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Review Paper

Impact of Integration of Renewable Energy Sources on Power System Stability, Fault Protection and Location: A Review

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ABSTRACT: Power generation is typically based on fossil fuels, which contribute to global warming. As a result, to mitigate global warming, Renewable Energy Sources (RES) are being integrated into power systems as superior alternatives to traditional fuels for generating energy. However, integration faces socioeconomic and technical hurdles. This review examines the issues posed by RES integration to power system stability, fault protection, and location. The knowledge-based approaches, impedance and low frequency-based methods, and high frequency and travelling wave methods are fairly used to solve the issues of fault location in power systems. The knowledge-based methods are more exact and faster than the other two fault location methods assessed. The Flexible Alternative Current Transmission System (FACTS) devices, as well as the allocation of Distributed Generation Sources (DGS), the Superconductivity Fault Current Limiter (SFCL), the Controllers, and the virtual DGS, are used to address the challenges of power system stability caused by the integration of RES in the system. These findings are important to researchers and power system operators because, if implemented, they can increase the usage of RES sources in the power system, reducing global warming and ensuring a sustainable environment.

Highlights:

- The impact of RES on fault location is solved using knowledge-based methods.
- Optimized and programmed relays are applied to mitigate the impact of RES on protection schemes.
- Virtual DGs are applied to solve the impact of RES on power system stability.

keywords: renewable energy Sources, Stability, Fault Protection

INTRODUCTION

Power generation relies on fossil fuels and nuclear radioactive materials for electricity generation, the world is confronting global warming, air pollution, and oil spills. As a result, a global movement to reduce reliance on fossil fuels was launched, with RES being highlighted as one of the best strategies to reduce green gas emissions and preserve the environment (Zahedi, 2011). The worldwide replacement of fossil fuels with renewable sources for electricity generation (Zarei and Zarei, 2012) has opened up new research frontiers in the application of renewable technologies for promoting Hydro, Wind, Photovoltaic, Geothermal, and Bio-power generation as environmentally friendly methods of generating electric power. In 2018, RES generation capacity accounted for 26% of global power generation (Kusch-Brandt, 2019). The percentage is a sign of encouragement in the growth of RES use and the global push for the replacement of fossil fuels with Renewable Energy Sources (Kusch-Brandt, 2019). The

capacity of RES electricity generation in 2018 was 2,378 Giga-Watts (GW). The most capacity was contributed by hydropower (1,132 GW), followed by wind power (591 GW). Furthermore, PV took third place with 505 GW, while bio-power generation took fourth place with 130 GW. Bio-power generation capacity ranked fifth with 66.143 GW, followed by 13.3 GW of geothermal power capacity. The capacity of Concentrating Solar Thermal Power (CSP) was 5.5 GW, whereas the capacity of Ocean Energy was 0.5GW.

Aims of integration of RES in power system

The advantages of integrating renewable energy into power systems include reduced global warming and the provision of reliable, secure, and inexpensive electricity to residential, commercial, industrial, and administrative locations (Qazi et al., 2017). Other advantages include lower transmission and distribution costs, lower maintenance costs, postponed expansion of transmission infrastructure, improved system voltage profiles, and increased dependability (Labis et al., 2011). Government subsidies for the use of alternative fuels, advancements in renewable technology, and increased energy generation capacity to satisfy the country's high demand all aided in the integration (Kuiava et al., 2014). However, one of the disadvantages of RES is that its outputs are unstable.

The stochastic output power of RES

Because of the stochastic nature of solar irradiance and wind speed, the output power of RES such as wind and solar is stochastic. As a result, before connecting ReDGs to the grid, developers must meet stringent regulatory standards for power quality, voltage and frequency management, and fault ride capabilities. One of the traditional remedies to voltage and frequency instability at the outputs is to store power generated from renewable sources in batteries before sending it to consumer terminals. However, given the high cost of battery storage and maintenance, this solution is too expensive. As a result, the researchers presented various alternate alternatives.

Regulatory requirements for integration of the RES

Because of the unstable output power of RES, Standard IEE P1547-2003 was enacted as a regulatory requirement for their grid connection (Basak et al., 2012) to govern their impact on power system stability, fault ride through, harmonics, fault protection, and placement. These standards address power quality, reactive power support, ReDG fault ride-through capabilities, voltage and frequency regulations, and so on (Tsili and Papathanassiou, 2009). Similarly, the International Electro-technical Commission (IETC) and the leading countries in the development and use of renewable energy sources adopted comparable guidelines. Furthermore, the key to meeting these requirements is to resolve the technical challenges depicted in (Figure 1), namely:

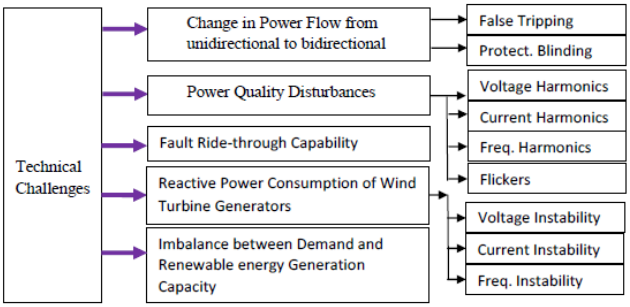

Figure 1: Schematic view of technical challenges faced by the integration of RES in the power system (Kaddah et al., 2015; Prakash et al., 2015; Singh and Reddy, 2013; Tiwari et al., 2014).

• Change, especially, a switch from unidirectional to bidirectional power flow in the distribution system.

• Harmonics in voltage, current, and frequency, as well as flickers

• Induction Generator Wind Turbines consume reactive power from the grid.

• The disparity between demand and distributed renewable energy sources.

Technical challenges faced by the power system due to the integration of RES

The integration of RES with their modern control schemes in the power system has created many technical challenges to power system operation. These challenges are depicted in (Figure 1) namely false tripping; protection blinding; unbalancing between demand and power generated from RES; fault ride-through capability of RES; harmonics; flickers; voltage and current instability as well as frequency instability (Kaddah et al., 2015; Prakash et al., 2015; Singh and Reddy, 2013; Tiwari et al., 2014). In addition, the difference in fault current levels, bi-directional current flow, equipment loading, and voltage swell and voltage dips are other technical challenges. All the challenges are because of differences between the steady and dynamic behaviour of a conventional power system and the grid integrated with RES in the distribution system.

Related works, contributions, and organization of the review

Labis et al. (2011) stated the cost-effective and environmentally sustainable way of providing electricity to a village is to replace fossil fuels with RES. In addition, the result obtained shows the integration of RES in the distribution system is cost-effective for supplying electricity to a remote village, compared to fossil fuels for twenty years' period, considering fuel cost and cost of green gas emission. Zahedi, (2011) reviewed the factors that aid the integration of renewable and non-renewable DGs in the power system, some of the problems been faced, and the prospects of RES. The authors considered the impact of different types of RES and their locations on power losses and voltage stability. However, they did not consider the impact of RES integration in power on fault protection and location**.** Kennedy et al. (2016) considered the technical challenges of the micro-grid protection system due to the high penetration of RES in the distribution system. Moreover, the result showed that the application of auto-reclosers and coordination of protection devices can resolve the technical challenges of the micro-grid protection, both in grid-tie and in islanding modes of operation. In addition, the authors recommended the increase of duration of attempt reclosure to more than two seconds, and the application of fast communication between protection devices to enhance their speed and selectivity. However, the applications of rule-based algorithms, optimization techniques for uniform tripping or improved relay protection coordination remain unreviewed. In addition, the authors did not study the challenges faced by fault location in power systems due to the high penetration of DG.

Lupangu and Bansal, (2017) reviewed the challenges faced by the present state of Photovoltaic system integration in power systems, due to policies, PV cell development, Maximum Power Point Tracker (MPPT), the impact of power electronic inverters and converters, methods of managing energy and scheduling, power quality and control. Pesaran et al. (2017) reviewed the application of optimal allocation of DGs in the distribution system considering objectives functions and, constraints using different optimizers. They stated that the optimization techniques could enhance the accuracy, efficiency, security, power quality and reliability of the power system integrated with Re-DGs. However, the same authors did not review the technical challenges faced by the fault protection and location schemes and power system stability due to the integration of RES in the power system.

Review gap, its importance and relevance

The review aims to fill in the above-mentioned gap. Moreover, its objectives are to review the progress made in solving the technical challenges of power system stability, Fault Protection and Location due to the integration of RES in the Power System. In addition, it would report the unsolved technical challenges. This review is important and relevant to the researcher community and the power system operators, the equipment manufacturers, and the policymakers. This is a means of enlightening them with new methods of solving the challenges and the present research trends in solving the challenges. These would enhance the utilization of renewable energy sources for achieving the united nation framework convention on climate change (UNFCCC) signed in Rio de Janeiro in June 1992. This review has four sections. The first section is the introduction; the second section discussed the benefits and demerits of RES integration in the power system. The third section is the summary of challenges faced by System Stability, Fault Protection, and Location Schemes due to RES integration into the power system. The fourth section contains the research works conducted to solve the challenges faced by fault protection, and location due to RES integration in the system. Section five Lastly, the review contains the conclusion, which summarized the main points.

CATEGORIES OF POWER QUALITY DISTURBANCES

The power quality disturbances are categorized into voltage changes, current changes, transients and harmonics in the dynamic state (Khokhar et al., 2015). The first category is caused by line fault or connection of huge loads, while the second category is a result of a lightning strike or capacitor bank switching (Khokhar et al., 2015). The third class is due to the introduction of power electronic converters and nonlinear loads in the power system (Khokhar et al., 2015). The authors in ref. (Jusić, 2016) stated that the power quality problem is a result of unsatisfactory analysis and the un-optimal placement of DGs in the distribution system.

Benefits of integration of RES in the power system

Abdel-Ghany et al. (2015), Tan et al. (2013), Karatepe et al. (2015), Borges, (2012), and Abdi and Afshar, (2013) reported improvements in power quality and reliability if DGs are appropriately positioned and sized in the power system (Figure 2). The incorporation of renewable energy sources (RES) into the distribution system for electricity supply to rural settlements avoids the high cost of establishing long distribution lines and saves the expense of expanding transmission capacity (Chaurey et al., 2004). The appropriate placement of DGs in a distribution system near load centres can avoid the need to transport a substantial amount of power, reducing stress on transmission lines (Lopes et al., 2007). (Short, 2004). It can reduce copper losses (I2R losses) (Kalambe and

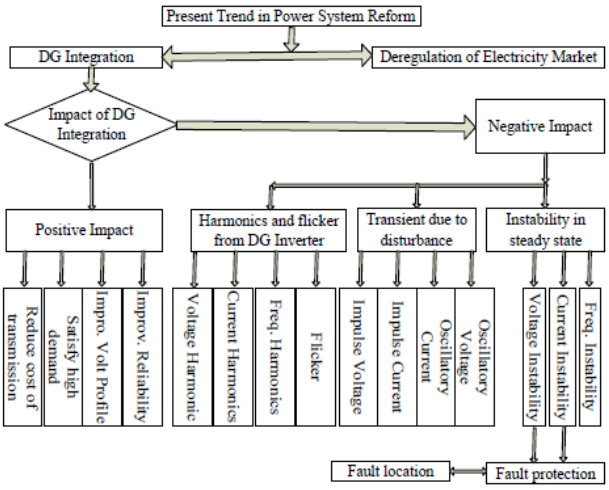

Figure 2: Block diagram of positive and negative impacts of RES integration in power system

Agnihotri, 2014), (Pepermans et al., 2005), (Kansal et al., 2013). Optimally placed DGs in the distribution system can defer the expansion of transmission line and feeder capacities (Wang et al., 2010), (Brown and Koutlev, 2001). Figure 2 shows the merits and demerits of RES integration in the power system. The optimally operated DG can reduce the cost of power system operation, because of flexibility in its operation during fluctuation of electricity demand (Benoit I, 2003). The incorporation of DGs into the distribution system can solve the problem of feeder overloading (Zeinalzadeh et al., 2015). It can also reduce environmental pollutants, resulting in lower greenhouse gas emissions and healthcare spending (Viral and Khatod, 2012). This form of integration has a short lead time and a minimal investment risk (Celli and Pilo, 2001). The integration of DGs in distribution system segments is simple and can be completed in a short *time (Viral and Khatod, 2012).* The distribution system's small segmented DG can carefully track the changing load pattern (Viral and Khatod, 2012). Because DGs are smaller in size than main generation facilities, they require less space, making their connection in the distribution system close to the load easier (Gozel et al., 2005). (Viral and Khatod, 2012). Furthermore, connecting the RES in the power system in an inefficient manner might result in some disadvantages, as discussed in the next subsection.

Demerits of RES integration in the power system

As illustrated in (Figures 3 to 6), the integration of RES in the distribution system has a detrimental influence on the electricity system. Harmonics in the distribution system can be introduced by DG integration (Short, 2004). Wind turbine DG blade rotation is affected by tower shading, resulting in voltage flicker in the DG output (T. Sun et al., 2005). Because of fluctuations in solar irradiance and wind speed, the output power of PV and wind turbine DG is unstable (Viral and Khatod, 2012). If DGs are not optimally allocated, this can bring instability to the system (Viral and Khatod, 2012) and may cause excessive voltage levels and an increase in power losses (Viral and Khatod, 2012). During islanding operations in the distribution system with connected DGs, the line crew and the public can be endangered due to overvoltage in the system (Short, 2004), (Khamis et al., 2013).

TECHNICAL CHALLENGES FACED BY POWER SYSTEM STABILITY, FAULT PROTECTION, AND LOCATION

The incorporation of DG into the distribution system has resulted in an increase in fault currents and a lack of coordination in power system safety (Abdel-Ghany et al., 2015). Basak et al. (2012) reported the challenges to fault protection and detection, and the stability of the system. Technical challenges like transient instability, voltage, and current variations can occur in the system with embedded DGs when a big disturbance like fault occurs in the system. This occasionally results in purposeful or unintended grid islanding operations. When the system is subjected to lightning strikes or human error, the issues become more viable (Gururajapathy et al., 2017). According to (Gabr et al., 2017), environmental conditions, outdated infrastructure, and poor maintenance are some of the leading causes of system malfunctions. Faults are unavoidable, and they occasionally impede the continuous delivery of safe and reliable electricity to consumers (Alanzi et al., 2014).

Once they have occurred, system protection schemes must take proactive measures to protect operation employees, and power equipment, and assist the power system in maintaining a safe and steady electricity supply to load centres. To do this, power utilities devote significant amounts to the research and development of fault protection methods, control and stability measures, and power system integration with RES. Furthermore, the use of these sources affects the quality of power delivered to consumers, the decreases in operational costs, and the high returns on investment.

Technical challenges faced by fault protection and location

Figure 3 depicts the fault current contributions of DG1 and DG3 during faults A and B. The connected DGs contribute to the fault currents, transforming the current flow from unidirectional to bidirectional (Boutsika and Papathanassiou, 2008). The flow change interferes with the performance of the relay protection coordination (Gopalan et al., 2014). Moreover, the disruption must be resolved. Another challenge facing the integration of wind

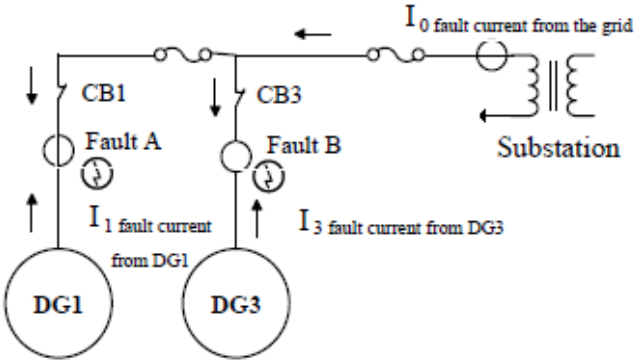

Figure 3: Fault current contributions of DG1, DG3 and the grid into faults A and B

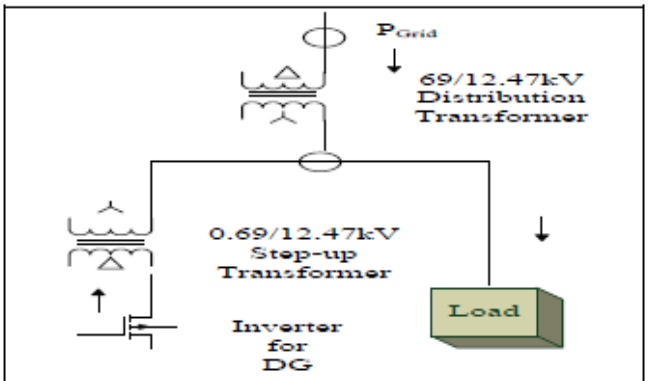

Figure 4: Circuit for connecting Inverter-based DG to the grid (Gerald et al., 2005)

power generation is the consumption of variable reactive power by wind Squirrel Cage Induction Generator Wind Turbine from the main grid. The consumption has a direct negative impact on voltage and transient stability of the power system and its power quality if not properly managed. The consumption pattern is stochastic as a result of the stochastic nature of the wind turbine because of variation in wind speed. Other factors responsible for the stochastic output power of Photovoltaic (PV) and Wind DGs in the power systems are PV panel shedding, shadow effect of wind tower on rotor blades, the vibration of turbine tower, gearbox and blades.

Bidirectional current flow and difference values of fault currents

The impact of DG integration in the distribution system on power system protection methods is determined by the system topology, number, and type of DGs linked. The integration transformed the power flow in the system from unidirectional to bidirectional current flow, as seen in (Figures 3 and 4). Furthermore, this alters the pre-fault and post-fault current levels (Singh and Reddy, 2013). Figure 4 depicts a circuit schematic for linking synchronous and inverter-based DGs to the grid. Furthermore, the synchronous-based DG contributes a higher fault current (Pgrid) than the inverter-based DG (Gerald et al., 2005). As a result, it has a significant impact on power system security (Zeineldin et al., 2015).

The small difference between pre-fault and post-fault currents in PV power generation

Renewable DG output power is stochastic, and there is a slight variance in pre-fault and post-fault current levels in PV power generation. As a result, a distribution network that includes PV power generation necessitates sensitive fault current prevention coordination algorithms (Zhan et al., 2016; Singh et al., 2016). Generally, a distribution network integrated with RES required well-coordinated relay protection, which can quickly eliminate the fault section in the network and maintained electricity supply to unaffected feeders. To improve the reliability backup protection must be introduced to take over the function of the main protection (Zeineldin et al., 2015) in case of its failure. The authors in ref. (Chang, 2016) believed relay protection coordination should ensure fast, selective and reliable relay function, to disconnect the fault section and maintain the power supply to the remaining network This is achievable by redesigning the conventional protection and location, and diagnostic techniques of the network taking into consideration the impacts of DGs.

False tripping and protection blinding of conventional protection schemes

The bidirectional current flow in the power system due to the integration of the renewable DGs has affected the operation of conventional protection schemes because their response cannot clear the fault, due to false tripping and protection blinding (Tiwari et al., 2014), as shown in Figure 5 and 6 respectively. Relay 2 in Figure 5 measured fault currents from the substation and DG connected in the adjacent feeder. This makes the relay record a high fault current leading to tripping of the healthy feeder (Xyngi and Popov, 2010). The relay in Figure 6 did not have the fault current contribution of the DG; hence decrease in the value of the measured fault current. This leads to protection blinding, in which the relay refused to trip. The magnitude of false tripping and protection blinding depend on the types of DGs, and their locations as well as the fault positions in the power system.

PROGRESS MADE IN SOLVING THE TECHNICAL CHALLENGES FACED BY FAULT PROTECTION AND LOCATION

It is very crucial to resolve the technical challenges faced

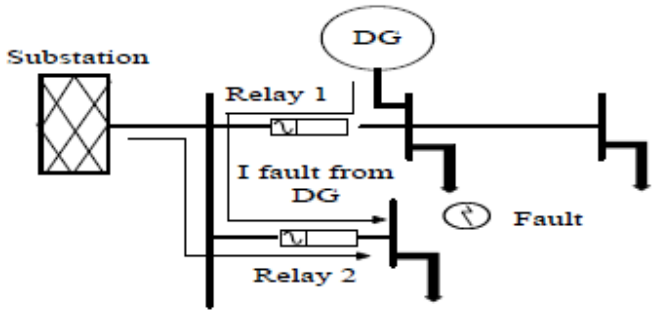

Figure 5: False tripping of relay due to fault current contribution from DG (Xyngi and Popov, 2010)

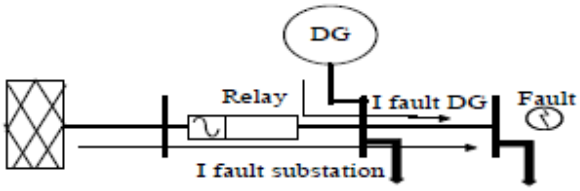

Figure 6: Protection blinding by relay due to fault current division of DG (Xyngi and Popov, 2010)

by fault protection and location schemes due to the integration of RES in the power system. Therefore, the power system operators and researchers are making more effort in developing different solutions for fault protection, identification, and location (Bahmanyar et al., 2017) to enhance the integration of RES in power. Moreover, this is a better way of generating electricity in an environmentally friendly way, leading to a reduction in global warming.

Application of algorithm and optimization techniques

The effects of erroneous tripping and protection blinding were addressed by (Xyngi and Popov, 2010) by employing the IEC61850 communication standard and the fast busbar-based relay algorithm, which can offer uniform tripping of varied CBs. Communication and pickup status of time delay and over-current relays were used in ref (Guo et al., 2016) to improve relay protection coordination for fault protection and location. In the previous reference (Zeineldin et al., 2015), optimization of dual relay settings was applied, which increased relay protection coordination. In ref. (Shih et al., 2014), relay coordination was improved by optimizing the sensitivity and selectivity of the directional over-current relay using a differential evolution technique.

Application of updating the relays trip settings improved reclosing, tripping time and coordination

Turner and Member, (2012) enhanced the relay protection coordination through reduction of reclosing and tripping timing by applying high-speed communication assisted tripping and sectionalizing the distribution system using numerical relays. Mahat et al. (2011) reported the improvement of relay protection coordination through updating its trip settings using relay status detection technique; current measurement and time over-current characteristics of the relay to locate fault sections, leading to islanding formation. While Sinha and Zaidi, (2015) reported on relay coordination improvement by employing definite time over-current relays and directional overcurrent relays to handle the protection problem of various fault current levels during islanding operation and when the island is reconnected to the main grid.

He et al. (2017) recommended the use of local information coordination and regional information sharing between substations and master substations to tackle the problem of the complex corporation and parameter settings in relay backup protection. Singh and Reddy (2013) improved relay protection coordination by implementing communication between DGs and relays for changes in relay settings and fault section isolation anytime the network topology changed.

The relay protection coordination improvement was accomplished in (Orji et al., 2017) by using a microprocessor-based multi-function monitor and protection coordinate method to segregate fault sections, locate HIF and arcing faults, and let the health sector of the microgrid to stay operational (Orji et al., 2017). The improvement of relay protection coordination by microprocessor-based relay programming to overcome the problem of fault current level disparity between grid linked and island modes of low voltage microgrid was reported in (Zamani et al., 2011).

The researchers have applied the knowledge-based, impedance matrix and low frequency, high frequency and travelling wave methods to solve the challenges faced by fault location schemes as reported below.

Application of statistical and artificial intelligence methods for fault location

Jian-cheng, (2014), Biscaro et al., (2016), statistical analysis and wavelet transform methods were utilized to locate faults in the HVDC distribution line in three phases

balanced radial feeder. For the location of a single fault, the method in (Jian-cheng, 2014) is confined to the use of a distributed parameter model of the HVDC distribution line and a travelling wave speed of 2.99x 106 m/s.The speed of the travelling wave affects measuring accuracy in this method, which has to be investigated. According to Biscaro et al. (2016), fault features were retrieved using wavelet transform and faults were identified using the Fuzzy-ARTMAP neural network. This strategy is efficient, quick, and intelligent. In, it was stated that advanced signal processing in wavelet, ANN, and fuzzy logic systems were used to detect HIF in subterranean distribution networks (Rafinia and Moshtagh, 2014).

It has a detection inaccuracy of 1.5 per cent for load changes and fault circumstances. The fact that only one DG was incorporated into the distribution network is one of its limitations. Jamil et al. (2015) used Discrete Wavelet Transform and Fault Location Scheme to detect ten types of faults in an unbalanced underground distribution network, where fault inception angle and loads had little effect on the outcome.

The approach has a 95% accuracy rate. At 0.9° fault initiation angle, it is limited to zero-ohm fault resistance. The authors, however, did not investigate the measurement accuracy of different fault resistance values at different fault inception angles. Chang, (2016), Jain and Gawre, (2016), and Ali et al. (2017) reported on the use of ANN, two-layer feed-forward neural network, probabilistic neural network, power spectrum wavelet transforms, discrete wavelet transforms, and wavelet transforms for detection, extraction, classification, and location of faults in distribution networks Ngaopitakkul and Leelajindakrairerk, (2017).

The method in Chang (2016) has a drawback in that it only applies to a transmission network in an industrial scenario where a lump parametric model was evaluated. The technique's downside is that it employs the transmitting end feeder measurement method, which is less accurate than the two-feeder end measuring approach. The method in ref. (Jain and Gawre, 2016) has a limitation that only a single failure in the middle of a long distribution line (200km) was considered. Therefore, the effect of introducing multiple faults, on classification accuracy achieved (97.905%) can be investigated. The shortcoming of Ali et al., (2017) technique is that only a single line to ground HIF was examined. Furthermore, it entailed a time-consuming procedure of creating a reference database. The authors' code was not changed to capture the LLG and LLLG high impedance problems. The method in ref. (Ngaopitakkul and Leelajindakrairerk, 2017) has a fault classification accuracy of 99% and a computed fault distances accuracy of 100%. It involved the use of transposed short underground distribution line model. This method was applied to a transposed medium overhead distribution line. The authors in ref. (Kong et al., 2016) applied the foraging technique of Bacteria, and parametric coding to model the transient currents measured from Fault Terminal Units (switches). They applied this technique to locate the fault in a distribution system with three DGs. The advantage of the method is the detection of fault events with EMI in the transient currents measured.

Application of statistical and artificial intelligence (AI) methods for fault diagnosis

Santos et al. (2017), Mortazavi et al. (2018), and Santos et al. (2018) reported on the application of DWT, statistical wavelet transforms, decision trees, and vector machines for diagnosing HIFs in the distribution system (Kar and Samantaray, 2016). The technique in ref. (Santos et al., 2017) has the advantage of being able to group high and low-frequency HIF voltage components and distinguish them from three-phase fault and switching events.
Its downside is that it only allows for the insertion of one DG. The search field reduction method has a 54.44 per cent accuracy for detecting HIF and 54.44 per cent accuracy for locating HIF. The approach in (Mortazavi et al., 2018) has a restriction in that it only applies to short distribution lines (70km). The developed algorithms have a 56.2 per cent accuracy in recognizing 153 linear load switching occurrences. As a result, there is an opportunity for improvement.

The method in (Kar and Samantaray, 2016) has a restriction in that it is applied to micro-grid. The method's shortcoming is that 70% of the fault characteristics from MODWT were used to train the classifier. Particle swarm optimization, ANN, Genetic Algorithms, and the bistable system were employed for fault diagnosis in the active distribution network in (Ge Liang et al., 2014) and (Gao et al., 2016).

The method's drawback (Gao et al., 2016) is that it can only identify SGF when used with two DGs on a short distribution line (20 km maximum length). The method's drawback is that it requires a lot of computations. The approach in ref. (Ge Liang et al., 2014) has one DG in the simulation model, which is a limitation. The statistical and AI strategies for addressing the unfavourable impact of DG on power system failure diagnosis, only the authors of (Ge Liang et al., 2014) and (Gao et al., 2016) use up to three synchronous Generators as DGs in distribution systems to locate faults using AI approaches. They did not consider the DGs because they are not environmentally friendly. Most researchers' knowledge-based techniques did not cover numerous faults of varied resistances and fault inception angles. Furthermore, this has an impact on the precision of the approaches used.

Application of the impedance matrix and low frequency-based method

Alanzi et al. (2014), and Bakar et al. (2015) reported on a fault location approach that uses voltage measurements in

the distribution substation before and during the fault (2014). In the 33kV distribution network, Alanzi et al. (2014) used Clark's Transformation and voltage similarity approaches to identify and locate the 1 and 10 LGF, LLGF, LLF, and LLLF faults at 0° and 90° inception angles.

To extract and localize HIF faults in the 11 kV subterranean distribution network, Bakar et al. (2014) used discrete wavelet transformations and multi-resolution analysis. The authors used an approach that involved measuring the voltage of the sending end feeder in the distribution substation. Furthermore, as compared to two-feeder end voltage measurements, it does not produce improved findings. Due to the low average absolute differences in Wavelet Transform coefficients utilised, the prediction-based ranking analysis technique may not always yield a correct conclusion (placement of fault section).

To locate HIF, single, and multiple failures in the distribution system, an impedance matrix and algorithm were employed. Gazzana et al. (2014), Daisy and Dashti, (2016), Soheili and Sadeh, (2017), Torres et al. (2014), Ma and Tian, (2016), Sun et al. (2017), Gazzana et al. (2014), Daisy and Dashti, (2016), Soheili and Sadeh (2017). The method's drawback in (Torres et al., 2014) was that it was only used to detect defects in feeders. It can detect defects in distributors and service mains after being modified. The method in (Ma and Tian, 2016) has the limitation that its accuracy in determining fault distances is dependent on the type of fault. It can only calculate one defect distance at a time. This review suggests that it be modified to compute numerous fault distances for distinct fault kinds.
The advantage of the method in (Sun et al., 2017), it can detect single and multiple faults and is independent of the type of faults and fault impedances. The method in (Gazzana et al., 2014) has 99.08% accuracy in the estimation of 0 Ω and 15 Ω LGF, LLGF, LLF, LLLF fault distances in 13.7 kV feeders. Moreover, the accuracy in estimating the location of the 30-Ω fault in the same feeders is 99.02%.

The method needs improvement for the estimation of fault distances of two-phase to the ground and three phases to ground fault configurations in 33 kV primary distribution feeders of different topologies. The method in (Daisy and Dashti, 2016) has maximum errors of 0.43% for 100Ω faults and 0.1623% for 50Ω faults, obtained from simulation results. The method can locate a single phase to ground fault, using a balanced distributed parameter of the distribution line model. Therefore, it needs modification for application to asymmetrical short and medium distribution lines, to capture three-phase faults.

The approach of Soheili and Sadeh, (2017) detects HIF with an accuracy of roughly 95% and is unaffected by network configuration, fault impedances, or fault distances. However, the narrowband frequency spectrum of the measuring instrument utilised (ION 7650) rendered measuring the basic fault features related to three-phase currents and single-phase voltages impossible.

Application of the impedance matrix and three-phase equation method

For fault location in distribution networks, (Gabr et al., 2017), (Si et al., 2016), and (Time Domain Analysis for Fault Location in Power Distribution Systems Considering the Load Dynamics, 2017) used voltage and current measurements at distribution substations, the formulation of impedance matrix and three couple phase equations, and dynamic load modelling. The authors of (Gabr et al., 2017) did not use the iterative approach and included several circumstances, such as intermediary loads, time-dependent loads, no balanced condition, and distribution line topology, in their overview of this method.

The method described in (Gabr et al., 2017) can be used to locate faults in an imbalanced 11kV distribution system with a single step-down transformer. As a result, it may be modified and used to find problems in a 33kV balanced distribution system with numerous transformers and a ring topology of feeders. The method's limitation (Si et al., 2016) is that it can only detect a single-phase problem. As a result, it can be changed to capture LLF, LLGF, and LLLGF. The method described in (Time Domain Analysis for Fault Location in Power Distribution Systems Considering Load Dynamics, 2017) may detect faults in unbalanced distribution networks that are single-phase, double phase, or three-phase. Nonetheless, the accuracy of its fault location estimation is dependent on the measurement time of stable and transient voltages and currents.

Application of substation voltage and current measurement method

Majidi et al. (2014), and Ren et al. (2014) employed voltage and current measurements at distribution substations and feeder nodes before and after fault occurrences to find single faults and HIF in distribution networks (2014). The results of (Majidi et al., 2014) can locate LGF, LLGF, LLF, and LLLF of varied resistance values satisfactorily. The method's scope can be expanded to detect problems in a three-phase distribution system with active RES. The method in (Ren et al., 2014) has the following advantages: it can find HIF faults in mesh and radial distribution networks with two DGs. It is confined to HIF detection and has a 1% error rate. As a result, its scope can be expanded to include numerous sorts of problems. The fault's reactance value and the Fibonacci approach were used to locate the fault in the active distribution system (Orozco-Henao et al., 2017). The technique's advantage is that it uses fewer measuring nodes than the traditional method, such as the line reactance method. Its disadvantage is that as line loading decreases relative to nominal load or fault distances increase, the accuracy of the computed fault lengths decreases.

In summary, the disadvantages of the methods in (Time Domain Analysis for Fault Location in Power Distribution Systems Considering the Load Dynamics, 2017) and (Orozco-Henao et al., 2017) are the fault distance estimation accuracy, which is dependent on the period the fault voltages and currents were measured. Furthermore, as line loading is reduced relative to the nominal load, or fault distances are increased, the inaccuracy of computed fault distances increases.

Application of high frequency and travelling wave method for fault location

The derivatives of transient voltage travelling in the system model can be used to find faults in the HVDC distribution system (Jian-cheng, 2014). To calculate the fault distance, the scientists used a moving wave with a speed of $2.96x10^6$ m/s. According to Goudarzi et al. (2015), the fault lengths in a 34 bus radial unbalanced distribution system are calculated by estimating the variations in the times taken by the fault transients to pass the measurement nodes within the system. Furthermore, the authors used the discrete wavelet transform to alter the temporal differences.

IMPACT OF RES INTEGRATION IN POWER SYSTEM ON SYSTEM STABILITY

Transient stability was described by Mahdad and Srairi (2013) as the ability of synchronous machines in the power system to continue running in an ordered manner after a short circuit fault, critical line tripping, or other large disruption. Furthermore, the generators must have extremely strong inertial responses to dampen transients. As a result, system operators and researchers have been interested in the inertial frequency responses of generators for many years. The most prevalent causes of transient instability in the power system include fault application and clearance, transformer energising and de-energizing, massive loads, transmission line outages, and generator outages. A large-scale power system's stability was determined by the change in system frequency caused by an imbalance between power generation and load demand (Laouer et al., 2014) and (Kusch-Brandt, 2019). In general, the swing equation is used to determine the transient stability of machines in a two or Single Machine Infinite Bus (SMIB) system.

$$M\frac{d^2\delta}{dt^2} = Pm - Pe \quad (1)$$

Where M is machine inertia constant in Js^{-1}, δ is its rotor angle in electrical degree º, P_m is the generator input power (mechanical) in mega-joules, P_e is generator output power in megawatts and t represents time in seconds.

The equal area in the power-rotor angle curve, the critical clearance angle and time are the yardsticks applied to determine the stability of the power system consisting of up to three machines. For systems consisting of multiple machines, the power flow studies using computer application programmes like Dig SILENT-power factory, Electromagnetic Transient Programme (EMTP), MATLAB, and Power world Simulator are applied to determine system stability.

Methods of evaluating the power system stability

The magnitude and penetration degree of RES in the power system determined the stability of the regional power system. As a result, assessing system voltage stability and reactive power exchange between the grid and RES is required for the incorporation of large RES in a distribution system. FACTS technologies are employed at PCC to adjust for reactive power to alleviate the instability problem caused by load variations (Salehi et al., 2006). The authors of (Wu et al., 2016) reported on the use of a Frequency monitoring network (FNET/Grid Eye) for power dynamics measurement in a vast region of distribution networks in twenty nations over ten years. Moreover, Eq. (2) is applied to determine the relationship between the rate of change in system frequency $\frac{df}{dt}$, initial frequency f_o, power imbalance $P_i - P_g$ and system inertia H.

$$\frac{df}{dt} = \left(P_i - P_g\right)\frac{f_o}{P_g} * 2H \quad (2)$$

Furthermore, it demonstrates that the rate of change of system frequency is inversely related to the operating capacity of the power system. The Short-Time Fourier Transform (STFT), Continuous Wavelet Transform (CWT), Wigner-Ville Distribution (WVD), and Hilbert-Huang Transform (HHT) signal analysis methods were employed in ref. (Transform, 2014) to analyse system frequency variations in distribution networks.

Didier et al. (2015) investigated the performance metrics of resistive and inductive fault current limiters for improving transient stability in a single transmission line machine infinite bus. Furthermore, the critical clearance angle and critical clearance duration are yardsticks used to determine transient stability. The many strategies offered by researchers to address the detrimental impacts of RES on power system integration are discussed below:

Methods of solving the technical challenge faced by Power System Stability

The techniques applied by researchers to solve the

negative impact of RES integration on power system stability are:

1) The application of FACTS devices.
2) Allocation of DG in the distribution system for transient stability enhancement (Viral and Khatod, 2012).
3) The application of resistive and inductive fault current limiters (Kushwaha et al., 2017).
4) Application of dynamic voltage restorer (DVR) and braking resistor (BR) in synchronous DG for improvement of critical clearance time (Sinh and Bhagatwala, 2017), (Taiwo and Tiako, 2017).
5) The application of Controllers for reactive power control at PCC between DG and the grid (Tuyen et al., 2017).
6) The application of virtual DG as inertia for damping the transient in an inverter-based DGs integrated into the power system.
7) Application of rotor circuit control in Wind Turbine Rotor wound Induction generator.
8) The application of a power system stabilizer.
9) Application of fast exciter in synchronous the generator or switching of parallel transmission line for power system stability enhancement (Parvathy S. and Thampatty, 2015).
10) Application of reclosers, circuit breakers and bridge fault current limiters for system voltage stability
11) Application of battery for storage of energy generated by RES in the power system for stability enhancement.

Progress made in solving power system instability using FACTS devices

When a severe disturbance occurs in the system, Jayashri and Kumudini (2009) highlighted the requirement for reactive power assistance at PCC to mitigate transient instability in the distribution system embedded with DG. While employing non-linear inductive SFCL and STATCOM, the authors in (Mahdad and Srairi, 2013) increased the margin stability and critical clearance time transient stability indices of synchronous generators in a power system with DG when a three-phase short circuit fault occurs. Using Unified Power Flow Controllers, the authors in ref. (Rohan and Thakur, 2012) improved the critical clearing time of machines in transmission lines under various forms of short circuit faults.

Progress made in solving power system instability using hybrid methods

The improvement of transient stability in two machines infinite bus system under three-phase and two-phase short circuit faults was achieved through minimization of the rotor angle differentials of machines using resistive SFCL (Didier and Lévêque, 2014). The enhancement of transient stability of the multi-generator bus system was achieved through the reduction of mechanical and electrical torques of the generators through CB coordination and connecting of hybrid SFCL in the system (Seo et al., 2013). Sadi and Ali, (2015) improved the kinetic energy, load angle and critical clearance time indices during transient in distribution network under three phases and two-phase short circuit faults, by connecting hybrid SFCL and effective reclosure of circuit breakers in the network.

Mirabadi et al. (2014) increased transient stability in a single machine infinite bus power system that was subjected to damping and inertia parametric uncertainties as a result of a three-phase short circuit fault and immediate load shifts. To improve transient stability, the authors used the Robust Optimal H2 State Feedback Controller. The project integrative technique (C. Wang et al., 2018) was proposed for improving the transient stability of PV DGs connected to the power system by using virtual synchronous DG to control inertia and damping the transient in synchronous DG, using active and reactive grid power control loops connected between the PV DGs and the grid. Its disadvantage is the variety of possibilities for configuring the virtual synchronous DG settings. Furthermore, poor parameter selection can exacerbate the problem of transient stability.

CONCLUSION

Renewable energy sources such as wind energy, solar energy, biomass, geothermal, hydrogen and fuel cells are getting much attention as substitutes for fossil fuels, for promoting a friendly way to the environment for generating electric power. The aims of integration of RES in the power system are the improvement of power quality, system reliability; reduced copper losses (I2R); reduction of the high cost of installing long distribution lines or expanding transmission capacity; reduction of the cost of power system operation and improved flexibility in its operation, during fluctuation of electricity demand. The findings of the review are:

1) The present research trend to solve the challenges faced by fault location schemes in power systems is the application of knowledge-based methods, impedance, and low frequency-based methods, while the high frequency and travelling wave methods are fairly used.
2) From the merits and demerits of the three categories of fault location methods reviewed, the knowledge-based methods are more precise and faster compare to the other two methods.
3) The researchers applied Circuit Breakers; DG allocation; definite time and over-current relays; optimization of sensitivity and selectivity of DOCR; communication and pickup status of over-current relay; programming of microprocessor-based relays; information coordination and sharing to solve the challenges faced by fault protection schemes because of RES integration in

power system.

4) The challenges to power system stability due to DGs integration in the system were mostly resolved by researchers by application of SFCL; CBs coordination; connecting of hybrid SFCL, Controllers and virtual DGs to solve the instability at the outputs of renewable DGs.

5) In addition, researchers applied FACT devices at PCC to meet the high reactive power demands of type II and IV wind energy sources for enhancement of power system stability. These research findings are important and relevant to the researcher community, power system operators, equipment manufacturers, and policymakers because they provide them with different methods and research trends for addressing the technical challenges of power system stability, fault protection, and location when RES are integrated into the system. This can help RES power generation capacity development to satisfy the United Nations Framework Convention on Climate Change (UNFCCC), which was signed in Rio de Janeiro in June 1992.

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