Advancing CAMIC: Innovations and Future Directions in the Cyclic Analytical Method for Instrumentation and Control

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Abstract: In the domain of nuclear installations´ analysis and other areas relevant to safety, the integration of important information into various analytical tools is of paramount significance. Traditional methods for PSA such as FTA, FMEA and CCF analysis often require repetitive input of similar data, leading to time intensive processes. CAMIC III addresses this challenge by combining different information in a unified application. CAMIC was originally developed by GRS as a comprehensive method for analyzing PLD-based I&C components through a cyclical four-step process: PDCA. CAMIC II extended this approach to include all digital I&C components, alongside the development of the initial CAMIC application, which facilitated user engagement and support.

CAMIC III builds on these foundations by incorporating CCF analysis, thereby extending the range and depth of its analytical capabilities. A significant advance is the conversion of the CAMIC application to a web-based platform. This change enhances accessibility, allowing the users within a network to use the application without the need for installations on individual computers. Furthermore, the integration of an API in the PSA code RiskSpectrum® streamlines the process, enabling efficient uploading of the results directly into the CAMIC database. This innovation does not only simplify the analytical approach but also notably improves the user experience.

The paper provides a practical demonstration of performing a CCF analysis using the advanced CAMIC application with integration in RiskSpectrum®. It demonstrates how CAMIC's web-based application facilitates an efficient and comprehensive CCF analysis. Insights from the practical application for real nuclear scenarios are given, emphasizing their benefits for increasing the accuracy and efficiency of safety assessments for nuclear installations.

Keywords: Common cause failure, Cyclic Analytic Method for Instrumentation and Control, probabilistic safety assessment, programmable logic device based I&C.

1. Introduction

The safety and reliability of I&C systems in nuclear installations is essential. These systems must be thoroughly analyzed to ensure they meet stringent regulatory requirements and perform reliably under various conditions. Traditional methods for analyzing I&C systems, such as fault tree analysis (FTA) [1], failure modes and effects analysis (FMEA) [2] common cause failure (CCF) [3] analysis, often involve repetitive and time-consuming processes. To address these challenges, the CAMIC (*C*yclic *A*nalytic *M*ethod for *I*nstrumentation and *C*ontrol) series has been developed by GRS. CAMIC provides a structured approach to I&C (instrumentation and control) system analysis through a cyclical process that ensures continuous improvement. Over the years, the CAMIC series has evolved to incorporate new features and enhancements, culminating in the latest version, CAMIC III.

CAMIC III aims to further streamline and enhance the analytical process by integrating advanced tools and transitioning to a web-based platform. Key advancements include the addition of CCF analysis, a more flexible and user-friendly flowchart, and the ability to read and utilize data from the probabilistic safety assessment (PSA) code RiskSpectrum® [4]. These improvements are designed to provide a more robust and efficient tool for professionals conducting safety assessments in nuclear installations.

This paper provides an in-depth look at the evolution of the CAMIC series, the methodology and tools used in CAMIC III and the significant advancements that have been made. Chapter 2 provides an overview of the evolution of CAMIC, detailing its development from the initial version to the latest enhancements, outlining the foundational principles of CAMIC I [5], the expansion and introduction of the CAMIC II [6] application and the ongoing development of CAMIC III. Chapter 3 provides deeper insights regarding the specific changes of the CAMIC methodology introduced in CAMIC III, covering the integration of CCF analysis, the development of a more flexible and modular flowchart and the transition to a web-based platform, including the technical details of the CAMIC III application with its backend and frontend technologies. Chapter 4 presents the CAMIC Test TeSys 2 scenario, providing a detailed example of how CAMIC II has been applied in a system important to safety, illustrating the practical use of CAMIC III in evaluating system reliability and compliance with regulatory standards. Finally, Chapter 5 summarizes the key findings, discussing the implications of CAMIC III in the field of nuclear safety with an outlook to potential future developments and enhancements of the CAMIC series.

2. Background

In the domain of nuclear safety, the analysis and assessment of I&C systems are crucial for ensuring operational reliability and compliance with regulatory standards. The development of methodologies and tools that streamline these processes is essential for efficient and effective safety assessments. In the following, an overview of the development of such a methodology, CAMIC, is given.

The CAMIC series represents a progressive evolution in the methodology for analyzing I&C components, particularly in the context of nuclear installations PSA. Initially designed to address the complexities associated with Programmable Logic Device (PLD)-based I&C systems, CAMIC has expanded its scope over the years to include all digital I&C components and to integrate advanced analytical tools.

In this chapter, the various versions of CAMIC are briefly presented, detailing the significant advancements and enhancements that have been incorporated over time. First, an overview of CAMIC I, which established the basic principles of the methodology, is given. This will be followed by a discussion of CAMIC II which introduced a more comprehensive approach and a user-friendly application to better support the analysts. Finally, the ongoing development of CAMIC III is presented, aiming to further enhance the analytical capabilities and user experience through the integration of advanced tools and a web-based platform.

2.1. Evolution of CAMIC

The CAMIC series represents a progressive evolution in the methodology for analyzing I&C components, specifically in the context of nuclear installations. Developed by GRS, CAMIC was initially designed to address the complexities associated PLD-based I&C systems.

The first version, CAMIC I, established a structured approach to analyzing PLD-based I&C components through a four-step cyclic process: plan, do, check, and act (PDCA). This cyclic process facilitated systematic planning, execution, verification, and implementation of actions, ensuring continuous improvement and refinement of the analysis. An easy-to-follow flowchart was provided to guide the users through the PDCA cycle, helping them understand and execute each phase effectively.

2.2 PDCA Cycle

The PDCA cycle is a fundamental component of the CAMIC methodology, providing a structured approach for the analysis and a continuous improvement of I&C systems. This cycle encompasses all steps from the initial planning and preparation through to the implementation of necessary changes based on the results of the analysis.

<u>Plan</u>
In the planning phase, all relevant information required for the analysis is collected. This involves compiling documents and data pertinent to the assessment of the control technology (LTE) within the planned control technology architecture (LT architecture). The planning process does not include the development of the LT architecture itself, which is assumed to be pre-existing. However, adjustments to the planned architecture can be considered during the evaluation process.

Key Activities in the Plan Phase:

- Collection of all relevant technical information and requirements related to the LTE and LT systems.
- Identification of requirements from national and international regulations as well as additional requirements such as customer specifications.
- Example: Replacing a programmable control component with a complex, computer-based component to meet regulatory requirements and enhance reliability by eliminating existing CCF potential.

Do

Based on the information gathered in the planning phase, the actual analysis is conducted. This involves a sequence of analytical steps tailored to the specific question or component under evaluation. Different analytical tools such as FMEA, FTA and CCF analysis can be applied.

Key Activities in the Do Phase:

- Execution of various analytical steps using appropriate tools.
- Evaluation of intermediate results to determine the sequence of analysis steps.
- Assessment of potential negative impacts of LTE failures within the LT system.

Check

In the check phase, the results of the analysis are compared to the information and requirements collected during the planning phase. This step ensures that the planned changes to the LT architecture or the proposed LTE comply with all relevant requirements and that the impacts identified during the analysis are acceptable.

Key Activities in the Check Phase:

- Validation of analysis results against initial requirements and collected information.
- Verification that planned changes meet all regulatory and performance criteria.
- Evaluation of whether the impacts of the changes on the LT system are acceptable.

Act

If all requirements are met, the cycle can be exited, and the planned changes to the LT architecture, such as the installation or replacement of a complex control component, can be implemented. If any requirement is not met, there are two options: either modify the plans for the LT architecture or adjust the requirements to allow for another iteration of the PDCA cycle or abandon the plans and exit the cycle.

Key Activities in the Act Phase:

- Implementation of planned changes if all requirements are satisfied.
- Decision-making regarding adjustments to plans or requirements if any criteria are not met.
- Repeating the PDCA cycle with revised plans or abandoning the project if necessary.

Figure *1* illustrates the PDCA cycle used in the CAMIC methodology. It highlights the continuous improvement potential and structured approach to analyzing and implementing changes in the LT architecture.

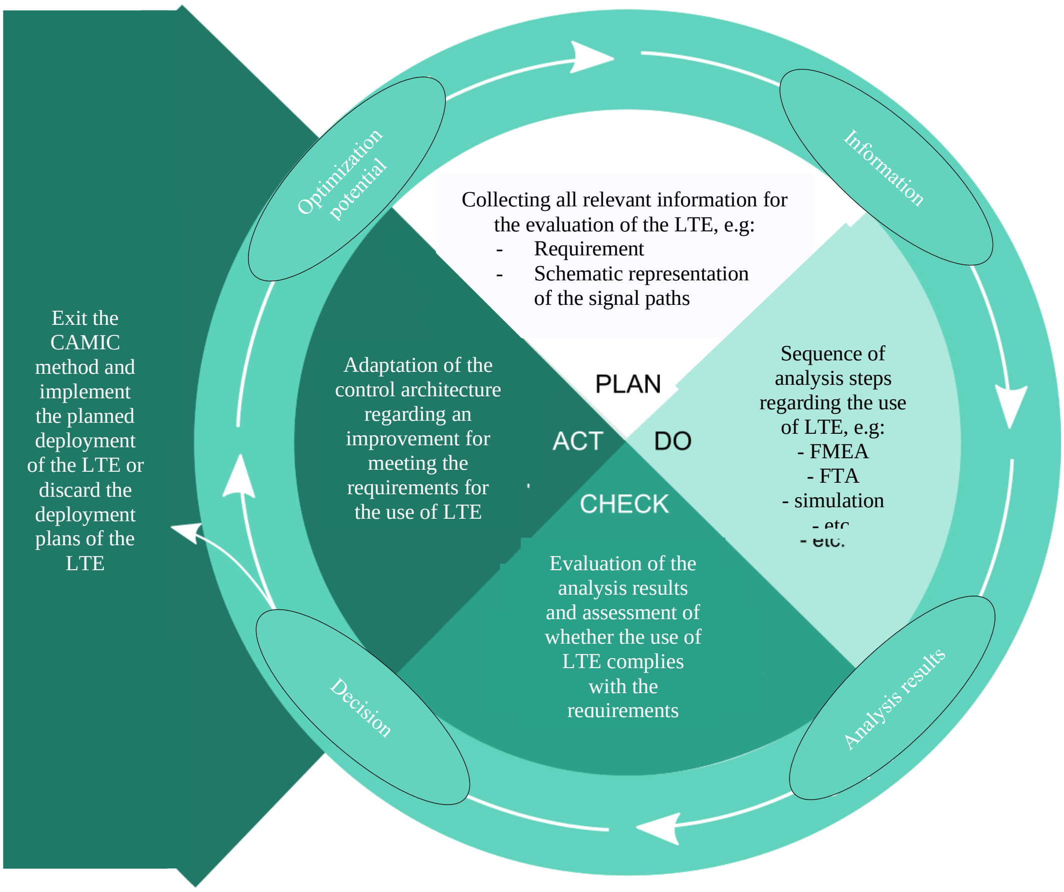

Figure 1. Illustration of the PDCA cycle used in the CAMIC methodology

Based on CAMIC I, CAMIC II expanded the scope to include all digital I&C components. This version also introduced the initial CAMIC application, providing a user-friendly interface to support and engage users in the analytical process. The CAMIC II application improved accessibility and usability, enabling a broader range of professionals to efficiently conduct detailed I&C analyses. To further support users, the flowchart initially developed for CAMIC I was significantly expanded in CAMIC II. This more detailed flowchart addressed the complexities of programmable and computational LTEs, providing comprehensive guidance through each step of the PDCA cycle. The enhanced flowchart ensured that users could navigate the intricacies of analyzing these advanced systems with greater ease and precision.

In addition, the second research and development (R&D) project, RS1560 "CAMIC II", developed a computer based CAMIC application that provides users with even more detailed guidance on the CAMIC method. This application allows for the evaluation of computer-based and programmable LTE as a project which can be conducted collaboratively by multiple users. A MySQL database was created specifically for CAMIC to facilitate this process. Users can organize and carry out evaluations seamlessly through individual user accounts. Upon launching the application, each user must log into the database. Users can then create a new project or open an assigned existing project. The CAMIC method has been accurately implemented in the application, guiding users step-by-step through the analytical process.

The application also supports the storage and sharing of relevant documents in the database, making them accessible to other users. A topic search function has been implemented, allowing users to search the database documents by predefined topics. This feature is available in both English and German, accommodating documents that do only exist in English. Furthermore, the application can generate a largely automated report on the progress and interim steps of the evaluation as a Word document at any time. The CAMIC application also allows users to specify analysis results, project specifications, relevant references, and citations, presenting them clearly in a report.

As an additional analytical tool, CAMIC II incorporates the diversity matrix [7] developed by GRS. This matrix helps analyzing the diversity of I&C components throughout their lifecycle, from requirements and development to operation and maintenance. It links the components of an I&C system with relevant diversity characteristics, facilitating comprehensive diversity assessments. The matrix is adaptable, allowing users to tailor it to specific evaluation subjects and I&C architectures, ensuring relevant aspects are considered in each analysis.

3. CAMIC III

CAMIC III is currently under development, aiming to enhance and expand the capabilities introduced in previous versions. This latest version incorporates significant advancements such as the integration of a CCF analysis, a more flexible and user-friendly flowchart, a modular checklist approach, and a transition to a web-based platform. These enhancements are designed to provide a more robust and efficient tool for safety assessments in nuclear installations.

3.1. Changes in the CAMIC Methodology

One of the primary enhancements in CAMIC III is the addition of the CCF analysis. This integration extends CAMIC's analytical capabilities, allowing for a more comprehensive assessment of potential failure modes and their impacts. CCFs can lead to the simultaneous failure of multiple components due to a single shared cause, which is particularly critical in safety-critical systems like those in nuclear installations.

3.1.1. CCF Integration

The CCF analysis in CAMIC III is done by systematically analyzing the dependencies and interactions between components that could lead to simultaneous failures. By identifying common factors or causes that could trigger multiple failures at once this analysis helps understanding the overall system vulnerability and implementing strategies to mitigate these risks. To support this, CAMIC III utilizes the diversity characteristics matrix that was already implemented in CAMIC II. This matrix aids in assessing the diversity of I&C components, ensuring that different components are varied enough to prevent a single failure from affecting multiple components.

3.1.2. Modular Flowchart

The flowchart used in CAMIC has been made more flexible and user-friendly. The updated flowchart is modular, incorporating a checklist approach that guides users through each step of the PDCA cycle with greater ease and precision. This checklist allows users to easily switch between the steps of the PDCA cycle. For example, if new information is received while in the "Do" phase, users do no longer need to complete the entire cycle before making adjustments. Instead, they can directly return to the "Plan" phase, enter the new information, and determine if analytical steps need to be repeated or if they can proceed from the "Plan" phase.

Additionally, the modular design opens the possibility to use the analytical tools independently of the full PDCA cycle. Users can select and apply specific tools as needed without having to follow the entire PDCA process, providing greater flexibility and efficiency in conducting analyses. As a result, no visual flowchart representation is now needed. Instead, the CAMIC application incorporates the underlying flowchart in the code, streamlining the user experience.

3.2. CAMIC Application

The CAMIC III application represents a significant advancement in the field of safety assessments for nuclear installations. Building upon the robust framework established in earlier versions, CAMIC III introduces new functionalities and enhancements aiming at improving the efficiency, accessibility, and comprehensiveness of the analytical processes. Two key aspects of these advancements include the integration with RiskSpectrum® and the transition to a web-based platform.

3.2.1. Integration of RiskSpectrum®

By integration in RiskSpectrum®, CAMIC III simplifies the workflow for performing safety assessments. Users can seamlessly transfer data between the two applications, reducing the time and effort required to perform comprehensive analyses. CAMIC III can read files from RiskSpectrum® and use this information for further analysis, such as a CCF analysis (see Figure *2*). This integration enhances the overall efficiency and effectiveness of safety assessments for nuclear installations. Since the data is not entered manually, the process is less prone to errors. In addition, the automation and the uncomplicated data transfer between both applications save working time.

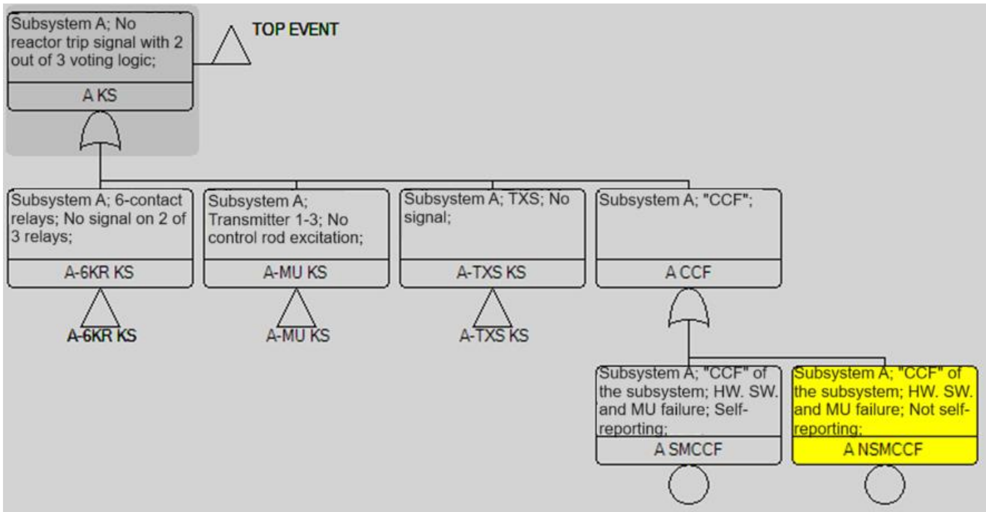

Figure 2. Connection to RiskSpectrum®

3.2.2. Web-Based CAMIC Application

The transition to a web-based platform is another significant advancement in CAMIC III. This change enhances the accessibility and usability of the CAMIC application, allowing users within a network to access the tool without needing to install it on individual computers.

The web-based platform offers several advantages, including:

- *Ease of Access:* Users can access the application from any networked device, providing greater flexibility and convenience.
- *Centralized Data Management:* Data are stored centrally, facilitating real-time collaboration and data sharing among users.
- *Reduced Maintenance:* Eliminating the need for individual installations simplifies maintenance and updates, ensuring that all users have access to the latest version of the application.

To achieve this web-based functionality, CAMIC III utilizes Django for the backend and React for the frontend.

Django Backend

Django is a high-level Python web framework that encourages rapid development and clean, pragmatic design. It is known for its robust security features, scalability, and versatility. Django handles the server-side operations of the CAMIC application, managing database interactions, user authentication, and the overall business logic. Its powerful admin interface and built-in features significantly reduce the time and effort required to develop complex web applications.

Django delivers an API (*A*pplication *P*rogramming *I*nterface) to connect the backend and frontend, allowing seamless communication between them. The frontend can then take data from this API to present them to the user. This interaction is essential for dynamic data representation and real-time updates. The Django admin interface displays the projects stored in the MySQL database. This interface provides a clear and organized view of project data, enabling users to efficiently manage and interact with various aspects of their projects. A list of projects allows users to perform administrative tasks such as adding, editing, or deleting projects. The API interface in a web browser will later be utilized by the React frontend to retrieve the data necessary for display. The Django REST framework's API root lists the available API endpoints, providing options to explore and interact with the API. It is a crucial component that facilitates seamless communication between the backend and frontend, ensuring efficient data exchange and dynamic content rendering.

React Frontend

React is a JavaScript library for building user interfaces, particularly single-page applications where efficient updating and rendering of components are crucial. Developed by Facebook (now Meta Platforms, Inc.), React allows developers to create large web applications that can change data, without reloading the page. The React frontend provides a dynamic and responsive user experience, enabling users to interact with the CAMIC application seamlessly. React's component-based architecture ensures that the user interface is modular and maintainable, making it easier to implement new features and updates. The React frontend of the CAMIC III application has a clean and organized layout. It is a homepage with a navigation bar at the top, allowing users to access various sections such as Home, My Projects, and Project Information.

By combining Django and React, CAMIC III leverages the strengths of both technologies to deliver a powerful, user-friendly web application. Django's robust backend capabilities complement React's dynamic frontend, resulting in a cohesive and efficient platform for conducting safety assessments in nuclear installations.

The structure of CAMIC III is designed to optimize both backend and frontend operations, ensuring seamless interaction between users and the application. This structure is illustrated in Figure 3, showing how Django is connected to the MySQL database, handles user management, and provides access to projects for logged-in users. The Django backend efficiently manages data storage, user authentication, and project access control. It ensures that only authenticated users can access the relevant projects and perform necessary operations.

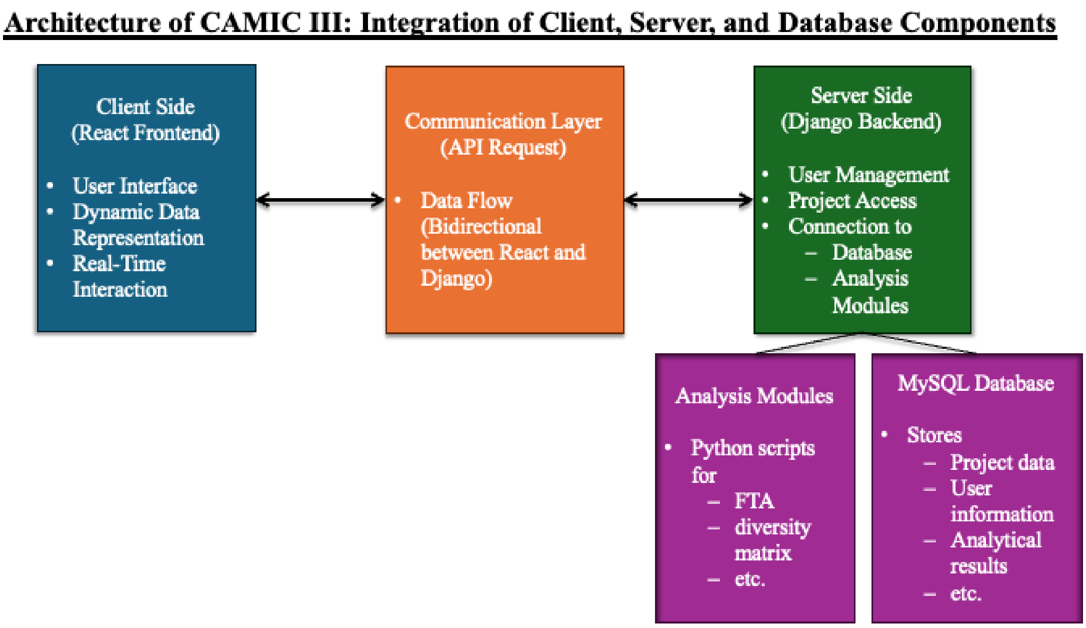

Figure 3. Scheme of the CAMIC III architecture

On the frontend, React dynamically represents this data to the user, offering an intuitive and responsive interface. React components fetch data from the Django backend and render it in a user-friendly manner, enabling users to interact with their projects, view analyses, and input new information seamlessly. This interaction between Django and React creates a robust, secure, and efficient platform for performing safety assessments.

Crucially, the architecture also includes dedicated analysis modules for various analytical tasks, such as FMEA and diversity matrix evaluations. These modules are integrated within the server-side operations managed by Django, ensuring that complex analyses can be performed efficiently and accurately. The results of these analyses are stored in the MySQL database, along with project data and user information, making them readily available for further review and action. This comprehensive approach enables CAMIC III to provide detailed, data-driven insights that are essential for thorough safety assessments.

4. Example: CAMIC Test TeSys 2

This example illustrates how CAMIC II works through the project scenario CAMIC Test TeSys 2. In CAMIC II, a comprehensive flowchart guides the analysis process by presenting a series of questions and tasks. Depending on the responses to these questions and the outcomes of the tasks, the subsequent steps in the analysis can vary, following different procedures labeled from A to G (for more information, see [6]).

In the scenario CAMIC Test TeSys 2 selected in the R&D project, it was assumed that a client (e.g., GRS) is planning a new system called TeSys ("TestSystem"). TeSys in this scenario is a system important to safety. TeSys is a relatively simple system consisting of two interconnected tanks. Water can be released from the higher tank to the lower tank via a valve, and conversely, water can be pumped from the lower tank to the higher tank using a pump. The fill levels of the two tanks are measured by level sensors (each with only one redundancy) and monitored by a control system to prevent, for example, the pump from running dry (see [8]).

The contractor was tasked to examine if TeSys meets the single-failure criterion as formulated in the German nuclear Safety Standard KTA 3501 [9]. The client provided the following document:

A description of the system (process engineering and control technology).
The project start date was agreed to be May 1, 2021, with all work to be completed within the same calendar year. The project scenario description was created such that an FMEA was necessary for processing. Additionally, the expected lack of diversity (in this scenario, the system consists of only a single redundant train) was to be investigated and documented using a diversity matrix.

Test Execution

A test project ("CAMIC-Test TeSys 2") was first created in the CAMIC application, then the analysis was started according to the CAMIC methodology. The processing of the “Plan” phase involved compiling relevant documents and data pertinent to the assessment of TeSys. Documents were uploaded to the CAMIC database, and the documentation of the requirements from KTA 3501 could rely on the already available document in the database.

In the “Do” phase, the following responses were given to the initial questions to determine the procedure:

Step 10: D-c010-e000:
Are the signal paths of multiple control functions affected using new control devices (of the same or different types)?
Since only one control function was considered in the scenario, this question was answered with no (NO).

Step 11: D-c011-e000:
Is the control level (e.g., priority control) of these control functions affected using new control devices (of the same or different types)?
As the scenario involves a planned system including the control level, this question was answered with yes (YES).

Step 12: D-c012-e000:
Are multiple actuator types involved in the execution of the control function, in which new control devices are planned?
The system considered in the test scenario contains only one control function to protect a single actuator. Therefore, this question was answered with no (NO).

Based on the responses to steps 10, 11, and 12, the procedure E of the CAMIC methodology was selected. Some important steps (questions and analysis steps) of this procedure are considered in more detail below.

Step 15: D-c115-e000:

Is the same type of control device used in the control level of all process engineering redundancies?
Since only a single redundancy is present in the system, this question was answered with yes (YES).

Step 16: A-c123-e000:
Generic investigation of the new control devices planned for the control level using an FMEA and consideration of the failure mode impacts on the control function. A FMEA was conducted in this step. It was found that there is a failure mode that can lead to the failure of the only considered actuator.

Step 17: D-c124-e000:
Did the FMEA of the control devices reveal a failure mode whose failure impact can lead to failure or erroneous activation of the considered actuator type when fulfilling the triggering criteria of the control function?
Based on the result of the previous analysis (see step 16), this question was answered with Yes (YES). After processing the subsequent steps 18 and 19 (D-c125-e000 and A-c126-e000), it was immediately evident that there is insufficient diversity (not even redundancy) in this case.

Step 20: D-c127-e000:
Are there indications of a potential CCF for the planned type of control device and the other redundancies in the control level?
Based on the previous analyses and the fact that only a single redundancy is planned, this question was answered with yes (YES).

Step 21: D-c128-e000:
Adaptation of the diversity matrix to the relevant characteristics of the control devices
In this step, the method of the diversity matrix available within the CAMIC application was applied for documentation of the lack of diversity. Since the lack of diversity is obvious in this test scenario, only a few representative diversity characteristics and components of the control system were considered, documenting this lack.

After several additional questions and the documentation of intermediate results in steps 22 to 26, the “Do” phase was completed. The processing of the subsequent CHECK and ACT phases was analogous to the standard CAMIC methodology. It was found in this scenario that the requirements for the control system were not met (see step 29, D-c302-e000), and a corresponding report was created for the client.

This example demonstrates how CAMIC II works and provides a baseline for comparing the same scenario using CAMIC III following the next year. By applying CAMIC III to the TeSys 2 scenario, we aim to evaluate the enhancements in flexibility, efficiency, and comprehensiveness of the new methodology. Potential comparisons could include the effectiveness of the updated flowchart, the integration and impact of CCF analysis, and the overall user experience with the web-based platform.

5. Conclusions and Outlook

The CAMIC series has demonstrated significant progress in the methodology for analyzing I&C systems, particularly within the context of nuclear installations. Starting from CAMIC I, which provided a structured PDCA cycle for evaluating PLD-based I&C components, the methodology has evolved to include CAMIC II, expanding its scope to all digital I&C components and introducing a computer-based application for more detailed and collaborative analyses.

CAMIC III, currently under development, aims to further enhance these capabilities by integrating advanced tools such as CCF analysis and transitioning to a web-based platform. These enhancements are designed to provide a more robust and efficient tool for safety assessments, improving accessibility, data management, and user experience. The planned comparison of CAMIC II and CAMIC III using the CAMIC Test TeSys 2 scenario will provide valuable insights into the improvements and flexibility introduced in the latest version.

By leveraging modern web technologies like Django for the backend and React for the frontend, CAMIC III ensures a scalable and maintainable system that can adapt to future needs and integrate with other tools and databases.

Looking ahead, there are several exciting possibilities for further developing and enhancing the CAMIC web-based application. One promising direction is the integration of CAMIC with other tools and databases such as the GRS VERA database for reportable events and the GRS TECDO database for collection of technical documents. This integration would enable seamless data exchange and enhance the comprehensiveness of safety assessments by incorporating a broader range of data sources.

Furthermore, there is potential to train a LLM on these integrated databases. Such an LLM could assist users by providing intelligent, context-aware recommendations and answers based on the vast amount of data available in the databases. This capability could significantly enhance the efficiency and accuracy of the analysis process, guiding users to the most relevant information and best practices for their specific scenarios.

These advancements are expected to enhance the functionality and usability of the CAMIC application, making it a more effective tool for safety assessments in nuclear installations. By incorporating new technologies and continuously improving its features, CAMIC aims to provide robust support for PSA.

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References

[1] Deutsches Institut für Normung (DIN) e.V. Fehlzustandsbaumanalyse. DIN EN 61025. Beuth-Verlag, Berlin, 2007 (in German).
[2] Deutsches Institut für Normung (DIN) e.V. Analysetechniken für die Funktionsfähigkeit von Systemen – Verfahren für die Fehlzustandsart- und -auswirkungsanalyse (FMEA). DIN EN 60812. Beuth-Verlag, Berlin, 2006 (in German).
[3] Dhillon B. S., Anude O. C. Common-cause failure analysis of a non-identical unit parallel system with arbitrarily distributed repair times. Microelectronics Reliability, 33. Jg., Nr. 1, 87-103. 1993.
[4] Kumar M. RiskSpectrum: Emerging Software for Nuclear Power Industry, 10.1109/INREC. 2010.5462562. 2010.
[5] Piljugin E. et al. Neue Methoden zur Bewertung der Zuverlässigkeit fortschrittlicher Mensch-Maschine-Schnittstellen, digitaler leittechnischer Einrichtungen und personell-organisatorischer Einflüsse, GRS--460, Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) gGmbH. Köln, August 2017 (in German).
[6] Gebhardt P. et al. Weiterentwicklung der CAMIC-Methode zur sicherheitstechnischen Bewertung digitaler Leittechnik, GRS- 655, Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) gGmbH. Köln, November 2021.
[7] Jopen, M. et al. Entwicklung eines Ansatzes zur Analyse der Netzwerktechnologien in sicherheitsrelevanten Leittechniksystemen hinsichtlich Verbreitung und Auswirkung postulierter Fehler, GRS-377, Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) gGmbH, Köln, 2015.
[8] Müller C. et al. AnTeS – Entwicklung und Anwendung des Analyse- und Testsystems der GRS, GRS-648, Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) gGmbH. Köln, March 2021.
[9] Nuclear Safety Standards Commission (KTA, German for Kerntechnischer Ausschuss). KTA 35101 (2015-11) Reactor Protection System and Monitoring Equipment of the Safety System. November 2015. www.kta-gs.de/e/standards/3500/3501_engl_2015_11.pdf.