Integration of **Diagnostics** and **Protection**

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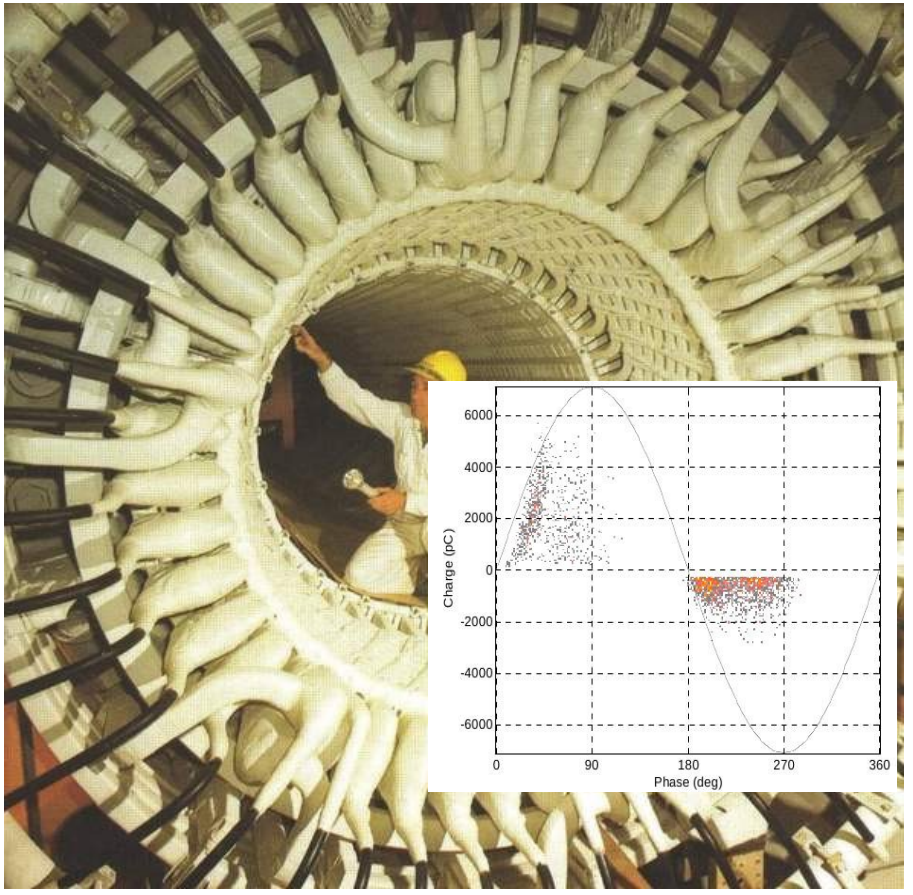


Diagnostics and ...

We hear these words in a LOT of industry sectors,
and beyond (e.g. medicine)

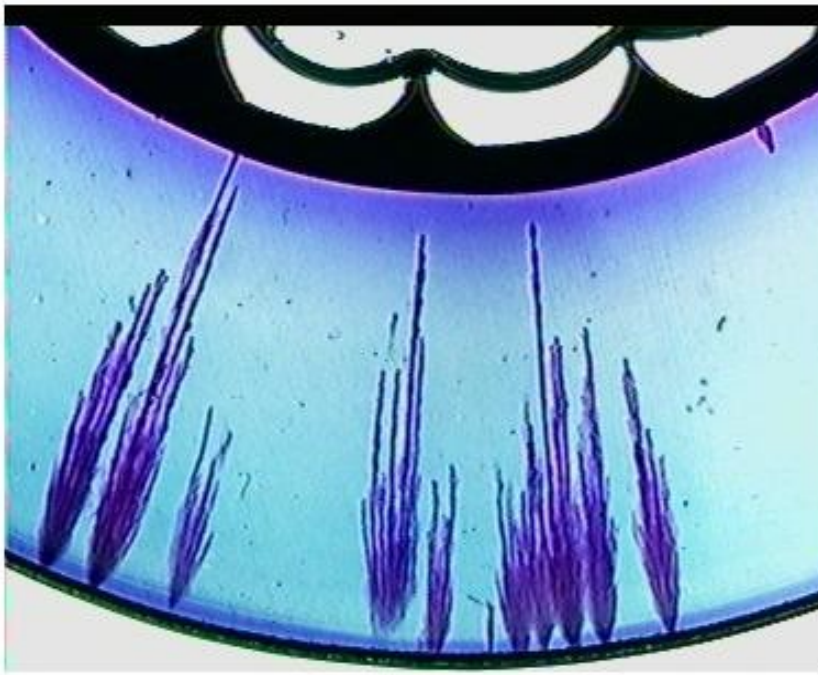
What does DIAGNOSE mean?

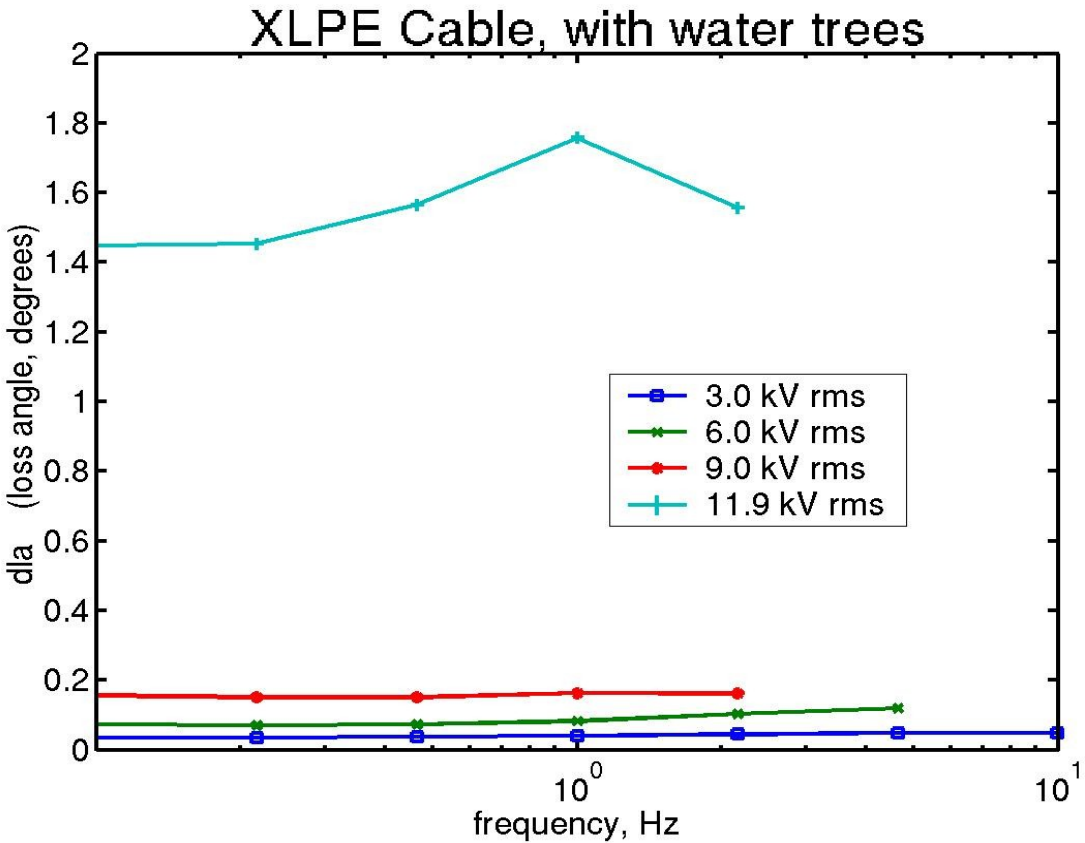
Diagnostics and ...

DIAGNOSE: infer something about a state …

Like: Is there a big air-pocket in my generator's insulation?

Or: Has this cable got severe water-treeing?





Diagnostics and P*

DIAGNOSE: infer something about a state …

We can expect this to be based on:
some sort of measurement or observation, and
on background knowledge or pattern-recognition.

but, is *"inferring something about a state"* useful by itself?

…. what's the "P*" word [above]?

Diagnostics and Prognostics

P* == PROGNOSTICS

Meaning: Infer something about future behaviour.

Might be done from a diagnostic result,
or directly e.g. pattern-recognition from earlier failures.

traditionally a weak spot in our research!

Pedantry:

Actually: for power-system equipment subject, people tend to say diagnostics to mean the whole thing.

Some other people, e.g. in industrial processes, appear more precise in the separation of these words

Diagnostics and Prognostics

So: we have inferences about *state* and *future behaviour*.

Are *these* useful – now that we're making some prediction?

As far as I see, **action** must sometimes be needed, if prognostic results are to be useful!

→ **e.g. service, replace, sell company quickly, ...**

Some of these could be classed as *maintenance*.

Notice here the HUMAN IN THE LOOP

Diagnostics and **Monitoring**
“DIAMON”

(now we're back to the sloppy use, where “diagnostic” includes prognostics)

Classic power-area definition of **diagnostics**:

… a method performed **OFFLINE**

Possible advantages, compared to online:

More control over stimuli.
Less noise.
Use 1 instrument for >>1 apparatus.
No permanent installation of sensors needed, that could impact reliability.

Monitoring or **“Condition Monitoring” (CM)**

… commonly implies **ONLINE**

Possible advantages, compared to offline!

Actual operating conditions.
No delay in seeing a change.
Trends of parameters with equipment loading, etc.
Avoid spending downtime on measurements!

Diagnostics and Monitoring "DIAMON"

Offline examples:

Partial-discharge measurement of generator windings at 0.2 – 1.2 ***U*n** .

Polarizationcurrent measurement of generator winding or cable.

Frequency-domain dielectric spectroscopy of transformer (assess moisture).

Online examples:

Permanent monitoring of PD in generator windings during service.

Monitoring of surge-arrester current in normal AC service conditions.

now to **Protection**

Classic PROTECTIVE RELAYING (today's overall subject)

Mitigate effect on SYSTEM, when a component fails.
Fast clearing of line faults, Generator out-of-step, etc

Mitigate damage to COMPONENTS from external or internal causes:
Limit thermal and magnetic-force stresses, ...

And could mention safety of people, animals, etc!

NOTE:
Based around **power-components**: {bus,line,trafo,etc}-protection
Measurements generally are **local** to the equipment
Autonomous – and *short time* is often crucial.

Other protection (not quite within the above framework)

WAPS – highly non-local
SPS – system-oriented: not necessarily faulty component
LV-net – some simple fused systems don't warrant the term “relaying”

Monitoring *vs.* Protection

Measure
A wide range of measured quantities many be used, depending on the application.

Next step: inform the human overseer!
Simple or complex preprocessing
Notify: e.g. an alarm, email, etc.

Measure
Usually more conservative measurands!

Next step: decide (perhaps 5 ms?) whether this is trip or no trip! Act!

Big differences: **autonomy** and **urgency**.

- **Protection** is difficult because a decision is needed “now”, and errors have costs (think “security and dependability”).

- **Monitoring** *is* also difficult because the signal is weak:
detect *before* a failure, giving time for planned corrective action.

Monitoring & Protection

So …. how might we expect these quite different systems/disciplines to be more **integrated** in the future?

Monitoring & Protection, Integrated!
PAC ... MAP / DAP (?)

Just one way of classifying the possibilities:

Level 1. Sharing a box [and processor?] (IED)

Level 2. Convergence and diversification of sensors

Level 3. Information sharing: synergistic assistance.

Level 4. Learn from each other's methods

Level 5. Unified intelligence, for more than the traditional apparatus !

[not the sort of phrase I like making up – but I can't make it less cheesy in the space]

Monitoring & Protection, Integrated!
PAC ... MAP / DAP (?)

Level 1. Shared box (IED)

Save space: cheaper → probably not very exciting, academically

With today's style of IED, this limits choice of vendors for each subsystem, …
for future, might consider universal IED + apps, where the apps are multi-vendor

Level 2. Convergence and diversification of sensors

Non-conventional sensors for protection: shared from monitoring.
Monitoring easily able to use process-bus data that's primarily there for relays.

Level 3. Information sharing: e.g. share knowledge on the state

Level 4. Learn from each other's methods

Level 5. Unified intelligence, for more than the traditional apparatus !

Monitoring & Protection, Integrated!
PAC ... MAP / DAP (?)

Level 1. Shared box (IED)

Level 2. Convergence and diversification of sensors

Level 3. Information sharing: e.g. share knowledge on the state

E.g. *Adaptive protection* settings, *based on the monitoring* system's anxieties!

- actually an extension of current-practice, but automated and not just 0|1.

Level 4. Learn from each other's methods

Protection using more inputs: e.g. multiple current and voltage.

And more *types* of input: e.g. HF/LF current and voltage, vibration, temperature..

- again, more an extension than a fundamentally new principle: there's a long history to blocking, enabling, checking multiple sources, etc.; but prior to highly digitalized sensors, this wasn't so practical.

Level 5. Unified intelligence, for more than the traditional apparatus !

Use of many sensors. Choice of many actions. Spanning >1 component.

Possible external knowledge about system state and maintenance work.

Probabilistic choice of right action, in a continuum between DIA – PROT.

Monitoring & Protection, Integrated!

Time for questions and comments ?

Picture: perhaps less severe damage, if monitoring of PD or gas-types had lowered relay threshold this day?