TG-701 GROUND FAULT RECTIFICATION

Introduction

Fauji Fertilizer Company Limited has two Urea plants near Sadiqabad, Pakistan. Electrical power source to this ammonia-urea complex, are two Gas Turbines TG-701 & TG-702, serving relentlessly as a backbone of the plants for the past 30 years. MARK-II is installed on TG-701. TG-701 turbine has had Speedtronic and 125VDC power supply ground faults since 2003. These ground faults caused many mysterious outages on the turbine. History data analysis reveals at least one tripping or emergency shutdown each year that can be attributed to these ground faults. Attempts for the detection and rectification of these ground faults were made in several turnarounds with no success. This year in plant turnaround Oct-2009, this long awaited target was accomplished.

This paper gives a brief overview of the sequence of the jobs conducted to find both the ground faults one by one. It gives an insight to the hidden problems that engineers came across while dealing with Mark-II control system of General Electric, installed on the Gas Turbine. It also unveils some ingenious ideas that helped us to tackle with the grounding problem.

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Background

TG-701 MARK-II control system has three possible sources of ground faults namely 'Speedtronic Ground Fault', '125VDC Ground Fault' and 'Thermocouple Ground Fault'. The 'Speedtronic Ground Fault' and '125VDC Ground Fault' were hampering the turbine's smooth operation and functioning for the past seven years. The latest tripping of TG-701 occurred in September just one month before the turnaround 2009 as a direct effect of '125VDC Ground Fault'.

Ground faults are extremely dangerous to any type of electrical or electronics systems. Besides outages they can cause sparking and damage to hardware.

Ground faults are annunciated when one of the two poles, positive or negative, is grounded. The fault should be addressed in first opportunity as grounding of second pole will result in sparking and tripping of the machine.

Based on above, the overhaul of Speedtronic MARK-II System and rectification of both ground faults were planned in the TA-2009.

System Maintenance

Preliminary numeric and photographic sample data of MARK-II control system was collected at different phases of TG-701 shutdown. The data was later used for ground fault analysis and comparative study, once the fault was removed. This data helped us in determining the Speedtronic ground fault as permanent fault and the 125VDC as intermittent fault. Thermocouple ground fault was ruled out because the thermocouple ground fault detector card SGDE was not on alarm.

The Speedtronic voltage levels under fault condition are shown in the table below. A clear abnormal shift of 4.5VDC in all power supplies and COMs with respect to ground is highlighted.

Once the ground fault was removed the voltage shifts were normalized.

			REGULATOR	SGDD
SNO	SUPPLY	TERMINAL	VDC	VDC
1	P28	P28,PCOM	28.03	28
2		P28,GND	23.68	23.6
3		PCOM,GND	-4.3	-4.54
4	P12	P12,ACOM	11.99	11.9
5		P12,GND	7.52	7.5
6		ACOM,GND	-4.39	-4.46
7	N12	N12,ACOM	-12.04	-11.99
8		N12,GND	-16.3	-16.15
9		ACOM,GND	4.6	4.3
10	P5	P5,DCOM	5.08	4.92
11		P5,GND	0.53	0.62
12		DCOM,GND	-4.56	-4.44

Table: 1 Speedtronic Voltage Levels with Ground Fault

Ground fault indication was consistently persisting on the First-out Panel before turnaround. It was due to the actuation of both, Speedtronic SGDD card and the 64D relay for 125 VDC ground fault detectors.

Ground fault rectification activity started with complete over hauling and cleaning of MARK-II control system. Following modules were dismantled and cleaned:

Speedtronic Page: Speedtronic page or 1L page contains control and logic cards of the system, 126 in number. All cards were taken out checked, cleaned and inserted back.

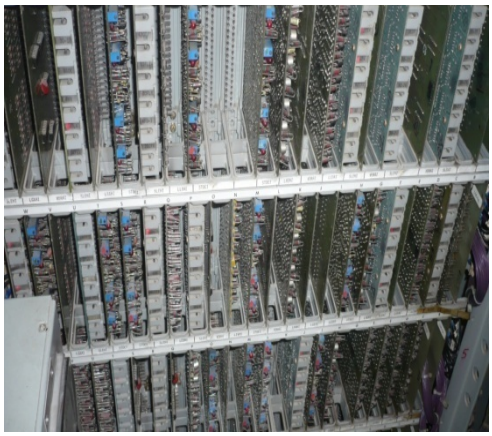

Fig1: Speedtronic Page Cards

On the rear side of this page thousands of wires are connected. All these connecting wires were checked and cleaned.

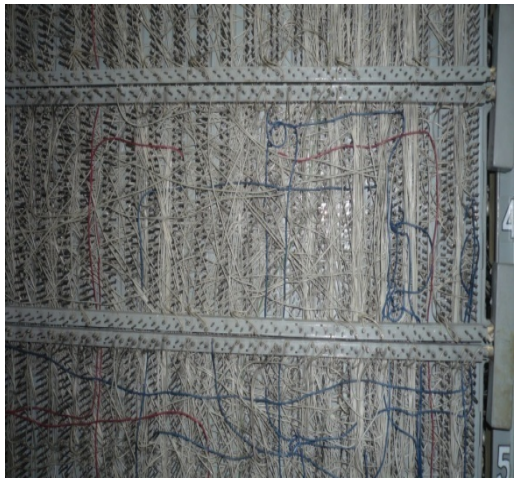

Fig2: Speedtronic Page Rear View

Black Start Inverter: Black Start Inverter was dismantled from the control panel and taken to electrical shop for maintenance and checking of aging components.

Fig3: Black Start Inverter Installation

Power Supply Module: Bulk power supply module was overhauled in electrical shop. Its power switching cards EPSU and EPSV were found in bad condition covered with carbon dust. These cards were cleaned, checked and re-installed. One capacitor was replaced as it was showing zero microfarads.

Fig4: Bulk Power Supply Module

Final Regulator Module: All power supply cards (+28VDC, +12VDC, -12VDC, +5VDC, Bus Monitor card) of Final Regulator were taken to instrument shop, checked and overhauled. The supply connections at the back of regulator rack were cleaned and lugs were changed where required.

Fig5: Final Regulator Supply Cards

Source Selector Module: Source selector was removed from the cabinet, overhauled in the shop and reinstalled.

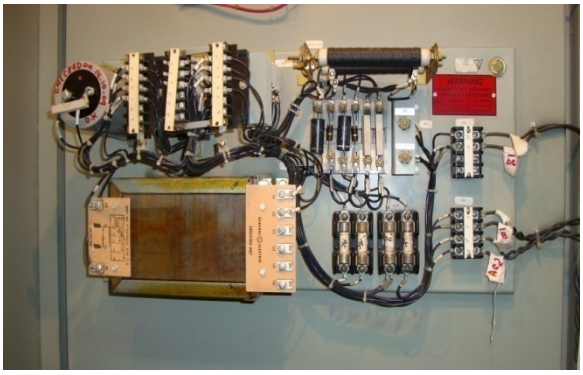

Fig6: Source Selector

Speedtronic Relay Page: All 70 relays on relay page were taken out, cleaned and checked for contact & coil resistance. Relays with higher contact resistance were replaced. Cable connections at the back of Relay page were also cleaned. Mechanical actuation of relays was also checked.

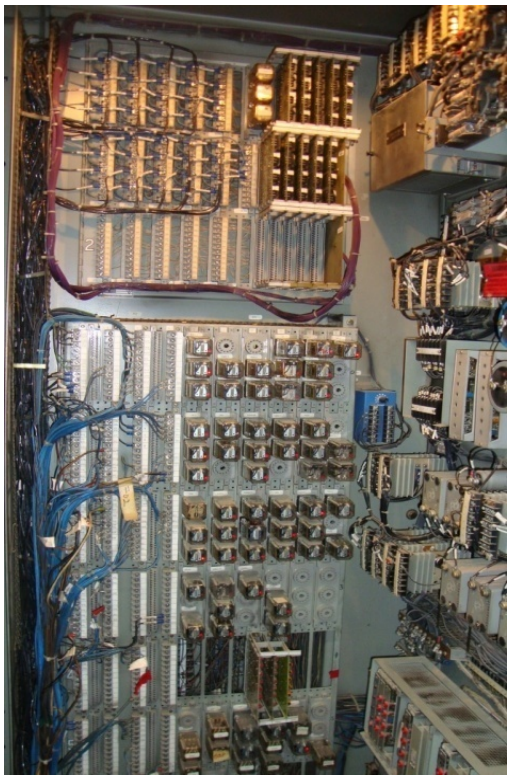

Fig7: Relay Page and Remote Annunciator

Remote Annunciator Module: The Module was taken to the instrument shop for overhauling. All cards and relays on this panel were also checked cleaned thoroughly.

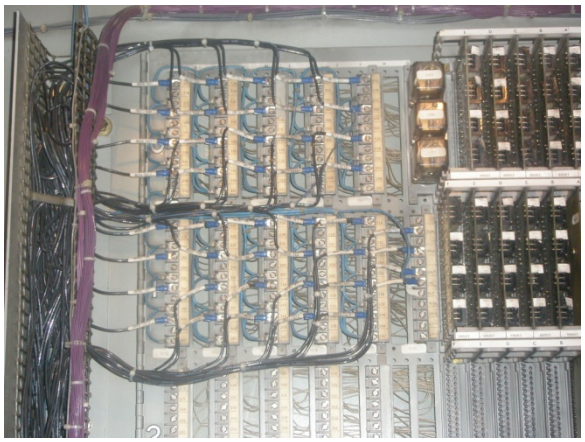

Fig8: Remote Annunciator Module

Remote Annunciator Panel: Mark-II UCR panel was also cleaned and checked for any faulty instruments. Fused bulbs and lamp holders were replaced.

All above modules were extremely dirty and had carbon dust deposition. They were removed from their location for the first time and were attended in workshop.

Overhauling of 10 local annunciator cards and 17 receptacle cards was done at site. Terminal strips HCTB, LCTB, and RTB were also cleaned. Twelve Input Isolator cards were overhauled. One card was also replaced afterwards.

All fused bulb and lamp holder of local and remote panels were also changed.

Once the maintenance was completed system was re-installed, integrated and powered up.

MARK-II Calibration

Calibration of different controls and protection loops was performed. Checking & calibration of power supply, Speed control loop, acceleration control loop, temperature control loop, PCD bias adjustment, over-temperature, speed protection and start-up control was performed.

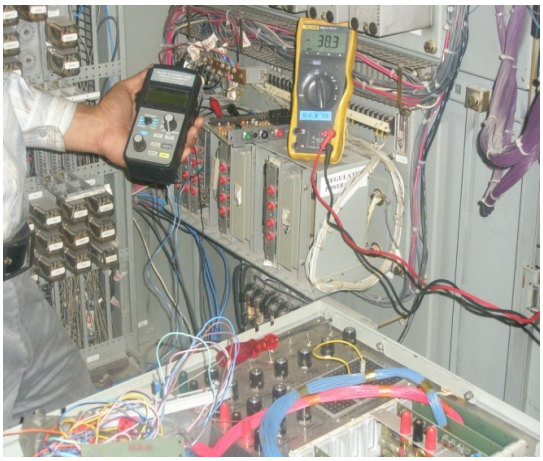

Fig9: Speedtronic Calibration Setup

Speedtronic Ground Fault

Speedtronic ground fault was persisting on SGDD ground detector card and on the first-out panel. It was necessary to isolate wiring and hardware step by step while observing the status of ground fault indication.

All 126 cards on Speedtronic 1L page were pulled out one by one. Each card has 51 pins. Ground fault indication kept persisting till the last card was pulled out.

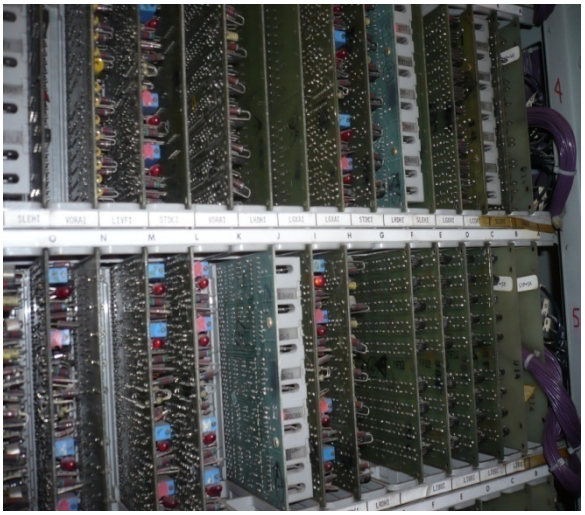

Fig10: 1L Page Cards

In the end only SGDD ground detector card was left on the 1L page and ground fault indication was there on the card. This confirmed that there was no grounding on any of the 125 cards pulled out of 1L page.

In the next step all power supply cables 28VDC, +12VDC, -12VDC, 5VDC, PCOM, ACOM and DCOM were disconnected on 1L page. These are 130 power supply cables disconnected from the vertical and horizontal buses of 1L page.

Disconnection sequence of power supply cables was from horizontal bus one by one from bottom to top.

There was a problem in disconnecting power supply of the first row of 1L page. This action would have disconnected the SGDD card from power supply whereas its ground fault indication was important to us in troubleshooting.

A technique was adopted to overcome this problem. SGDD card was powered up outside the 1L page. External biasing was provided to the card through the wires directly from Main Bus Bar. This step helped us a lot in catching the ground fault. 1L page was then completely disconnected from Main Bus Bar. Yet ground fault Indication persisted, ruling out the ground fault in 1L page.

Fig11: SGDD Card Wired & Powered Up Outside its Slot

Once the card was functioning all the power distribution cables of regulated supplies 28VDC, 12VDC, -12VDC, 5VDC, PCOM, ACOM, DCOM

were disconnected one by one from the main bus bar.

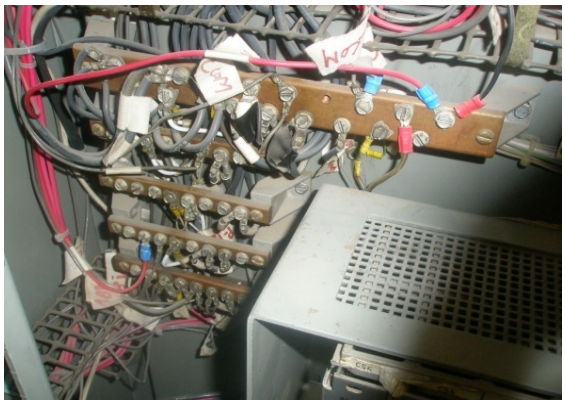

Fig12: Main Bus Bars of 28VDC, +12, -12, +5 & COM

In the above step REMAN module, Local annunciator module, thermocouple processing module and synchronizer module were disconnected. SGDD ground fault indication still persisted. A total of 235 cables were removed while isolating all above modules from Main Bus and their respective Terminal Blocks.

Fig13: Thermocouple Module & Annunciator

After disconnecting about 50 more cables we found the suspected cable on -12VDC distribution circuit. The cable was physically traced and it led us to the fuel gas pressure transmitter 96FG.

To conclude the grounded part, 96FG was disconnected from the area JB while -12VDC still connected to main bus bar. SGDD card indication remained reset. The situation was verified several times.

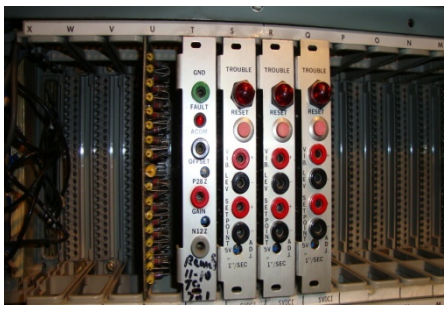

Fig14: SGDD Card Indication Reset

Voltage level of complete system was rechecked for analysis. Voltage shift in all regulated supplies and COMs normalized as highlighted in the table. No effective voltage between supply, COM and ground was found. It was concluded that Speedtronic ground fault is removed from MARK-II system. Complete system was re-assembled. All cables/modules were connected one by one to detect any other possible cause of Speedtronic ground fault. Finally 1L page was reconnected to the bus bar.

			REGULATOR	SGDD
SNO	SUPPLY	TERMINAL	VDC	VDC
1	P28	P28,PCOM	28.03	28
2		P28,GND	28.08	28.1
3		PCOM,GND	-.72	-.72
4	P12	P12,ACOM	11.99	11.9
5		P12,GND	11.86	11.83
6		ACOM,GND	-.73	-.73
7	N12	N12,ACOM	-12.04	-11.99
8		N12,GND	-12.3	-12.15
9		ACOM,GND	.76	.73
10	P5	P5,DCOM	5.08	5.02
11		P5,GND	4.9	4.89
12		DCOM,GND	-.75	-.71

Table2: Speedtronic Voltage Levels without Ground Fault

No ground fault appeared in re-assembling the system. SGDD card was re-installed.

Fig14: Faulty Fuel Gas Transmitter 96FG

New transmitter 96FG was installed in the area. During a thorough examination of faulty 96FG in the workshop the black signal cable of 96FG was found showing only 1.7Ω resistance with ground. The Ground Fault persisted even when the suspected cable was de-soldered from the PCB board. Finally, it was concluded that the signal terminal and ground terminal of PCB board of 96FG were short.

Fig15: New 96FG Installed

125VDC Ground Fault

125VDC Ground fault was categorized as an intermittent ground. It appeared occasionally on 64D ground detector relay and would reset immediately. The data pertaining to 125VDC power supply was collected for analysis.

There was an abnormal shift in 125 DC voltage levels indicating a Ground Fault. This type of Ground Fault is hard to find as it is subject to circumstances.

			AS FOUND	NORMAL
SNO	FUSE	TERMINAL	VDC	VDC
1	FU-12	FU12+,GND	128	65
2		FU12-,GND	12	-65
3	FU-7	FU7+,GND	132	65
4		FU7+,GND	1.2	-65
5	FU-6	FU6+,GND	132.5	65
6		FU6+,GND	1.55	-65
7	FU-5	FU5+,GND	133	65
8		FU5+,GND	.09	-65
9	FU-4	FU4+,GND	132.6	65
10		FU4+,GND	.07	-65

Table3: 125VDC Voltage Level with Ground Fault

During one of its random appearances the Ground Detector Relay 64D remained actuated for some time. Immediately, all the fuses were pulled out one by one starting from FU-7. The ground fault normalized as soon as FU-4 negative supply fuse was pulled out. The grounding appeared again immediately after the re-installation of the fuse FU-4.

FU-4 fuse supplies power to all of the input isolator cards ISOL. All these cards and their respective circuits were checked. Some variation in the voltages with ground was observed on ISOL SIIE0G card.

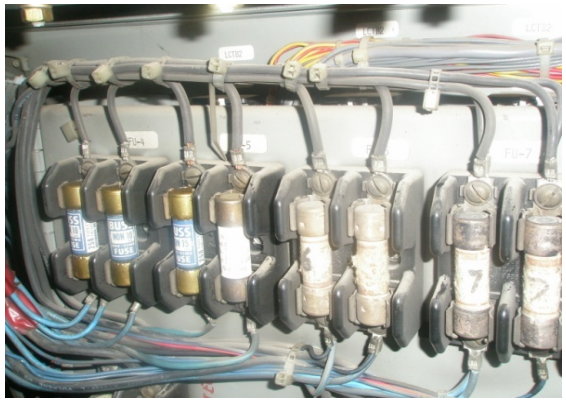

Fig16: 125VDC Fuses

The voltage level on SIIE0G card was found between 56 to 48 VDC. These inputs were related to Boiler damper and Bypass damper logic and were coming from AIU-4 cabinet. Some pairs of this multi-core cable were also terminated on RTB and HCTB1.

This multi-core cable was disconnected from both ends the turbine and AIU-4 side in UCR rack-room and cable was meggered and were found healthy. Furthermore, AIU-4 logic was also analyzed and cables were physically traced. Meggering of area cables of Boiler Damper and Bypass Damper was also performed. Although the variation was noticed in voltage levels but even after disconnecting the AIU-4 cabinet from Speedtronic system 125VDC ground fault appeared regularly. Hence it was obvious that AIU-4 did not participate in the ground fault.

Ground fault checking procedure was also incorporated in routine checking / calibration of switches, limit switches, fire detectors, probes, FDs, Spark Plug etc. Special formats were made for each instrument. Ground detector relay was still energized after all these checks were performed.

In subsequent step SOVs were checked for the ground fault. 20FD liquid fuel SOV was found grounded and rectified immediately. Same procedure was repeated for liquid fuel purge SOV 20PL and fuel clutch SOV 20CF. Still 125VDC Ground Fault persisted in the system indicating multiple Ground Faults.

The 125VDC ground fault was finally found in the cables entering the MARK-II cabinet from bottom. These cables were routed over a channel support. On the top of these cable was a horizontally bolted plate. These cables were pinched in between the support and the top metal cover plate. Any weight / load on the upper plate would press these cables against the sharp edges of support.

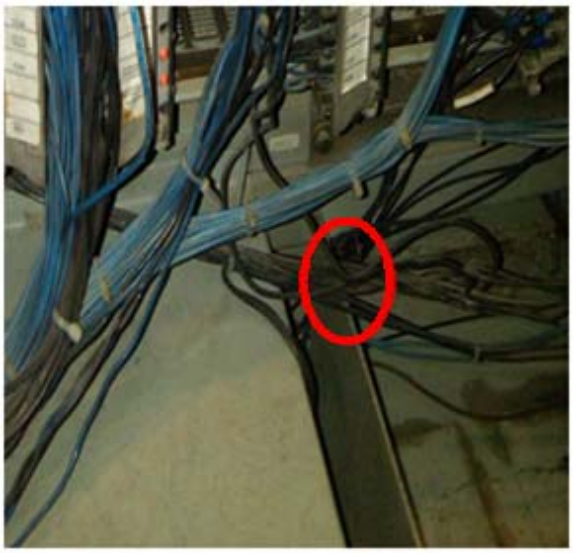

Fig17: Top plate taken aside to see the cables over the vertically mounted support

Two out of seven pairs of this cable were in use. One of the cores had a major cut while others had minor cuts.

Fig18: Cut on the Grounded Cable

The cables were then insulated, protected and properly routed to their respective locations. The cables which were not being used in the

system were separated and adequately secured for future use.

The Ground Fault indication on First-out panel reset immediately as soon as 125VDC ground fault was rectified. Voltage levels normalized after the removal of 125VDC ground fault.

			AS LEFT	NORMAL
SNO	FUSE	TERMINAL	VDC	VDC
1	FU-12	FU12+,GND	67.2	65
2		FU12-,GND	-64.3	-65
3	FU-7	FU7+,GND	67.3	65
4		FU7+,GND	-64.7	-65
5	FU-6	FU6+,GND	-67.2	65
6		FU6+,GND	63..93	-65
7	FU-5	FU5+,GND	-67.0	65
8		FU5+,GND	-64.7	-65
9	FU-4	FU4+,GND	67.13	65
10		FU4+,GND	-64.77	-65

Table4: 125VDC Voltage Level without Ground Fault

Recommendations

Once the Ground Fault is removed from the system, more responsibility comes on our shoulders. Following are our suggestions.

1. Adequate time should be given in turnaround for troubleshooting of Speedtronic controls.
2. While detecting a Speedtronic ground fault the SGDD card can be removed from its slot and biased from Main Bus
3. While biasing SGDD card externally never insert another SGDD card in slot `1L0T as it would give ambiguous results. Use only one SGDD card to detect Ground Faults
4. Complete boiler damper and boiler bypass damper logic should be shifted into its respective MARK-II and MARK-V control system thus eliminating unnecessary long cables, complicated logic and a potential threat of ground fault
5. 125VDC ground fault also exists in TG-702; therefore adequate time should be allocated in first available opportunity to rectify this ground fault

Conclusion

Ground fault has existed in the TG-701 in different forms consistently from 2003 to 2009. Negative 12VDC supply of 96FG was grounded. If the positive 12VDC supply cable was grounded for even a moment, it could have caused severe results. By design there are no protection fuses in Speedtronic as in 125VDC circuit.

Power supply switching protection system is available on bulk power supply hence it is at lesser risk than the Speedtronic. Still the 1L page, 1R Page, Local Annunciator, and Remote Annunciator, Thermocouple Processing module, Flame Detector Module, Spark Plug ignition Module, synchronizer and Relays could have directly affected by grounding of the other bus.

Authors

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