Protection System Maintenance Program Choices – TBM, CBM, and PBM

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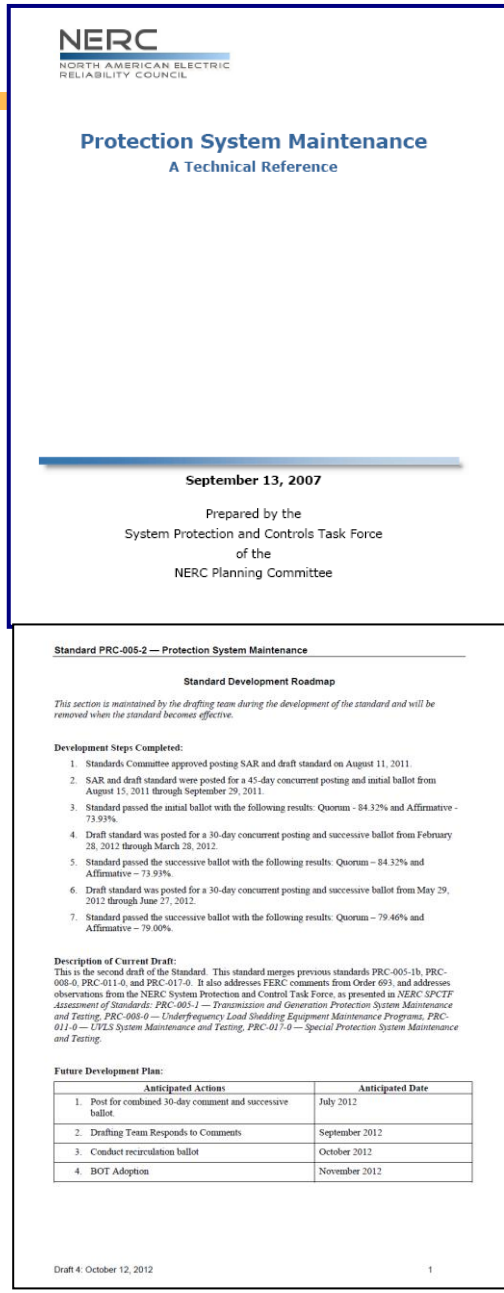
Goodbye, NERC PRC-005-1

- In 2007, FERC Order 693 declared it mandatory & enforceable.
- **No** specific maintenance requirements (FERC wanted this fixed).
- You must have a ***documented*** maintenance *program*.
- You must have a ***factual basis for time intervals***.
  - *Where do I find that???*
- You must have *concrete* evidence that you are doing ***everything*** in your program – 100 % execution.
  - *Weak evidence = you're not doing it.*
- Audits yield highest noncompliance compared to other NERC standards, and *companies have been fined*.

February 24, 2014 – FERC Order 793 makes PRC-005-2 mandatory & enforceable – a new deal.

PRC-005-2 key features

- ***Time Based Maintenance (TBM)*** base program has **maximum maintenance intervals** and **minimum activities** according to component type – many tables of specific requirements.
  - What FERC wanted in Order 693.
- Includes ***Condition Based Maintenance (CBM)*** extensions to maintenance intervals for **performance-monitored components.**
- Includes ***Performance Based Maintenance (PBM)*** management process to extend maintenance intervals for **reliable components**.
  - Minimum activities are standard across all methods.



NERC
NORTH AMERICAN ELECTRIC RELIABILITY COUNCIL

Protection System Maintenance
A Technical Reference

September 13, 2007

Prepared by the
System Protection and Controls Task Force
of the
NERC Planning Committee

Standard PRC-005-2 — Protection System Maintenance

Standard Development Roadmap

This section is maintained by the drafting team during the development of the standard and will be removed when the standard becomes effective.

Development Steps Completed:

1. Standards Committee approved posting SAR and draft standard on August 11, 2011.
2. SAR and draft standard were posted for a 45-day concurrent posting and initial ballot from August 15, 2011 through September 29, 2011.
3. Standard passed the initial ballot with the following results: Quorum - 84.32% and Affirmative - 73.93%.
4. Draft standard was posted for a 30-day concurrent posting and successive ballot from February 28, 2012 through March 28, 2012.
5. Standard passed the successive ballot with the following results: Quorum – 84.32% and Affirmative – 73.93%.
6. Draft standard was posted for a 30-day concurrent posting and successive ballot from May 29, 2012 through June 27, 2012.
7. Standard passed the successive ballot with the following results: Quorum – 79.46% and Affirmative – 79.00%.

Description of Current Draft:
This is the second draft of the Standard. This standard merges previous standards PRC-005-1b, PRC-008-0, PRC-011-0, and PRC-017-0. It also addresses FERC comments from Order 693, and addresses observations from the NERC System Protection and Control Task Force, as presented in *NERC SPCTF Assessment of Standards: PRC-005-1 — Transmission and Generation Protection System Maintenance and Testing, PRC-008-0 — Underfrequency Load Shedding Equipment Maintenance Programs, PRC-011-0 — UVLS System Maintenance and Testing, PRC-017-0 — Special Protection System Maintenance and Testing.*

Future Development Plan:

Anticipated Actions	Anticipated Date
1. Post for combined 30-day comment and successive ballot	July 2012
2. Drafting Team Responds to Comments	September 2012
3. Conduct recirculation ballot	October 2012
4. BOT Adoption	November 2012

Draft 4: October 12, 2012 1

News – Implementation Plan for PRC-005-2

Event	Date	Requirement(s)	Significance
Enforcement date – regulatory approval	2/24/2014		60 days after filing in US Federal Register
	4/1/2014		Beginning of first calendar quarter following regulatory approval
12 months after first calendar quarter	4/1/2015	R1 – Have PSMP w/method & CBM doc R2 – Have PBM program if used R5 – Manage unresolved maint. issues	100% Compliant
18 months after…	10/1/2015	R3 – Do TBM & have complete records R4 – Test PBM items & have records	100% Compliant for activities with max. Table intervals under 1 calendar year
24 months after…	4/1/2016	R3, R4	30% Compliant : 3 calendar year activities
36 months after…	4/1/2017	R3, R4	100% Compliant: 1≤ x < 2 calendar years
			60% Compliant: 3 calendar year activities
			30% Compliant: 6 calendar year activities
48 months after…	4/1/2018	R3, R4	100% Compliant: 3 calendar year activities
60 months after…	4/1/2019	R3, R4	60% Compliant: 6 calendar year activities
			30% Compliant: 12 calendar year activities
84 mo.(7 years)…	4/1/2021	R3, R4	100% Compliant: 3 calendar year activities
108 mo. (9 years)…	4/1/2023	R3, R4	60% Compliant:12 calendar year activities
156 mo. (13 years)	4/1/2027	R3, R4	100% Compliant:12 calendar year activities

Basics - which components and systems?

- Protective relays which respond to *electrical* quantities,
- Communications systems necessary for correct operation of *protective functions*,
- Voltage and current sensing devices *providing inputs to protective relays*,
- Station dc supply associated with protective functions (including station batteries, *battery chargers*, and non-battery-based dc supply), and
- Control circuitry associated with protective functions *through the trip coil(s) of the circuit breakers* or other interrupting devices.

FERC Order 758 (2010) and forthcoming PRC-005-3 will add ***certain reclosing relays*** that could impact reliability of large generating plants by misoperating. Coming – mechanical…

Which protection systems must comply?

NERC reliability standards apply to the Bulk Electric System (BES) – *previously* defined by regions.

Now - NERC standard definition – Project 2010-17.

- Transmission, generation, some distribution owners.
- Generally, 100 kV and above.
- Protection systems for critical generating plant equipment.
- UFLS, UVLS schemes & SPSs that protect the BES – even equipment at distribution.
  - Some easier tests for distribution components.

Only *maintenance* testing is covered

Commissioning assumption:

- The system was *already commissioned*, so we don't have to retest correctness of wiring, configuration, functioning.
  - ***NOTE:* Commissioning test *includes* first maintenance test!**
  - FERC now wants NERC to develop a *commissioning test standard* – a long journey coming for the industry.

To determine in *maintenance* test:

- Has *any element of hardware* needed for fault protection failed or drifted?
- Are the *settings as intended*?
- Test settings, or use a tight *settings management process* - are settings what we officially signed off?

Electromechanical relay maintenance testing

We don't know if they are working unless we test them.

- They can drift, change characteristics, or fail.
- Test settings & calibration = apply V & I.
- Check voltage and current *inputs* (CT, VT) with instruments.
- Test trip circuits.
- *Track repair & calibration history* - manage fleet or unit problems over time.

Same for analog solid state relays.

Microprocessor (uP) relay CBM

Self-monitoring features

- No calibration adjustment or drift.
- Multiple processors communicate constantly & check for failures.
- A/D converters check calibration.
- Relay logic checks *consistency* of measurements.
- Power supply or catastrophic failure – dead man alarm.
- Data communications failure – heartbeat traffic stops.
- *Behavior* - It protects correctly or (usually) blocks and reports problems.

Microprocessor (uP) relay CBM

Maintenance verification and testing:

The relay instruction book tells you what is monitored (not *how*).

Monitors everything needed for protection except:

- Check that ac input values are accurate.
- Check that status input states for protection are read properly.
- Contact/status outputs can operate connected circuits – e.g. trip outputs.
- Check or prove that settings are ***as intended***.
  - Check against controlled, managed archive.
  - *This is **not*** checking for correct application/calculation.

TBM & CBM of uP relays - Table 1-1 of PRC-005-2

Component Attributes	Interval	Maintenance Activities
Unmonitored protective relay	6 years	Verify that settings are **as specified** *Non-microprocessor relays:* Test; and calibrate if needed *Microprocessor relays:* Test protection I/O Verify ac measurements.
Monitored microprocessor relay with alarming for failures	12 years	Verify settings are as specified. Test operation of protection I/O. Verify ac measurements.
Monitored microprocessor protective relay as above plus Auto comparison check of ac measurements Alarming for change of settings Some monitoring of protection I/O	12 years	Test operation of protection I/O that isn't monitored. *Remote SCADA trip test = never touch the relay until it alarms!*

PRC-005-2 maintenance tables

Tables 1-X exclude distribution UFLS, UVLS, SPS parts – see Tables 1-4(e) & 3

- Table 1-1 - Protective Relays
- Table 1-2 - Communications Systems
- Table 1-3 - Voltage and Current Sensing Devices Providing Inputs to Protective Relays
- Table 1-4(a) - Protection System Station dc Supply…
  - (a) Using Vented Lead-Acid (VLA) Batteries
  - (b) Using Valve-Regulated Lead-Acid (VRLA) Batteries
  - (c) Using Nickel-Cadmium (NiCad) Batteries
  - (d) Using Non Battery Based Energy Storage
  - (e) For non-BES Interrupting Device - SPS & non-distributed UVLS & UFLS
  - (f) Exclusions due to Station dc Supply Monitoring Devices and Systems
- Table 1-5 - Control Circuitry Associated With Protective Functions
- Table 2 - Alarming Paths and Monitoring
- Table 3 - Maintenance Activities/Intervals - distributed UFLS & UVLS Systems

Verifying the complete protection system

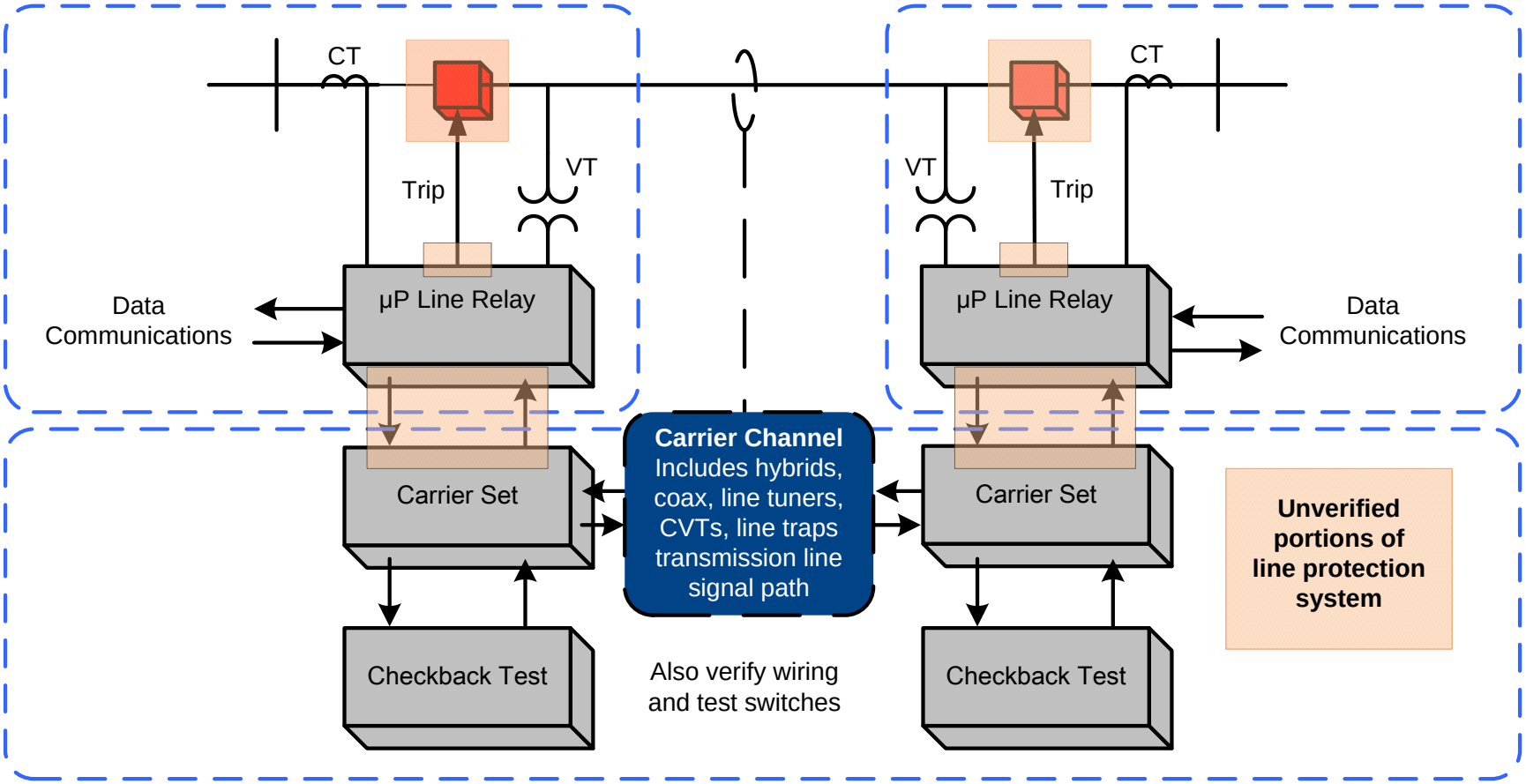
Every part of the system that is required for correct protection performance must either be:

- Monitoring and alarmed, or..
- Tested periodically.
  - No gaps – overlapping checks.
  - Monitor or test alarming paths.
- In general – E/M relays, uP relay contacts – <u>anything that moves</u> – *must* be tested periodically.
- PRC-005-2 accepts internal monitoring of uP relays.
  - New 2013 IEEE PSRC Task Force ITF27 looking into the monitoring completeness of relays.

System monitoring

- SCADA compares metered values from relay with any other independent source to verify relay ac measurement, CT and VT signals, ac input wiring.
- Monitor *continuity* of trip circuit (TCM).
- Check consistency of inputs (52a and 52b).
- Heartbeat or repeated, monitored communications paths alarm if information flow stops.

Close *most* CBM gaps with system monitoring



- Assume two redundant systems reporting analog metered values that SCADA compares automatically & alarms.
- Trip outputs and breaker tripping must still be tested (but not necessarily at the same time).

CBM benefits

Monitoring advantages over human testing:

- Continuous verification – fix it as soon as it fails - ***Protection reliability improvement.***
- Non-invasive - ***no risk of damage or human error trips***.
  - No risk of leaving equipment in a non-operating state.
- ***Frees human resources for asset replacement*** & fixing problems.

Performance Based Maintenance (PBM)

- The new killer app in protection system maintenance!
- Apply to known reliable relay types with low failure rates.
  - Stable, reliable EM types.
  - Microprocessor relays including unmonitored units.
- Maintenance time interval could reach 20 years!

PBM Program in Attachment A of PRC-005-2

Key definitions for PBM failure rate analysis

PRC-005-2 Attachment A defines:

- Equipment groupings - ***segments***
- Failure counting criteria – ***countable events***

to assess Protection System component failure rates & adjust maintenance intervals.

1. ***Segment*** - Protection Systems or components of a consistent design standard, or a particular model or type from a single manufacturer.

- Segment must contain at least 60 components (to start).
- Consistent performance is expected across the entire population.
- Attrition may reduce population to 30, no lower.

Key definitions for PBM failure rate analysis

2. ***Countable Event*** – A **failure** requiring **repair or replacement**, any condition which **requires corrective action**, or a misoperation attributed to hardware or calibration **failure**.

NOT countable events –

- Test findings or misoperations due to *product design errors*
- Software errors/firmware version problems/firmware bugs
- Relay settings different from ***specified***
- Configuration, wiring, application errors (includes bad settings)
- Maintenance to optimize a unit that met specifications
  - e.g. tuning calibration that was not out of limits.

If the problem was not there before failure event, and happened on its own, it is probably a failure.

Coded maintenance results in database

Test result categories	Countable Event?
OK	No
In cal limit - adjusted	No
Out of cal limit - adjusted	Yes
Failed unit repaired	Yes
Failed unit awaiting repair	Yes
Failed unit replaced - recommissioned	Yes
Was OK but corrected functional issue (e.g. pitted contacts burnished)	Yes
Firmware change	No
Repair program - unit was OK	No
Setting error corrected	No
Application error - replaced - recommissioned	No
Wiring error corrected	No
Other	No

- Test technicians should complete a field with standard codes for maintenance outcomes.
- Database can be searched by PBM assessment tool for countable versus non-countable outcomes for all tested units in a segment during the last year.
- Assessment result under 4% can be generated automatically.

PBM process steps

1. List & **document *segments*** (at least 60 components in each).
2. Perform specified TBM (o*r, already have TBM records?)*
3. Is *segment* failure rate (*countable events*) under 4% last **year**?
4. Increase TBM interval until failure rate expected to approach 4%.
5. But…test at least 5% of *segment* per year.
   - *Effective 20 year interval!*
6. Review results annually – check that segment is under 4%.
   - *3-year mitigation plan for rash of failures over 4%.*

Review and analysis can be automated in maintenance database.

Multiple users can aggregate compatible records to meet population minimum.

When to apply PBM

- NERC FAQ gives examples of how to manage PBM with barely suitable components & small extension benefit
  - e.g. extend from 6 to 8 years – *really messy analysis*.
- *Author's recommendation* – use PBM *only* for segments with failure rate experience less than 1.5% to 2%.
  - There are plenty of components that are this good.
  - Components likely to remain in stable PBM program without constant adjustment and re-planning of testing program.

Documentation is key for compliance audit

- Document the program (PSMP) with intervals and activities – what have you chosen to do?
- Perform every required activity, on every component, within the chosen schedule.
- Keep records of dates & results for every component.
- For CBM - document *Protection System* monitoring features.
  - Standardize designs, or this is difficult.
- For PBM – conduct annual review for each population segment, document results per Attachment A, and keep records.

Role of technicians

Do CBM and PBM eliminate jobs?

Other trends are pushing in the opposite direction:

- Shorter technical life of newer uP relays = more frequent replacement.
- Utilities struggle to free technicians for increasing asset renewal & commissioning.
- At some utilities, *lack of technicians* is the limiting factor in asset renewal – *not capital budget*!

Utilities that keep using TBM on reliable legacy equipment or monitored new equipment are at risk of falling behind with management of aging assets.

- Train technicians on laboratory test panels for troubleshooting of monitored P&C designs.

Conclusions - 1

- NERC PRC-005-2 is becoming mandatory & enforceable.
- TBM (industry's habit today) will always be acceptable if intervals & activities comply with standard tables.
- Create systems for documenting all field TBM activity.
  - Start categorizing **countable events** (for later PBM).
- Design CBM to extend intervals and eliminate most human testing, while improving reliability.
- Create design documentation and a settings management process to support CBM.

Conclusions - 2

- Use PBM – the killer app to extend intervals of reliable devices.
  - Create **segments** with database functions.
  - Use the **countable event** results to automate annual failure rate calculation.
- Find all documents for Project 2007-17 on NERC web site: http://www.nerc.com/filez/standards/Protection_System_Maintenance_Project_2007-17.html

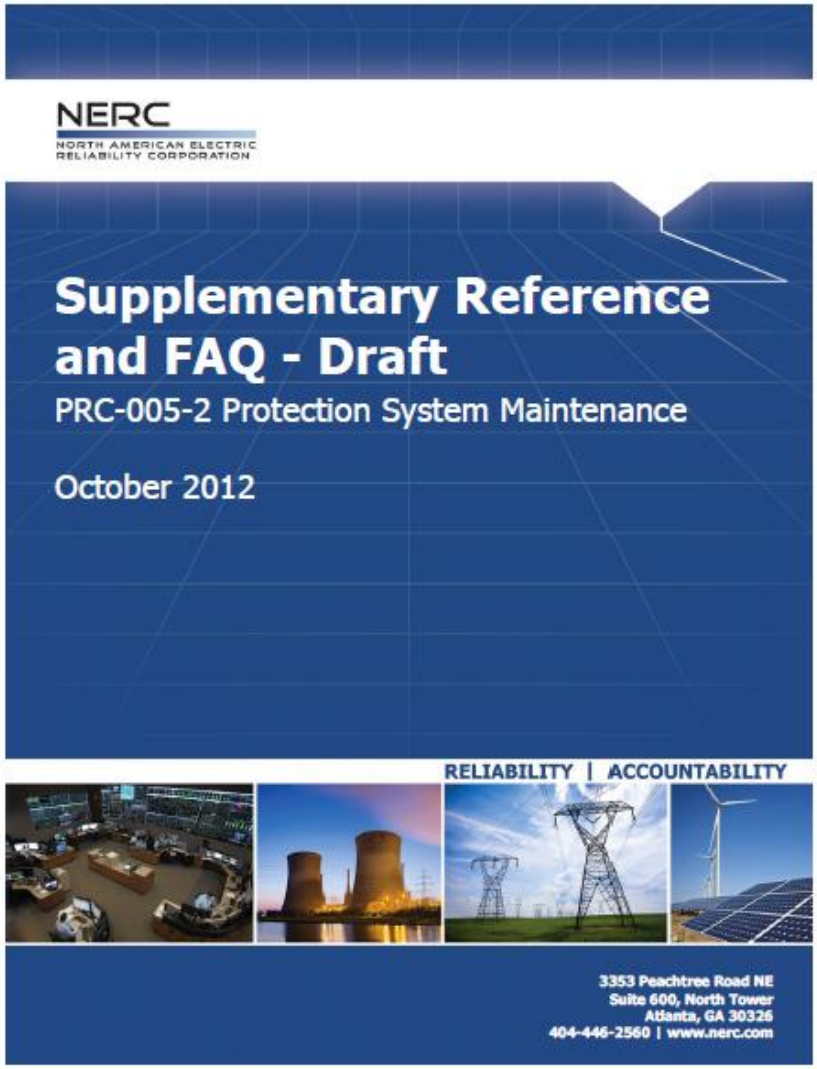
(All apparent spaces in URL have underscores, obscured above)

Use the Supplementary Reference and FAQ!

105 pages of practical help:

- FAQ answers
- Requirements explained
- Interpretations
- Tips and tricks
- Tutorial info on Protection System components
- Record keeping advice
- Audit handling advice

Your industry colleagues working to help you succeed!



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