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Real-Time Broad Integrating Power System Protection and Control

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ABSTRACT

Real-time communication between the wide area protection and control system and the substations is made feasible by the maturation of synchronized wide area communication technology. It has been acknowledged that the current protection and control system to manage this real-time data is inadequate. In order to examine the future growth of protection and control systems, this study starts by analyzing the development history of power system protection, paying particular emphasis to the recent advancements in the field of wide-area and integrated safeguards. Subsequently, the notion of integrated broad area protection and control is presented, demonstrating how a hierarchical protection and control system offers protection and management for regional or wide area power substations/plants, along with their corresponding power.

1. INTRODUCTION

The introduction of the first electro-mechanical over current relay around the turn of the century, power system protection came into being. As seen in Fig. 1, the bulk of the protection principles used in protection relays today, including over current, directional, distance, and differential protection, were created during the first three decades of the 20th century. The advancement of contemporary science and technology, particularly in the areas of electronics and computers, has aided in the development of relay technology, including the components, materials, and manufacturing process used to create the hardware structure of relay protection devices. Simultaneously, significant theoretical advancements had been achieved in the software, algorithms, and relay protection systems. As Fig. 1 illustrates, advancements in contemporary technology drive advancements in power system protection.

Conventional relays are being replaced with microprocessor-based digital and numeric relays in all power system protection domains nowadays. Nonetheless, a lot of the same protective relaying ideas continue to be important today. A centralized computer system-based centralized substation protection system was suggested for use in the late 1960s [1]. This marks a significant turning point in the development of power system protection. The concept of an all-encompassing integrated protection scheme, in which the protection package would encompass more than that because there was no computer gear, software, or communication technology available to support the concept, it was not extensively used until recently. Since then, successful advancements in relay technology have been made possible by the use of digital techniques.

Power system protection advanced thanks to developments in the 1980s and 1990s, particularly the "Adaptive Protection" and AI-based protection solutions that were suggested during that time. Inverse Definite Minimum Time Over current (IDMT) protection was first used in the early stages of protection history, and thus marked the beginning of adaptive protection. The development of computing technology and related control theory in the 1980s made the notion crucial. It can be characterized as a novel kind of relay protection that can alter its characteristics, performance, or set value based on the power system's fault status and mode of operation.

Adaptive relay protection works by protecting the power system to the greatest extent feasible in order to enhance protection efficacy. The benefits of adaptive relay protection include increased system response, increased dependability, and increased financial gains. It has many potential uses in the areas of auto enclosure, transformer protection, distance protection, and generator protection, among others. Research has shown that more thorough system operation and fault information are needed through communication networks in order to achieve the protection of the system adaptive to the operation mode and fault status. Electronic and computer technology, as well as artificial intelligence technologies like fuzzy logic, genetic algorithms, artificial neural networks, and evolutionary algorithms, fault distance measurement, direction protection, and other related tasks. The features of an artificial neural network include self-organization, distributed storage, parallel processing, and self-learning. Artificial intelligence will be used to enhance the speed and precision of defect analysis and detection, paving the way for the creation of an intelligent diagnosis system in the future.

The protective relays' performance has increased as a result of these advancements. Nevertheless, the focus of these advancements has been on refining traditional relaying methods; the application of adaptive and artificial intelligence techniques has not produced any noteworthy new relaying concepts. Simultaneous with the power network's ongoing development in the 1990s, research into non power system frequency fault detection techniques to speed up relay response times was spurred by the need for quick fault clearance to enhance system stability.

As a result, the so-called "transient based protection" relays—which use fault-generated transients for transmission system protection—were developed. These relays are based on travelling waves and superimposed components. Research has revealed that the defect produced high frequency. The use of a cutting-edge communication method, the global positioning system (GPS) in power system protection, as seen in Fig. 1, is another significant milestone. Specifically, broad area power networks can be protected by the newly proposed protection relay principle [3, 4]. The idea of wide-area protection with an emphasis on control aspect was introduced after the development [5]. Reexamining the idea of centralized protection is now possible due to the surge in the signal processing power of relay platforms and the availability of appropriate communications schemes in recent years.

According to research [6] on the idea of "Integrated Protection," data from various power plants and component parts can be used to develop new protection schemes and philosophies. These could have a number of advantages over the current protection methods that are based on the specific plant or component. Substation area protection [7] has rapidly emerged as a useful field for study and use in this regard.

Additionally, as information technology has advanced, there has been interest in using big data techniques (as seen in Fig. 1) and cloud computing [8] to enhance power performance. Conversely, the advancements in substation integrated automation technology offer the necessary technical foundation to maximize the integration and combination of monitoring, control, protection, and measuring devices and systems. Relay protection and integrated automation are being implemented, and this is reflected in resource sharing, remote control, and information exchange. The control, signal, measurement, billing, and other circuits are integrated into the computer system to replace the traditional control protection cabinet, with the remote terminal unit and microcomputer protection device serving as the core. This can lower the amount of space and equipment needed and increase the secondary system's dependability. The relay protection device is essentially a high performance, multifunction computer

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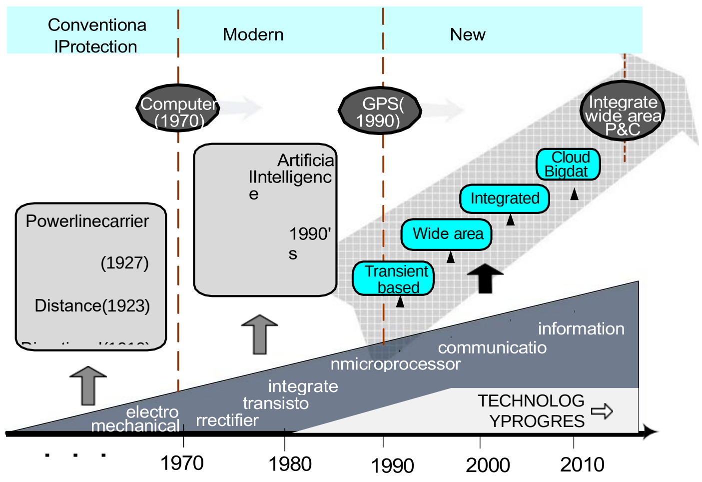

Fig.1.HISTORY OF POWER SYSTEM PROTECTION

The rapid advancement of information technology and high-speed communication networks has led to notable advancements in power system protection. In recent years, power system control and broad area control have become more prevalent, especially in integrated and wide-area protection.

2.Current progress broad protection

The rapid advancement of communication technologies in recent years has made the sharing of information across large distances feasible. In this way, the wide area measuring system's introduction offers a fresh concept for power system protection system design.

The transient based protection in 1996 , where GPS time synchronization was crucial to the design , is where the first wide-area protection idea originated. A summary paper from 1997 that methodically describes the idea of the so-called "wide area protection" , primarily emphasizing the area's management element, came right after this. Wide area protection based on innovative algorithms that are generated from the measurements of several information points can offer quick, Integrated defense

The advancement of digital technology has led to more and additional safeguarding features for any particular device (line, transformer, generator, and so on) have been put into use to a certain extent within a single protective device of incorporation. As an illustration, a numerical line protection. Relays may be used for current differential or distance functions. as the primary defense, as well as directed and over current serves as a fallback defense. The most recent changes in communication and microprocessor technologies offered fresh methods for generating novel defense tenets .Making plans founded on the data gleaned from several power plants and parts, which might possess notable benefits over the current defense methods specific to each plant or component. In contrast to substation area or centralized protection defense), the combined defense does not only consolidate the relay

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According to research on the idea of "Integrated Protection," data from various power plants and component parts can be used to develop new protection schemes and philosophies. These could have a number of advantages over the current protection methods that are based on the specific plant or component. Substation area protection has rapidly emerged as a useful field for study and use in this regard.

Relay protection and integrated automation are being implemented, and this is reflected in resource sharing, remote control, and information exchange. The control, signal, measurement, billing, and other circuits are integrated into the computer system to replace the traditional control protection cabinet, with the remote terminal unit and microcomputer protection device serving as the core. This can lower the amount of space and equipment needed and increase the secondary system's dependability. The relay protection device is essentially a high performance, multifunction computer thanks to the advanced computer and communication network, which is It can communicate any information about the protected components to the network control centre or any terminal, as well as acquire any information from the network regarding the functioning and malfunction of the power system. Accordingly, under typical operating conditions, every microcomputer protection device is capable of performing not only the relay protection function but also measurement, control, data communication, and other functions. It can also achieve the integration of protection, control, measurement, and data communication.

3.Integrated defense

In order to attain a specific level of integration, an increasing number of protection functions for any given equipment (line, transformer, generator, etc. have been included within one protective device with the advancement of digital technology. For instance, a numerical line protection relay may have backup protection in the form of directional and over current functions, with distance or current differential acting as the primary protection. Recent advancements in microprocessor and communication technology have made it possible to develop new protection principles and schemes based on data from several power plants and components. These methods have the potential to be significantly more advantageous than the current ones that are based on a single plant or component. Integrated protection does more than just centralize the relay, in contrast to centralized protection (also known as substation area protection).

4. Broad area management

Wide-area power system operation and control will be greatly improved by the growing deployment of wide-area measurements. They offer voltage and current phasor data that is precisely synchronized to a shared time reference that is supplied by GPS. Thus, to increase system awareness and reliability, a variety of power system monitoring and control applications can be implemented in the system. These applications include dynamic model online estimation and validation, real-time congestion management, real-time stability estimation, and enhanced state estimation based on mixed Remote Terminal Unit (RTU) and Pharos Measurement Unit (PMU) measurements. The most significant and difficult applications, however, are those that use large area stability real-time detection and control to stop blackouts

5. Novel idea and advancement

A revised idea for integrated wide area protection and control, or IWAPC, has been put up recently based on the previously cited advancements. The concept focuses primarily on the integration of protection and control, especially at the wide-area or regional level. This integration is intended to offer several advantages to the protection and control system in the future, such as the ability to combine the

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three lines of defense system and online self-healing decision making to prevent large area power network cascading tripping. A three-level hierarchically coordinated system, backed by a specially created real-time synchronized wide-area communication network, is the basis of the integrated broad area protection and control concept, which is presented.

The cloud computing system, which is specifically made to carry out a number of auxiliary tasks for substations and power networks, is also supported by the information platform. Apart from the fundamental features of relay protection, the platform should possess a substantial capacity for storing fault information and data, quick data processing capabilities, robust communication features, and additional security features. It should also have control devices and a scheduling network to facilitate the sharing of system data, information, and resources, as well as the ability to perform remote monitoring through the computer monitoring system of substation communication. With the help of the suggested platform, future substation equipment architecture may be altered to offer a flexible framework for creating an interactive grid, enhancing power grid security and dependability in the process.

.2.Combined regional and wide-area security and control

Fig. 2 shows the proposed integrated wide area or regional protection and control system (IWAPC).

Power transmission and distribution networks have advanced quickly. Examples of this include distributed generation and energy storage in distribution networks, series compensation in AC lines and high-voltage DC lines in transmission systems, etc. Compared to normal systems, these new advancements produce significantly more intricate properties. As a result, the current protection and control system will be unable to handle the new systems, which is why the IWAPC system has been propose.

As can be seen, the IWAPC system is made up of various components at different levels: at the bottom are the integrated multiple-function intelligent equipment at the local level; at the top are the wide area communication network, the integrated wide area information platform, and the integrated wide area (regional) protection and control at the wide area level; and at the bottom are the substation communication network and the integrated substation protection and control. The real-time synchronisation information platform and the high-speed wide area communication network are the main components of the system In accordance with the three-level dispatching (country, province, regional) architecture, the IWAPC is further extended to dispatching in order to accomplish the integration of dispatching automation, protection, and control of the power grid and to implement the functions of regional protection, control, and dispatching managements. Intelligent equipment with multiple functions at the local level.

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The substation's intelligent equipment, as seen in Figure 2, is integrated multiple-function secondary equipment that includes the metrology measurement, intelligent terminal, PMU, local protection, and MU. All real-time data sampling and information transmission to the wide area P&C and integrated substation P&C are handled by the equipment. Additionally, it receives and executes control commands from the IWAPC and the integrated substation P&C. 90% of the connected line sections can receive local protection when the equipment is incorporated into main power apparatuses. power system control and wide area control in recent years, particularly in the wide-area and integrated protection. Along with other incorporated features like a defect recorder, data storage, network analysis, etc., it includes a redundant setup to assure reliability power system control and wide area control in recent years, particularly in the wide-area and integrated protection. Along with other incorporated features like a defect recorder, data storage, network analysis, etc., it includes a redundant setup to assure reliability.

Integrated Substation Protection and Control

Line, bus, transformer protection, switch failure, auto reclosure, automated bus transfer, UFLS, UVLS, overload inter tripping, and substation control capabilities are all integrated into the substation P&C. It achieves substation backup protection, safety automatic control, etc. by utilizing data from the entire substation. The conventional protection system's stage over current protection, breaker failure protection, and dead zone protection are replaced by current differential protection, which is configured using the CBs as units.

Combined Regional and Wide-area Security and Control

Fast protection is possible with the IWAPC, which was created specifically for the control and protection of the power network. Furthermore, they both incorporate automatic UVLS and UFLS, frequency and voltage control, oscillation detection, out-of-step separation, and other features. Furthermore, the gearbox cross-section safety P&C function is also incorporated into the IWAPC. The IWAPC effectively coordinates the wide area (regional) protection and control in order to achieve significant improvements in the protection and control of power systems. This is in contrast to conventional protection and control, which are separated in both design and operation. Coordinated security and control across large regions The IWAPC was developed especially for the control and protection of the power network, enabling fast protection. Additionally, they both have functions like out-of-step separation, oscillation detection, frequency and voltage control, automatic UVLS and UFLS, and others. Moreover, the IWAPC incorporates the gearbox cross-section safety P&C function .To significantly improve power system protection and control, the IWAPC efficiently coordinates wide area (regional) protection and control. Conventional protection and control, on the other hand, are designed and operated differently.

On the other hand, PTN may overcome the shortcomings of SDH rigid bandwidth by employing packet-switched core to realize statistical multiplexing and efficient packet service transfer.

It can also offer high-quality operations, maintenance, administration, and services. In order to ensure complete sharing of dynamic and transient information for all electrical measurements, breaker status, and protection operations, a self-healing fiber optical network is used to connect several substations in the area. High reliability IEEE-1588 technology is used to ensure the synchronisation timing of the sharing data, to prove the data for the integrated wide area protection and control.

SDH is still a possibility for the task, though, as electricity networks have made extensive use of it.

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Coordinated Information System

Substations are installed with a variety of intricately designed electrical equipment that is challenging to maintain. The system network has grown along with the massive amount of information in protection and control due to the ongoing advancements in power system automation and intelligence level. The internal power system data is not well interoperable among systems due to the fact that each piece of nformation is gathered and stored by a distinct device in each individual system, and complicated communication protocols sometimes result in the creation of information islands. As a result, sharing of the measurement data and protective control mechanism is prohibited, which limits the integration of information. In order to further improve, the protection and control of the smart grid must deal with the demands of the application's new scenario.

In order to attain a specific level of integration, an increasing number of protection functions for any given equipment (line, transformer, generator, etc.) have been included within one protective device with the advancement of digital technology. For instance, a numerical line protection relay may have backup protection in the form of directional and over current functions, with distance or current differential acting as the primary protection. Recent advancements in microprocessor and communication technology have made it possible to develop new protection principles and schemes based on data from several power plants and components. These methods have the potential to be significantly more advantageous than the current ones that are based on a single plant or component. In contrast to substation area protection or centralized protection, integrated protection does more than just centralize the relay hardware and software.

A revised idea for integrated wide area protection and control, or IWAPC, has been put up recently based on the previously cited advancements. The concept focuses primarily on the integration of protection and control, especially at the wide-area or regional level. This integration is intended to offer several advantages to the protection and control system in the future, such as the ability to combine the three lines of defense system and online self-healing decision making to prevent large area power network cascading tripping. The idea of integrated wide area protection and control is presented. It involves the protection and control of wide area or regional power using a three-level hierarchically coordinated system that is backed by a specifically created real-time synchronized wide-area communication network.

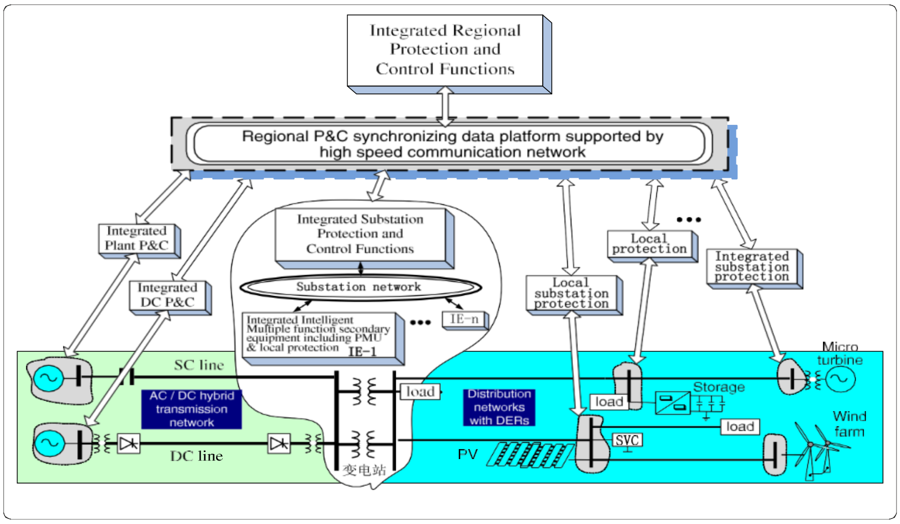

Fig.2 Integrated wide area protection and control

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The real-time synchronized information platform gathers data from a large region with accuracy and uses data mining to look into the logical relationships between the real-time data in order to improve fault tolerance, sensitivity, and dependability. Circuit breakers' statuses and other static, dynamic, and transient measurements are among the information obtained from the platform. In order to carry out sophisticated protective and control activities for the power network, valuable information is taken out of the data and assigned to a number of specifically created calculation algorithms on the platform. Sets of data must be transferred across the platform, and the application determines the speed at which the data must be transferred. For example, slow speed is required for contingency analysis, near real time speed is required for monitoring, real time speed is required for control, and high speed is required for wide area protection, specifically time synchronization. High-speed synchronized communication network

The quick communication network of the IWAPC system is among its most crucial components. In this regard, the Packet Transport Network (PTN), the most recent advancement in communication networks, would be a preferable option to carry out such a task. The Synchronous Digital Hierarchy (SDH)-based multi-service transport platform is the primary application for the current power communication network. Its advantages include low latency, high reliability, and end management capabilities in addition to its high efficiency for carrying TDM services. SDH technology did, however, eventually show its limitations with the advent of new trends in smart.

The Function of Transmission Cross-Section Safety P&C.

Grid growth, including low bearing efficiency and limited flexibility for data services. On the other hand, PTN can use packet-switched core to achieve statistical multiplexing and effective packet service transfer .inter- tripping and substation control function, etc. It utilizes information from the entire substation to achieve sub- station backup protection and safety automatic control ,etc. The CBs are used as units to configure the adaptive backup protection, and current differential protection is used to replace the stage over current protection, breaker failure protection and dead zone protection in the conventional protection system. Maintenance, management, and operation. Using high reliability IEEE-1588 technology to ensure the synchronisation timing of the sharing data, to prove the data for the integrated wide area protection and control, a self-healing fibre optical network is used to connect several substations in the region, ensuring full sharing of dynamic and transient information for all electrical measurements, breaker status, and protection operations.SDH is still a possibility for the task, though, as electricity networks have made extensive use of it.

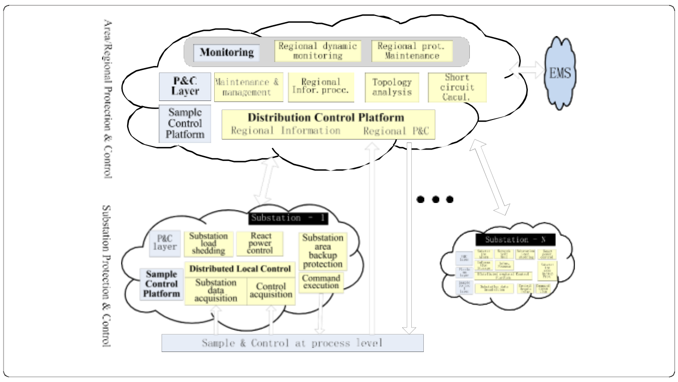

Fig.3.Structure Of Distributed Power Cloud

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Large-scale power cloud

A distributed cloud system is intended to carry out tasks at the substation and regional levels, including wide area fault location, fault line selection, power quality monitoring, protection settings, etc. It is based on the information platform previously described. As seen in Fig. 3, the enhanced functions also encompass life cycle, operation management, and equipment monitoring.

Each substation currently has a variety of secondary equipment types placed to fulfill various purposes, and the number of equipments is significantly increased by the growing number of distributed energy resources with tiny capacities added to the system. Complex functions in a specifically designed distributed "cloud" system will enable these instruments to be implemented with a much lower equipment expenditure. Process level data is received by the substation-level cloud, and the "processing ability of cloud" can be fully utilized by the cloud computing platform to lessen the strain on terminal secondary equipment. The computing clouds benefit from substantial processing power based on demand thanks to big data techniques. Updating the software to accomplish a range of task processing and performing constant upgrades to increase the equipment's processing capabilities are not necessary. The cloud system offers numerous other benefits, including the ability to share information across large areas, standardize software and algorithms, save money on equipment purchases, occupy less space in substations, and require less labour for upkeep and operation.

CONCLUSION

In this study, an integrated wide area protection and control system with a hierarchical structure that combines local, substation, and regional protection and control is presented. The real-time protection and control information platform and the proposed high-speed synchronized communication network support the system, which encompasses both distribution and transmission networks. The system provides quick protection as well as total control over the whole power network by fusing cutting-edge protection methods with the most recent advancements in control technology. It presents an opportunity to combine the three lines of defense into a single, unified system that would better guarantee the safe and dependable operation of the electrical grid. A distributed power cloud system is also intended to operate based on the system information platform. With ongoing developments in information, communication, and measurement technologies, the system has a promising future in real-world use. It is reasonable to anticipate enhanced protection and control performance overall from the suggested system. However, it is equally crucial that the system's practical implementation be easily controllable, user-friendly, and cost-effective for it to be relevant in power system applications. The authors contend that the suggested integrated protection and management at vast area level provides an enticing path forward to accomplish these goals

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