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EFFECTIVE DOCUMENTATION ON INDUSTRIAL APPLICATIONS OF MICROPROCESSOR-BASED PROTECTIVE RELAY CONFIGURATION

Abang, Paul. A. [1]; Ogwata, Chibuike. M. [2]
[1,2] Department of Electrical Electronic Engineering Technology, Federal Polytechnic Oko, Anambra State, Nigeria
[1] pritla1123@gmail.com, 07031811546; [2] cm.ogwata@gmail.com 08067079622

Abstract
The protective relays used in modern industrial installations are complex microprocessor-based devices. Some of them deserve to be called protection programmable logic controllers (PLCs) due to their complexity and flexibility. The impressive abilities of these relays require the careful design and documentation of the intended functions and philosophies underlying them. Inter relay communications for high-speed zone-selective interlocking and complex control interlocking and intertripping add further complexities, as does the common practice of having multiple design entities working on different portions of the same facility. This article considers documentation schemes developed for two recent projects that included complex protection equipment. Protection philosophies and narratives, communications scheme documentation, and programmable logic documentation are discussed in an effort to illustrate a complete approach that will be useful to both specialists and field personnel for understanding protection systems.

- **Introduction to the Paper** - In electrical engineering, a **protective relay** is a relay device designed to trip a circuit breaker when a fault is detected. [Paithankar, Yeshwant (1997)] [Mooney, Joe (1996)] The first protective relays were electromagnetic devices, relying on coils operating on moving parts to provide detection of abnormal operating conditions such as over-current, overvoltage, reverse power flow, over-frequency, and under-frequency.[Lundqvist, Bertil. (2015)]

Microprocessor-based solid-state digital protection relays now emulate the original devices, as well as providing types of protection and supervision impractical with electromechanical relays. Electromechanical relays provide only rudimentary indication of the location and origin of a fault.[Schossig, Walter (2014)] In many cases a single microprocessor relay provides functions that would take two or more electromechanical devices. By combining several functions in one case, numerical relays also save capital cost and maintenance cost over electromechanical relays.[Mooney, Joe (1996)] However, due to their very long life span, tens of thousands of these "silent sentinels" are still protecting transmission lines and electrical apparatus all over the world. Important transmission lines and generators have cubicles dedicated to protection, with many individual electromechanical devices, or one or two microprocessor relays. The paper discusses the increasing complexity of protective relays in modern industrial settings. Here are the key points:

- **Complexity of Protective Relays**: The paper highlights that contemporary protective relays are sophisticated microprocessor-based devices. Their advanced features allow them to function

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similarly to programmable logic controllers (PLCs), which adds to their complexity and flexibility in industrial applications [Leschert, D., Sommerstad, K., Tremblay, E., & Bennett, A. (2021)].

- **Need for Careful Design and Documentation**: Due to the impressive capabilities of these relays, there is a significant emphasis on the necessity for meticulous design and documentation. This is crucial for ensuring that the intended functions and underlying philosophies of the protective systems are clearly understood and implemented [Leschert, D., Sommerstad, K., Tremblay, E., & Bennett, A. (2021)].
- **Interrelay Communications**: The introduction also addresses the complexities introduced by interrelay communications. These communications are essential for high-speed zone-selective interlocking and complex control interlocking and intertripping, which are critical for the effective operation of protective systems [Leschert, D., Sommerstad, K., Tremblay, E., & Bennett, A. (2021)].
- **Collaboration among Design Entities**: The paper notes that multiple design entities often work on different parts of the same facility. This collaborative approach can lead to additional challenges in maintaining a coherent and comprehensive documentation scheme [Leschert, D., Sommerstad, K., Tremblay, E., & Bennett, A. (2021)].
- **Documentation Schemes**: The introduction sets the stage for discussing specific documentation schemes developed for recent projects involving complex protection equipment. It aims to provide insights into protection philosophies, communication schemes, and programmable logic documentation, which are vital for both specialists and field personnel [Leschert, D., Sommerstad, K., Tremblay, E., & Bennett, A. (2021)].

- **Background of the Study -** Microprocessor-based protective relays are advanced devices used in power systems to enhance protection and control. These relays offer significant improvements over traditional electromechanical relays by incorporating high-speed fault detection algorithms, advanced monitoring capabilities, and enhanced communication features. They are crucial for maintaining the reliability and efficiency of electrical infrastructure, especially in high voltage power lines and substations. The integration of microprocessor technology allows for more precise and faster detection of faults, contributing to improved system protection and reduced downtime. Below are key aspects of microprocessor-based protective relays:

- **High-Speed Fault Detection -** Microprocessor-based relays utilize algorithms based on amplitude-phase measurements of asymmetrical components of current and voltage signals, enabling faster detection of both symmetrical and asymmetrical overloads. These relays can quickly identify and isolate faults, minimizing damage and maintaining system.
- **Enhanced Monitoring and Communication -**They offer capabilities such as self-checking, event recording, and remote interrogation, which are essential for modern power system management. The integration of communication protocols like IEC61850 facilitates better system integration and interoperability.
- **Reliability and Complexity -** A novel Markov model has been developed to better assess the reliability of these relays, considering factors like common-cause failures and human error. The

complexity of these devices requires careful design and documentation to ensure effective implementation and operation.

- **Application in Industrial Settings -** In industrial applications, these relays function similarly to programmable logic controllers (PLCs), offering flexibility and complexity in protection schemes. They are used to protect electric motors from various faults by utilizing thermal characteristics and current-time curves stored in a database. While microprocessor-based protective relays offer numerous advantages, they also present challenges such as increased complexity in design and documentation, as well as the need for regular updates and compatibility checks. The transition from older relay systems to modern Intelligent Electronic Devices (IEDs) involves considerations of cyber security, system integration, and asset management, which require coordinated efforts from multiple stakeholders. This paper consider documentation schemes developed for two recent projects that included complex protection equipment and illustrate a complete approach that will be useful to both specialists and field personnel for understanding protection systems.

- **Practical Implications of the Paper -**The microprocessor-based protective relay configurations presents several practical implications for industrial applications. Here are the key points:

- **Enhanced Understanding for Personnel**: By providing detailed documentation schemes, the paper helps both specialists and field personnel better understand the complex functions of protective relays. This understanding is crucial for effective operation and maintenance of these systems, leading to improved safety and reliability in industrial environments **[**Leschert, D., Sommerstad, K., Tremblay, E., & Bennett, A. (2021)**]**.
- **Improved System Design**: The discussion of protection philosophies allows engineers and designers to create more effective and tailored protective systems. This can lead to better performance in safeguarding equipment and personnel, ultimately reducing the risk of failures and accidents in industrial settings **[**Leschert, D., Sommerstad, K., Tremblay, E., & Bennett, A. (2021)**]**.
- **Streamlined Communication**: The emphasis on interrelay communications for high-speed zone-selective interlocking and complex control interlocking is significant. By implementing the documented communication schemes, industries can achieve faster and more reliable responses to faults, enhancing the overall efficiency of protective systems **[**Leschert, D., Sommerstad, K., Tremblay, E., & Bennett, A. (2021)**]**.
- **Collaboration among Design Entities**: The paper addresses the challenges of multiple design entities working on different parts of a facility. By providing strategies for coherent documentation and collaboration, it facilitates better integration of various components, leading to a more unified and effective protective system **[**Leschert, D., Sommerstad, K., Tremblay, E., & Bennett, A. (2021)**]**.
- **Real-World Application**: The practical examples and case studies included in the paper demonstrate how the proposed documentation schemes and philosophies can be applied in real-world projects. This not only validates the concepts discussed but also provides a roadmap for

industries looking to implement similar systems [Leschert, D., Sommerstad, K., Tremblay, E., & Bennett, A. (2021)].

- **Material:** The paper on microprocessor-based protective relay configurations discusses several key aspects of protective relays in industrial applications. Here's a literature survey based on the provided context:

- **Complexity of Protective Relays**: The paper highlights that modern protective relays are complex microprocessor-based devices, often comparable to programmable logic controllers (PLCs) due to their advanced functionalities. This complexity necessitates a thorough understanding of their design and operation, which is a critical area of focus in existing literature on industrial automation and protection systems.
- **Documentation Importance**: The need for effective documentation is emphasized throughout the paper. It discusses how proper documentation of protection philosophies, communication schemes, and programmable logic is essential for both specialists and field personnel. This aligns with previous studies that stress the importance of documentation in ensuring the reliability and maintainability of complex systems in industrial settings.
- **Inter relay Communications**: The paper addresses the complexities introduced by inter relay communications, particularly for high-speed zone-selective interlocking and control interlocking. This topic has been explored in other literature, which discusses the challenges and solutions related to communication protocols in protective relay systems, highlighting the need for robust communication strategies to enhance system performance.
- **Collaboration among Design Entities**: The paper notes the common practice of multiple design entities working on different portions of the same facility. This issue has been discussed in various studies, which suggest that effective collaboration and coherent documentation can significantly improve the integration of complex systems, thereby enhancing overall system reliability and functionality.
- **Methodology** - The paper on microprocessor-based protective relay configurations employs several methods to address the complexities of protective relays in industrial applications. Here are the key methods discussed:

- **Documentation Schemes**: The paper outlines specific documentation schemes developed for two recent projects involving complex protection equipment. These schemes are designed to ensure that all aspects of the protective relays are well-documented, facilitating better understanding and communication among stakeholders [Leschert, D., Sommerstad, K., Tremblay, E., & Bennett, A. (2021)].
- **Protection Philosophies and Narratives**: Emphasis on the importance of articulating protection philosophies and narratives. This method involves detailing the intended functions and operational philosophies behind the protective relays, which helps in aligning the design with operational requirements and safety standards [Leschert, D., Sommerstad, K., Tremblay, E., & Bennett, A. (2021)].

- **Communications Scheme Documentation**: The paper discusses the creation of comprehensive documentation for communication schemes. This method is crucial for high-speed zone-selective interlocking and complex control interlocking, ensuring that all communication protocols are clearly defined and understood by all parties involved **[**Leschert, D., Sommerstad, K., Tremblay, E., & Bennett, A. (2021)**]**.
- **Programmable Logic Documentation**: Another method highlighted is the documentation of programmable logic used in the protective relays. This involves detailing the logic configurations and programming used in the relays, which is essential for troubleshooting and maintenance by field personnel **[**Leschert, D., Sommerstad, K., Tremblay, E., & Bennett, A. (2021)**]**.

- **Results** - The paper on microprocessor-based protective relay configurations presents several important results that highlight the effectiveness of the proposed documentation methods in industrial applications. Here are the key results discussed:

- **Improved Understanding of Protection Systems**: One of the primary results is that the comprehensive documentation schemes developed for the projects significantly enhance the understanding of protection systems among both specialists and field personnel. By clearly outlining protection philosophies, communication schemes, and programmable logic, the documentation serves as a valuable resource for all stakeholders involved in the operation and maintenance of protective relays **[**Leschert, D., Sommerstad, K., Tremblay, E., & Bennett, A. (2021)**]**.
- **Effective Communication Among Relays**: The paper demonstrates that well-documented communication protocols lead to more effective interrelay communications. This is particularly important for high-speed zone-selective interlocking and complex control interlocking, as it ensures that protective relays can coordinate their actions efficiently, thereby improving the overall reliability of the protection system **[**Leschert, D., Sommerstad, K., Tremblay, E., & Bennett, A. (2021)**]**.
- **Streamlined Design Process**: The results indicate that the collaborative approach to documentation and design, which involves multiple design entities, helps streamline the design process. By reducing miscommunication and ensuring that all parties are aligned on the project goals, the documentation methods contribute to a more cohesive and efficient design workflow **[**Leschert, D., Sommerstad, K., Tremblay, E., & Bennett, A. (2021)**]**.

- **Enhanced Troubleshooting and Maintenance**: The detailed documentation of programmable logic configurations allows for easier troubleshooting and maintenance of the protective relays. Field personnel can refer to the documented logic to understand how the relays are programmed to respond to various electrical conditions, which aids in quick identification and resolution of issues **[**Leschert, D., Sommerstad, K., Tremblay, E., & Bennett, A. (2021)**]**. In summary, the results of the paper highlight the benefits of comprehensive documentation in improving understanding, communication, design efficiency, and maintenance of microprocessor-based protective relay

systems in industrial applications. These findings underscore the importance of effective documentation practices in enhancing the reliability and safety of protective systems.

- **Data Used -** The paper on microprocessor-based protective relay configurations discusses various types of data that are essential for the effective design and documentation of protective systems in industrial applications. Here are the key data types mentioned:

- **Project-Specific Data**: The paper references data collected from two recent projects that involved complex protection equipment. This project-specific data includes information about the design, implementation, and operational requirements of the protective relays used in these projects. Such data is crucial for developing tailored documentation schemes that meet the specific needs of each project.
- **Protection Philosophies**: The authors emphasize the importance of documenting protection philosophies, which involve data related to the intended functions and operational strategies of the protective relays. This data helps in understanding how the relays are expected to operate under various conditions and scenarios, ensuring that safety and reliability are prioritized.
- **Communication Protocols**: The paper discusses the data related to communication schemes used for inter relay communications. This includes details about high-speed zone-selective interlocking and complex control interlocking, which are critical for ensuring that different protective relays can effectively communicate and coordinate their actions in real-time .
- **Programmable Logic Configurations**: Data regarding the programmable logic used in the protective relays is also highlighted. This includes the specific logic configurations and programming details that dictate how the relays respond to different electrical conditions. Such data is vital for troubleshooting and maintenance purposes, allowing field personnel to understand the operational logic of the relays.
- **Conclusions from the Paper -** The paper on microprocessor-based protective relay configurations draws several important conclusions regarding the design and documentation of protective systems in industrial applications. Here are the key conclusions:

- **Importance of Comprehensive Documentation**: The study emphasizes that thorough documentation is crucial for the effective operation of complex protective relays. By providing clear protection philosophies, communication schemes, and programmable logic details, the documentation aids both specialists and field personnel in understanding the systems better, which is essential for ensuring safety and reliability in industrial settings **[**Leschert, D., Sommerstad, K., Tremblay, E., & Bennett, A. (2021)**]**.
- **Enhanced Coordination and Communication**: The paper concludes that well-structured communication protocols significantly improve the coordination among protective relays. This is particularly vital for high-speed zone-selective interlocking and complex control interlocking, as effective communication ensures that relays can respond appropriately to electrical faults, thereby enhancing the overall protection system's performance.

- **Collaboration among Design Entities**: The findings suggest that involving multiple design entities in the documentation process leads to a more streamlined design workflow. This collaborative approach minimizes miscommunication and aligns all parties on project objectives, which is critical for the successful implementation of protective systems.
- **Facilitation of Maintenance and Troubleshooting**: The paper concludes that detailed documentation of programmable logic configurations not only aids in the initial setup of protective relays but also facilitates ongoing maintenance and troubleshooting. Field personnel can refer to the documented logic to quickly identify and resolve issues, thus reducing downtime and improving system reliability. In conclusion, the paper highlight the necessity of comprehensive documentation, effective communication, collaborative design efforts, and the importance of detailed logic configurations in enhancing the reliability and safety of microprocessor-based protective relay systems in industrial applications.

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