Pakistan Journal of Scientific Research (PJOSR)
ISSN (p): 0552-9050
Volume: 2, Number: 2, Pages: 27- 32, Year: 2022

System Design to Enhance the Efficiency of Power System Protection

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Received: 19/09/2022, Revised: 30/11/2022, Accepted: 15/12/2022

Abstract- **There are several chances to enhance the effectiveness of power system protection with wide area monitoring (WAM). Some of these prospects and the driving force behind their growth are discussed in this essay. Monitoring the adequacy of relay characteristics, supervisory backup protection control, more intelligent and adaptive system protection, and developing a unique system integrity protection scheme are some ways. Because of the new issues facing the security of modern power systems, WAM presents the appealing potential for strengthening protection. It is getting more and harder to choose a relay which suits well for the loading circumstances and eventualities due to the increasingly diverse operating conditions of power systems. The oversight of protecting the backup help improve instrument for averting or reducing the scope of shutdowns since the malfunction of relays has led to the onset and progression of 70% of blackouts. Modern power networks are becoming increasingly interconnected and complicated, which has increased their susceptibility to large-scale disruptions and led to several recent shutdowns.**

***Index Terms*—Protection, energy system, stability.**

I. INTRODUCTION

One of the most significant recent advancements in current power systems is wide area monitoring (WAM). Phasor measuring units were made possible by advancements in synchronized measurement technology (PMUs) [1]. This knowledge has proven to be a priceless tool for developing new software programs that may enhance [2-6] the several recent blackouts caused by protection system flaws [7-8]. As a result, there is a lot of interest in the potential role that WAM may have in improving power system protection.

Furthermore, because primary protection only covers one section of the power system, it has a restricted requirement for large area measurements. The measurements can be cast-off to monitor the presentation of power system protection components with less stringent criteria for reaction time (like backup protection) and are less discriminating. The measurements can also be the foundation for developing innovative system integrity guard schemes, adaptive system protection, and even brand-new protection ideas (such as real-time balancing of security and dependability). The potential improvements cannot be realized with wide-area measurements alone. The substation now has access to unheard-of levels of computing power because the development of digital relays greatly expands the range of tasks that any protective system may offer [9].

A proper communication infrastructure must be available to support any wide-area application in addition to the availability of WAM and greater processing capability. Different wide-area protection (WAP) ideas may require additional communication [10]. For some (such as intelligent controlled islanding [11]), measurements may need to be sent once every cycle from various places, but for others, binary signals may need to be supervised.

A dependable, rapid response speed may need minimal latency and jitter, and maintaining cyber security will be crucial to preventing malevolent third parties from using WAP as a weapon to bout the control system. Therefore, a thorough assessment of the communication requirements must be a key component of any broad area protection scheme's design [12].

The evolving nature of electricity systems is causing WAP to become more and more relevant. There are three primary factors: owing to the greater variety of possible operating circumstances, Demand-side participation and changes to the generation mix; greater power system interconnection; larger feeds from neighbouring systems; shrinking operating margins. These elements have driven the creation of fresh, WAM-supported protection ideas. These innovative concepts span a wide spectrum of complexity and ambition due to protection's various difficulties [13].

The following are some of the concepts that have been suggested and how they can assist in solving some serious risks to the effective operation of power system protection:

1. How wide-area disturbances and cascade failures contribute to control system shutdowns.
2. They guaranteed the safety of stoppage relays in the more difficult power system working circumstances.
3. It reduces the impact of concealed issues that emerge under pressure.

4. The modification of organization protection measures to the actual formal of the system.
5. Distribution system-wide protection.

II. WIDE AREA MONITORING

To create a single snap of the power scheme for a particular period, WAM gathers dimensions from isolated sites throughout the power system in real-time. A crucial part of WAM, synchronized dimension technology (SMT) enables measurements to be precisely time-stamped utilizing judgement signals from the global positioning system (GPS). These time brands make it simple to aggregate the measurements and provide a consistent baseline for phase angle measurements.

The most popular type of synchronized measurement technology is the PMU, which was created in the early 1980s [1]. The IEEE C37.118 standard specifies an obligatory degree of dimension recital [14] and a message protocol [15] for these capacities, which PMUs make at a rate of once every cycle. It is important to note that this standard allows the measurement streams to contain both continuous and discrete values. This enables the protocol to broadcast binary status signals and waveform measurements.

A WAMS's architecture can be extremely complex, and [15, 16] offers several examples of creating one. The communication network's latency, jitter, and dependability in a WAMS are critical factors in determining if the WAMS is appropriate for supporting protective services. The communication delays guarantee that the protection quality is adequate.

III. PROTECTION SYSTEM CHALLENGES

A. OVERVIEW OF THE POWER SYSTEM

Disconnecting faulty or overloaded components from the power supply protects them from an impairment, stops the error from compromising safety, and shields the adjacent region from grave hazards.

The protection can be divided into main and backup equipment protection, generally provided through breaker operations. Primary protection prevents equipment damage by separating the protected equipment from the rest of the system. It operates in just 3*4 cycles and is extremely selective. Any errors that are not resolute by the main protection are the responsibility of the backup protection. It moves slower than the main protection to maintain optimal synchronization and is less selective. Having backup system security is extra problematic since it covers a bigger portion of the system and is more reliant on its state of operation. Protection must strike a balance between two important criteria. Dependability and security are these. Assuring that the protection system performs as it should be what is meant by dependability.

Assuring the protective mechanism doesn't activate when it shouldn't be security. Security and dependability, however, are opposed objectives. SIPS uses predetermined movements constructed on independent system research to safeguard the system from this particular set of eventualities [13]. These actions will be carried out when a particular set of input circumstances are met [10]. A mix of both may be needed for a SIPS to be activated and start operating. Protective systems need to work together and coordinate their efforts, especially as they grow more intricate, comprehensive, and adaptive. This prevents undesired interactions that could lead to maloperation or perhaps directly produce hidden failure modes.

B. CASCADE FAILURES

Cascade failures are a series of power system failures that happen one after another, and each one is caused by the failures that came before it, such as a series of line tripping brought on by the breach of temperature limits. Cascade failures can happen very soon after the initial occurrence and have been a factor in several recent blackouts. Most existing power system protection cannot respond quickly enough to prevent these cascades. Therefore, it is appealing to investigate the possibility of safeguarding the power system's security against wide-area disturbances. The system's potential cascade initiators must be identified, and any stressful conditions that could make it susceptible to them [12].

For instance, local protection can relieve a thermal overload, protecting the strength in the process. The harshness of the excess in relation to the asset's significance for system security cannot be determined by this local protection. A series of thermal overloads can follow if this object is removed immediately. The proposed protection can be utilized to implement security-aware protection measures resistant to wide-area disturbances and cascading failures. Last but not least, even if a human operator is trained, the difficulty of the devices underlying wide-area disruptions and the speed with which they might lead to system collapse may make it impossible for them to be properly managed [13]. Wide area protection provides the chance to deliver the automatic steps required to maintain system security.

C. RELAY FUNCTIONING IS APPROPRIATE YET INCORRECT

Numerous cascade failures and blackouts have been caused by protective relays operating improperly. Most protective relays now in use have set features that don't change depending on the actual system conditions. This indicates that this safeguard may function properly but in an unsuitable manner. Changes in power system operating procedures, such as a greater focus on economic and environmental issues, have worsened this issue. Due to these changes, a wider range of generation mix and load flow patterns have emerged. As a result, the system's fault level and load flow pattern are subject to rapid change, and the spectrum of potential operating circumstances is expanding. As a result, it is more difficult to choose the protection locations that will be appropriate for all expected operating situations and eventualities. This has made choosing the right protection settings significantly more difficult. This has influenced how protection relays, especially backup protection relays, operate properly but inappropriately [14].

D. HIDDEN FAILURES

Modern power system protection faces obstacles and is becoming more sophisticated, but it still operates admirably, and practically all relay operations are accurate and suitable. However, some significant blackouts have been started and spread due to improper protective measures. It results in an improper operation of the relay and the removal of system components due to another switching event referred to as a hidden failure [15].

Hidden failures are sporadic occurrences that aren't an indicator of poor relay design. They don't instantly result in a mistaken operation, but they will when another event happens nearby. Only faults that result in a relay operating wrongly are considered hidden failures. Failures that prevent the relay from functioning are not hidden failures because redundant protection should be able to handle them. In addition, transient failures, such as those that occur while switching, are not concealed failures; rather, they result from defective design and cannot be monitored.

As is shown in Fig. 1, it compares the type of system failure one for a region-3 stage remoteness relay. A concealed failure will occur if the contacts on T3 fail and become permanently closed. This is because Z3 must also be closed. Therefore, the failure of T3 does not immediately result in a malfunction. When Z3 ends in the presence of any error in regions 1-3, the line will promptly and without delay trip in the case of a fault. On the other hand, if the contacts of Z1 fail and become permanently closed, there won't be a hidden failure. This is because the line will trip at the time of the failure. Although this is a mistake, the line trip was quickly caused. Therefore, it is not a covert failure.

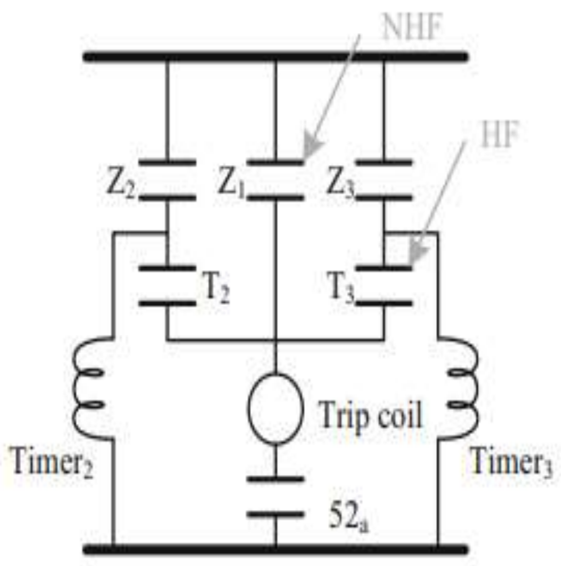

FIGURE 1: Hidden versus non-hidden failure.

Only when a hidden failure results in an improper operation or when the malfunctioning component is examined will it be found. Ongoing calibration, maintenance, and protection evaluation could find and fix any hidden faults that are now present. But it is well known that maintenance can lead to unnoticed problems. It is crucial to create WAP principles that can lessen the effects of hidden failures when they are discovered.

IV. INCREASING PROTECTION THROUGH WIDESPREAD SURVEILLANCE

The general goal of exploiting broad area observation to improve protection is to develop new shield ideas that will reduce the likelihood of blackouts occurring and their severity when they do. The following are the main areas where WAM can help to protect the power system.

- Steer clear of improper relay settings.
- We are controlling large-scale troubles.
- We are reducing the effects of concealed disasters.
- We are maintaining appropriate stability between protection's dependability and security.

Wide area monitoring plays a very limited function in protecting primary equipment. This is due to the requirement that primary protection consistently offers a response to any problem with the element it guards. WAM is a beneficial instrument for enhancing the presentation of backup protection [2].

Wide area measurements can be used to develop supervisory backup protection plans, more sophisticated system protection measures, and brand-new protection paradigms. These protection functions include [8] the following examples.

- Adaptive relays modify their situations in response to changes in the system state.
- Better multi-terminal line protection.
- The adaptive end-of-line shield keeps an eye on the distant breaker and switches to an instantaneous characteristic.
- Modify relay settings momentarily to guard against malfunction when picking up a cold load.
- Intelligent controlled islanding employs an adaptively controlled separation to prevent an uncontrolled system separation.

A. WARNING OF THE PENETRATION RISK OF RELAY CHARACTERISTICS

This application aims to recognize when a relay's observed impedance approaches the characteristic of a healthy relay. Protection engineers are alerted to a relay configuration that may not be appropriate using this information later [9]. This idea does not employ large-area measurements or directly enhance protection efficacy. However, it uses the communication network required for broad-area monitoring to produce useful data that can aid protection experts in enhancing protection. This technique could be used on crucial relays susceptible to load encroachment, power swings, or relays that would suffer more serious repercussions from any malfunction.

B. PREVENTING LOAD ENCROACHMENT

The impedance relay's load ability is the maximum load that can be separated from a defect. Reactive power flows and voltage at the bus, which can change significantly under stressful situations and power swings, are quite important here. The settings of relays may be compromised by heavily loaded lines, resulting in an improper and unsuitable tripping action. The impedance relays' load encroachment contributed to recent blackouts. This compromise is probably going to become increasingly wasteful [10]. Adjustment can address this problem thanks to the computational power of digital relays [11].

C. ADJUSTING THE BALANCE

Protection now in place is geared toward dependability. This propensity for dependability, however, can lead to inaccurate and improper tripping actions during a wide-area disruption. This poses a serious hazard to a strained system since losing just one component can hasten the system's slide into a waterfall catastrophe or even a shutdown. Then it is desirable to tip the scales of this negotiation in favour of security under pressure when environmental factors (such as power fluctuations) can raise the probability of errors and expose covert flaws [12].

As shown in Fig. 2, switching is accomplished out of all of the relay jaunt signals. The controlling signal selects the reasonable grouping to decide the breaker trip signal.

Inspired by [15], this strategy might make it less likely that a fault would be fixed. However, there is very little chance of a fault not being fixed with the current protective strategy. Because it delivers a large reduction in the likelihood of an incorrect protective response, increasing stressed circumstances and bringing the system closer to a blackout [13].

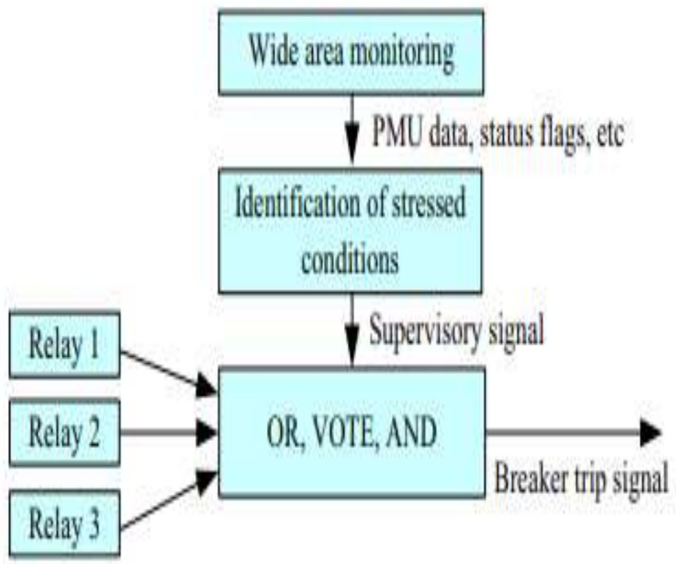

FIGURE 2: Protection by switching.

This type of protection may successfully address the problem of concealed failures.

D. BACKUP ZONES SUPERVISION

Recent blackouts were shown to have a major zone 3 relay malfunction as a contributing factor. These relays may behave in an undesirable manner due to the anomalous experienced. In Fig. 3, examples of system behaviour that could result in a relay malfunction are displayed. Using signals picked up from distant PMUs to supervise backup protection is one example of how this might be done. In Fig. 3, we show an illustration of this.

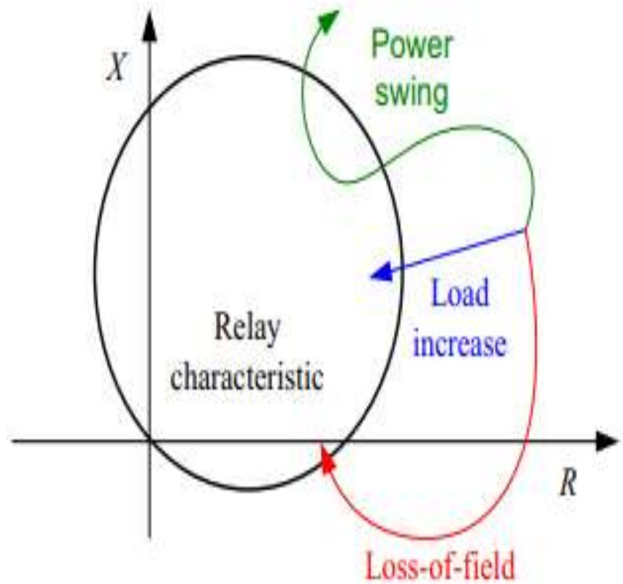

FIGURE 3: System behaviour.

Furthermore, this idea may be improved by using measurements of negative sequence currents.

The remote PMUs are situated inside the backup relay's protection zone and monitor the current flow. These components convey a discrete pickup signal to the backup relay using a straightforward pickup feature. Recently, approaches were created on a large area and current directories [8], which are developed with a specific focus on improving backup protection. Additionally, recent

For the unique and difficult scenario of series compensated lines, work [6] has suggested a scheme. These techniques can either supplement or replace current region 3 relays. The majority of the time, this shedding is performed utilizing a series of steps initiated when a specific frequency threshold is exceeded [8]. It is acknowledged as an efficient way to control the frequency deviation with less load shedding to shed loads more quickly following a lack of infeed [9]. However, it might be difficult to balance the advantages of faster response times and the danger of unneeded shedding.

Frequency regulation is a growing area of concern in isolated power systems. Asynchronous generation replaces conventional synchronous generation, which reduces system inertia and permits bigger, faster frequency variations [10, 11].

SIPSs, like all forms of protection, implement corrective measures to shield the power system from the effects of emergencies. However, SIPS are becoming increasingly popular because of their capacity to recognize complex emergent risks to the power system and act swiftly and decisively in a way that other forms of protection.

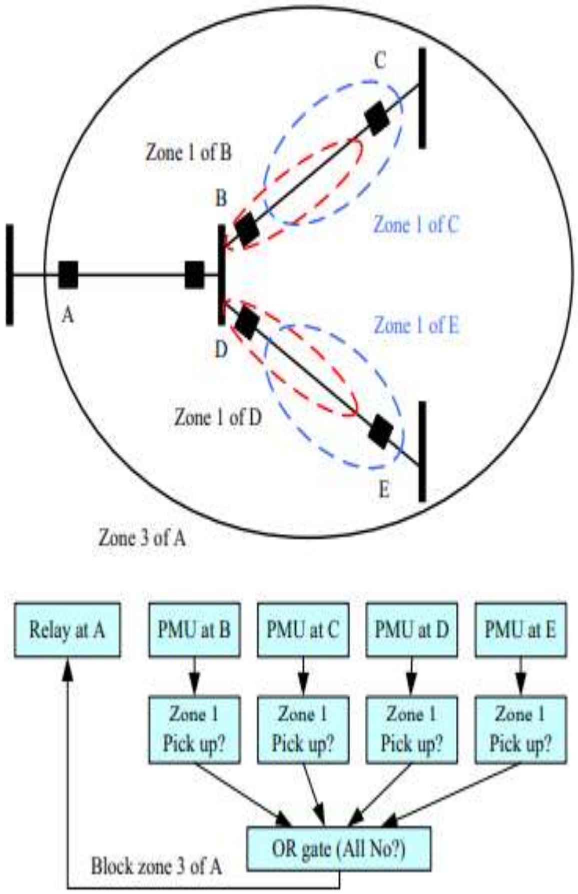

FIGURE 3: Hidden versus non-hidden failure.

As shown in Fig. 4, for instance, event-based SIPS can act right away in the wake of a severe contingency or series of contingencies instead of anticipating the system state's unavoidable degradation.

Because of the complexity of innovative SIPS and their widespread use, it isn't easy to properly coordinate all SIPS in a power system. This is crucial since a SIPS's malfunction could have far-reaching effects. Additionally, as certain SIPS are wide-area, it is necessary to coordinate the SIPS of nearby systems.

A. APPLICATION OF WAP

It is further affected by the evolving nature of power networks and any potential advantages of wide area protection and must also be taken into account while making these improvements shown in Fig. 5.

A particularly noteworthy development is the growing interconnection of DG, which has led to distribution networks—increasing wide-area monitoring systems' effectiveness by switching from simpler to more intricate systems. These are just two of the new dangers this has brought to distribution system protection [8, 9], depending on the relative positions of the fault, the relay, and the DG.

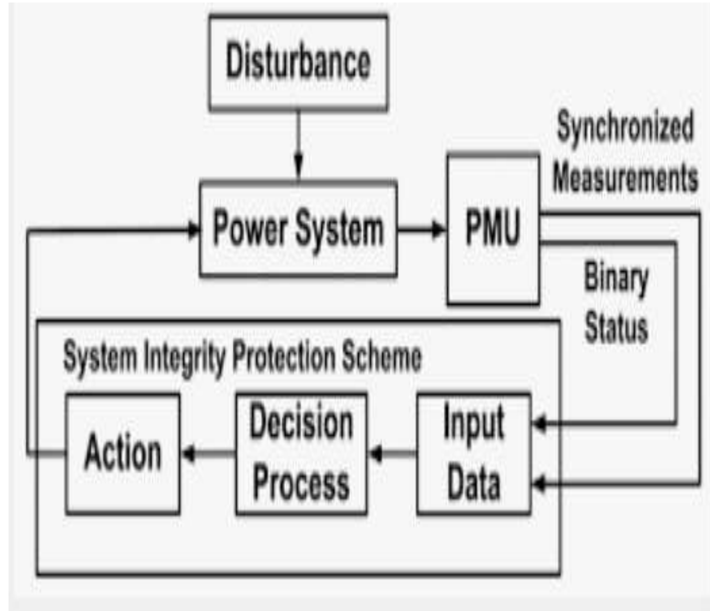

FIGURE 4: Hidden versus non-hidden failure.

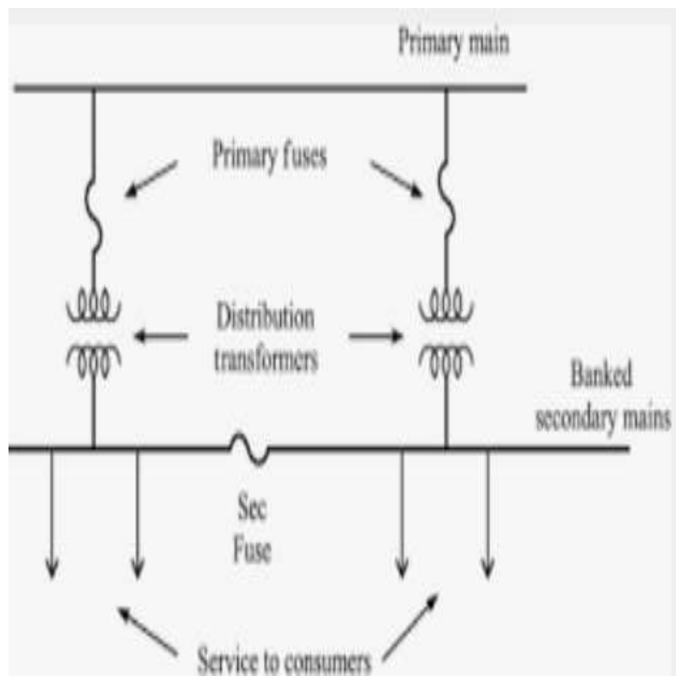

FIGURE 5: Hidden versus non-hidden failure.

Due to these dangers, IEEE standard 1547 advises disconnecting DG during faults. This glaring obstacle prevents DG from contributing significantly to system operation under pressure. New protection ideas that function better are needed to get beyond this obstacle. In these more intricate distribution networks, WAP that uses data from numerous sites to swiftly and selectively clear the problem is an appealing solution. The novel ideas put forth include:

- The use of directed overcurrent relays in place of the common ones seen in current systems.

- It enhanced pilot protection.
- The application of multi-agent systems that can keep an eye on numerous locations and make a judgement about adaptive relaying.
- Thermal protection relays that integrate dynamic ratings and DG coordination with an inference engine to manage loads.

V. CONCLUSION

Modern power systems have several chances to improve backup protection and system protection through using WAM. These improvements can help decrease the possibility of malfunctioning relays, reduce the effects of covert disasters, and develop new methods for controlling large-scale conflicts. These advantages show that increasing the elasticity of power systems in contradiction of demanding circumstances rather than fault isolation is the major goal of WAM. These new ideas should be carefully implemented to decrease the occurrence and severity of shutdowns and permit more fast service renovation. The novel ideas are implemented along with a new solution for the system's protection without any non-connectivity. The proposed solution provides the development's usefulness and a stable solution against the hidden errors; if any error occurs, it solves within no time. Because of this, the architecture utilized to improve this protection will play a crucial role in deciding its success.

FUNDING STATEMENT

The authors declare they have no conflicts of interest to report regarding the present study.

CONFLICT OF INTEREST

The Authors declare that they have no conflicts of interest to report regarding the present study.

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