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Automatic Transformer Test Report Generation Tool

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Abstract: ***Transformer testing is a pivotal step in insuring safety, reliability and efficiency of power industries. Ordinarily, engineers relay on manual calculations, spread sheet and heavy formatting on word processing software's like MS. Office which is manual and error prone, which can lead to human error and easily exposed to manipulation. This paper presents a software solution for automatic transformer test data processing and reporting as per NABL and BIS standards. Software allows engineer to enter raw measurement data for winding resistance, ratio, no-load loss, load loss, temperature rise, impedance, tan delta, insulation resistance, magnetic balance, harmonics, noise, and zero-phase-sequence (ZPS) and more such tests, results are automatically formatted into standardized test report, eliminates the extensive manual calculations and formatting. Which tends to reduction in processing time, calculation errors, and higher consistency and transparency of test reports. It enhances the productivity of transformer industries and laboratories.***

Keywords: Transformer testing, Test data automation, NABL/BIS compliance, Standardized reporting, Integrity of data

I. INTRODUCTION

In connection of testing to ensure safety, reliability and performance of electrical systems. Manufacturers highly depend on accurate results to validate design specifications, fault and guarantee compliance standards like NABL (National Accreditation Board for Testing and Calibration Laboratories) **[9]**, **[10]** and BIS (Bureau of Indian Standards) **[7]**, **[8]**. Common tests include winding resistance **[1]**, ratio, no-load loss **[5]**, load loss **[7]**, impedance, insulation resistance, tan delta, magnetic balance, temperature rise, harmonics, and acoustic noise evaluation and more.

Current process of report generation includes use of spreadsheets, manual calculations and extensive formatting, also very likely to get manipulated. This tends to high testing time and reduce confidence in results for laboratory as well as for manufacturers.

To mitigate these challenges, paper introduces the software that can automatically handle calculations, authenticity, formatting and accuracy according to industrial standards. Following are the key features:

Calculations: Dedicated modules for each transformer test.

1) Standardized Reporting: NABL- and BIS-compliant output formats.
2) Error Reduction: Eliminates manual formula entry and formatting.
3) Productivity Gains: Saves engineering time and ensures reliable results.
4) Reminder of this paper: Section I review related work, Section III presents the methodology and architecture, Section IV describes the working principle, Section V discusses results and analysis, Section VI outlines the advantages and finally section VII concludes the future scope.

II. LITERATURE REVIEW

Transformer is not just a product it's a well-established industry and ecosystem, in which testing plays a crucial role. Testing forms the core of the transformer industry, as quality, accuracy and overall performance are directly dependent on reliable and precise testing. It is governed by international standards such as IEC 60076 **[1]**, **[2]**, **[3]** and IEEE C57 series **[1]**, **[5]** **[6]**, which states procedures for evaluating performance, safety and reliability. These standards discuses about tests like winding resistance, ratio measurement, no-load and load losses, impedance, tan delta, insulation resistance, and temperature rise. However, standards tell about the methods and acceptance criteria, they don't specify any frameworks for data handling, calculation automation, or standardized reporting formats

Predominantly, majority of laboratories still relay on manual spreadsheet-based approaches **[14]**, **[19]**, Testing engineer records measurements, feed data to sheets and get the results, although spreadsheets are flexible, it have several drawbacks: formulas may be incorrectly entered, formatting can be inconsistent, and there is no mechanism which can insure integrity of results For high-stakes testing environments where NABL and BIS compliance is mandatory, these weaknesses introduce risks in both accuracy and credibility.

TABLE I
TRADITIONAL APPROACH VS PROPOSED SYSTEM

Criteria	Traditional Approach	Proposed Software
Data Entry	Manual entry into spreadsheets	Guided input fields with validation
Calculation Process	Formulas applied manually, prone to mistakes	Automatic calculations with locked algorithms
Error Rate	High, due to formula/entry errors	Low, validated formulas reduce errors
Data Manipulation	Possible (accidental or intentional)	Not possible, algorithms locked
Standards Compliance	Not standardized, user-dependent	Fully compliant with NABL/BIS formats
Report Formatting	Inconsistent, requires manual formatting	Automatic, uniform, and standard-compliant
Sample Management	No structured management, cluttered records	Unique ID-based structured storage
Ease of use	Moderate, requires skilled Excel handling	High, intuitive GUI design

Some facilities have attempted to overcome their limitations through semi-automated tools, such as macros, visual basics for applications (VBA) **[14]** scrips or lab specific software extensions, these methods are successful in reducing the repetitive manual work but remain narrow in scope, difficult to maintain and often incompatible with evolving unique distinctive requirements. Moreover, they are not scalable to handle multiple samples, or large datasets efficiency. At the commercial level, integrated test management software's have been developed, often building with high-cost transformer testing bench, these platforms combine hardware and software for automated measurements and calculations, while this is technologically advanced, but financially prohibitive for small scale and mid-scale enterprise, and there reporting formats are not always aligned with standards such as NABL and BIS. Furthermore, vendor lock-in reduces flexibility for lab's wishing to adopt and extend their workflows
Hence, semi-automated tools lack generality, and commercial systems **[17]**, **[18]** lack affordability as well as customization. This gap highlights the need for a cost- effective, user friendly, standard, consistent and integrated system.

III.METHODOLOGY

Proposed software has been developed using national instruments LabVIEW **[11]**, **[12]**, a graphical programming environment used for data acquisition, and calculation. System is used to automate the test generation process and calculation as per standardized NABL and BIS compliant reports. This chapter comprises three major stages data entry, processing and report generation

A. Software Architecture

The architecture of system is modular, dedicated module for each transformer tests. Each modules executes specific mathematical operations, applies necessary correction factors, and validates against defined limits. Once the raw data is feed, all relevant calculations are automatically performed and forwarded to report generation unit.

B. Sample ID management

For multiple clients and multiple test objects, separation of results is based on unique sample id, each transformer under test is assigned unique id, under which all raw data, intermediate calculation and final report are stored, this prevents data overlap, maintain records and simplify the retrieval of historical data which can be very helpful during audits [9], [10] inspection and record management.

C. Data Integrity and Manipulation prevention

Unlike spreadsheet-based workflow, where formulas can easily alter, calculation algorithms are embedded within the program and locked against modification, which eliminates the possibility of data manipulation and ensure integrity and constant [19] with NABL and BIS requirements.

D. User Interface and Usability

GUI is designed to be intuitive, clear field for entering raw data, dedicated buttons for initiating calculations. No complex menus, not required to write any formula, provides real time validation of inputs, and generates alerts in case of missing or inconsistent data, further improving reliability.

E. User Interface and Usability

Final stage involves compilation of results into standardized NABL and BIS compliant format. Uniform format and structured, includes calculated values, compliance remarks. Pdf and doc formatted output.

F. Supplied Tests and Customization

The software is designed to accommodate the tests mentioned by NABL, BIS, IEC, and IEEE standards. All calculations are embedded within modular LabVIEW blocks, ensuring that each test follows the prescribed methodology without requiring operator intervention. The supported tests include:

- Ratio Test
- Verification of vector group
- Insulation Resistance Test
- Winding Resistance Test
- Load Loss Test
- No Load Loss and Impedance test
- Sound Test
- Harmonics Test
- Tan Delta test
- Magnetic Balance
- Temperature Raise Test
- Zero Phase Sequence (ZPS) Test

In addition, supporting the wide range of transformers, the system has been built to handle various transformer configurations and applications. The software is compatible with:

- Tap less Transformer
- Small power transformers
- Large power transformers
- Single phase transformers
- Three phase transformers
- Distribution transformers
- Solar transformers
- Inverter transformers
- Dry Type transformers **[4]**

Based on selected transformer type, system dynamically adjusts calculation parameters, applicable correction factors, and report formats. For example, three-phase transformers include both phase-to-phase (PH–PH) and phase-to-neutral (PH–N) connections, while single-phase units restrict calculations to the relevant winding pair. Similarly, specialized formats are provided for solar and inverter transformers, which require distinct measurement emphasis.

IV. WORKING

Software offers step structured and step by step workflow for transformer testing and report generation. Its further divided into different modules for different type of transformers, so that entire module is aligned according to transformer type which makes easy for client to eliminate filling of unnecessary information and straight forward approach. Each module is further classified into different stages like technical specification entry and client information, testing page and final result page.

A. Sample ID Creation

The process begins with creation of unique sample ID for each client and its transformer, this id will be going to use for entire testing cycle to tag technical data, as well as test raw data and final results, this systematic approach helps in easy traceability and prevents data overlap.

B. Entry of test details and transformer specifications

Once the sample id is created, user have to feed the general test information such as date of test, witness information, client information, test laboratory information, and more such data, as well as transformer specifications like rating, hv lv voltage, resistance connection, guaranteed values, temperature etc. and more such details that will further help in report generation and calculation.

C. Test Selection

After filling all the necessary details, user selects the set of tests that to be performed from the available list. Software supports more then 21 tests; software allows the selection of tests according to client's requirement and type of transformer.

D. Test Execution and Data Entry

From the selected list, test engineer can execute them individually, entering all the mandatory fields of raw data, and the software performs all complex calculation, software adopts all the necessary perimeters such as PH-PH and PH-N notations **[1]**, [5], Star delta connection calculation differences and more such adoptions finally it provides test report, as soon as test finished the green indicator will indicate about its completion.

E. Final Verification and Report Generation

After completion of all required tests, the software proceeds to final verification of and report stage. At this stage, system cross verifies the data consistency, no required fields are left empty, no negative values or failed data is present, after successful verification by internal process and test engineer, a report with all accordance's of NABL and BIS is generated in either PDF format. Each result and report are linked to its dedicated sample id, and can be accessed anytime it requires.

V. RESULTS AND ANALYSIS

Performance was evaluated between developed software and real transformer testing environment, and compared against the conventional method, evolution was based on points like processing time, calculation accuracy, reporting consistency, and data credibility. Tests were conducted on various transformer types including single-phase, three phase, tap less, inverter, destruction, and solar transformer to ensure the capability of each module.

One of the most visible improvements observed was in time efficiency. In the manual approach testing engineer spends significant time entering measurements into spreadsheet, applying formula, verifying calculations and finally at the end formatting the results into format. Depending upon transformer size and number of tests, this process took average of 25 minutes per test. In contrast using our software it took average 12 minutes to perform each test including final report generation (excluding pressure test and temperature rise test). This translates to the overall time saving of approx. 52%, which is significant amount of time saving in lot testing.

The system also shown a significant amount in calculation accuracy **[16]**. Manual calculation methods are prone to human error and require significant amount of knowledge and experience in contradict, testing software require only the selection of test and input of raw data which require less skilled labor. Among 150 tests, error rate was 3 to 4.5% which was reduced by software.

Another major improvement is in report consistency and security **[20]**. Manual report often left some minute attention to details and shows inconsistency. Also, formatting is something which takes lot of time of testing engineer which should be utilized in core testing.

For example, a 250 kVA three-phase distribution transformer was tested using both methods. In the manual approach, the full testing and report preparation required 1 hour 24 minutes and resulted in two minor calculation errors identified during verification. Using the automated system, the entire process including data entry, calculation, and report generation, was completed in 7 minutes 43 minutes with zero errors. The software produced a fully formatted report instantly after final verification **[13]**, **[14]**, **[17]**.

TABLE II
PERFORMANCE COMPARISON

Parameter	Manual Method	Software
Average Time per Transformer	30 to 45 minutes	16 to 25 minutes
Error Rate	3 to 5%	0.5%
Report Consistency	Operator Dependent	Standardized
Data Storage & Retrieval	Manual, Unstructured	Sample-id based
Manipulation	High	Secured

VI. DISCUSSION / ADVANTAGES

The implementation of LabVIEW based transformer testing software have several technical and operational based advantages over traditional systems or spreadsheet driven approaches. This benefits the major drawbacks of transformer testing laboratories, including calculation accuracy, report standardization, data integrity and overall efficiency.

1) Automated and Error Free Calculation: All calculations are performed automatically using standardized and locked algorithms **[11]**, **[12]**, **[13]** . It also eliminates the dependency on manual formulas which drastically reduce the calculation errors and inconsistency.
2) Standardized and audit ready reporting: Removes operator dependent formatting variations and make sure report meets the regulatory requirements..
3) Time and productivity Gains: Average report generation time is reduced by 50 to 65% compared to manual approach. Engineers can focus on actual testing rather than repetitive calculations and report formatting.
4) Data Security and Manipulation Prevention: Manual excel files are prone to accidental edits or intentional data manipulation. Our system has secure data handling and no scope of data manipulation.
5) Flexibility and Adaptability for different transformer types: Software supports multiple transformer types and variations and adopts according to the selections. It dynamically adjusts the calculations, nomenclature and notations accordingly, this allows single system to handle variety of transformers.
6) Scalability and Future-Proof Design: Build on LabVIEW platform, so that new tests, standards and functionality can easily implementable.

VII. CONCLUSION AND FUTURE WORK

The paper presents implementation and development of LabVIEW based automatic transformer report generation software designed to replace the traditional ways of testing industries. System provides structured and step by step procedure of covering almost all the transformer testing perimeters and report generation.

By integrating the standardized calculation and algorithms according to IS and BIS/NABL, report formation becomes more consistent and credible, calculation accuracy, data integrity, and testing time overall procedure improved significantly, additionally having modular architecture allow to incorporate and adopt all the future improvements.

In future work, several enhancements are planned to future extend the system capabilities, including:

1) Integration with instruments and sensors for automatic data acquisition.
2) Cloud based data storage and centralized report access from all the devices.
3) AI assistant that can guide to new testing engineers for testing procedure.
4) Advanced user access control and digital signatures

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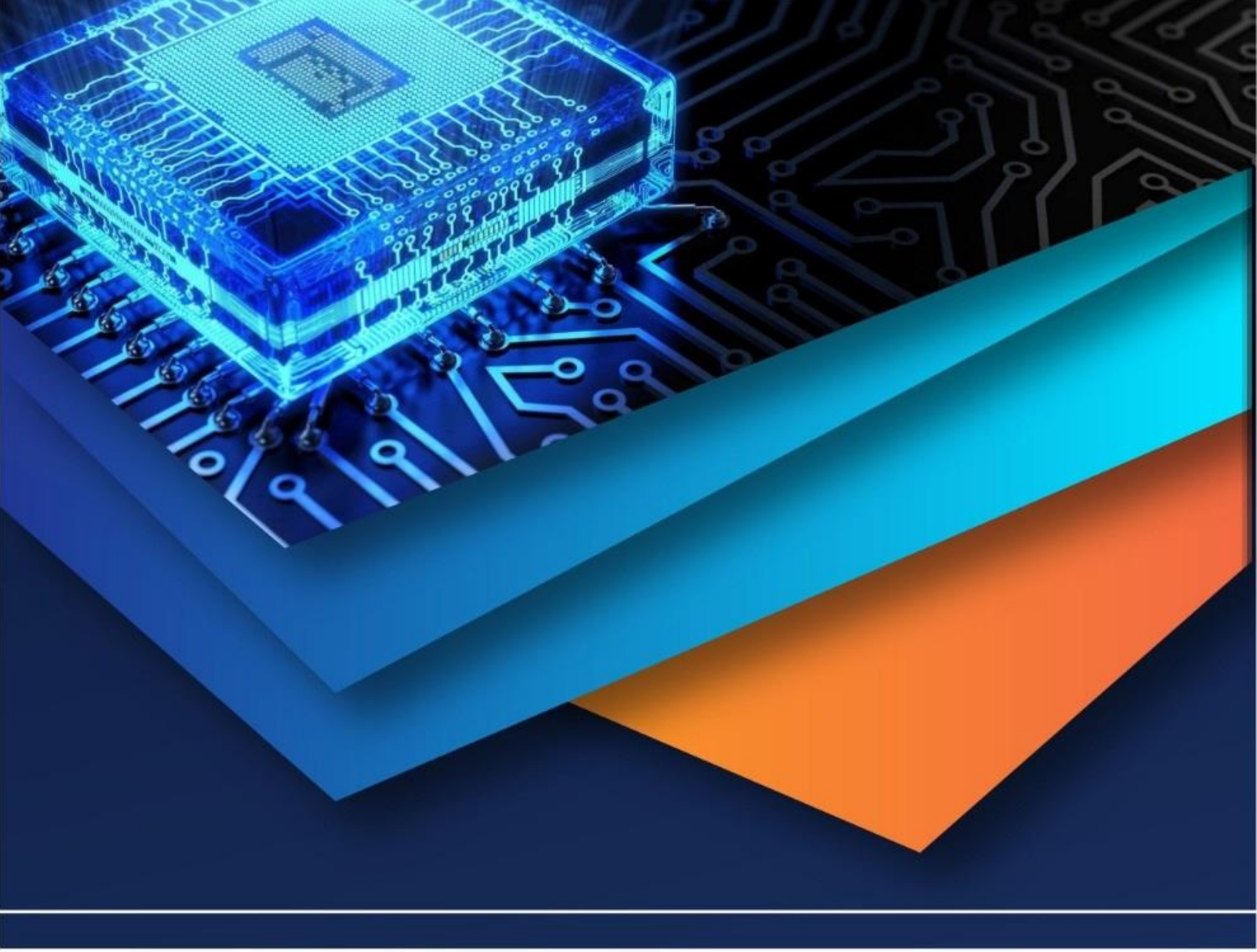

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