Integration of Diagnostics and Protection

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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?
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

\[ P^* = \text{PROGNOSTICS} \]

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.
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 $U_n$.
- Polarization current 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.
So .... how might we expect these quite different systems/disciplines to be more integrated in the future?
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?