conclusion

1) Digital Excitation system offers high degree flexibility and redundancy to suit the user requirement resulting in saving in panel wiring & hardware.

2) The logic for customized requirements such as Heat run test, PT supervision, interlocks and Plant Automation can be achieved by utilizing powerful software features of the Digital AVR.

3) Selection of peripheral equipment such as excitation Transformer, DC /DC Converters, Contactors, sensors, Transducers need critical consideration as reliability of these component plays crucial role in achieving overall reliability of AVR.

4) The optimization of Monitoring functions like Rotor over temp, converter input supply, Aux. supply monitoring etc and inbuilt protection functions helps to achieve the trouble free operation of AVR system over its life cycle.

5) Detailed factory inspection will help reduce the commissioning time and rework.

6) System interface issues such as AVR input supply, Heat run arrangement, Field flashing source, Aux supplies etc needs to be taken care during design stage to ensure satisfactory operation of AVR under transient and steady state condition.

7) Installation of Digital AVR in a dust free environment will increase reliability and life of the AVR.

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