# Power System Protection Strategies to Improve Safety and Control

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Power system protection is one of the prime concerns in the modern power system. The amount of expansion in consumption has put the power system to a halt lately, in the form of system failure, which results in an interruption in power supply and the worst-case scenario a blackout. The pieces of equipment often used function on high voltage rating and are in an operating mode for most of the time, so the chances of any catastrophic failure have ways remained a probability. To narrow these events and to protect the equipment, different strategies have been discussed in this paper to increase the life span and enhance the functioning of the power system. The system wasn't designed to handle the present-day challenges and changing the entire system isn't economical and feasible at once. Therefore, these clever solutions have emerged with time such as digital protection involving the latest type of relays like microprocessor-based relays and wide are monitoring schemes that enhance the component's reliability and strengthen the protection of the power system network. This paper considers various power system protection strategies, and it also compares the aforesaid strategies with numerous parameters.

**Keywords**: WAM, Relay, Power system, Security, Fault, Protection, Safety.

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# 1 Introduction

The power system is a complex network of multiple electric pieces of equipment that are connected to serve a single purpose of supplying electric power from generating end to the consumer side. To achieve this task, various devices and equipment like a transformer, transmission lines, construction of towers, motors, etc. are installed between sending and receiving ends. Generally, these pieces of equipment function on variable voltage ratings depending on their operation. As these types of equipment are mostly under operating conditions, faults are common phenomena in power system. For example, a natural phenomenon like the lighting strike increases the current in transformers, which may destroy their winding, leaving it function less [1]. This results in the loss of electric power and may also cause a shutdown in a particular area where the fault occurred. Plus, the equipment is costly and requires manpower to install, load, and unload, which takes time. Therefore, it is a must to abate these happenings by improving the power system protection. Similarly, symmetrical and unsymmetrical faults may occur due to numerous factors like short circuits, and insulation failure of devices. Moreover, the harsh weather conditions like strong winds, which may lead the surrounding trees to fall or lean on the distribution lines, may risk the protection of the lines. Protection of every device and component of a power system is the utmost priority, but the transformer plays an important role in stepping up and down the voltage. Power system protection has advanced towards the wide area monitoring and intelligent communication control from the conventional protective relaying. Since 1990, the power system protection has shifted to the use of semiconductors and microprocessors and recently the concept of wide area monitoring and integrated protection is emerging continually. Thus, different techniques and strategies have been considered in this paper, which improves the protection and safety of the power system, especially with transformer protection. Differential protection is one of the significant protection schemes which can be applied to transformers as well as the alternator against the winding faults. [2] The new developments in power system protection are with the development of the wide area monitoring and the communication technologies .This paper is broadly divided into three sections. Sections I cover the transformer differential schemes, section II covers the wide area monitoring, Section III presents the other protection strategies, Section IV presents the role of integrated substations, and Section V includes the conclusion and references.

# 2 Protection Schemes for the Transformer

One of the important components of the power system structure is the transformer. The most common scheme which is used for its protection is differential protection. Although this scheme can be used for the alternator protection, here it is elaborated for the transformer only.

## 2.1 Transformer Differential Protection

This method of protection is very reliable and quick as compared to other methods for internal fault detection of a transformer. It is usually used where the rating is above 5MVA. If there is any discrepancy found between primary and secondary current in the transformer, the differential relay will get activated, resulting in tripping the CB's of the transformer. The entire operation of this protection is established on the concept that in ideal circumstances current inside secondary in multiple (i.e. 2) transformers found in primary and secondary of a transformer are identical. As a result, there is no difference in the multiple currents (i.e. i1 & i2) which are regulated through the protection. On the other hand, when an abnormal condition occurs, the value of current i1 & i2 gets unlike forcing the relay to trip.

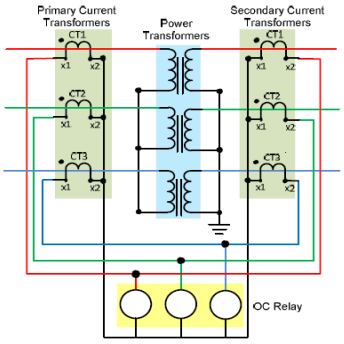


**Figure 1.** Schematic diagram of differential protection demonstration [3].

## 2.2 Transformer Restricted Earth Fault Protection

The interior abnormalities in an earth fault of a transformer are solved by employing restricted earth protection. Here, the secondary winding of each phase of a current transformer is joined, and same terminals are attached with the secondary of a neutral CT. The Neutral current transformer or the NCT is formed when the CT is connected with the neutral of a PT (Power Transformer). It is a supporting type of differential protection provided to the transformer. At the time of the internal fault, the CT has sole unbalance fault current only therefore the working of REF relay comes into play.

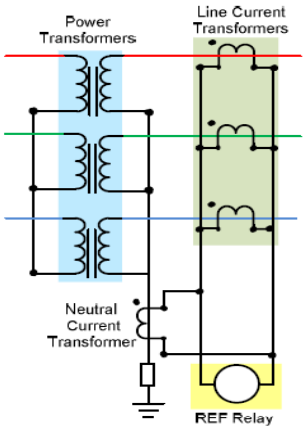


**Figure 2.** Schematic diagram of REF protection demonstration [3].

# 3 Wide Area Monitoring

Another way to enhance the protection of a power system is by making use of wide-area monitoring. Nowadays, power system protection needs monitoring due to the latest challenges faced in modern times. Monitoring is needed as the malfunctioning of protective equipment like relays has been the prime cause in 70% of shutdowns in the form of blackouts [4]. By employing monitoring in power system these situations can be avoided to a great extent for uninterrupted power supply. As it is very hard to recognize the intricacy inside a power system network, WAM provides a great assist in identifying the problems. In-sync behavior of the system with supervision is the salient features of this technology. The up rise in the pertinent part of Wide area monitoring has been ridden by the character of power system.

The broad span of feasible working conditions has arisen because of the varying demand-side involvements. The enlargement inside the interdependence of power system and the trimming of operating limits because of economic enforcement in parallel with the ever-growing intricacy of the power system network are the main driving forces for the increasing need for wide area monitoring. The topmost concern of WAM is to improve the protection by creating fresh concepts that minimize fault and failure conditions in the system [5]
Major areas where Wide area monitoring can play a crucial role in power system protection are:
1) Fixing inappropriate relay configuration triumphing over faulty conditions.
2) Directing wide area interruptions.
3) Proving reasons to describe abnormality in power system and diminishing the impact of concealed failures.
4) Establishing satisfactory stability between the security & reliability of system.
The objective of shielding in power system is to secure each component of the network from any external, internal damage, or fault. Extensive amount of area need to come under the WAM and high grade of material needs to be installed to diminish any failure due to extreme conditions [6]. The concept of WAM proposes the possibility to make monitoring strategies for back-up security. With this modern types of power system protection can overcome faults and interferences, some example are: Adaptive relays which can alter their own settings according to the operation, enhancement in the safety of multi-terminal lines, avoiding faulty operation in wintry load pickups by adapt relay, installing digital relay of its own supervision to find out system abnormalities.

# 4 Other Protection Strategies

Apart from the differential protection schemes, there are many strategies that can be used to improve the reliability of the network, which further strengthens the protection and improve the safety.

## 4.1 Avoiding Load Encroachment

The most extreme load that can be recognized from an issue is the capacity of loading in impedance relay. This is profoundly subjected to the voltage at the bus and responsive power stream. These can fluctuate during high tension in the power system. Intensely stacked lines or high tension lines might infringe on the settings of transfers and cause wrong and unseemly stumbling activity in the relay. All of it has been a major role behind blackouts and shutdown of the system due to the load infringement of the impedance relay [7]. It happens because the setting of the relay hangs in the balance between the wanted values and the highest value in the particular area which the relay can encounter. The settlement should oblige a wide scope of conceivable framework conditions and possibilities. This settlement is weak and can be easily tempered by an unexpected event. This is because it depends on a disconnected or unmonitored system of the environment and contingencies. Therefore, the configuration of the relay might not withstand the forthcoming challenges of load demand in the distant future.
The ever-changing essence of present-day power framework with the emergence in a notable irregular generation that the settlement might experience degrade in its efficiency as the disparity between max load demand and standard load changes drastically [8]. Digital relays play a major role in overcoming these issues with its computational abilities, which results in reducing the input for load current inside it.

## 4.2 Tuning the Equilibrium between the Security and Dependability of Protection

Protection sketching often comes across the challenge of finding the right tuning and balancing between the order of dependability and security. The present layout has been installed and laid out by leaning towards the side of dependability. During the ideal working of a system, when the menace of a random fault is critical and the dropping of a sole element can be bared because of the intrinsically significant degree of excess in a sound power framework, dependency is appealing in those cases. But in large

regions, this dependency on the power system could cause undesirable tripping action. All this could lead to cascade failure inside a pre-strained power system network, so it's recommended to transfer the balance of this course towards security. There are ample workable combinations to merge O/P of distinct relays for getting the equilibrium in dependency and security. Here, WAM can be put to work to find any type of stain on the power system which can be tuned to move the setting from dependability-security and vice versa in order to avoid any possible interruption.

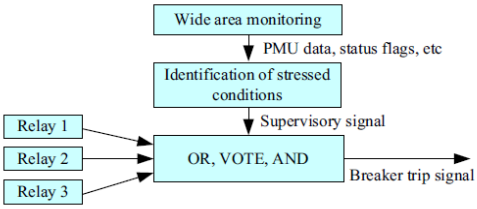


**Figure 3.** Wide Area Monitoring to change the balance between dependability & protection [5].

The following can be attained by utilizing AND and OR logic. Administered signal picks the suitable AND & OR combination, which is used to decide the trip signal for every relay trip signal [9]. Random faults are well handled by this type of protection which is formed on WAM. Employing many relays in a single function will increase the stability of the system, as a single trip or false trip won't affect the overall operation. As a result, the concealed failure inside any of the relays will not stop the entire system from functioning. This kind of concealed failure can take place in any element. Therefore, the intricacy of the protection scheme needs evaluation to reference self-collapse or malfunction [10].

## 5 System Integrity Protection Schemes

The faults and contingencies faced inside a broad region are beyond the abilities of conventional protection techniques therefore, system integrity protection is needed to secure the power system. New integrity protections schemes are emerging day by day as the accessibility to live monitoring has risen in parallel with the advancement in the power system. Now the SIPS have the potential to deal with vast region disruptions under different working conditions. Steps for achieving SIPS:

i) Figuring out the stained condition inside a system
ii) Characterizing the amount of risk to our system
iii) Planning the resolution for a particular threat
iv) Cooperating and working
v) Precise execution to provide correctness inside the system.

System integrity can carry out these operations which are distributing load demand over different sources to decrease the stress on main supply by *load shedding *switching operation in shunt reactors and breaking resistors *interrupting the line supply* establishing control in High Voltage Direct Current transmission, etc. [11].

## 6 Integrated Substation Protection and Control

The protection and control of a sub-station unite the role and protection of different power system components like autobus transfer, protection of transformer, substation jurisdiction, and many more [12]. Moreover, current diff-protection takes over the stage over-current, breaker malfunctioning, and dead zone protection. To achieve the protection using these schemes which are discussed in this paper various protection equipment like relay and the circuit breaker plays a crucial role. Circuit breakers have a vital role, as these are used as units to find the compatible backup technique. Although the circuit breaker disconnected the faulty system from a healthy system in the power system, it's the relay that

provides a signal to the circuit breaker that makes it work accordingly. Earlier the protective relaying in the substation was achieved with the electromagnetic or induction relays which become obsolete these days due to the advancement of technology like static, numeric relays, and microprocessor relays. The integrated protection focused on the new algorithm to improve the performance of the existing system rather than the centralized control, which is basically through the measurements from the multiple points [13]. The intelligence and data gathered from the substation aid in attaining reserves for security and protection of auto control.

# 7 Conclusion

As the load demand has ballooned with the increase in energy consumption, power system protection and security have become more complex. It is very important to protect the power system equipment from fault while maintaining the security to get an uninterrupted power supply. This not only improves efficiency but also ensures the safety of the equipment. Different types of equipment have their own protection scheme, which has been acquainted for grasp. Transformers are equipped with Differential Protection and REF protection using a relay for their internal protection. Wide area monitoring that can detect faults, like inappropriate triggering of a relay, has been conversed. Further, the use of system integrity protection schemes improves the functioning of a system, which successfully helps in lowering the overall stain on the system. Likewise, other methods, such as avoiding load encroachment, turning the equilibrium between security and dependability of protection, and integrated substation & control combined, help to serve the sole purpose of enhancing the protection and security of the power system. To achieve success in obtaining a reliable power system and smooth control, digital protection and intelligent techniques like wide area monitoring and integrated operation is adapted these days rather than the mechanical methods. As technology is progressing continuously, new techniques like cloud big data are also gaining the attention of researchers in the field of power system protection, which can lead to a bright future in the protection and control sector.

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