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# Editorial: Advanced protection for the smart grid

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Editorial on the Research Topic
Advanced protection for the smart grid

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## 1 Introduction

Recently, a growing trend in clean renewable power integration to electric grids has been observed around the globe. This trend aims to reduce carbon emissions by reducing dependence on fossil fuel-based electricity generation. As per the International Renewable Energy Agency 2023 (IRENA, 2023) report, 27.8% of electricity generation is shared by renewable sources, including hydroelectric, wind, solar, bioenergy, and geothermal energy (IRENA, 2023). The renewable total electricity generation counts for 7,858 T Wh in 2021. The two most promising sources are wind and solar energy, which account for 23% and 13%, respectively. Further, wind-based and solar-based energy generations, 15.7% and 22.7%, respective annual growth, were observed in 2021 compared to 2020. Trends indicate further development in these sources to meet future electricity needs. The electricity generation from solar power plants and wind farms is mainly distributed in nature and spread over broad geographical areas. These sources are also called distributed energy resources (DERs). These renewable sources are integrated into the grid through various static power converters. As a result, system electrical inertia reduces compared to the same done through rotating machine-based conventional sources. This makes the electric network protection task very challenging (Bakkar et al., 2023). Modern technologies such as power electronics-based flexible AC transmission systems (FACTS) devices to control and smooth power flow over the networks also add protection issues (Albasri et al., 2007).

## 2 Protection issues with renewable power integration

Proper electrical protection is necessary to run power networks with the highest reliability. Increased penetration of converter-interfaced distributed generations (CIDGs) and the deployment of smart grid technologies are changing fault current levels and flow direction, challenging the existing protection schemes (Hooshyar and Iravani, 2017). Reduction in system inertia is one of the main reasons for modern protection challenges at the transmission and distribution levels. At the transmission level, conventional protection schemes using distance protection philosophy are affected by reduced fault current as the percentage of low energy power contribution from DERs increases. The correct fault direction and location are also challenging because of the heavy integration of renewable-based electricity generation into the grid. Removing the faulted section must be faster to prevent system instability at the transmission level where the zone-1 setting of the distance relay is responsible for this task. In the conventional system, distance relays work appropriately. However, in the modern renewable-rich transmission system, fault currents are lower which causes zone-1 to remain silent and zone-2 usually clears the fault of the distance relay which acts slower. On the one hand, the renewable-rich system has reduced inertia; on the other hand, fault clearing will take longer, which may result in stability issues. This may result in a widespread blackout. Therefore, there is a need for advanced protection schemes for the modern grid, called smart grid.

Power distribution networks face protection issues from the transmission systems because of massive renewable integration at the distribution level. Traditional distribution networks are radial, and power flow is unidirectional from an electric substation to the loads through electric feeders. However, the integration of renewables at distribution feeders disturbs the unidirectional flow of current during the faults (Hong et al., 2021). Not only the fault current magnitude but also the direction of the flow of fault current is also affected by the integration of renewables to the distribution level. Such distribution networks are termed active distribution networks (ADNs). The protection of renewable-rich ADNs is under scrutiny because the change in fault currents and network reconfiguration creates protection coordination issues (Zarei and Khankalantary, 2021). Extensive research activities are going on to provide simple and reliable solutions to the protection challenges of ADNs.

Additionally, the formation of microgrids (AC, DC and hybrid AC-DC) and their grid-connected and islanded mode operation provide several benefits by improving reliability and resiliency. Furthermore, networked microgrid systems are emerging and more reliable and resilient electricity infrastructure that can withstand harsh environmental conditions by isolating one another and powering by their internal sources (Alam et al., 2022). However, providing proper protection to such systems is more challenging. Existing protection schemes are prone to such changes. High impedance faults are going unnoticed and leading to damage to the system. Advanced protection schemes developed considering such issues can mitigate these impacts and maintain proper protection coordination. Adaptive protection, islanding detection, communication-assisted protection, and synchronized wide-area measurement-based protection schemes are emerging as potential solutions to the protection issues of the modern smart grid. Artificial intelligence (AI) based protection schemes may help to provide adequate answers to the smart grid's protection challenges because of renewable integration and new technological adaptations.

The adaptive protection scheme is one of the advanced protection schemes which can provide reliable protection to the smart grid. Figure 1 shows one of the adaptive protection schemes (Alam et al., 2019). The system's topology and operating states are dynamically tracked in such schemes. If any significant changes in the network, such as loss of a line, generator, transformer, or large load changes (addition/removal), are observed, then relay settings are updated. In directional overcurrent-based protection schemes, the fault current calculations are performed under those operating conditions. The protection coordination status is checked with the obtained fault current values at various relay locations. In case of any miscoordination, relay settings are calculated using the updated fault information and older settings are replaced with newer settings (Alam, 2019). Similarly, in the distance protection scheme, zone settings and differential protection schemes, slop settings are updated following a major change in the system operating condition (George et al., 2023).

## 3 Identified areas of research on advanced protection to the smart grid

This Research Topic aimed to provide field deployable solutions to smart grid protection issues. High penetration of DERs, FACTS devices, dynamically changing network topology, and grid decentralization pose several protection challenges, although they provide flexible, reliable and resilient network operation. Indeed, the existing protection practices do not appropriately handle many issues caused by such changes. The ADNs and the formation of microgrids and networked microgrids add more protection challenges at the distribution level. The key research areas identified in this special call of papers on the Advanced Protection of the Smart Grid are the following.

- Development of adaptive protection scheme for smart grid
- High impedance fault detection and location scheme
- Protection of active distribution networks
- Protection of AC and DC microgrids
- Communication-assisted and Wide-area measurement system-based protection
- Application of artificial intelligence and soft computing techniques for power system protection

In addition to these key topics, a few more topics are very relevant in smart grid protections, such as the impact assessment of different types of DERs on fault current calculation, anti-islanding protection and fault direction identification in renewable rich networks.

## 4 Contributions to advanced protection to the smart grid

In this Research Topic, 24 papers were submitted, of which only 13 were accepted for publication. The key contributions of the accepted papers are briefed here.

Prabhu et al. propose an intelligent distance relaying scheme that utilizes only current measurements for a series-compensated line integrated with a wind farm system. In this scheme, the fault detection task is performed using the signs of the half-cycle magnitude differences of the line end positive-sequence currents,

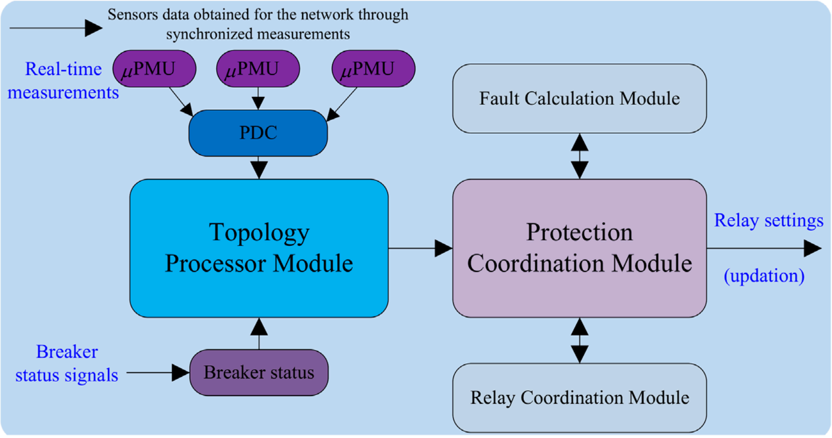

FIGURE 1
Adaptive protection scheme.

and the fault classification task is performed using only the local current measurements processed through the Fourier–Bessel series expansion bagging ensemble classifier.

Nobakhti and Ketabi propose a protection scheme based on impedance that can detect high-impedance faults in both islanded and grid-connected modes of low-voltage and median-voltage microgrids. Additionally, it can handle load and generation uncertainty and network reconfigurations.

Liang et al. propose a novel approach for fault location in transmission lines using power line communication (PLC) equipment. In this approach, the channel frequency response obtained from the PLC receiver is used to estimate the high-frequency input impedance to monitor and locate the ground fault of the power grid in real-time.

Li et al. propose a direct current circuit breaker (DCCB) failure protection method and a secondary accelerated fault isolation scheme of voltage source converter-based high-voltage direct current (VSC-HVDC) grids. The scheme achieves the accelerated isolation of DC faults after the failure of the DCCB and avoids the trip of the AC circuit breaker effectively which is verified through PSCAD simulation.

Esmail et al. propose simultaneous series and shunt earth fault detection and classification using the Clarke transform for power transmission systems under different fault scenarios. The fault detection time of the proposed schemes is reported to be as low as 20 ms. The behaviour of the proposed schemes is tested and validated by considering different fault scenarios with varying locations of fault, inception angles, fault resistance, and noise.

Kant et al. introduce an advanced short-circuit protection scheme for a bipolar DC microgrid. It is based on the multi-resolution analysis of travelling waves using discrete wavelet transform. The proposed approach is tested on a 500 V ring-type bipolar DC microgrid test model in the MATLAB/Simulink environment and validated with the real-time OPAL-RT simulator.

There are some miscellaneous contributions in this Research Topic.

Zeng et al. propose an interline hybrid DC circuit breaker by combining SCR string and a small number of H-bridge modules (SCR-IHCB). The proposed SCR-IHCB can block the DC fault of two adjacent lines by sharing only one main breaker branch (MB) mainly composed of low-cost SCR string and H-bridge module instead of IGBT-in-series string. He et al. propose multi-port hybrid DC circuit breakers (M-HCBs) with fewer devices for fault blocking in multi-terminal VSC-HVDC systems.

Zhang et al. discuss arc fault detection using ResNet and gamma transform regularization. Xiong et al. analyze overheating fault alarming for compact insulated busways in buildings by gas sensing. Vishnuram et al. present a comprehensive review of EV power converter topologies charger types infrastructure and communication techniques. Zhou et al. introduce the gas production law of free gas in oil-immersed power transformers under discharge faults of different severity. Finally, load frequency control of the power system based on an improved AFSA-PSO event-triggering scheme is presented by Huang and Lv.

## 5 Future scope of study

Further scope of this Research Topic is on providing solutions to high-impedance fault detection and location, developing wide-are measurement-based advanced backup protection schemes and artificial intelligence-based protection schemes for the smart grid.

## Author contributions

MA: Writing–review and editing, Conceptualization, Investigation. AA: Writing–review and editing, Investigation. TK: Writing–review and editing, Investigation. SN: Investigation, Writing–review and editing. MS: Writing–review and editing, Investigation.

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## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

## Publisher's note

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