

# Intelligent Power System Protection Data Management: How Should India Embrace Best Developed Practice?

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## Abstract

*The growing complexity of digital protective relays has given rise to many challenges for electrical network owners and operators. Internationally, there have been a number of well-reported problems associated with the management and control of digital relay parameterisation – and the resulting critical impact on transmission and distribution networks and customers.*

*India faces a major increase in the investment and development of its electrical power networks. Each manufacturer of protective relays, in addition to each supplier of electrical test equipment, has their own off-line setting software. Data is rarely consolidated or used for decision making once testing is complete.*

*There is a rapidly growing issue of growing data complexity - major amounts of key off-line protection system data (E.g. Protection settings)– without a simple mechanism to manage, assimilate and turn the data into useful information for electrical power network owners and operators. Simply, there are no de-facto standards today for control of this growing problem.*

*Maintenance of numerical protective relays, and the increasing need to amend settings with the ongoing development of the power networks and the growth in load, will exacerbate the data management problem for both Indian utilities and industrial power users.*

*The authors will describe an alternative technique designed to assist electrical network operators and managers; the technique provides better management of digital protective relay data throughout the operational life of the device.*

*Certain European utilities have addressed these same critical issues using intelligent process management tools. The authors will present some case material and learning points from the application of these new techniques. This will include techniques to simplify the checking of settings, especially when in service, and automated approaches to greatly improve the quality of protection testing and associated test records.*

*Finally, the authors acknowledge that the Indian context is somewhat different from some developed network infrastructures. However, the authors propose how Indian network operators can derive significant, immediate benefits from being able to “leapfrog” the conventional approach to protective relay data management through the application of new intelligent maintenance regimes.*

## **Introduction**

With substantial economic growth linked to the development of the power sector, and specifically the growth of the transmission and distribution infrastructure, India faces a number of the challenges faced by other developed and developing nations: the new Intelligent Electronic Devices (IEDs) now implemented in power networks create ever increasing amounts of data and exhibit an exponentially increasing complexity in setting, adjustment and recording. The slide from “Data Complexity” to “Data Chaos” is recognised in many places where traditional approaches to substation data management are no longer able to cope adequately.

This paper outlines the conventional approach to the control and management of data associated with IEDs, and considers some of the growing challenges and pitfalls encountered with the implementation of numerical protections. In reviewing alternative techniques and best practices in other leading industrial countries, the authors offer some observations as to how similar issues can be addressed by and in the specific context of the Indian power sector. Specific examples of the critical impact of protection IED data complexity on network performance are developed and reviewed as part of the analysis.

## **Network Development: Issues for Indian Network Owners & Operators**

India, together with other developing nations, continues with the electrification of rural areas and at the same time must reinforce its networks to provide sufficient capacity to meet increasing industrial and commercial demands.

There will be significant emphasis upon investment into the core Transmission and Distribution (T&D) infrastructure in India for the foreseeable future; the implementation, testing and commissioning of IEDs will be a critical factor in this. In parallel, Network Operators in India, as elsewhere, are faced with the expectation of stakeholders (customers, regulator, government) that they will be able to continue to “do more, with less.” India’s plans to push forward with electricity network deregulation will increase emphasis upon efficiency and effectiveness of both capital and revenue expenditures.

However, the experience of other major industrialised nations [1, 2, 5] is that significant growth in T&D infrastructure investments does not, on its own, deliver improvements in network reliability, dependability or performance, nor does it come without its own new challenges and pitfalls.

In any electrical power network there are typically some specific, critical connections where, if the power flow is interrupted, significant economic, business and social impact would occur. Such connections include:

- Industry: particularly continuous production processes, including primary metals, petrochemicals, manufacturing using mechanized production technologies.
- Infrastructure: rail and metro networks.
- IT-dependent industries: global software and IST support centres.

These connections are typically protected and controlled by IEDs. Degraded performance or connection failure, without parallel support or other contingency, will impact the economic and business performance of both the immediate customers and the region in general because inward investment plans usually take account of supply quality and reliability.

IEDs associated with the primary plant can develop copious amounts of data and information that, in many cases, end up as “data islands”, or even a “data archipelago”. This presents the dilemma now present in a number of organizations: the proliferation of data, including both on-line and off-line test results, and what to do with it.

During the lifetime of an asset, there are a lot of data created. From design documents (e.g. network diagrams, IED configuration files, wiring schedules, test procedures) through commissioning documents including Site Acceptance Tests, maintenance and refurbishment documents, checklists and test protocols. All documents together are important evidence of a reliable and correctly managed network. To maximise efficiency and controllership, a rigorous process is required.

International experience of electricity industry deregulation has been shown to lead directly to increased emphasis on efficiency of operations, maintenance and service levels – all of which impact network technical activities. International experience in the domain of substation circuit breaker diagnostic test [7] reveals demands for shorter time periods for testing, particularly because higher utilisation factors will mean that the switchgear is less often available to be taken out of service. Any proven, reliable techniques to systematically shorten test and commissioning times on site – without compromising quality and integrity of the testing – are of clear and direct economic benefit to network owners and operators.

In the Indian context, utilities and industries may not yet face the same problems of reducing availability of expert technical staff as is seen in other leading industrial nations with the impending retirement of the Post War “Baby Boom” generation. What is seen already in India is that knowledgeable resources emigrate to nearby financially strong regions (e.g. the Gulf region). This might lead to a shortage of key resources for domestic grid development during the next several years.

## History of Data Management: Complexity Approaches Chaos

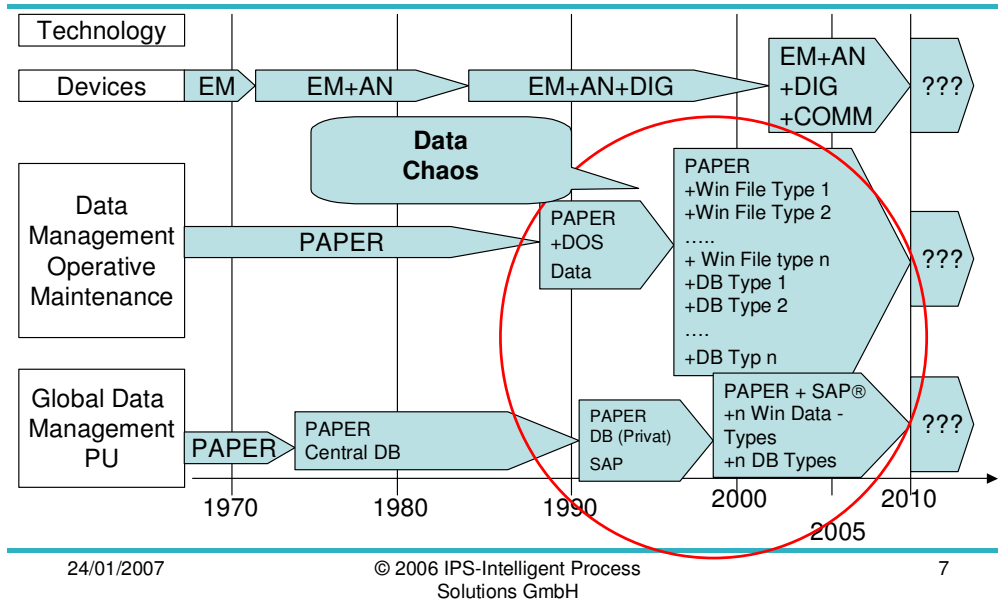
Over the last decades, network owners and operators have moved from electromechanical to IEDs. Because protection assets have typical application life spans of between 15 and 40 years, there is often a multi-generation technology mixture on most networks.

During the change in relay technology from electromechanical through electronic to digital and numerical, associated data capture and maintenance management regimes has moved from paper-based into digitized media. The onset of digitization has created a huge increase in the volume of acquired data, so that there is now a mix of paper and digitized media.



**Figure 1: Process steps in the life cycle of the network**

Figure 2, below, illustrates the progress of data management associated with operational testing over the timeframe of this protection technology progression.



**Figure 2: Data Management Roadmap for Power System Protection Technology Evolution**

**Key:**

- |     |                                |      |                |
|-----|--------------------------------|------|----------------|
| EM  | Electromechanical Technology   | COMM | Communications |
| AN  | Analogue Electronic Technology | PU   | Power Utility  |
| DB  | Database                       | Win  | MS Windows®    |
| DIG | Digital Technology             |      |                |

The red circle highlights the large number of different ways in which data is transferred and stored today. This is the area where the application of alternative database management techniques is able to offer new approaches to critical substation data management. “Data Integrity” becomes “The Strategy”. “Use and be used” becomes “a must” strategy within new information technology.

India has a major opportunity to benefit from new techniques and technology developed and applied in other leading deregulated Industrial nations. Further, India would gain full advantage of the increased personnel safety of those involved in commissioning testing.

## Operational Issues from the Key Constituencies

### Network Owners / Operators

Recent high profile cases in the international arena [3, 4, 5] have shown the critical impact that numerical IEDs, and in particular, numerical protection devices can have on network performance. The simple human error of failing to correctly select or set any of the numerical protective relays has been shown to lead to catastrophic supply interruptions.

Key Business Performance Metrics (E.g. Customer Minutes Lost) will directly benefit through better, automated checking of new, and historic protection settings, against calculated and

approved values. There are also often statutory requirements or industry codes of practice that involve the management and storage of relevant documents, including IED settings and test & verification protocols. A failure to produce these documents in a post-event review may be to risk legal proceedings for compensation by those affected. The ultimate driver is the need to use best practice to achieve lowest operational cost.

### **Original Equipment Manufacturers (OEMs)**

OEMs – specifically designers and manufacturers of IEDs and test equipment – are faced with a dilemma: the drive to pack more and more functionality and flexibility into products, whilst significantly increasing the complexity for the user to apply, set, test and commission the product in an overall automation scheme. Each family of products is supplied with its own bespoke management software. Additionally, different IEDs has different data structures which are supported by different software formats: this further increases problems with data complexity and management (Data Chaos).

Advanced IED data management has clear benefits for the OEM expert in a specific domain or application. Knowledge management can generate new business opportunities associated with software upgrades and knowledge-related services.

### **Specialist Commissioning Service Organisations**

Many countries are now seeing the emergence of specialist commissioning organizations. With core power system skills becoming rarer in certain regions, the optimal use of specialists has never before been so important.

At the same time, growing complexity of IEDs and the increasing range of equally flexible test solutions is causing the administrative and training burden to increase substantially.

### **Site Test & Commissioning Engineers**

Whether part of a utility, industrial company or third party supplier, site engineers continue to search for better ways to improve their efficiency and effectiveness.

As the number and complexity of setting software programs and test equipments increases, so does the pressure on the site engineer to master each of them. Concerns remain that the engineer is overburdened with administration, leaving less time for critical preparations and technical reviews prior to plant energisation – and the resulting impact of any human errors or miscalculations.

With pressure to “do more with less” inherent in the industry, and as India’s T&D networks develop at ever-increasing pace, specialists continue to search for better ways to support site engineering staff. Building their own knowledge base with support of a library of best practices will improve their work efficiency.

A reliable and efficient mechanism to reduce preparatory documentation and administration through standardisation – and a method to automate data capture and reporting would enable site staff to focus on the critical issues of technical performance. With a mobile system all necessary documentation and data are available on test site. Also, new solutions for site engineers using database applications can be capable of providing rapid means to cross-check and verify

calculated and actual device settings – and hence give improved confidence prior to primary circuit energisation.

Simply: what would it be worth to a site engineer to allow them to focus on their primary responsibility: the safe verification and energisation of the network – without the downside of further increasing administration and multiple software tools?

### Network Asset Managers

The active management of the critical T&D network assets is an essential part of the responsibility of the network owner / operator. However, despite the development of many comprehensive asset management solutions, there remains an inconsistent approach in the T&D industry towards the collection of critical off-line test data, from the initial period of commissioning and first energisation, through network modification and upgrade.

### Substation Intelligent Data Management: Practical Experience from the Field

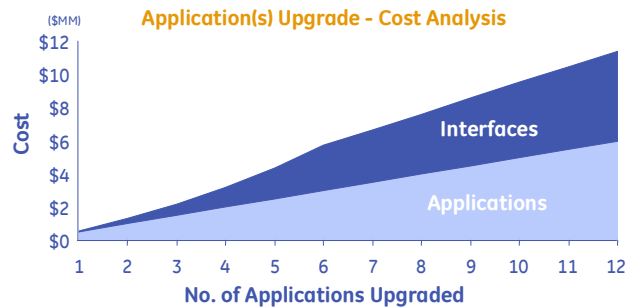
Traditionally, site installation testing, commissioning, maintenance and testing have been performed with one test equipment, providing one report per test. The test report is conventionally a print out, sometimes on thermographic paper, or a stand-alone electronic file, none of which are “archive safe.” Thermographic text fades within a few years and needs to be transferred to a more resilient medium, e.g. by Xerox photocopying. Further, experience of major users [6] has shown that reports from other associated commissioning tests (e.g. circuit breaker timing, micro Ohm measurements) are not associated with protection measurements on the same circuit breaker bay. This imposes a significant amount of additional administrative work in keeping legacy test data in order. The traditional method of test data recording and storage has often failed to provide the necessary knowledge base, especially for cases where different substation providers or subcontractors have been hired over the years.

### Changing the Paradigm: From Data Complexity to Competitive Advantage

Figure 3 illustrate the dilemma faced by the T&D industry. The direct and indirect integration cost for +10 systems was found to be higher than the sum of the direct costs of the applications themselves.

In the context of this paper, there would be both a direct cost (efficiency) and operational advantage (effectiveness) to both the network owners / operators and the contractors involved in the use of such systems if an alternative approach to management of multiple IED product and test equipment IT applications is established. Further, if the method of working could also be simplified, so that less experienced test engineers can be put to greater use. Both the expensive time

#### T&D Challenges - Technology Integration



**Figure 3 : Integration costs versus cost of core application of IT-based applications in the Power Industry.**

of top commissioning specialists and the substation equipment outage time can be reduced. The resulting streamlined testing process will lead to more efficient workforce scheduling and associated test equipment.

Figures 4 and 5 are schematic representations of how the data islands normally produced by IEDs and associated test equipments (Figure 4) are addressed by the application of intelligent data management techniques (Figure 5).

In figure 4 the flow of data between primary sites and the maintenance management systems typically relies on manual paper-based transfer.

## Operative Maintenance Management

- Location: PU/Center/Office

### Technical information and maint. management:

- Data bases : SAP® ; GIS,MAXIMO, PRIVAT PU Developments...
- Various software formats i.e. EXCEL, WORD,OMICRON,Programma etc.
- Paper documentation

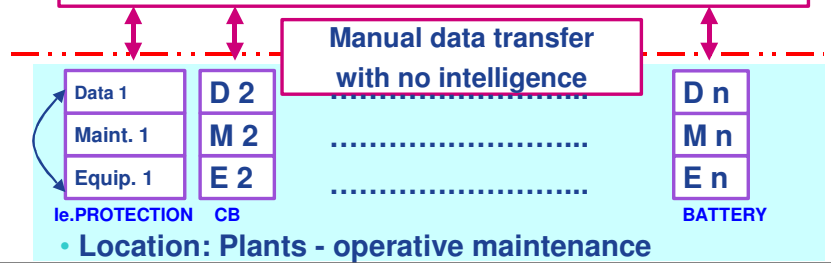


Figure 4 - Schematic Interpretation of Conventional Manual Data

The alternative approach described in this paper employs:

- A standard, intuitive user interface (based on the Microsoft® Outlook GUI)
- A Mobile, Intelligent, Expert System to manage substation protection test data, built upon a de facto standard database environment (SQL).
- Enterprise-wide, controlled access to all test data and results.
- Storage of both test data and test documentation.
- Storage of test data and results.
- Storage and management of standard test templates and associated documentation for all leading protection IEDs.
- Standard interfaces with leading test equipment software, including GE Energy’s Programma range, and Omicron devices.
- Test result management, importing the results of tests carried out from the test object / test equipment.
- A standard relay type library.
- Comprehensive database reporting and analysis tools.

With reference to the schematic interpretation (Figure 4), operational data is transferred in both directions. Setting files, test procedures and manuals are needed from the management system to perform the testing or operative maintenance, whilst test operative checklists and test documents need to be sent back and stored in the management system.

Figure 5 shows an effective “middlewear” layer which links plant level information through an automated, standard process to the enterprise business systems.

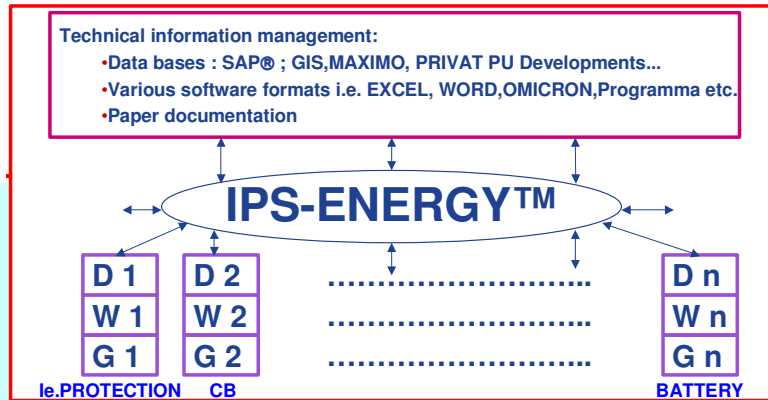
With the application of Microsoft SQL 2005 server technology, secure synchronisation (mirroring and failover clustering [6]) of data is established. This results in users being able to share the information, in a controlled manner, throughout the enterprise. Importantly, because each site test engineer's laptop contains a mirror of the database, the data is also available in the field.

With the laptop data being changed in the field (i.e. without connection to the database), reconnection to the server enables an automatic secure synchronisation process to occur.

This ensures central data accuracy and promotes secure control of the critical test data.

## Operative Maintenance Management

### • Location: PU/Center/Office



### • Location: Plants - operative maintenance

**Figure 5 - : Application of Expert Systems to IED Technical Information Management**

## Benefits of the integrated approach

Implementation of these new techniques by a number of leading European utilities [8] has provided a number of significant, unique benefits:

- **Linkage:** Connection between protection data, testing, documentation and IED settings, giving the linkages and traceability missing with conventional protection data management. This provides valuable information, should fault forensics be required to understand plant or network performance issues.
- **Open system approach:** supporting multiple vendors of IEDs and test equipment. This allows both the network owner / operator and site engineer to integrate their existing IED and test investments into the new data management strategy.
- **Mobility:** the new approach based on SQL database techniques provides a fully Mobile system, with offline mode and automatic and secure synchronization between client and server. This benefits both the field test engineer, in supporting autonomy and operational requirements, and also the corporation, now interested in consolidating critical asset data for improved capital and revenue expenditure control.
- **Standardised User Environment:** Both network owner/operator and protection test and commissioning authority have the opportunity to apply best-developed practice through their own standard User Defined Views and Rights. This benefits the test engineer through improved simplicity and clarity, whilst giving improved confidence through better data security.
- **Embedded intelligence:** The approach uses intelligent tools to model a relay, benefiting the test engineer through improved application simplicity and direct time saving in preparation and during site testing.
- **Data Import:** Setting import from relay into database through the intelligent interface with data comparison mechanism.
- **Significantly Reduced Process Administration:** Clear separation between testing action and document management is provided through multiple applications of standard, proven formats

(e.g. test data reports, conceived once and of a consistent and professional high quality) together with a robust document and data management process, conceived with the network owner/operator's asset management needs in mind.

- Unified reporting: the approach is both test instrument and test occasion independent, providing consistent recording and reporting irrespective of who undertakes the testing, when it is done and with which test instruments.
- Continuous Library Update: Libraries of test templates for the IEDs are updated and expanded continuously as part of a complementary support service. This removes a major administrative burden from the management of site test engineering and commissioning staff.
- Customisation: the system is flexible and can be set up and tailored to fit different customer needs and investments already made in processes and documentation (e.g. settings, templates can be reused).
- Fast Implementation: The expert libraries with most commonly used protection models, test templates, import filters, best practices enable rapid implementation of the system.
- Easy deployment and improvement management by using central replication mechanism.
- Increased power supply safety and reliability through correct protection setting and testing management.

From a systems standpoint, this technique provides a number of benefits including:

- Improved data security: Secure, robust and full, enterprise-wide, access to a library of authenticated settings and test records, both at a detailed level for field personnel
- Better management information: Executive summary reports for business decision-making and administration.
- Single point of access: Other documents that are associated with the test object, including user manuals, service instructions, commissioning reports, and drawings are also readily available via the same system.
- Better version control: Central management (single, current version) and access to associated software for results and settings analysis is made from one common user interface.
- Data Integrity: Implementation of all Protection data within one system and within one structure accessible to all required entities.

For the site engineer, the benefits of a single, integrated approach to protection and test data management have been demonstrated to include:

- Efficiency increasing: by using always accessible centralised expert knowledge base
- Better data management: all records in the same format, reducing significantly the preparatory and post-test administration;
- Better, simpler management reporting providing accurate, concise primary plant status reports;
- More complete analysis and review of test data settings and comparison with historic settings: giving more complete verification of IED (and specifically protection) setting amendments prior to primary plant re-energisation;
- Improved repeatability of testing: all test staff being able to use a common test plan, irrespective of the test equipment being used.

## Summary and Conclusions

In this paper, the authors have outlined the opportunities for India to leverage best-developed practice in the management of critical IED data as a precursor to improved network performance.

The substantial growth and asset development planned over the next several years in the Indian electrical network provides a significant opportunity for network operators to benefit from advanced, intelligent test data management techniques:

Reliable power in the transmission and distribution infrastructure is fundamental for the expansive Indian industry and business sectors and to continue to encourage International direct investment.

1. Improved verification and data management techniques for critical numerical protection devices provide contractors and their test engineers with the means to achieve a higher quality, more reliable service.
2. The application of such systems actively supports improvement of the industry safety record and practice.
3. A substation asset management database system for critical test data can help with the optimization of field maintenance work and planning through intelligent software integration.
4. The availability of detailed test records on level enables key field engineers to focus upon critical technical issues and contractors to provide a more consistent, high quality service.
5. The test engineer gains greater focus on critical test activities, rather than administration. Further, it promotes job enhancement and career progression for the junior engineer.
6. Using an expert intelligent system will improve know-how management.

India needs its rapidly developing transmission and distribution network to grow and meet the increasing demand for power. By embracing new techniques, Indian utilities and major power users can minimise some of the consequential risks that have been seen to arise in other major industrialised nations as a result of accelerated network investment and the increasing complexity of numerical Intelligent Electronic Devices, or loss of key test data, through the application of innovative best developed practices in data management.

## References

- [1] "Recent Blackouts in US, UK Scandinavia and Italy: Is it Contagious?", Janusz W BIALEK, University of Edinburg, Scotland,, 24 August 2003
- [2] "Why Investments Do Not Prevent Blackouts", D KIRSCHEN, G STRBAC, UMIST, England, 2003.
- [3] "Poor Installation Caused Power Cuts", BBC.co.uk, 1 October 2003
- [4] "Blackouts Could Spark 12 Million GBP Fine", BBC.co.uk, 10 January 2005
- [5] "Recent Blackouts in US/Canada and Continental Europe: Is Liberalisation to Blame?", JW BIALEK, University of Edinburg, Scotland, 2003
- [6] Microsoft SQL server 2005, Microsoft web site.
- [7] "Improving Efficiency and Safety in HV Circuit Breaker Testing: How Should India Embrace Best Developed Practice?", Linus CLAEISSON et al, GridTech, Delhi, 5-6 February 2007.
- [8] IPS-Energy, [www.ips-energy.com](http://www.ips-energy.com)

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