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Design and Analysis of Selective Cross Tripping Protection Scheme on 250 MVA (220/132kV) Auto Transformer

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Abstract – This research explores protecting electrical systems from overload, a common issue when transmission lines or equipment face excessive loads. It focuses on forced tripping, vital in power management at transmission substations and power plants. Overloading can cause cascade tripping, leading to extensive shutdowns. In literature, the solution proposed is cross-trip scheme, which protects healthy transformers from unnecessary overloading and tripping when operating in parallel, preventing total network disruption. A significant disadvantage is that the cross-tripping scheme often lacks selectivity. It may cause tripping of healthy or non-overloaded components due to an issue in a parallel circuit, which can lead to inefficiencies and potential damage to equipment. The study's innovation lies in introducing the Selective Cross Tripping scheme, a method that uses transformer load to decide which circuits to trip. It incorporates a unique device that trips circuits based on the transformer's load, thereby enabling proactive power load management. This scheme avoids system overload, one of the most damaging events in power system operation. It isolates circuits based on transformer load, preventing the need to entirely shut down the system or trip unaffected circuits, saving significant operational and financial costs. The study also highlights how the Selective Cross-Trip device can reduce revenue loss by maintaining the power system's integrity and ensuring uninterrupted operation of unaffected parts. This method balances the need to protect the system's hardware and minimize financial losses. The study also compares the Selective Cross Tripping scheme with the standard Cross Tripping scheme, demonstrating the superior efficiency of the former. It significantly outperforms the latter by ensuring continuity of unaffected parts, reducing revenue loss, and maintaining power system integrity.

Keywords –Selective Cross Tripping Scheme, Forced Tripping Phenomenon, Transmission Substations, Power Plants, Overloading, Transformer Load

1. Introduction

The use of auto transformers has become increasingly prevalent in various industrial sectors due to their cost-effectiveness and efficiency in facilitating voltage transformation. However, like all electrical equipment, auto transformers are not exempt from potential faults. These faults, if undetected and unaddressed, can lead to overloading, overheating, and even failure of the transformer, causing significant operational disruptions, property damage, and potential fire hazards. Consequently, there's an indispensable need for a tripping scheme in auto transformers to detect, diagnose, and mitigate these potential issues [1].

A tripping scheme is a protection mechanism that interrupts the current flow whenever a fault occurs in an auto transformer. The tripping scheme is not merely a luxury, but a necessary safety requirement in maintaining the operational integrity of the auto transformer. It plays a pivotal role in safeguarding both the electrical infrastructure and personnel from potential harm caused by electrical faults [2] – [3].

Faults in an auto transformer can occur due to a multitude of reasons, including internal faults within the transformer, overloading, short circuits, and overheating. The major concern with these faults is that they can be disastrous if not detected and resolved promptly. Overloading or overheating of an auto transformer, for instance, can lead to the breakdown of insulation, resulting in internal short circuits and potentially even causing a fire [4].

This is where the importance of a tripping scheme comes into play. Upon detecting a fault, the tripping scheme is designed to interrupt the current flow to the transformer instantly, thereby preventing further damage. It not only isolates the faulty auto transformer from the rest of the electrical system to mitigate the fault's impact on the overall system but also prevents the escalation of the fault condition [3].

The speed and reliability of the tripping scheme are crucial to its effectiveness. Given the potential for rapid escalation of faults in electrical equipment, a delay in tripping can lead to catastrophic consequences. Therefore, the tripping scheme must react quickly to faults and should be robust and reliable to always ensure its effective functioning. The tripping scheme should also cause minimal disruption to the rest of the electrical system. This means it should be designed to redistribute the load efficiently in case a fault results in the tripping of an auto transformer [3].

It's worth noting that the implementation of a tripping scheme in auto transformers is not just about the immediate safety of the electrical system. It's also about preserving the longevity of the auto transformer itself. By promptly addressing potential faults, a tripping scheme can prevent the wear and tear of the auto transformer that could otherwise shorten its lifespan. This translates into long-term cost savings, making the tripping scheme an economically sound decision as well [4].

In conclusion, the need for a tripping scheme in auto transformers cannot be overstated. As auto transformers continue to play a significant role in our electrical systems, ensuring their safe and reliable operation becomes increasingly important. A well-designed and reliable tripping scheme serves this purpose, offering a robust defence against the potential risks associated with auto transformer faults. It's not just about preventing catastrophic events but also about maintaining operational continuity and efficiency, highlighting the crucial role of tripping schemes in our electrical systems. In this research work, a Selective Cross Tripping scheme is proposed to prevent auto transformers from overloading.

2. Literature review

When Power system undergoes sever faults, transmission network components get overloaded and complete power blackout occurs which badly affects country economy [5]. In the state of power system emergency, isolating loads is necessary to keep the system stable [6]. Relay protection can disconnect overloaded network components, increasing system load and increasing the possibility of instability loss and cascading tripping [5]. In areas where a 220 kV (or 132 kV) network is shunted by a 500 kV (or 220 kV) network, this problem is especially urgent because, in the event that an upper voltage transmission line trips, the lower voltage networks become overloaded and are more likely to disconnect from the central section (which is most loaded), increasing the risk of widespread blackouts.

The best control strategy for preventing system overloading is load shedding. Numerous authors have proposed load shedding methods to prevent network components from being overloaded. İn [7], a suggestion was made to use the influence coefficients and centralised algorithms to accomplish the desired load shedding automation. For the purpose of minimising disturbances, the control issue might be partially decentralised, i.e., the system separated into distinct subsystems. The intelligent devices, which were proposed in [8], are a logical algorithmic approach that maintains transient stability while also removing the overload of the network's components. İn [9], presented two adaptive combinational load-shedding techniques that increase the frequency and voltage security of electrical systems in the event of a significant power loss that results in blackouts.

The load isolating practice in Pakistan for overcoming the system over loading specially at Transmission substation component is carried out through cross trip scheme. This scheme is efficient in controlling the over loading issue of the network components. Load mitigation is also performed using network parameters like voltage, frequency, active and reactive powers. The load shedding provides balance of active power but reactive power loss by transformer is left unattended and in [10] proposed balancing technique for both parameters. Proposed transmission line overload protection scheme which monitors the online Voltage and current along with weather data forecast through thermal behavior of transmission network [11]. Load shedding scheme based on Artificial Neural network (ANN) for optimum load cut off and Stability index (SI) for voltage collapse measurement or stability of system voltage profile is presented [12]. Load-shedding scheme (LSS) for a North American wastewater treatment plant evaluates the shedding scheme on islanded network in event of sever disturbance by categorizing the scheme into two stage primary and secondary load disconnection through implementation of telecommunication and information Technology (IT) based topology for the network [13]. This article compares the efficiency of load curtailment through grasshopper optimization algorithm (GOA) versus the particle swarm optimization (PSO), grey wolf optimization (GW), and genetic algorithm (GA) keeping in view the voltage safety margin (VSM) of islanded system [14]. Here comparison of inertia of power network through decentralized adaptive under frequency with conventional UFLS schemes through measurement of loads virtual inertia [15]. Proposed a novel continuous UFLS scheme in proportion with frequency change for conventional stage by stage Under frequency load shedding scheme which in sever system disturbances is a prime protection scheme so far [16]. Simulated results for convolutional neural networks (CNNs) critic and actor networks are utilized for Load shedding keeping the voltage instability with in rage through Deep Reinforcement Learning (DRL) [17].

The cross-tripping Protection scheme already in practice in Pakistan National power network is nonintelligent in sense it didn't consider the load on equipment at post fault situation to prevent overloading on it.

The literature suggests the implementation of a cross-trip scheme as a solution to safeguard healthy transformers from needless overloading and tripping when functioning in parallel, thus averting a complete network breakdown. However, this scheme has a prominent shortcoming: it often fails to be selective, leading to the tripping of healthy or non-overloaded components due to problems in a parallel circuit. This can trigger inefficiencies and potential equipment damage.

The novelty of the study comes in the form of the Selective Cross Tripping scheme. This innovative approach uses transformer load to decide which circuits to disconnect, thereby allowing effective power load management. The strategy integrates a specialized device that trips circuits according to the load on the transformer, preventing system overloads, which are among the most destructive events in power system operation.

By isolating circuits based on transformer load, the necessity to completely shut down the system or trip unaffected circuits is circumvented, leading to significant savings in operational and financial costs. The study further illuminates how the Selective Cross-Trip device can curtail revenue losses by maintaining the integrity of the power system and ensuring the continued operation of unaffected sections. This approach strikes a balance between protecting the system's hardware and minimizing financial losses.

The study also pits the Selective Cross Tripping scheme against the traditional Cross Tripping scheme, illustrating the superior efficiency of the former. The Selective Cross Tripping scheme considerably surpasses the traditional one by maintaining the operation of unaffected parts, reducing revenue loss, and preserving the integrity of the power system.

3. Solutions towards Autotransformers Overloading

The protection of auto transformers is a matter of utmost importance in electrical engineering. Any fault within these transformers could lead to substantial damage and disruption in power systems, incurring significant financial costs and potential safety hazards. There aretwo solutions to protecting auto transformers and ensuring the uninterrupted operation of electrical systems.

- Cross tripping scheme
- Selective Cross tripping scheme

3.1. Cross Tripping Scheme

A cross tripping scheme is essentially an interconnected protective mechanism that provides a failsafe for the auto transformer and associated circuits. It is typically used in scenarios where auto transformers are linked together or where the auto transformer is a critical component in a larger electrical system. The primary objective of a cross tripping scheme is to ensure that a fault in one section of the system does not escalate and affect other areas. This is achieved by coordinating the tripping of multiple circuit breakers throughout the system in response to a detected fault.

The operation of a cross tripping scheme is both swift and coordinated. When a fault is detected by sensors or protective relays in the system, the cross tripping scheme is triggered. This scheme communicates the fault detection across the system, resulting in the tripping of associated circuit breakers. By doing so, the cross tripping scheme isolates the faulty section, hence mitigating the spread of the fault to other areas of the system.

The design and implementation of a cross tripping scheme involve a precise understanding of the system's layout and operational characteristics. Notably, it's important to consider the coordination between different protective devices. The devices must act in harmony to ensure that only the circuit breakers necessary for isolating the fault are tripped. Unnecessary tripping could lead to disruptions in power supply, hence the need for careful coordination.

Moreover, the reliability and speed of communication between the protective devices are key to the successful operation of a cross tripping scheme. Advanced communication protocols, such as IEC 61850 GOOSE (Generic Object Oriented Substation Event) messaging, are often used to ensure fast and reliable communication between devices. This enables the cross tripping scheme to react swiftly upon the detection of a fault, minimizing the potential for damage.

Another aspect of cross tripping schemes is the integration of intelligent electronic devices (IEDs) that are equipped with self-diagnostic and reporting capabilities. These devices can identify and alert operators of potential issues before they escalate into more serious problems, allowing for proactive maintenance and repairs.

3.1.1. Pseudocode of Cross Tripping Scheme

Step 1: Initialize the system:

- Set all circuit breakers to the "closed" state.
- Set all fault detectors to "monitoring" mode.

Step 2: Monitor the system continuously:

- Obtain real-time data from sensors related to current.
- Evaluate the data to identify any anomalies or deviations from the norm.

Step 3: If a fault is detected:

- Identify the faulty component and its location.
- Send a signal to the associated circuit breaker to open and isolate the faulty component.
- If the fault is not isolated (i.e., it persists or escalates), identify the next upstream circuit breaker.
- Send a signal to the identified upstream circuit breaker to open, further isolating the fault.

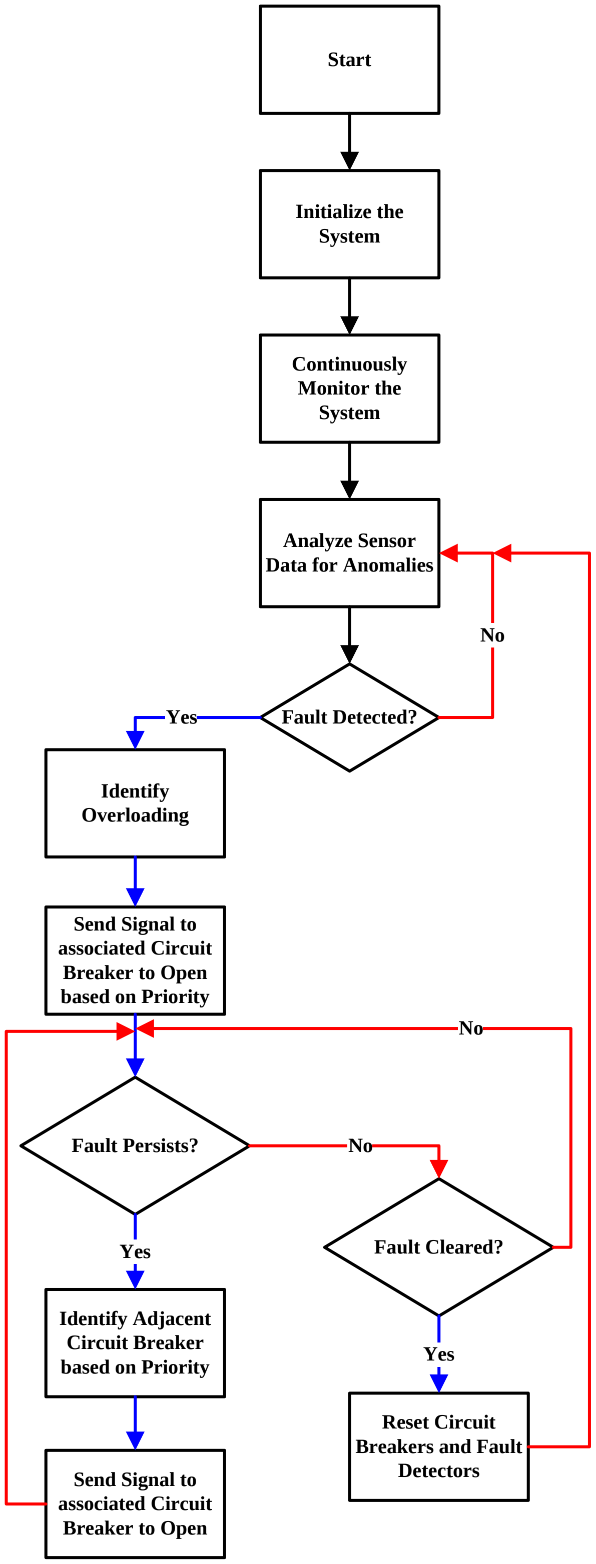

Fig 1. Flowchart of Cross Tripping Scheme for protection of Auto Transformers

Step 4: Communicate the fault detection across the system:

- Use communication protocols (e.g., IEC 61850 GOOSE) to send messages about the fault to all protective devices in the system.
- Coordinate the actions of all protective devices based on these messages.

Step 5: Continue to monitor the system:

- If the fault is cleared, reset all circuit breakers and fault detectors to their initial states (i.e., closed and monitoring, respectively).
- If the fault persists, keep the associated circuit breakers open and continue to isolate the fault until it is resolved.

Step 6: Repeat the process from step 2.

Fig 1. Show the flowchart of Cross Tripping Scheme for protection of Auto Transformers.

3.2. Selective Cross Tripping Scheme

Selective cross tripping schemes have emerged as a key solution for auto transformer protection, offering a comprehensive defense against potential faults. Given the crucial role of auto transformers in our electrical systems, such schemes are not only desirable but indispensable.

Selective cross tripping schemes are built on the principle of selectivity, also known as discrimination. Essentially, this means that the scheme is designed to disconnect only the smallest possible section of the network in case of a fault, ensuring minimal disruption to the power system's overall operation. This is achieved by carefully coordinating the tripping of multiple circuit breakers throughout the system in response to a detected fault.

The operation of a selective cross tripping scheme is based on swift and precise action. Once a fault is detected in the system, the scheme activates, triggering a sequence of actions designed to isolate the faulty section. The protective devices involved in the process are interconnected, and their actions are coordinated to ensure that only the circuit breakers necessary for isolating the fault are tripped.

The effective implementation of a selective cross tripping scheme relies heavily on the precise coordination of various protective devices in the system. These devices are calibrated to respond in a specified sequence, depending on the type and location of the fault. For instance, if a fault occurs in a particular auto transformer, the circuit breaker directly associated with that transformer would trip first. If the fault persists, indicating a possible issue in the upstream circuit, the adjacent circuit breaker would then be tripped, and so forth. This coordinated response helps limit the impact of the fault on the broader system.

A key aspect of selective cross tripping schemes is the communication between protective devices. This communication needs to be swift, reliable, and accurate to ensure a fast and appropriate response to a fault. Modern communication protocols, such as IEC 61850 GOOSE (Generic Object Oriented Substation Event) messaging, are often used in these schemes, facilitating seamless and real-time communication between devices.

Furthermore, the integration of intelligent electronic devices (IEDs) in the scheme contributes significantly to its effectiveness. These devices come with self-diagnostic and reporting capabilities, enabling early fault detection and proactive system maintenance. They can identify potential issues before they escalate into full-blown faults, thus allowing operators to take preventive action.

3.2.1. Pseudocode of Selective Cross Tripping Scheme

Step 1: Initialization:

- Set all circuit breakers to the "closed" state.
- Set all fault detectors to "monitoring" mode.

Step 2: Continuous Monitoring:

- Collect real-time data from sensors related to current.
- Process the data to identify any anomalies or deviations from the norm.

Step 3: Fault Detection and Diagnosis:

- If a fault is detected, identify the optimal faulty component and its optimal location.
- Send a signal to the associated circuit breaker to open and isolate the optimal faulty component.

Step 4: Selective Tripping:

- If the fault is not isolated (i.e., it persists or escalates), identify the next upstream circuit breaker.
- Send a signal to the identified upstream circuit breaker to open, further isolating the fault.
- Continue this selective isolation process until the fault is effectively contained.

Step 5: System-Wide Communication:

- Use advanced communication protocols (e.g., IEC 61850 GOOSE) to send messages about the fault to all protective devices in the system.
- Coordinate the actions of all protective devices based on these messages to ensure only necessary circuit breakers are opened.

Step 6: System Restoration:

- If the fault is cleared, reset the circuit breakers involved in isolating the fault to their initial states (i.e., closed).
- Return all fault detectors to their monitoring mode.

Step 7: Repeat the process from Step 2.

Fig 2. Show the flowchart of Cross Tripping Scheme for protection of Auto Transformers.

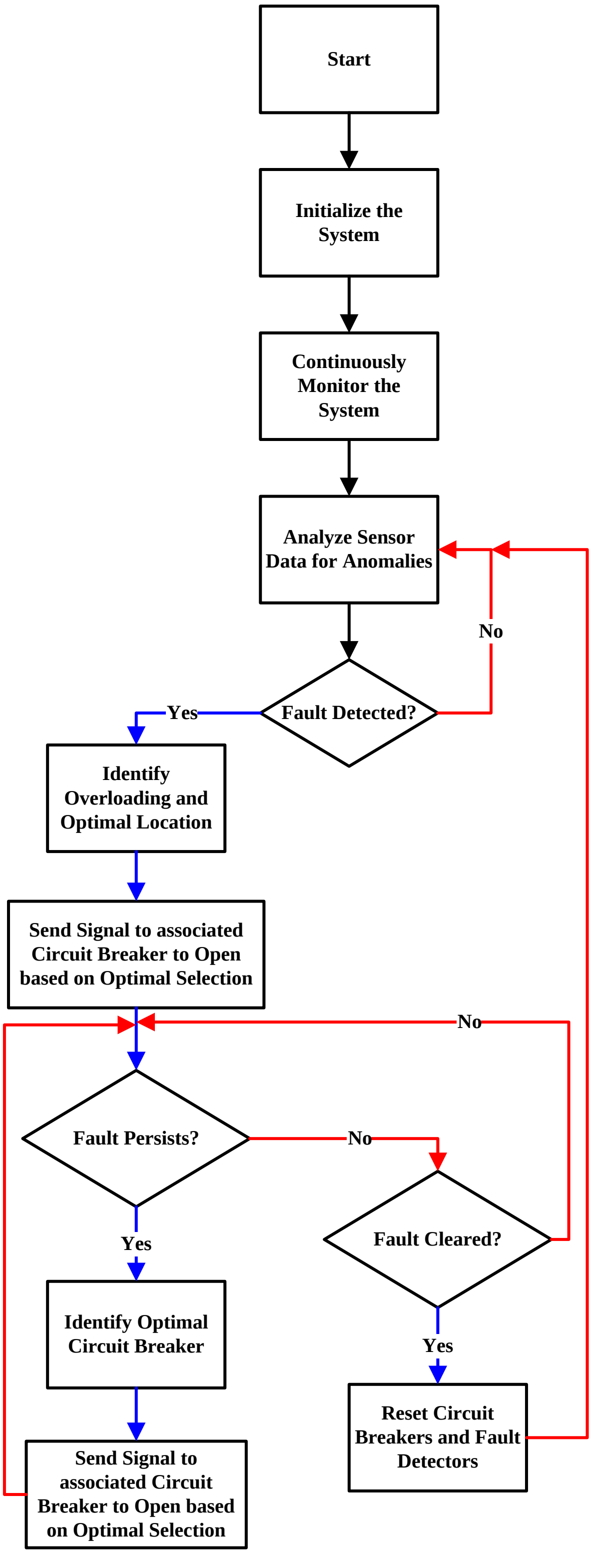

Fig 2. Flowchart of Selective Cross Tripping Scheme for protection of Auto Transformers

4. Test System

The test system in consideration comprises three auto transformers, each with a capacity of 1500A. These transformers are interconnected and supply power to a total of fifteen loads. The loads are categorized into three distinct groups, each containing five loads, and each group is connected to a corresponding auto transformer. Fig 3. Shows the Power Network components schematic diagram for proposed study.

Each auto transformer is equipped with a selective cross tripping scheme, a state-of-the-art protective mechanism that ensures minimal disruption to the power system in the event of a fault. Each transformer has its fault detection and analysis mechanism, consisting of a set of sensors and protective relays that monitor real-time current.

On detecting a fault, the selective cross tripping scheme of the affected transformer is activated. The associated circuit breaker of the faulty transformer is signaled to open, isolating the faulty component to prevent further escalation or propagation of the fault within the transformer. The remaining healthy transformers continue to supply power to their respective load groups, ensuring minimal disruption to the overall system.

If the fault persists or escalates beyond the isolated area within the faulty transformer, the upstream circuit breaker connected to the faulty section is identified and signaled to open, further isolating the fault. This process continues until the fault is effectively contained.

The selective cross tripping scheme integrates advanced communication protocols to facilitate swift and reliable communication between protective devices. As a fault is detected and isolated, information about the fault is communicated across the system. This enables the coordinated action of all protective devices and ensures the necessary circuit breakers are opened to isolate the fault.

Moreover, the test system is equipped with intelligent electronic devices (IEDs) that enhance the overall reliability and efficiency of the selective cross tripping scheme. These devices enable early fault detection and provide self-diagnostic capabilities, which aid in preventive maintenance and ensure the long-term stability of the system.

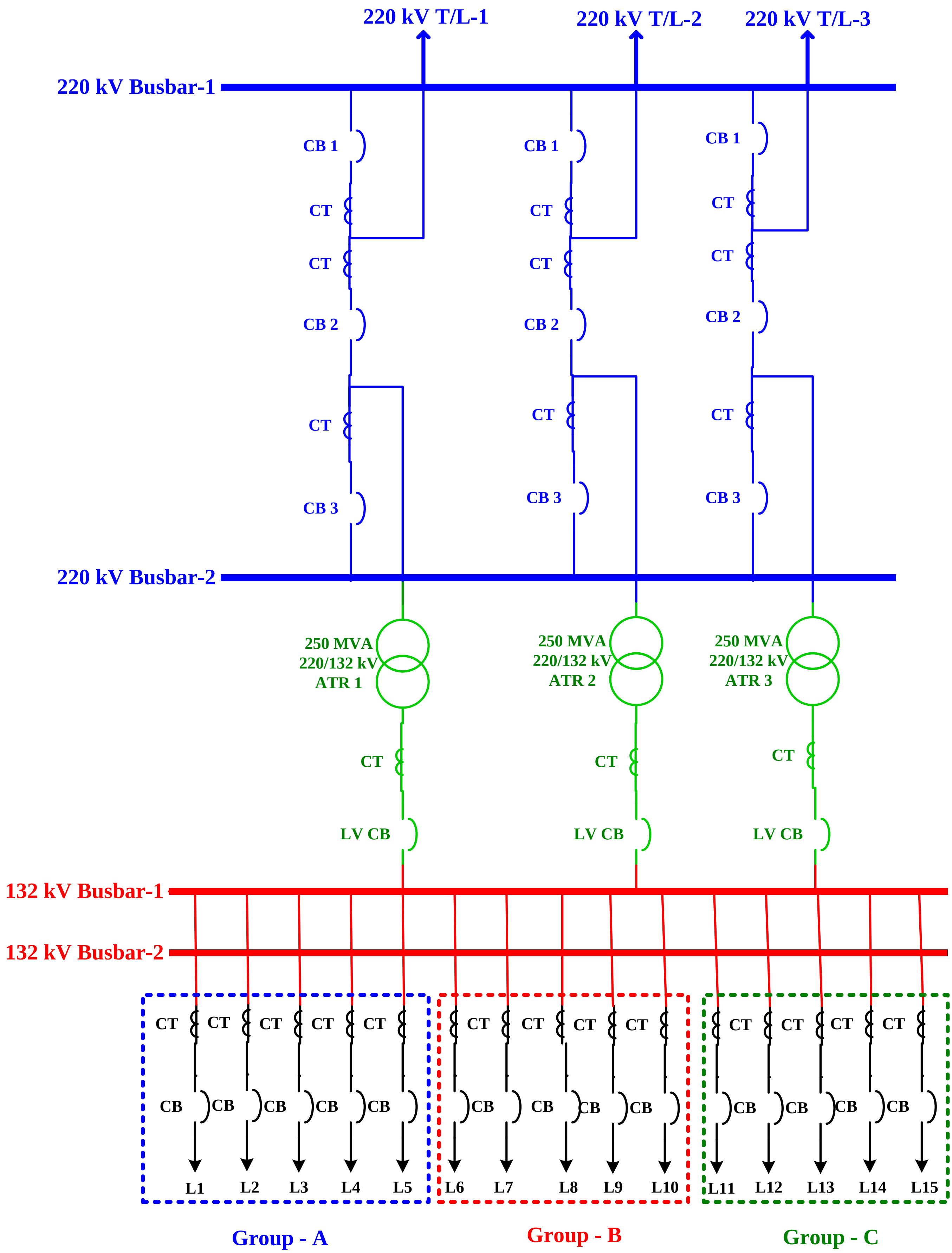

Fig 3. Power Network components schematic diagram for proposed study

5. SIMULATION RESULTS AND DISCUSSION

The results of a study assessing the performance of a Cross Tripping Scheme (CTS) and Selective Cross Tripping Load Shedding Scheme (SCTS) applied to a system of three auto transformers. Each transformer has a rated load capacity of 1500A. The system serves fifteen different loads, divided into three groups. Four different case studies was performed on the schemes to evaluates their performances as shown Table 1-3.

5. 1. Case Studies of Cross Tripping Scheme

Case 1:

In Case 1, the loads connected to each group in the system are specified, with each load ranging between 50A and 550A. The total sum of the loads in this case is 4550A, which is slightly more than the rated load capacity of the three transformers (4500A). This leads to an overloading condition by 50A. However, after the implementation of the Cross Tripping Scheme (CTS), 50A of load is shed and all other loads remain connected. The total sum of the loads remains at 4500A, and the efficiency of the Cross Tripping Scheme (ηCTS) in this case is 100%.

Case 2:

In Case 2, the loads connected to each group are slightly adjusted, resulting in a total sum of loads equal to 4650A, which exceeds the transformers' rated load capacity by 150A. After the implementation of the Cross Tripping Scheme, the first load (50A) and the second load (150A) are disconnected, reducing the total sum of loads to 4450A, just under the rated load capacity. The efficiency of the Cross Tripping Scheme in this case is approximately 98.89%.

Case 3:

In Case 3, further adjustments are made to the loads connected to each group, resulting in a total sum of loads equal to 4750A, overloading the system by 250A. With the implementation of the Cross Tripping Scheme, the first three loads (50A, 150A, and 550A) are disconnected, bringing the total sum of loads to 4000A. The efficiency of the Cross Tripping Scheme in this case is about 88.89%.

Case 4:

In the final case, Case 4, the loads connected to each group are again adjusted, leading to a total sum of loads equal to 4780A and an overloading condition of 280A. After the Cross Tripping Scheme is applied, the first four loads (50A, 150A, 50A, and 330A) are disconnected, bringing the total sum of loads to 4200A. The efficiency of the Cross Tripping Scheme in this case is approximately 93.33%.

5. 2. Case Studies of Selective Cross Tripping Scheme

Case 1:

In Case 1, the loads connected to each group range from 50A to 550A, totaling a sum of 4550A. This exceeds the total rated load capacity of the transformers (4500A) by 50A, creating an overloading condition. However, after the implementation of the Selective Cross Tripping Scheme (CTS), 50A of load is shed and all other loads remain connected. The total sum of the loads remains at 4500A, and the efficiency of the Cross Tripping Scheme (ηCTS) in this case is 100%.

Case 2:

In Case 2, the sum of the loads is slightly higher, amounting to 4650A, which overloads the system by 150A. After the application of the SCTS, the second load (150A) is disconnected, reducing the total load to 4500A, matching the transformers' rated load capacity. The efficiency of the SCTS remains at 100%, underlining its ability to manage overloading conditions effectively.

Case 3:

In Case 3, the total sum of loads is 4750A, overloading the system by 250A. With the implementation of SCTS, the fifth load (250A) in the series is disconnected, reducing the total load to 4500A, equating to the transformers' rated load capacity. The SCTS efficiency remains at 100% in this case as well.

Case 4:

Finally, in Case 4, the loads amount to a total of 4780A, overloading the system by 280A. After the SCTS is applied, the seventh load (400A) is disconnected, bringing the total load to 4480A, which is slightly less than the rated load capacity of the transformers. The efficiency of SCTS in this case is approximately 99.56%.

5.3. Comparison of Schemes

The two tables present an insightful comparison between a standard Cross Tripping Scheme (CTS) and a Selective Cross Tripping Load Shedding Scheme (SCTS) applied to a system of auto transformers. The primary difference between the two schemes lies in their response to overloading conditions.

In the case of the standard Cross Tripping Scheme, when an overloading condition is detected, the scheme disconnects loads starting from the smallest. While this approach does manage the overloading conditions, it might result in disconnecting more loads than necessary, thereby reducing the total load served. This is especially evident in Cases 2, 3, and 4, where the sum of the loads after the application of the CTS is less than the rated load capacity of the transformers. In contrast, the SCTS selectively disconnects the loads in a manner that allows the total load served to be as close as possible to the transformers' rated load capacity, leading to improved efficiency.

This selective disconnection of loads in the SCTS allows the system to maintain a higher operational capacity than the standard CTS. The efficiency of the SCTS is 100% in the first three cases, and it remains impressively high (99.56%) even in Case 4, where the initial overloading condition was the most severe.

Furthermore, the SCTS tends to disconnect larger loads when dealing with overloading conditions, thereby effectively managing the overloading with fewer disconnections. In contrast, the standard CTS begins by disconnecting smaller loads, often requiring multiple disconnections to manage the overloading condition.

In conclusion, the comparison of the two tables demonstrates the superior performance of the Selective Cross Tripping Load Shedding Scheme in managing overloading conditions in a system of auto transformers. By selectively disconnecting loads based on their magnitude, the SCTS is able to maintain a higher operational capacity and ensure a closer match to the transformers' rated load capacity than the standard Cross Tripping Scheme.

5.4. Efficiency Comparison

The provided table offers a direct comparison of the efficiency of the standard Cross Tripping Scheme (CTS) and the Selective Cross Tripping Load Shedding Scheme (SCTS) in managing overloading conditions across four different cases.

In Case 1, both schemes perform equally well, with both achieving an efficiency (η) of 100%. This implies that both the CTS and SCTS managed the overloading condition without disconnecting any loads, thereby maintaining the total load served at the maximum possible level.

In Case 2, the SCTS shows a slight improvement over the CTS, achieving an efficiency of 100% compared to 98.8889% for the CTS. This corresponds to an efficiency difference (η_diff) of 1.111%, meaning the SCTS was able to serve 1.111% more of the total load than the CTS.

The difference in performance becomes more apparent in Case 3, where the SCTS maintains its efficiency at 100%, while the efficiency of the CTS drops to 88.8889%. This results in a substantial efficiency difference of 11.111%, demonstrating the superior performance of the SCTS in effectively managing overloading conditions while maintaining as much of the system's operational capacity as possible.

In Case 4, the efficiency of the SCTS remains impressively high at 99.5556%, while the efficiency of the CTS is lower at 93.3333%. This corresponds to an efficiency difference of 6.2223%, indicating that the SCTS was able to serve 6.2223% more of the total load than the CTS.

In short, the comparison of the efficiencies of the CTS and SCTS across the four cases demonstrates the superior performance of the SCTS in managing overloading conditions. Despite varying levels of overloading, the SCTS consistently maintained a higher operational capacity, thereby ensuring a closer match to the transformers' rated load capacity than the standard Cross Tripping Scheme. The SCTS's selective approach to disconnecting loads based on their magnitude allows it to achieve higher efficiencies, thereby enhancing overall system performance.

Table 1: Results of Case Studies of Cross Tripping Scheme

Cases	**Loads connected to each Group**	**Sum of Loads**	**Rated Load of T/F**	**Over Loading**	**Connected Loads after CTS**	**Sum of Loads after CTS**	**η_{CTS} (%)**
1	50 150 450 350 550 400 200 500 350 150 250 350 300 200 300	4550	4500	50	0 150 450 350 550 400 200 500 350 150 250 350 300 200 300	4500	100
2	50 150 450 350 550 400 200 500 350 150 250 350 400 200 300	4650	4500	150	0 0 450 350 550 400 200 500 350 150 250 350 400 200 300	4450	98.8889
3	50 150 550 350 250 400 300 500 350 150 250 350 600 200 300	4750	4500	250	0 0 0 350 250 400 300 500 350 150 250 350 600 200 300	4000	88.8889
4	50 150 50 330 250 400 300 500 350 450 450 350 600 200 350	4780	4500	280	0 0 0 0 250 400 300 500 350 450 450 350 600 200 350	4200	93.3333

Table 2: Results of Case Studies of Selective Cross Tripping Scheme

Cases	**Loads connected to each Group**	**Sum of Total Loads**	**Rated Load of T/F**	**Over Loading**	**Connected Loads after SCTS**	**Sum of Loads after SCTS**	**η_{SCTS} (%)**
1	50 150 450 350 550 400 200 500 350 150 250 350 300 200 300	4550	4500	50	0 150 450 350 550 400 200 500 350 150 250 350 300 200 300	4500	100
2	50 150 450 350 550 400 200 500 350 150 250 350 400 200 300	4650	4500	150	50 0 450 350 550 400 200 500 350 150 250 350 400 200 300	4500	100
3	50 150 550 350 250 400 300 500 350 150 250 350 600 200 300	4750	4500	250	50 150 550 350 0 400 300 500 350 150 250 350 600 200 300	4500	100
4	50 150 50 330 250 400 300 500 350 450 450 350 600 200 350	4780	4500	280	50 150 50 330 250 400 0 500 350 450 450 350 600 200 350	4480	99.5556

Table 3: Efficiency comparison of both schemes

Cases	**η_{CTS}**	**η_{SCTS}**	$\eta_{diff} = \eta_{SCTS} - \eta_{CTS}$
1	100	100	0
2	98.8889	100	1.111
3	88.8889	100	11.111
4	93.3333	99.5556	6.2223

6. CONCLUSION

The research provides an in-depth exploration of protecting electrical systems from overload, a frequent problem when transmission lines or equipment experience excessive loads. The work notably focuses on forced tripping, an essential aspect of power management at transmission substations and power plants. While cross-trip schemes have been proposed as a solution to protect healthy transformers from unnecessary overloading and tripping when operating in parallel, they often lack selectivity. This can lead to the tripping of healthy or non-overloaded components, resulting in inefficiencies and potential equipment damage.

To address this issue, the study introduces an innovative Selective Cross Tripping scheme. This approach uses transformer load to determine which circuits to trip and incorporates a unique device that trips circuits based on this load, allowing for proactive power load management. By isolating circuits based on transformer load, it avoids the need to completely shut down the system or trip unaffected circuits, leading to substantial operational and financial savings.

Furthermore, the research shows that the Selective Cross-Trip device helps reduce revenue loss by ensuring the power system's integrity and uninterrupted operation of unaffected parts. When compared to the standard Cross Tripping scheme, the Selective Cross Tripping scheme demonstrates superior efficiency, significantly outperforming the former by maintaining continuity in unaffected parts of the system, reducing revenue loss, and preserving the integrity of the power system. Hence, the research underlines the importance of selectivity in tripping schemes for effective overload protection.

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REFERENCES

[1]. Vasilenko, N., Misrikhanov, M., & Shuntov, A. (2023). Once again on loading and capacity selection of autotransformers in transmission grids. In E3S Web of Conferences (Vol. 384). EDP Sciences.

[2]. Alasali, F., Saidi, A. S., El-Naily, N., Smadi, M. A., & Holderbaum, W. (2023). Hybrid tripping characteristic-based protection coordination scheme for photovoltaic power systems. *Sustainability*, *15*(2), 1540.

[3]. Bing, Z., Yanxia, Q., & Chunyu, Z. (2023, February). Study on Coordinated Control of New Energy Over-Frequency Ride-Through and Over-Frequency Generator-Tripping Scheme. In *Journal of Physics: Conference Series* (Vol. 2442, No. 1, p. 012006). IOP Publishing.

[4]. M. F. Ullah and A. Hanif, "Power quality improvement in distribution system using distribution static compensator with super twisting sliding mode control," International Transactions on Electrical Energy Systems, vol. 31, no. 9, 2021, Art. no. e12997, https://doi.org/10.1002/2050- 7038.12997.

[5]. L. Z. W. M. L. S. Aziz T, "Review on optimization methodologies in transmission network reconfiguration of power systems for grid resilience," Int Trans Electr Energ Syst. 2021;31:e12704. https://doi.org/10.1002/2050-7038.12704, 07 03 2021.

[6]. L. E. Maslennikov S, "Masle Adaptive emergency transmission rates in power system and market operation. IEEE Trans Power Syst 2009; 24:923–9," no. 2009, 2009.

[7]. D. Panasetsky, N. Tomin and D. Y. Victor Kurbatsky, "A New Intelligent Algorithm for Load Shedding," 2014International Conference on Power System Technology(POWERCON 2014)Chengdu, 20-22 Oct. 2014DOI: 10.13140/2.1.3373.2801, 2014.

[8]. N. Voropai, D. Efimov, . A. Osa, D. Panasetsky, E. Panasetsky and B. Karatayev, "Distributed Adaptive Load Shedding Scheme to Maintain Transient Stability and Prevent Overload," IFAC (International Federation of Automatic Control) Hosting by Elsevier Ltd, p. 554–559, 2015.

[9]. A. S. &. M. Sanaye-Pasand, "New Local Adaptive Load-shedding:," Taylor & Francis, 2012.

[10]. S. Agematsu, S. Imai R. Tsukui, H. Watanabe, T. Nakamura, T. Matsushima, "Islanding Protection System With Active And Reactive Power Balancing Control," in Developments in Power System Protection, Conference Publication No.479 0 IEE 2001., 2001.

[11]. C. Rehtanz and A. Kubis, "Response Based System Protection Scheme Against Line Overload Cascades," [Institution of Engineering and Technology 12th IET International Conference on Developments in Power System Protection (DPSP 2014) - Copenhagen, Denmark (31 March-3 April 2014)], (2014).

[12]. S. .. &. S. D. M. Sundarajoo, " A Load Shedding Scheme for Radial Distribution System Utilizing Artificial Neural Network.," International Journal of Advanced Electrical and Computer Engineering,, vol. 4(1), 2023.

[13]. M. W. A. W. A. P. Z. K. J. a. S. D. G. M. Asim Akhtar, " "Fast and Reliable Load-Shedding Scheme for Wastewater Treatment Plant -A acse study"," in G. M. Asim Akhtar, M. W. Ahmed, W. Allen, P. Zhang, K.

Jensen and S. Dasgupta, "Fast 2022 IEEE Electrical Power and Energy Conference (EPEC), Victoria, BC, Canada, 2022, pp., 2022.

[14]. M. M. O. Z. S. M. A. H. M. R. V. V. Masoud Ahmadipour, "Optimal load shedding scheme using grasshopper optimization algorithm for islanded power system with distributed energy resources," Ain Shams Engineering Journal, vol. 4, 2023.

[15]. B. W. a. H. W. P. He, ""Decentralized Adaptive Under Frequency Load Shedding Scheme Based on Load Information,," " IEEE Access, vol. 7, pp. 52007-52014, vol. 7, pp. 52007-52014, 2019.

[16]. C. Li et al., ""Continuous Under-Frequency Load Shedding Scheme for Power System Adaptive Frequency Control.," " in IEEE Transactions on Power Systems, vol. 35, no. 2, pp. 950-961, , vol. 35, pp. 950-961, , March 2020,.

[17]. C. L. C. F. X. L. a. Y. Z. J. Zhang, ""Load Shedding Scheme with Deep Reinforcement Learning to Improve Short-term Voltage Stability,"," in J. Zhang, C. Lu, C. Fang, X. Ling and Y. Zhang, "Load Shedding Scheme 2018 IEEE Innovative Smart Grid Technologies - Asia (ISGT Asia), Singapore, 2018.