A Programme and Project Management Framework for Predictive Analytics in Electrical Utilities [1]

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Abstract

Electricity suppliers are putting money into condition monitoring and data analytics so that they can foresee equipment failure rather than having to respond to it. Although there is a great deal of technical literature available on sensing, analytics and modelling, there is much less advice concerning how to handle such investments as projects and programmes that require changes to decisions, working practices and organisational habits. This article puts forward a programme and project management framework for implementing predictive analytics initiatives in electricity suppliers. At the project level, the framework consists of five phases (align and prioritise, prepare the data and sensing, develop and validate, integrate and deploy, and operate and scale), each phase being concluded by a stage gate which poses a specific question. At the programme level, a coordinating layer oversees a series of projects, the shared capabilities and the benefits across different types of equipment. Six cross-cutting disciplines apply to both levels. The framework is based on recent reviews of the technical field, a recent study into predictive analytics for substation equipment, ISO 21502:2020 on project management, ISO 21503:2022 on programme management and the PMBOK Guide, Seventh Edition. It is a conceptual framework and has not yet been tested empirically. Its aim is to provide sponsors, programme managers, project managers and engineers with a common structure for planning, governing and maintaining such initiatives.
Keywords: programme management; project management; electrical utilities; stage gates; benefits management; governance; data governance; predictive analytics

1. Introduction

Power transformers, circuit breakers, switchgear, cables and protection equipment are amongst the largest, most robust and capital intensive of electrical utility assets. Failure of any of these can result in supply outages, dangerous and costly situations and extensive repairs. Ultimately, power

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utilities are shifting from a reactive, scheduled servicing methodology to one based on condition and predictor maintenance supported by sensing and analytical technologies. The technical aspects of this transition have been well documented. Surveys and reviews have listed the methods, the enabling technologies and the hurdles, generally grouped into what is called predictive maintenance (Krupitzer et al., 2020; Zonta et al., 2020; Achouch et al., 2022). The management aspects have been less analysed. Despite the widespread presence of diagnostic technologies, many utilities continue to use manual inspections, portable dissolved gas analyses, vibration analysis, infrared thermography, and static nameplate data to determine the state of equipment, according to Ghosh and Mittal (2026). In a survey of 24 large US electric utilities, only two had previously tried federated learning; the authors attribute low adoption partly to the conventional separation of operating and technical roles in power utilities and partly to the computer skills involved in adapting existing infrastructure to a new approach. So it's organisational as well as algorithmic. If a predictive analytics project is to deliver value, it must improve the decisions made from the model's output. That can only happen if the entire data set, system, person and process ecosystem is aligned. That means the project team needs to be managing a programme. A project might be able to demonstrate its model on one equipment class, but taking that model to the whole of a utility is a programme, with shared data, shared skills and value emerging only when multiple projects come together.

The article provides a management framework for these types of initiatives within electrical utilities and makes three contributions. Firstly, it defines the features that set those initiatives apart from traditional capital projects. Secondly, it defines a five-phase project framework with phase gates and deliverables for each phase. Thirdly, it introduces a programme level as well as six cross-cutting disciplines that link the technical work to business value.

From data to decision: The Delivery Chain in a Utility

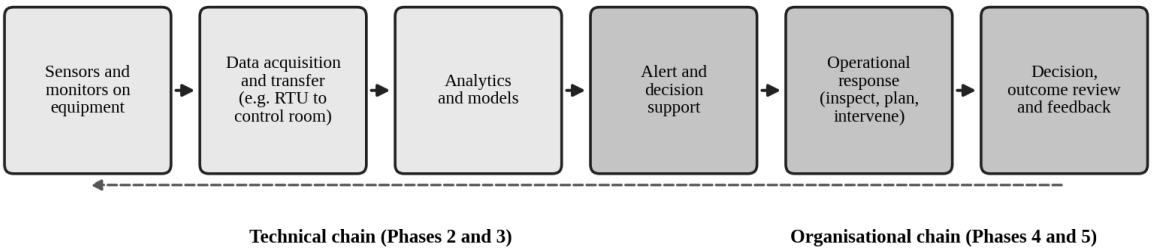


Figure 1: From data to decision: the delivery chain a utility initiative must complete (author's illustration, informed by Achouch et al., 2022, and Ghosh and Mittal, 2026)

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2. Context and Literature

2.1 The delivery context in utilities

An archetypal chain typically starts with sensors and monitors on equipment, leading to data acquisition and communication, and ending with analytics and decision support. Ghosh and Mittal (2026) mention an example of a substation in which sensor measurements are captured by the remote terminal unit in the substation control house, and then aggregated and transferred to the control room at the utility for monitoring. The analytics model is located above this chain. Achouch et al. (2022) categorize models for intelligent predictive approaches into condition-based maintenance, prognostics and health management, and remaining useful life estimation, and they illustrate an industry-level workflow with decision support. The risk is huge. Ghosh and Mittal (2026) estimate that the purchase of a high capacity substation transformer costs somewhere in the range of 10 to 15 million US dollar with a lead time of roughly 115 to 130 weeks. Early indication of failure is useful when the repair can't be done right away and increases the need to execute these projects successfully.

2.2 Why these initiatives are a distinct kind of project

Most capital projects in a utility deliver a physical asset to a defined specification. A predictive analytics initiative delivers a capability to make better decisions. Five characteristics follow from this, and together they shape the framework.

Value arrives through behaviour*:* Benefits are realised only when alerts lead to different inspection, repair or replacement decisions. A technically accurate model that no one acts on delivers nothing.

Data is a deliverable*:* Ghosh and Mittal (2026) point to sensor calibration inconsistencies across devices and utilities, and to heterogeneity that arises when equipment of different types or with different fluids is pooled. Data readiness therefore has to be planned, resourced and verified like any other deliverable.

Ownership is split*:* Engineering, operations, work planning, information technology and operational technology teams each hold part of the solution. Where these functions are siloed, as Ghosh and Mittal (2026) describe, no single group owns the whole outcome unless the project creates that ownership.

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Uncertainty is high and early*:* Whether a failure mode can be predicted with useful lead time is often unknown until data has been examined. This favours staged commitment over a single up-front plan.

The work does not end at handover*:* Models, thresholds and data feeds need monitoring and periodic review once in service. This is a management judgement drawn from practice and from the life cycle view in Achouch et al. (2022), who also note organisational, financial and data-source challenges.

3. Foundations for the Framework

3.1 Programme and project management guidance

ISO 21502:2020 specifies processes for project, programme and portfolio management that can be implemented on any type of project and using any delivery approach, whether predictive, incremental, iterative, adaptive or a hybrid of these. It covers the practice areas of benefit, scope, resources, schedule, cost, risk, issues and quality management. In this article these practice areas are used as the checklist on which to plan each phase of the framework. ISO 21503:2022 guides programme management and is intended for any organization, any size, and any degree of programme complexity. The standard defines concepts, roles, and responsibilities at a high level and does not define processes, methods, or tools. That lack of guidance is the motivation for developing a framework designed specifically for utilities: the standard shows what good programme management looks like, and the framework here aims to show how the concept might be made concrete for analytics programmes in electrical utilities.

The PMBOK Guide, Seventh Edition (Project Management Institute, 2021) is organised around principles and performance domains rather than prescribed processes.[2] The domains for stakeholders, development approach and life cycle, measurement and uncertainty are particularly relevant here, because these initiatives depend on engaged stakeholders, a life cycle that mixes planned and iterative work, and disciplined handling of uncertainty.

[2]The eight performance domains named in the PMBOK Guide, Seventh Edition, are Stakeholder, Team, Development Approach and Life Cycle, Planning, Project Work, Delivery, Measurement and Uncertainty (Project Management Institute, 2021).

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3.2 Organisational context

Initiatives of this kind should not stand alone as technology experiments. Programme and project management guidance treats this work as a means of delivering organisational strategy, not an end in itself. An analytics initiative should therefore be justified by, and report to, the utility's strategic objectives, risk appetite and investment governance. In practice this means a named sponsor, a named benefit owner and an agreed route for escalating decisions.

3.3 Design principles

5 Design principles: the above sources and the features defined in Section 2.2 were used as bases to derive 5 design principles for this framework. These principles apply in the programme layer in Section 5 to a number of projects.

Strategy-linked. Each step is clearly aligned to strategy, risk appetite and has a designated benefit owner.

Life cycle Hybrid: Planned phases and gates give governance. However the model development within Phase 3 is iterative.

Outcome-oriented gates: Gates require us to determine if value is still realizable, rather than only determining if work is in progress.

Data as a managed deliverable: Data quality, standards and governance have their own phase and acceptance criteria. People first. Process first. Training, procedures and decision rights are as much a product as the software and model.

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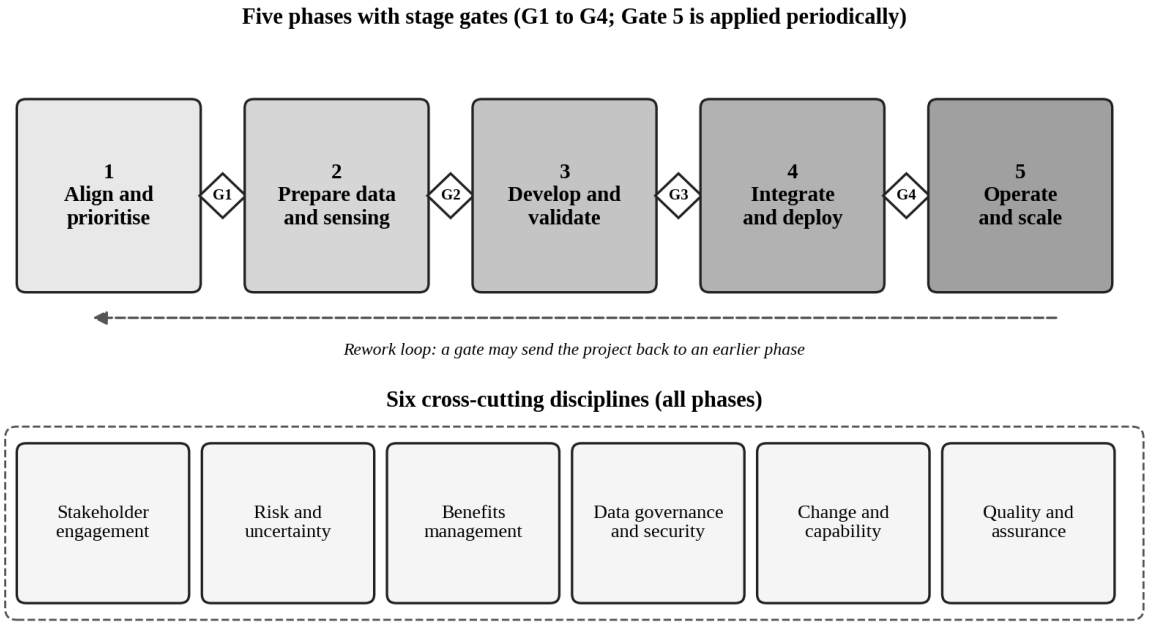


Figure 2: Five-phase project framework with stage gates and cross-cutting disciplines (author's framework)

4. The Proposed Framework

The framework has five phases, six cross-cutting disciplines (Section 6) and a programme layer (Section 5).[3] Table 1 summarises the phases. Gates 1 to 4 close the first four phases, and Gate 5 is applied periodically once the capability is in service. A project may loop back to an earlier phase if a gate is not passed, and a gate decision may be to proceed, to rework, to pause or to stop.

Table 1: Phases, deliverables and gate questions

Phase	Purpose	Principal deliverables	Gate question
1 Align and prioritise	Link the initiative to organisational objectives and select where predictive analytics is worth pursuing	Equipment criticality ranking, use cases in scope, business case, charter, governance structure	Is there a benefit-based case with a named owner and a clear link to organisational objectives?
2 Prepare data and sensing	Establish data that is fit for the decisions to be supported	Data inventory, sensor gap analysis, data standards, equipment grouping, data	Is the data sufficient, trustworthy and well

[3]The phase structure, gate questions, programme layer and cross-cutting disciplines are the author's synthesis of the cited standards and literature. They have not yet been tested empirically (see Section 8).

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		governance and security arrangements	enough governed to build on?
3 Develop and validate	Build and test analytical models against pre-agreed criteria	Baseline, candidate models, validation report, engineer review record	Do the models meet the agreed performance and actionability criteria, and do engineers trust them?
4 Integrate and deploy	Turn alerts into decisions and work	Integration with monitoring and work-management systems, alert-to-action process, procedures, training, pilot results	Does the alert-to-action chain work in live conditions, and are users ready?
5 Operate and scale	Sustain performance, realise benefits and extend to further equipment classes	Model performance monitoring, retraining plan, benefits review, lessons learned, scale-up plan	Are benefits being realised, and is the capability sustainable and ready to extend?

4.1 Phase 1: Align and prioritise

The initial stage determines where predictive analytics is worth using in the first place. The group prioritizes equipment by criticality, in terms of consequence and likelihood of failure, and then determines which failure modes could be detected early enough to make a difference. A failure mode is useful only if warning time exceeds the utility's inspection, planning and response window.

The business case, project charter and governance are also established in the phase. Benefits are described according to the measures the utility is familiar with, and each benefit has a benefit owner as per the benefits management approach in ISO 21502:2020. The sponsor is affirmed here along with the benefit owner, and the benefit link to the organisational objectives is identified. At Gate 1 the question is 'is there a benefit based business case with an identified owner and link to those objectives?'.

4.2 Phase 2: Prepare data and sensing

The second step verifies the data that you need to support the identified failure modes, is there and can you get to it. Activities involves recording all data, identifying the discrepancy between what you have and what you need and the quality and labelling of the failure data and work records. Ghosh and Mittal (2026) provide useful, practical guidance that can be readily translated into project specifications; the data should be collected in specific units and at a common sampling

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frequency. The equipment being modelled should be similar, modelled items should be categorised into similar groups (for example, circuit breakers with distinct interruption technology have different sensor fingerprints and should not be grouped together and dissolved gas analysis between mineral oil and synthetic ester transformers are not comparable). The uniformity of calibration, data ownership, access rights and security of the network carrying operational data should also be considered at this stage. Gate 2 asks whether enough good data is available and well governed.

4.3 Phase 3: Develop and validate

In phase three, analysts develop and then test the analytical models. The work is done in short sprints, but within the limits set at Gates 1 and 2. Before modelling starts, the analytics team and the engineers using the analysis agree on what "success" looks like (such as what metric they want to optimise, the minimum residual lead time needed, and what false alarm rate is acceptable). A baseline (for instance, today's threshold, inspection rule, etc.) is established so the model can be compared with the current method. Models need to be trained on untouched data, and testing results need to be under the review of reliability and operation engineers rather than data scientists. Owing to regulation, commercial or security reasons, raw data cannot be shared, and utilities could adopt a collaborative approach, such as Ghosh and Mittal (2026) review federated learning for substation equipment. Gate 3 asks are models meeting the performance and operability requirements specified and are engineers confident to adopt the models.

4.4 Phase 4: Integrate and deploy

Stage four is the implementation of the change. The team links the analytics to the existing monitors and work-management systems used by the utility, and lays out, step by step, how an alert eventually turns into an inspection or work order. It indicates who authorizes each step, revises or develops new documentation, and integrates the new processes with the operators, planners and technicians. The changes are trialled on one or several assets: the new way of working runs in parallel with the existing method for a specified duration so that the two can be compared. This is the gate where change control really counts. When there is no owner for an anomaly type, and no one has an accepted process to manage it, then the alert quickly joins the other noise. When false alarms circulate repeatedly, then users stop trusting them just as fast. So gate 4 asks: Will the alerting and response process function reliably in practice? Will users trust it?

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4.5 Phase 5: Operate and scale

The fifth phase moves the capability into business as usual and prepares for scale-up. The utility tracks model and data health, escalates the need for retraining or recalibration, reports against defined metrics and compares actual benefits with the business case. Lessons learned are documented and used to inform the scale-up plan for other equipment classes. Because scale-up means repeating Phases 2 to 5 for new equipment classes and sites, this is the point at which a single project hands over to a programme (Section 5). Gate 5 is applied periodically and asks whether benefits are being realised and whether the capability is sustainable and ready to extend.

5. The Programme Layer

A utility rarely stops at one equipment class. Once a first project has shown value, the natural next step is to repeat Phases 2 to 5 for further equipment classes, substations or regions. At that point the question changes from whether one project will deliver to how several related projects can be coordinated so that together they deliver more than they would separately. This is the idea behind programme management as described in ISO 21503:2022, and it is why the framework includes a programme layer (Figure 3). The layer has five elements.[4]

Programme vision and benefits map. The programme states the outcomes it exists to achieve, links each benefit to the projects that contribute to it, and names a benefit owner for each.

Waves of projects. Projects are sequenced in waves. The first project proves the approach on one well-chosen equipment class, and later projects reuse its data standards, gate criteria and training material, adjusting them as lessons accumulate.

Shared capabilities. Items that no single project should build alone, such as the data platform and data standards, security arrangements for operational technology, analytics skills and change support, are planned and funded at programme level.

Programme governance. A programme board, chaired by the sponsor, applies common gate criteria across projects, resolves conflicts over shared resources and decides whether to start, accelerate, pause or stop a wave.

[4]ISO 21503:2022 gives high-level guidance on programme management and does not prescribe processes, methods or tools. The five elements listed here are the author's adaptation of general programme management concepts to analytics initiatives in utilities.

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Dependency, risk and benefit tracking. The programme holds the register of interdependencies between projects, rolls up project risks, and tracks benefits across projects rather than within each one.

Table 2 contrasts the responsibilities at the two levels.

Table 2: Responsibilities at project and programme level

Topic	Project level	Programme level
Focus	Deliver one capability for one equipment class to agreed scope, time and cost	Deliver benefits across several equipment classes and sites
Benefits	Define and measure benefits for the equipment in scope	Consolidate benefits, avoid double counting and track realisation after projects close
Data and standards	Apply the data standards and grouping rules	Set and maintain the standards and the shared platform
Resources and skills	Plan the team for the project	Balance scarce specialists across projects
Risk and issues	Manage project risks and issues	Manage interdependencies and escalate risks that cross projects
Gates	Run Gates 1 to 5 for the project	Set common criteria and decide whether waves start, pause or stop
Ending	Hand the capability over to operations (Gates 4 and 5)	Close the programme when benefits are embedded in business as usual

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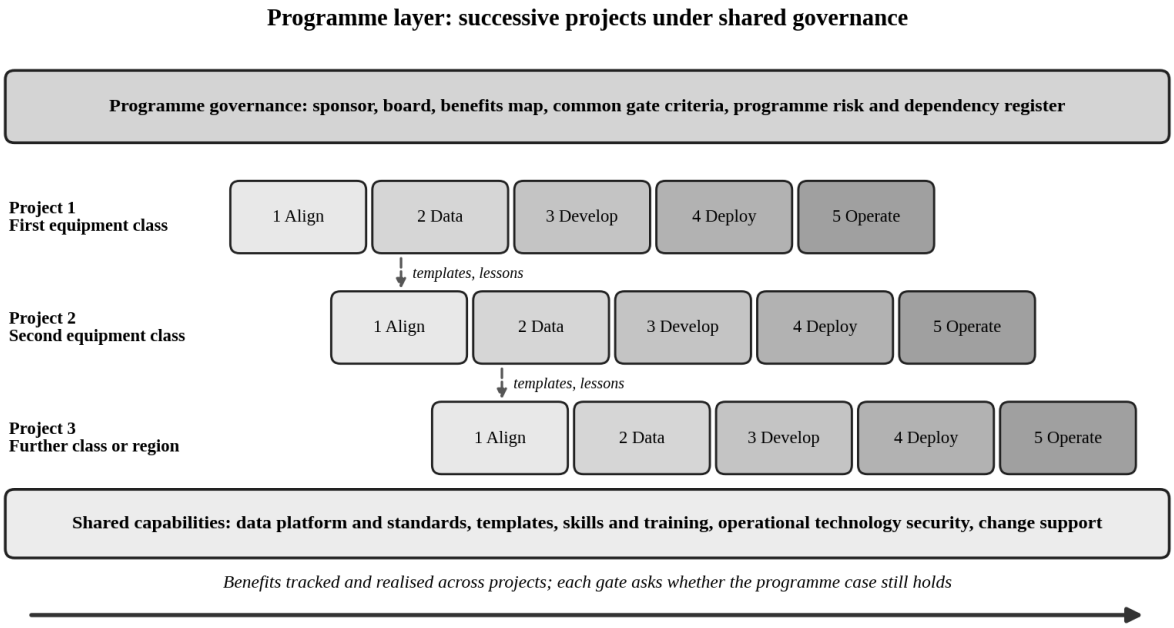


Figure 3: Programme layer: successive projects share governance, capabilities and a benefits view (author's framework)

Two practical points follow. First, the programme should be authorised in stages in the same way as its projects, with funding released against gate decisions so that an unpromising wave can be stopped early. Second, the programme should remain in place until benefits are embedded in routine operations. Closing it when the last model is deployed would repeat the pitfall of treating go-live as the end (Section 7.4).

6. Cross-Cutting Disciplines

Six disciplines run through all phases and through the programme layer. They correspond to practice areas in ISO 21502:2020 and performance domains in the PMBOK Guide, Seventh Edition, adapted to the circumstances of these initiatives.

Stakeholder engagement: As ownership is divided by functions, the project should deliver a permanent forum to align engineering, operations, work planning, information technology and operational technology, with decisions documented and escalation paths identified. At programme level, the forum involves sponsors from the business, and, where relevant, external stakeholders such as regulators and suppliers.

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Risk and uncertainty: The risk register should include availability and quality of data, sensor and calibration problems, model performance, false alarms and loss of trust, skills shortages, reliance on vendors and cybersecurity. Uncertainty of the degree to which results can be predicted is mitigated by staged funding against gates.

Benefits management: Benefits that were highlighted in Phase 1 should be traceable through each gate and will need to be checked post-deployment. If a benefit is no longer attainable, this will need to be flagged at the gate.

Data governance and security: Designation of data owners and stewards, establishing access and retention rules, and implementing protections for operational technology networks are defined at the outset and sustained over time.

Change and capacity building: Training, role definitions and procedure modifications are scheduled as outputs, and system users are engaged from Phase 1. Acceptance criteria are agreed at each gate, independent review is used when the impact of error is high, and decisions are recorded so they are auditable.

7. Guidance for Implementation

7.1 Start narrow and prove value

A utility new to this work is generally better served by one well-chosen equipment class than by a broad programme from the outset. The best first candidate combines high criticality, a failure mode with plausible warning time, and data that already exists in usable form. A successful first project builds credibility, exposes organisational obstacles at modest cost, and produces reusable templates for data standards, gate criteria and training, which become the first shared capabilities of the programme.

7.2 Roles and decision rights

Well defined roles avoid the diffusion of accountability that is typical of siloed organisations. The minimum list comprises an executive sponsor, a benefit owner who takes ownership of the benefits, a programme manager for multiple projects, a project manager per project, reliability/equipment engineers, data engineering and analytics specialists, representatives from the operational technology and cybersecurity functions and work planners. The steering group must have the benefit owner and operations function as members, not solely technical sponsors.

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7.3 Measuring progress

Indicators should cover both the project and the capability it creates. Leading indicators track readiness, for example the completeness of the required data, the share of alerts that engineers judge to be actionable, and the time from alert to inspection. Lagging indicators track outcomes such as unplanned outages, emergency work and operating cost on the equipment in scope.[5] At programme level, indicators should also show how well shared capabilities are being reused, for example how much of each new project's data preparation draws on existing standards. Baselines should be recorded in Phase 1 so that later claims of benefit can be checked.

7.4 Common pitfalls

Focusing on the algorithm. It is often tempting to choose a model before prioritising and preparing your data, which results in a technically exciting project that has no operational impact. Pump-unit different equipment Data pooling for mixing equipment. It can also be counterproductive to use data from different piece of equipment or technology, and data that uses different fluids in the same equipment. The same recommendation summarised in Section 4.2. Not following the alert-to-action pipeline. Without an alert to action process you cannot use all of the good alerts you get. No responsibility for governance and retraining. Run-to-end. Once other ownership transfers it's 'game over'. Implementing each project as a one-off. Lacking programme coordination, every project needs to rebuild data standards, templates and expertise, and outputs and benefits are all counted individually and inconsistently.

8. Limitations and Further Research

This is conceptual. It is based on published reviews, a recent investigation on utility equipment substation and also on some quite general international standards, thus is not field validated with any concrete utility programmes and projects. Literature appears to be very limited in this area, thus this is where most of the programme specific points are taken from one US study of three classes of equipment. Different localities such as UK may have different regulation, network, skills, budgets, and thus require a different framework. It is the programme layer that is predominantly written from general programme management guidance.

[5]The example indicators are illustrative. Each utility should select and define its own indicators, baselines and targets during Phase 1.

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A final test of the framework could be its use as a guide to case studies of implemented and dropped programmes and additional testing by panels of practitioners using the gate criteria. Other areas to investigate could be which of the cross-cutting disciplines best account for long term benefits, regional differences, programme governance and use in smaller utilities with less coverage.

9. Conclusion

While predictive analytics can be a canary in the coal mine for equipment that is expensive to replace and slow to fix, it is only when data, analytics, systems and people combine. This article has shown that implementing such predictive capabilities in electrical utilities can be as much about programme and project management as it is about the technology. It has described a five-phase project life cycle with stage gates, a programme layer of successive projects and common capabilities, and six cross-cutting disciplines.

With reference to ISO 21502:2020, ISO 21503:2022 and the PMBOK Guide, Seventh Edition, and drawing on recent literature, it provides a framework for utilities to decide where to put their money, get data in order, test models, have their models integrated in workflows, maintain the capability, and raise the level of capability across the organisation.

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