ROOT CAUSE ANALYSIS WITH CAUSE-EFFECT CHARTING, CUSTOMIZED SOFTWARE FOR NTPC TRIP ANALYSIS

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ABSTRACT

NTPC has a widespread and diverse fleet of power stations with varied age profile. Statistically it is a well established fact that unforeseen unit trips are inevitable. The complexity of power plant systems and numerous aspects related to design, implementation, erection, commissioning, operation and maintenance, renovation and modernization always introduce a degree of uncertainty leading to deviation from ideal or expected behavior. However, repetition of trips of similar nature is definitely avoidable. Every unit trip or near-miss invariably necessitates some change - design/system/process-oriented, procedure/policy/behavior-oriented or both. The correct way forward is comprehensive root cause analysis (RCA) of each incident, framing and circulating corrective action plan, implementing the plan with definite time frame and periodic review of expected result.

NTPC traditionally has methodical systems put in place for root cause analysis of each unit trip at site, Regional Headquarters and Corporate Headquarters level. Finalized trip reports are duly shared with all concerned stations and time-bound implementation is reviewed in specific forums. However, there is further scope for improvement in the method of capturing trip related information in a standardized manner, using menu-driven template based tool and user-friendly software interface for easy search-retrieval with pattern recognition.

The paper provides details of root cause analysis methodology of unit trips using cause-effect charting technique. Cause-effect charting is compared with traditional story-telling trip report, to indicate higher clarity, visual impact and learning potential. The concept is reinforced by sample case studies of C&I and mechanical related trips. Detailed suggestions for template design of the software interface are given.

1. INTRODUCTION

1.1 Need for RCA

Power plants require RCA in the context of the following scenario:

- Serious or fatal accidents – Personal safety
- Damage to equipment – Asset security
- Loss of generation (unit trip or partial loading) – Company profit
- Deviations from statutory regulatory norms – Grid related (RGMO, SPS) and environment related (CEMS, EQMS, AAQMS)
- Medical Emergencies – Personal healthcare as provided by organization's hospitals

1.2 Determining need for RCA based on Risk Assessment Matrix (RAM)

In order to determine the necessity of RCA for a specific incident, a risk assessment matrix (RAM) based on severity of consequences can be referred to. RAM classification can be based on either actual data (with historical occurrence frequency) or predicted data (probability/likelihood). A sample RAM classification based on severity of consequences and historical occurrence frequency is given at Figure-1.

CONSEQUENCES			HISTORIAL OCCURRENCE FREQUENCY				
Safety	Assets	Loss incurred	> 10 years	< 10 years	< 5 years	< 1 year	< 1 month
Minor Injury	Minor damage	Equipment outage, < Rs 50 k				SUGGESTED	SUGGESTED
Reasonable Injury	Reasonable damage	Partial loading, < Rs 5 lac	SUGGESTED	SUGGESTED	SUGGESTED	MANDATORY	MANDATORY
Major Injury with loss of work	Major damage, outage > 1 week	Unit runback, < Rs 25 lac	MANDATORY	MANDATORY	MANDATORY	MANDATORY	MANDATORY
Fatal Accident / severe health hazard	Multiple major damage, outage > 1week	Unit/station trip, > Rs 25 lac	MANDATORY	MANDATORY	MANDATORY	MANDATORY	MANDATORY

Figure-1 : Risk Assessment Matrix

1.3 RCA data collection

Typical sources of evidence data for RCA are given below:

- System generated logs/reports (eg. DCS trend, SOE, alarms)
- Physical evidence by inspection (eg. photographs of failed material)
- Design / implemented documents / procedures / practices on record
- Operation and/or maintenance log books (to be validated by facts)
- Interview summary – statements and opinions of persons involved (to be validated by facts)
- Failure analysis report for failed material (where applicable)

1.4 RCA cycle

Typical RCA cycle for a power plant incident in a large organization like NTPC should consist of the following steps:

- Accurate incident reporting with factual evidence data
- Cross-functional evaluation of the symptoms ("weed") and multiple underlying causes ("root") using effective RCA tools
- Arriving at implementable solutions after due approvals, with cost-benefit analysis
- Identifying all systems/equipment which pose similar vulnerability
- Time-bound action plan for implementation in all systems/equipment at all concerned stations
- Cross-verification and feedback of desired result, with look-out notice for unwanted after-effects post implementation
- Specific feedback to engineering design (where applicable) in order to eliminate repetition in new and upcoming stations
- Seamless online access for RCA final reports of all stations to all working level executives, to create awareness and contribute to learning organization concept

1.5 Need for a new RCA tool in NTPC context

The traditional "story-telling" method adopted in NTPC trip analysis reports may encounter the following drawbacks in some cases:

- Multiple interpretations of the incident report, due to possible missing logical links in narration
- Inadvertent omission of some significant causes (incomplete analysis)
- Inadvertent omission of some significant solutions as a result of missed causes (incomplete action plan)
- Cumbersome retrieval of specific trip related information (eg. summary of all drum level related trips in 500MW units at a glance) for pattern recognition
- Limited SAP access to detailed trip reports (document type ZTP) due to authorization restrictions, affecting learning potential of working level executives
- OS compilations [1] for yearly trip analysis reports for NTPC coal stations have been discontinued after 2011-'12 following start of regular trip report uploading in SAP

Figure-2 illustrates the breakup of trips at NTPC coal stations in the past decade.

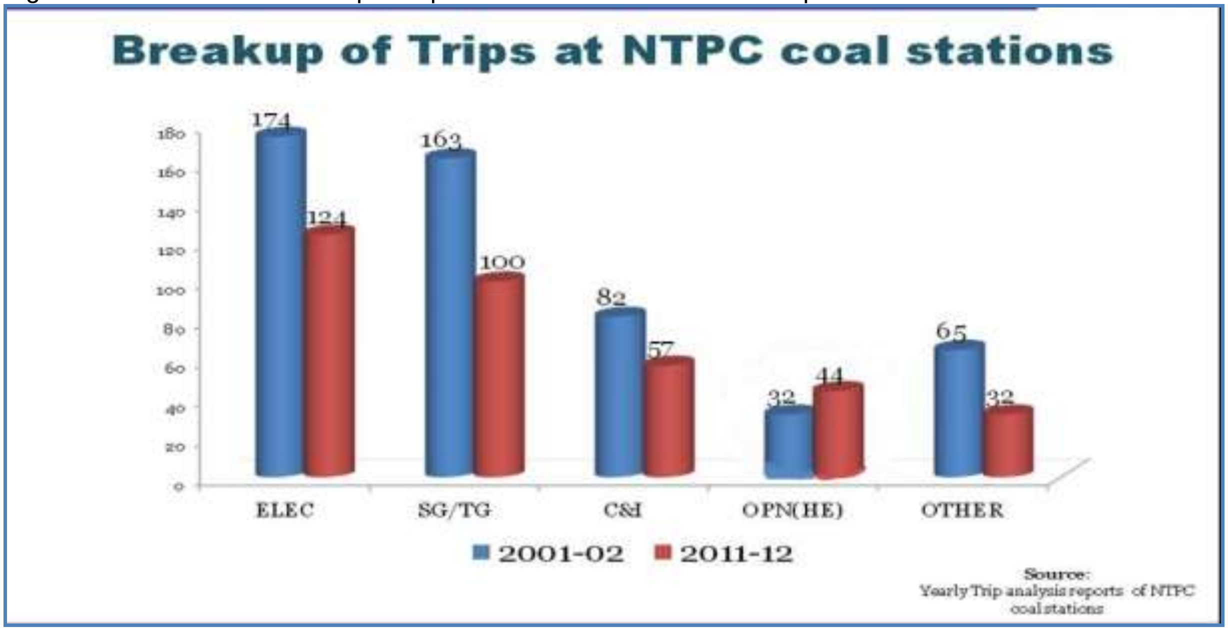

Figure-2 : NTPC coal station trips in the past decade

From the bar chart it can be seen that though there is overall reduction in number of unit trips, there is still a lot of scope for improvement.

1.6 Comparison of RCA tools

Figure-3 [2] shows a comparison of RCA tools/methods:

Method / Tool	Type	Defines Problem	Defines all casual relationships	Provides a casual path to root causes	Delineates evidence	Explains how soln. prevent reoccurrence	Easy to follow report	Score
Events & Casual Factors	Method	Yes	Limited	No	No	No	No	1.5
Change Analysis	Tool	Yes	No	No	No	No	No	1
Barrier Analysis	Tool	Yes	No	No	No	No	No	1
Story telling	Method	Limited	No	No	No	No	No	0.5
5 Why's	Method	Yes	No	Yes	No	No	No	2
Six Sigma	Method	Yes	Yes	Yes	Yes	Limited	Limited	5
Pareto	Tool	Yes	No	No	No	No	No	1
Fault tree	Method	Yes	Yes	Yes	No	Yes	No	4
Cause - Effect	Method	Yes	Yes	Yes	Yes	Yes	Yes	6

Figure-3 : RCA tools comparison

The cause-effect tree charting method of RCA has been chosen in this paper as most suited to power plant context due to its clarity and visual impact. It also facilitates easy search capabilities for historical incidents by simply selecting any one cause box and initiating a query, in the proposed customizable software.

2. RCA WITH CAUSE-EFFECT CHARTING

2.1 Cause-effect tree charting definitions

The key definitions used in cause-effect tree charting method are given below:

- Cause: An action, condition or event that results in an effect
- Condition: Contributing factor existing over a period of time before effect
- Event/action: Contributing factor that occurred just before the effect
- Evidence: Supporting data (typically needed for every cause)
- Solution: Corrective course of action (typically needed for root cause and some other specific causes only, based on RCA judgment)

2.2 Cause-effect tree charting norms

The norms followed in cause-effect tree charting method are given below:

- Tree may contain actual causes, probable causes and even relevant guesses (cannot be eliminated unless proven otherwise)
- Tree may be expanded up to a depth where design / system / process-oriented or policy / procedure / behavior-oriented actionable solution is feasible
- "Equipment failure" is only a symptom. Root cause may be operational (operated beyond design limits), maintenance-related (procedures not existing/correct/followed), or design-related (eg. wrong material selection)
- If an effect has multiple dominant causes/conditions, each of them has to be expanded further and investigated for suitable solution
- In some cases there can be conflicting views on equally dominant tree branches, and identifying a particular one as root cause. It does not matter. What matters is the solution to each of the dominant causes.

3. CASE STUDIES FOR CAPTURING UNIT TRIPS USING PROPOSED CUSTOMIZED SOFTWARE

3.1 Sample C&I related trip illustration

- Trip report by Story-telling method:

U-1 of XYZ plant (500 MW unit) tripped at ___ hrs on ___ date. Load was at 520 MW, when TDBFP-A tripped on spurious high vibration (cable screen termination was found missing later). MDBFP was available, but could not take start (in auto or manual) as one permissive (suction valve open) was not present at the time of TDBFP-A trip. Runback acted and top two running mills tripped, but remaining mills got suddenly loaded in auto. (This could not be noticed quickly during operational emergency as boiler desk engineer's attention was on fast reducing drum level). Running pump TDBFP-B loaded in auto to its maximum capability, but unit tripped on drum level very low after about 3 minutes.

- Trip report in RCA cause-effect tree charting software format is illustrated in Figure-4 (intermediate snapshot) and Figure-5 (completed snapshot)

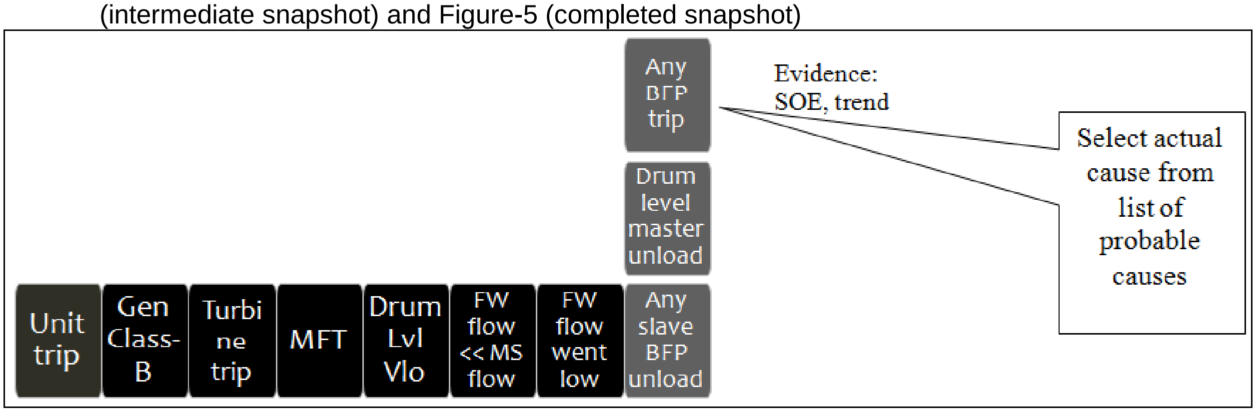

Figure-4 : RCA software entry demonstration for C&I trip case study (intermediate snapshot)

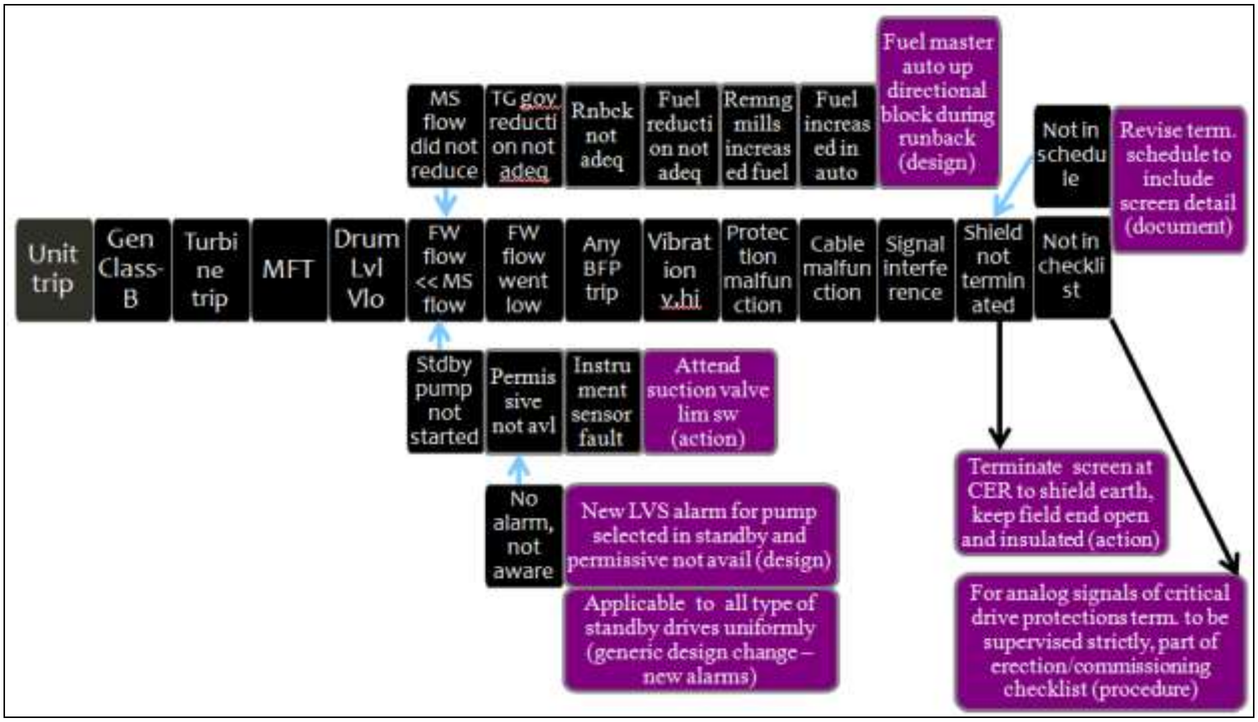

Figure-5 : RCA software entry demonstration for C&I trip case study (completed snapshot)

3.2 Sample mechanical related trip illustration

- Trip report by Story-telling method:

U-1 of XYZ plant (200 MW unit) tripped at ___ hrs on ___ date. Load was at 195 MW, when CEP-B tripped due to coupling failure (wrong grade bolts were later found to be used during previous pump overhaul). Note: pump does not have online vibration monitoring probes installed. Conditon monitoring frequency is monthly. As per design, only one CEP runs at full load, other one is standby. CEP-A was on permit for PM (PTW taken 1 week before, but could not be returned as some material got damaged during disassembly, for which spare was not available. Spare was being transferred from nearby site on urgency basis but could not be made available before incident). Hotwell level went very high, and led to poor condenser vacuum and turbine trip. Deaerator level was well below low alarm limit at the time of trip.

- Trip report in RCA cause-effect tree charting software format is illustrated in Figure-6 (completed snapshot)

3.3 Comparison of analysis for the two case studies

- Electrical and C&I trips: Solutions may tend to be more design / system / process-oriented, although human error can also be a significant contributor. Solutions may be complex, testing may be required to prevent unwanted after-effects. But they are sustainable in long-term due to definite repeatability. Thus possibility of trip repetition in many cases can be eliminated with correct design and timely implementation.

- Mechanical maintenance and Operational trips: Solutions may tend to be more procedure / policy / behavior-oriented. Solutions may be simple and straightforward. But they will be less sustainable in long-term (policy / procedures need enforcement, supervision and most importantly active participation and orientation of all persons involved). Thus possibility of trip repetition in many cases can never be eliminated.

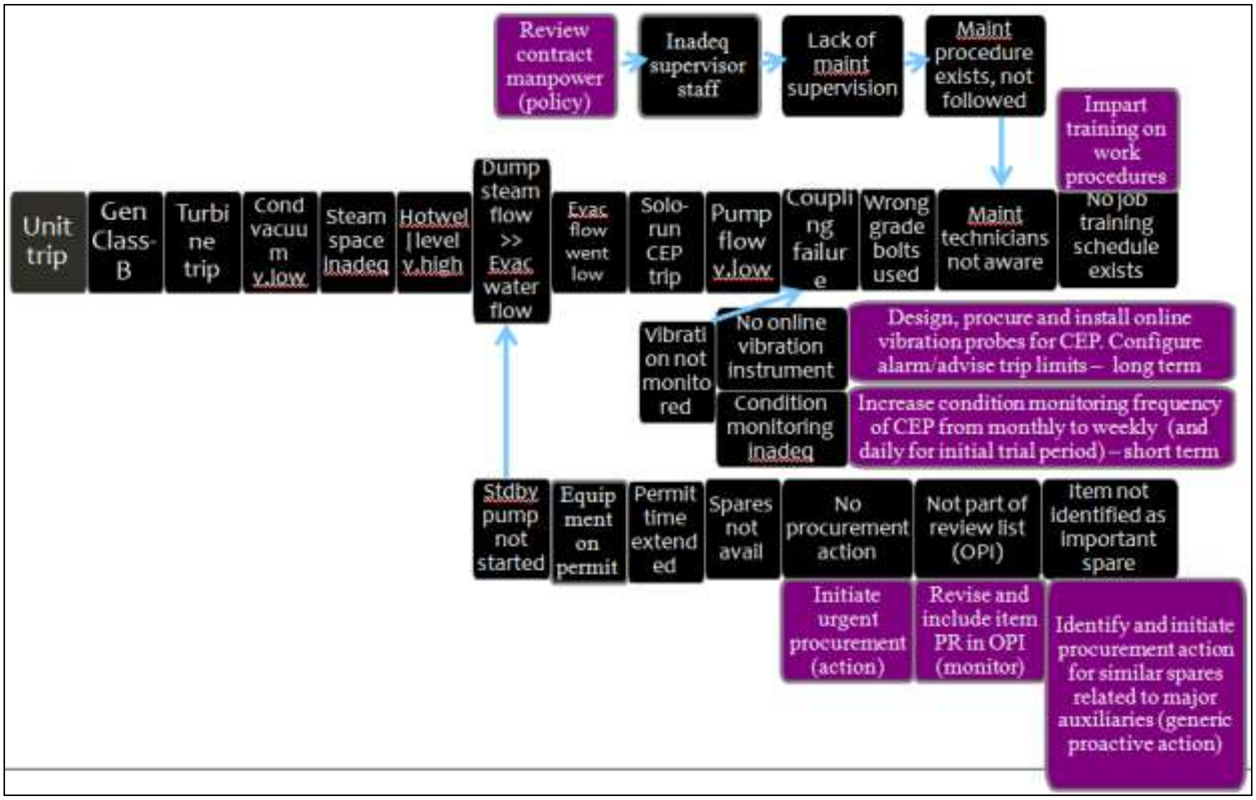

Figure-6 : RCA software entry demonstration for mechanical trip case study (completed snapshot)

4. RCA SOFTWARE PROPOSAL DETAILS

4.1 Software key characteristics

Key characteristics of the proposed RCA software using cause-effect charting are given below:

- User-friendly web-based software accessible across organization through intranet
- Centralized database server for authorized remote updation from various plants
- Predefined access control security levels:
  - ✓ User mode: Sites entering trip reports by click-expand method
  - ✓ Edit mode: Software owner updating tree database with new causes on need basis
  - ✓ Guest mode: All executives (browse learning cause-effect tree and search-retrieve)

4.2 Software tree basic structure design

Basic tree structure design considerations of the proposed RCA software using cause-effect charting are given below:

- Generic text to be used for cause box (eg. Any CEP trip instead of CEP-4B trip). This will help in generic search-filter results across all plants
- Specific numerical values of trip/alarm set points, time delays etc not to be mentioned inside cause box (different plants have different design values). Option for entering specific values can be given in remarks against each cause box
- Repetition of similar wording cause boxes to be avoided in different parts of the tree (eg. ‘Permissive not available’ or ‘protection malfunction’ is a generic cause, applicable at multiple places in the tree hierarchy)
- Implicit assumptions to be avoided while forming cause-effect tree eg. ‘Drum level V Low’ is not directly caused by ‘Any BFP trip’, there are ‘FW flow << MS flow’ and ‘FW flow went low’ / ’MS flow went high’ in between

4.3 Software desired interface features

Desired interface features of the proposed RCA software using cause-effect charting are given below:

- Click and Right-click options (new child / sibling etc, auto-color convention for boxes of cause/condition, solution, evidence etc)
- No manual-type entry for basic recording of an incident cause-effect tree (click-select-proceed from preconfigured options) for easy creation of new RCA trip report. Evidence and solution

boxes need to have preconfigured menu options as well as manual entry option (as some can be unique)

- Option to add evidences (mandatory), remarks and solutions (optional) to each cause/condition
- Database creation and retrieval of historical trips with search-filter options
- Auto-layout of blocks, print options for every page including search-filter
- Option to enter trip-code for incident as per existing classification

4.4 Software desired filter-search-retrieval features

Desired filter-search-retrieval features of the proposed RCA software using cause-effect charting are given below:

- Separate search window to retrieve list of unit trips based on filters (one or multiple filters can be active at a time):
  - (a) Station / Unit specific --- eg. Rihand U-3
  - (b) Trip main code / detail code-specific --- eg. C&I/FSSS
  - (c) Cause specific (selectable from tree browsing list) one or more --- eg. Drum level V low (AND) Any BFP trip
  - (d) Unit size specific --- eg. 500 MW units
  - (e) Given time frame --- eg. 2013 Jan to 2015 Jan
  - (f) Incident primary cause type --- unit trip / near-miss
- Inline search right-click option to retrieve list of RCA of unit trips in which a given cause played an active role --- eg. Right-click on cause “Any BFP trip” and retrieve list of incidents in which it was an active cause in the tree

5. NTPC INPUTS REQUIRED AFTER SOFTWARE TEMPLATE DEVELOPMENT

- RCA cause-effect tree template generation (one-time major activity: for ease of menu options for regular use, and to facilitate search-filter-retrieve based on causes – Standardizing tree for uniformity). This has to be carried out using domain-specific experience and expertise of multiple site and corporate engineering/OS executives
- RCA cause-effect tree template updation (intermittent activity: based on unique incidents that require new branches)
- RCA analysis and recording of historical unit trips in common database (one-time major activity: for filter-search-retrieval and statistics generation). This data mining exercise will generate sufficient base data, and help in revisiting old incidents for betterment opportunities
- RCA analysis and recording of new unit trips in common database (regular use by plants)
- Capturing near-miss incidents (potential unit trips) in similar format, along with search-filter options. In this case the starting point not would be unit trip, but the specific incident (eg. starting RCA with the cause “Any BFP trip”)

CONCLUSION

- RCA cause-effect charting technique is an effective tool for capturing major incidents / failures, and can be used in conjunction with existing story-telling method
- RCA through cross-functional team driven by factual evidence data will help in identifying root causes, direct causes and contributing (secondary) causes of failure
- RCA reports (cause-effect charting) generated in the proposed customized software tool will have more clarity and visual impact than traditional reports
- Proposed RCA customized software tool has good learning potential, and can be by included in PMI / ET / site training schedules
- Institutionalizing a customized RCA software for capturing and sharing unit-trip/near-miss incidents reduce forced-outages in the long run, with active participation

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