Enhancing Service Restoration in Tanzanian Power Grid Using Internet of Things Sensors and Renewable Energy Sources

Rukia J. Mwifunyi1[1,2*], Daudi C. Mnyanghwalo[1] and Shamte J. Kawambwa[1]
[1]*College of Information and Communication Technologies, University of Dar es Salaam, P. O. Box 33335, Dar es Salaam, Tanzania.*
[2]*College of Informatics and Virtual Education, University of Dodoma, P.O. Box 490, Dodoma, Tanzania.*
rukiahilda@gmail.com; daudicm@gmail.com; shamtej2@gmail.com
*Corresponding author

Abstract

The increased dependence on the electric power grid, coupled with the increasing number of new customers, motivates the need to improve the reliability and resilience of the electric distribution systems. Modern distribution systems are becoming more resilient against power outages due to the increasing integration of Distributed Energy Resources (DERs) and the availability of efficient mechanisms for load shedding. Several studies considered fault detection and Service Restoration (SR) as separate problems without considering the implementation feasibility of integrating both solutions. To ensure the resiliency in the power system, it is important to have proper mechanisms which integrate sensing, detection, and SR as one problem while considering the load shedding and DER for improved capacity. Hence, this study proposed an IoT-based-sensor network framework with an enhanced algorithm coupled with a Binary Bat metaheuristic algorithm for SR integrating sensing, detection, and restoration. The proposed algorithms have been tested in Tanzania's electrical distribution network, considering the inclusion of DERs and load shedding. The results showed that DERs' size and locations significantly impact restoration schemes' performance with a power loss reduction of 74%. Therefore, efficient SR schemes should consider optimal DERs placement and a combination of load shedding and DERs integration for improved performance.

Keywords: Service Restoration, Load Shedding, Distributed Energy Resources, Smart Grid, Internet of Things.

Introduction

The electrical power systems comprise the complex infrastructure extending from generation, transmission to the distribution network. These infrastructures are susceptible to faults for several reasons, including natural causes, tree contact, animal contact, and wear and tear (Karić et al. 2018). Faults once occur in electrical power systems may result in equipment damage which may subsequently cause power interruption or outage. Growing reliance on power grids and rising natural disasters drive the urgency to enhance reliability and resilience in electric distribution. This aligns with integrating intermittent renewable energy sources (Poudel and Dubey 2021).

Modern distribution systems are becoming more resilient against power outages due to the increasing integration of Distributed Energy Resources (DERs) and the availability of efficient mechanisms for Service Restoration (SR) (Fan et al. 2021). Several efforts have been made towards developing SR mechanisms for power distribution systems that can automatically

detect, identify, isolate, and restore the outage to improve grid reliability, resilience, and security in response to a wide variety of emergencies (Amin and Giacomoni 2012).

Sensing and detection form a significant part of the SR systems; it is responsible for continuously monitoring the network parameters to detect and classify faults whenever they occur, hence triggering the restoration mechanisms to take place. There have been notable advancements in electrical grid monitoring systems in transmission and primary distribution networks using Supervisory Control and Data Acquisition (SCADA) (Vignesh and Kirubakaran 2015). SCADA systems gather real-time measurements from the remote terminal units installed in transmission and primary distribution substations (Thamarai and Amudhevalli 2014). Further, development using the Phasor Measurement Unit (PMU) was invented with enhanced synchronization to take advantage of the Global Position System (Gou and Kavasseri 2014). The advancement in metering technologies has realized the use of Automatic Meter Readings (AMR) to be used for network monitoring purposes up to the distribution transformers (Mahmood et al. 2008). Further development in sensor technologies revealed the use of IoT-based sensors in different applications, including water, electrical, environmental, and health (Lestari et al. 2017, Loganathan et al. 2019, Luechaphonthara and Vijayalakshmi 2019). A study by Grilo et al. (2012) used wireless sensors and actuator networks to monitor and protect the substations. The study done by Cheddadi et al. (2020) proposed an IoT-based sensor to monitor a photovoltaic station. However, most existing studies focused on the transmission and primary distribution network, which is mainly stagnant and less complex compared with electrical Secondary Distribution Networks (SDNs) and hence could not be efficiently used for SR. Furthermore, most existing studies on IoT-based sensors did not focus on fault detection, they mainly focused on light applications to monitor few parameters.

The main goal of the SR scheme in legacy power systems is to promptly restore as many loads in outage areas as possible with the minimum number of switching operations and minimum losses within a short restoration time without violating network operating constraints (Latare et al. 2017, Rupa and Ganesh 2014). In an Active Distribution Network (ADN), the major control factors for SR schemes are network reconfiguration or load transfer, load variations, load shedding, and the involvement of alternative power sources (Zidan et al. 2017). Load shedding and DER are used in case of insufficient supply. Therefore, the SR in ADN is a multi-objective, multiple-constraint, and complex optimisation problem which needs optimisation methods (Zidan et al. 2017).

During SR, if the power supply is insufficient, an optimal load-shedding mechanism is conducted to remove some loads to reach the equilibrium state (Larik et al. 2018). For improved efficiency during SR, an optimal mechanism for load shedding is required (Larik et al. 2018). Several mechanisms for load shedding have been proposed, including heuristic approaches, mathematical programming, and metaheuristic algorithms (Owaifeer and Al-Muhaini 2018). It has been revealed that, with heuristic-based mechanisms, it is very difficult to model all possible situations due to the increased complexity of the power systems and variability of load demand, as it depends on the operator's knowledge and practical experiences (Zidan et al. 2017). Using metaheuristic approaches in decision-making leads to faster decisions than mathematical models and heuristic approaches (Zidan and El-Saadany 2012, Owaifeer and Al-Muhaini 2018, Solanki et al. 2007). Existing mechanisms in load shedding in power systems include; Genetic Algorithm (GA) (Guichon et al. 2012), Particle Swarm Optimization (PSO) (He et al. 2009, Mwifunyi et al. 2021), glowworm swarm optimization (GSO) (Mageshvaran and Jayabarathi 2015) and Grasshopper Optimization Algorithm (GOA) (Ahmadipour et al. 2022). The GA-based

algorithms have high accuracy but require more time to get the optimal solution. PSO, GSO and GOA may fall into local minimum and unstable convergence speed (El-Shorbagy and El-Refaey 2020).

Introducing DERs can bring some new features and support to SR for enhanced efficiency. The DER units can locally support loads during the restoration process, minimizing the number of switching operations, minimizing restoration time, and providing opportunities to restore additional unrestored loads (Shen et al. 2020). DER units inclusion enables power distribution networks to present more stochastic rather than deterministic operating conditions making the traditional SR schemes insufficient (Shukla et al. 2020). Several methods for DERs integration in distribution networks have been proposed, such as linear programming, quadratic programming, and metaheuristic algorithms. The impacts of including DERs on SR depend on the restoration plan, network structure, size, and location of DERs. Rhodes and Roald (2022) proposed restoration planning in distribution grids, analyzed the impact of different DER operational scenarios on the optimal restoration plan, and assessed the outcomes for customers with and without DERs. Wang et al. (2019) proposed an optimal restoration strategy for coordinating multiple sources to serve critical loads to maximize the number of loads restored, weighted by their priority. Ye et al. (2021) proposed a model for coordinating the actions of multiple installed DERs for unbalanced distribution system restoration.

Significant works have already been done to ensure service reliability in the power distribution network by proposing Fault Detection and Service Restoration (FDSR) mechanisms, DER control, and Load shedding mechanisms. Most published work considered fault detection and isolation, DER control, and SR independently (Le et al. 2018). It has also been revealed that the successful implementation of SR strongly depends on integrating different functions like DER control, FDSR, and protection into one unified and operational control

framework (Zidan et al. 2017). Moreover, studies on SR in power distribution networks considering load shedding (Owaifeer and Al-Muhaini 2018), DER integration (Wang et al. 2019), and both DER and load shedding (Wang et al. 2017, Ghasemi et al. 2019, Poudel and Dubey 2021) has been conducted using different approaches. In research published in 2021, Poudel and Dubey developed a two-stage approach for SR that took DER and network reconfiguration into account using mixed integer linear programming as an optimization algorithm. The complexity and size of the problem may result in a longer computation time for mixed integer linear programming (González et al. 2020). A Multi-stage restoration method for primary distribution systems with DERs and consideration of optimal load shedding was proposed by Wang et al. (2017) and Ghasemi et al. (2019). These studies were conducted in medium voltage distribution systems, and rule-based methods were used for decisions on optimal load shedding, which could not fit in large and complex networks. It is crucial to have appropriate procedures that treat sensing, detection, and SR as one problem while considering DER for increased capacity to ensure the power system's resiliency.

Despite the fact that there have been significant efforts to ensure the reliability and resiliency of the electrical power systems using different algorithms for SR, there are still challenges in the electrical SDN for most developing countries, including Tanzania (Fakih et al. 2020), where the restoration is still done manually. The factors affecting restoration mechanisms are as follows: the existence of many branches and sub-laterals (Kawambwa et al. 2021), lack of efficient systems for sensing and detection, lack of efficient systems to engage DER in the restoration process, and lack of efficient restoration mechanisms for the SDN. This study aimed at enhancing the SR in the Tanzanian power grid in case of insufficient supply through IoT sensors and renewable energy sources. The IoT-based sensor network monitors the electrical SDN, detects faults whenever they occur, and determines

the network's actual load demand. The proposed framework is focused on fault detection and SR as a single integrated framework considering load shedding and DER in the event of insufficient power supply. The main benefits of the proposed approach over the state-of-the-art are; (1) load shedding is carried out based on real available load demand obtained from the IoT-based sensor network; (2) decision making is performed using the Binary Bat optimization algorithm, which has not yet been applied in the restoration problem; (3) Unlike previous SR studies which focused on primary distribution network, this study focused on real electrical SDN.

Materials and Methods
Study area
Tanzania's electrical SDN, managed by Tanzania Electric Supply Company (TANESCO), is a case study. TANESCO employs SCADA and Distribution Management Systems (DMS) to address faults and enhance network efficiency swiftly. SCADA spans the country for transmission oversight, while DMS operates in Dar es Salaam to monitor primary distribution. The Tanzanian five-year national plan prioritizes renewable energy for improved reliability (URT 2021). Currently, the SDN lacks monitoring, relying on manual fault detection, causing prolonged downtime due to absent SR implementation. Efforts targeting network improvements and reduced downtime for robust service delivery are required.

In Tanzanian SDN, single distribution transformers are mainly used to save loads in the SDN; thus, a radial power flow analysis is used for identifying power system parameters. The SDN is not static, as it grows whenever new customers are connected to the network. According to Kawambwa et al. (2021), from January 2015 to September 2019, Tanzania utility companies have a growth rate of 32% per year. This growth rate is significant for the distribution network as it is associated with changes in the topology and increases load demand, impacting system performances.

Therefore, proper SR schemes are required to ensure power efficiency in such a dynamic system.

Mathematical problem formulation
This study focused on power system restoration, aiming to restore power to as many customers as possible by balancing their priorities. Two objectives were examined: maximizing customer restoration and minimizing power losses. Optimization incorporated constraints like voltage limits. Switching operation minimization was not studied because Tanzanian SDNs involve few switches due to their radial structure. Loss reduction was considered for safe power distribution in regular and emergency operations.

Objective function
Maximising the number of restored loads based on their priorities is as shown in Equation 1.

$$max(fx) = \sum_{i=1}^{N} w_i * L_i * y_i \qquad (1)$$

where L_i is the load at bus i, y_i: status of the load at the bus i, w_i: priority level of the load at bus i, x: network configuration undergoing SR represented by the status of switches, and N: total number of buses.

Minimisation of the power loss is given by Equation 2.

$$P_{loss} = \sum_{i=1}^{N} I_i^2 * R_i \qquad (2)$$

where P_{loss} is the total power loss, I_i is the current through branch i and R_i is the resistance of branch i.

Constraints
Bus voltage limits as expressed in Equation 3.

$$V_{\min} \leq V_i \leq V_{\max} \qquad (3)$$

where V_i is the voltage in i bus, V_{min}: minimum acceptable bus voltage (0.9 p.u) and V_{max}: maximum acceptable bus voltage (1.1 p.u.).

Proposed solution
Proposed framework
Electrical SDN needs to be monitored in real-time to detect and classify faults whenever they occur using appropriate sensor networks. The complexity and

ubiquitous nature of the electrical SDN make it difficult for the legacy sensor networks using SCADA and PMU systems to be deployed. The existing systems were relatively expensive, mainly centralized, and had limited processing capabilities. To ensure the resiliency in the power system, it is important to have proper mechanisms which integrate the sensing, detection, and SR as one problem while considering the DER. Hence, this study proposed an IoT-based sensor network framework with enhanced algorithms for FDSR.

Figure 1 presents the IoT-based sensor network framework that could monitor the network in real-time, detect faults whenever they occur, and relay the processed information to trigger restoration processes. The proposed SR mechanisms consider the use of DER and load shedding in case of insufficient power supply during SR. The sensor nodes are optimally placed by considering power system network observability. To enhance distributed processing, the Distributed Control Unit (DCU) receives data from multiple sensor nodes, processes the data, and takes some actions, such as engaging DERs and performing load shedding to restore services before involving the control center. In a real implementation, a single DCU controls small sections of the network to minimize the computation burden at the control center and improve system efficiency through distributed processing. The DCU sends data to the control center for further actions such as visualization and communication with third-party systems. The following section presents an algorithm for engaging the DERs and load shedding to enhance SR based on the framework shown in Figure 1.
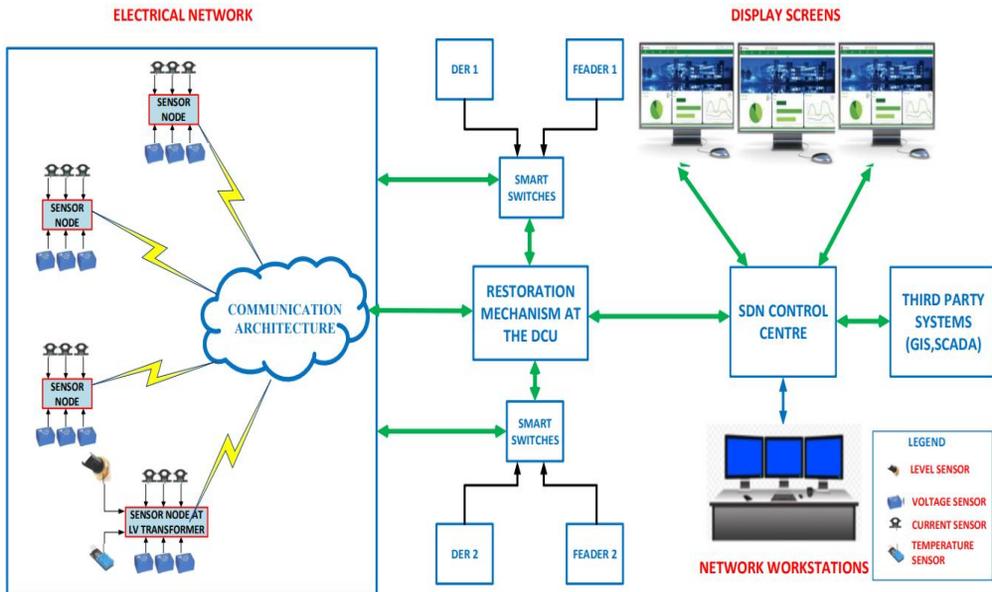
Figure 1: The proposed IOT sensor network framework.

Proposed algorithm

The study focused on two SR strategies, namely DERs integration and load shedding. Load shedding is used if the available power supply is insufficient to supply the available load demand; thus, some customers, especially low-priority customers, remain unserved to allow high-priority customers like hospitals to be served. If the area has renewable energy sources, some customers are served by these sources in collaboration with the primary grid. Generally, the choice of strategy to use depends on the current status of the electrical SDN. The flow chart of the proposed algorithm is presented in Figure 2.

The proposed architecture consists of sensor nodes, DERs, and a distributed control unit. The sensor node collects data and performs primary fault detection. From Figure 2, the sensor nodes continuously monitor the network for faults. When there is no fault, the sensor node stores the readings and sends data to the control unit after every 20 minutes. When faults occur, the sensor node sends data to the control unit immediately. Upon receiving fault data, the DCU locates the faults by running fault location algorithms. Then check the network load demand and available capacity. If the available capacity is enough, power is restored to all customers. If the available capacity is not enough, the control unit looks for other SR mechanisms such as load shedding and DER integration. If the DERs are available, the DERs are dispatched, then after, the load demand and available capacity are re-analyzed. If there are no other alternative sources and the demand is still higher than the available capacity, the DCU performs optimization for optimal load shedding. In all cases, the power system parameters are obtained after running a power flow method. In this study, a power flow method presented by Teng (2003) was used and the optimal loading shedding optimisation was implemented using a metaheuristic algorithm called Binary Bat Algorithm (BBA).

Binary Bat optimization algorithms

The optimal load shedding problem involves the identification of nodes that can be disconnected from the network while keeping other network parameters at the best possible conditions. The load-shedding problem is modeled in binary domains. Therefore, binary metaheuristic algorithms are among the best techniques to be used for solving such problems. The flexibility and superior ability to deal with different problems make metaheuristic algorithms popular compared to conventional optimisation techniques. Metaheuristic algorithms are designed to operate in continuous search spaces and others in discrete binary search spaces.

One of the most proficient metaheuristic algorithms is Bat Algorithm (BA), proposed by Yang and Gandomi (2012). The echolocation behavior of bats inspires the BA by mimicking the natural pulse loudness and emission rate of real bats. The BA comprises three elements: search frequency; loudness; and launch frequency (Li et al. 2021). Mirjalili et al. (2014) proposed a BBA to solve problems in discrete search spaces. The authors found that BBA outperformed binary PSO and Binary Genetic Algorithm (BGA) for tested problems. In this study, the BBA was used to solve load SR problems in the electrical distribution networks due to its good performance in solving problems in the binary domain. As presented by Mirjalili et al. (2014), the BA works by updating the bat's position in each iteration until the best solution is reached. In discrete binary spaces, position updating means switching between 0 and 1 values. The question is how to employ the bat velocity in continuous space to update the position in binary space. The bat velocity projected from continuous to binary search space using the transfer function is presented in (4).

$$S(v_i^t(t)) = \frac{1}{1+e^{-\left(v_i^t(t)\right)}} \qquad (4)$$

Where $v_i^t(t)$ is the velocity of particle i in k^{th} dimension at iteration t. A new particle position in binary form is obtained using (5).

$$x_i^t(t+1) = \{0, \; rand < S(v_i^t(t+1)) \; 1,$$
$$rand \geq S(v_i^t(t+1)) \qquad (5)$$

Where $x_i^t(t)$ is the velocity of particle i in k^{th} dimension at iteration t.
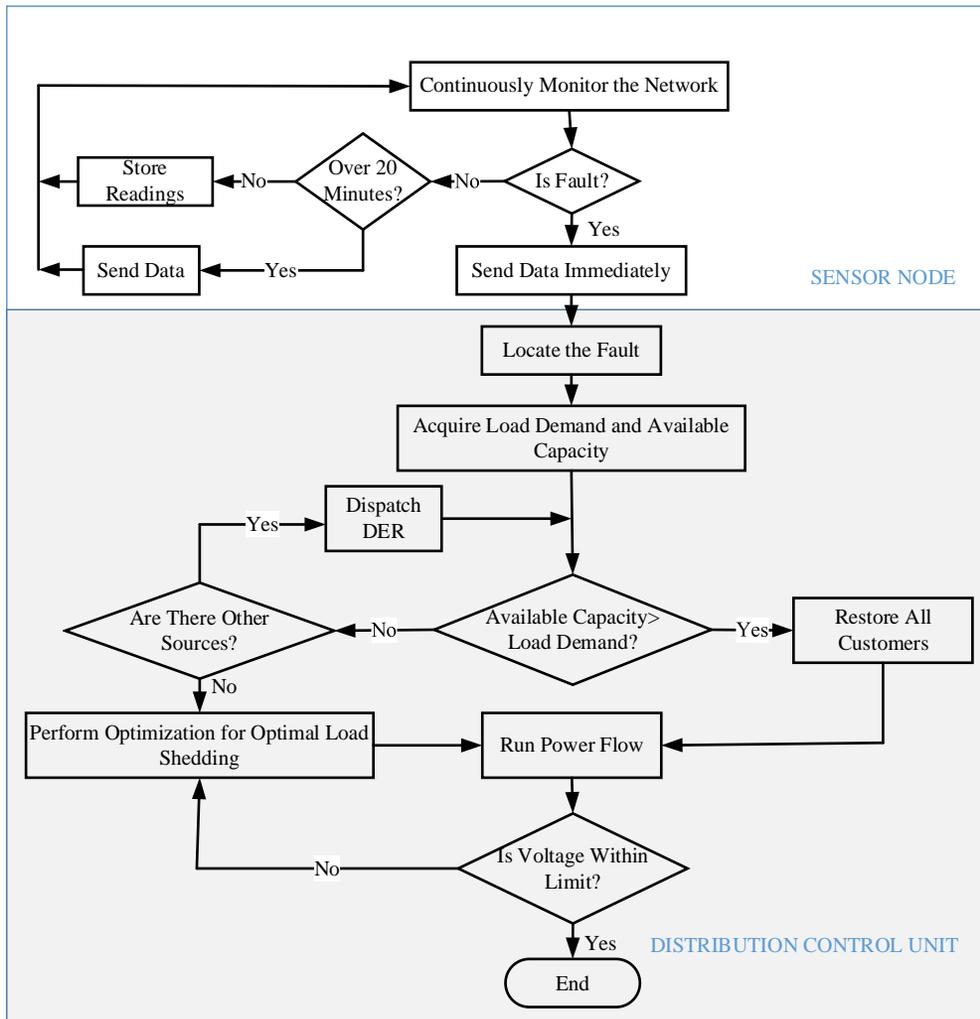
Figure 2:   Flow chart of the proposed service restoration architecture.

In solving the proposed SR problem, each bat particle represents a possible solution set. Each particle consists of binary values, ones, and zeros, with ones representing the retained nodes and zeros representing the removed nodes. Then, the BBA algorithm performs optimization of the problem and observes the constraints as presented in Section 2.3, until an optimal value is reached. The optimal value is the best particle in the possible solution set for each algorithm run. Evaluation of each particle is done using (1), after running power flow methods. More details of how the BBA works can be found in the study done by Mirjalili et al. (2014).

Results and Discussion
The proposed algorithm has been tested in the Tanzania SDN segment. The network data were taken from a study done by Kawambwa et al. (2021). The network comprises 79 nodes and accommodates 143 residential customers. The active peak load was 190 kW, and the reactive peak load was 142.5 kVar. The distribution transformer has a base voltage of 0.4 kV and 0.315 MVA. The minimum required voltage value for the Tanzanian power system is 0.9 p.u. Node numbering was acquired from the TANESCO GIS System. In a real distribution network, the priority of customers differs, therefore, this study

considered the priority of the nodes in three groups based on the weight. The considered priorities are high (1), medium (0.5) and low (0.1). It should be noted that the considered node priorities were not from TANESCO but were arbitrarily set to simulate the effects of node priority.

This study considered SR through the integration of renewable energy sources and optimal load shedding. Simulations were conducted considering two cases; the first tests the effects of DERs integration on the power system performances, and the second tests the performance of power systems due to a combination of DERs integration and load shedding. Power losses, voltage profiles, and the number of restored customers have been considered in all cases. All simulations were carried out using MATLAB 2017b on a 3.80 GHz 4 Cores core i7 computer with 16 GB RAM.

Case1: DERs integration in the electrical distribution network

In this case, the experiments were conducted to test the performances of power distribution networks due to the location and size of DERs. The DERs of 10 kW were placed at different locations considering different scenarios. The size of DERs was arbitrarily chosen. Figure 3 presents the integration of DER in the SDN compared to the baseline case. In Figure 3, the DER was placed at node 111 alone, at node 125 alone, and then at nodes 111 and 125 simultaneously.

Relative to the base case, with DER at node 111 and at node 125 alone provides the improved voltage profile, but still was below the minimum required threshold value of 0.9 p.u. as presented in Table 1. Although DERs of the same sizes have been used in both node 111 and node 125, the voltage profiles and power losses are different due to the influence of DERs location in the distribution network. Therefore, for efficient DERs integration in the distribution systems, optimal DERs placement is necessary.
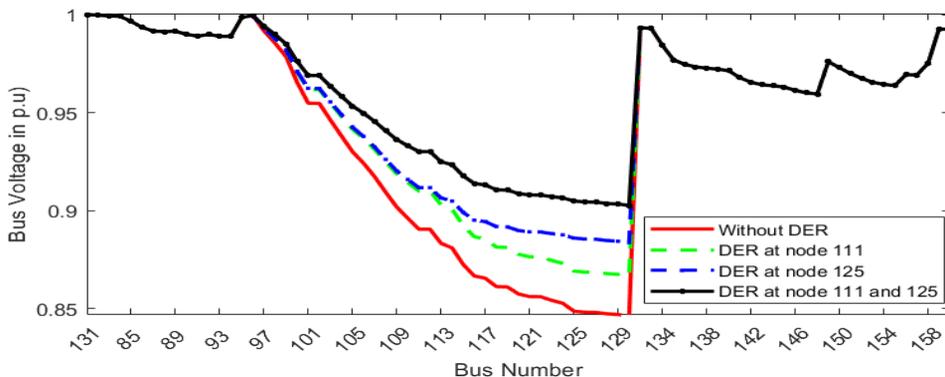
Figure 3: Voltage profile with DER only during service restoration.

Using two DERs simultaneously improves voltages to the acceptable value of 0.903 p.u. and reduces power losses, as presented in Table 1. This results showed improved performance of the system as the number of DERs increased. However, the allowed number of DERs and total injectable capacity is limited for each power system. When the limit is exceeded, the power system experiences negative impacts. Also, installing many DERs in the distribution network is not economically feasible.

Table 1: Service restoration results with consideration of DER

	Without DER	With DER at 111	With DER at 125	With DER at 111 and 125
Ploss	13.03565	10.40518	9.439849	7.476384
Qloss	7.039921	5.772302	5.37417	4.41762
Vmin	0.846271	0.86678	0.883679	0.902634

Case 2: Load shedding and DERs integration in the electrical distribution network

In this case the experiments were conducted to test the impacts of using optimal load shedding and DER in the SDN during SR compared with the baseline case. The voltage profile for the case of SR using load shedding only has been presented, as well as the combination of DERs and load shedding with a variation of DER capacity at different locations. The DERs of two sizes, 10 kW and 5 kW, were placed at different locations considering different scenarios. The considered scenarios were; load shedding only and a combination of load shedding, DERs integrations, and variations of DER capacity at different locations. The descriptions of the considered scenarios are presented in Table 2. The voltage profiles, power losses, and number of load shedding were considered. The BBA presented in the proposed solution section was used to provide optimal load shedding for considered scenarios.

Table 2: Descriptions of proposed service restoration scenarios

SN	Scenario	Description
1	Scenario 1	Base case
2	Scenario 2	With load shedding and one DER 10 kW at node 111
3	Scenario 3	With load shedding and one DER 10 kW at node 125
4	Scenario 4	Only load shedding without DERs
5	Scenario 5	With load shedding and DER of 10 kW at node 111 and 5 kW at node 125
6	Scenario 6	With load shedding and DER of 5 kW at node 111 and 10 kW at node 125

The voltage profiles for the base case, scenario 4, scenario 5, and scenario 6 are presented in Figure 4. The power losses are presented in Table 3, and the number of shed nodes is in Table 4. The results showed that scenario 4 and scenario 5 provided almost similar voltage profiles with improved performance relative to the base case. However, the number of shed nodes and power loss for scenario 5 is less than in scenario 4 due to the inclusion of DERs, as presented in Table 3 and Table 4. Therefore, including DERs in SR can help increase the number of served customers while improving power system performances, such as power losses and minimum voltage.

The results in Figure 4 show improved performance for scenario 6 relative to scenario 5. Scenario 5 and scenario 6 achieved the voltage level of 0.90 p.u. and 0.906 p.u., and power loss was 7.75 kW and 7.55 kW, respectively. Scenario 5 and Scenario 6 considered two DERs with interchanged sizes at node 111 and node 125. The results in Table 4 show that in a system without DERs or load shedding schemes, power systems experience significant power losses as the active power loss was reduced from 13.05 kW for base scenarios to less than 7.83 kW for other scenarios. Also, the total shedded load for scenario 6 is less than scenario 5, with 8.2943 and 13.2751, respectively.
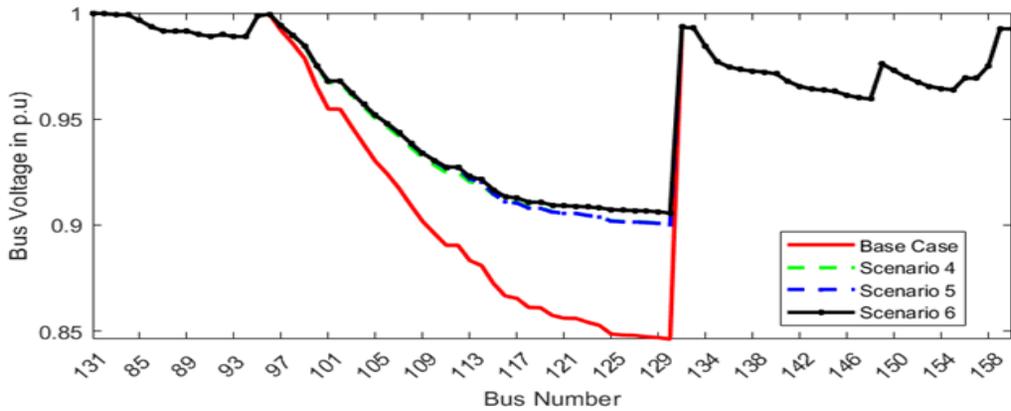
Figure 4: Voltage profile with DER and load shedding during service restoration.

In Scenario 2 and scenario 3 the DERs of the same size were used at different locations, but scenario 3 achieved a smaller number of shedding loads and less total load than scenario 2. Though scenario 6 has a larger size of installed DER than scenario 3, two nodes were shedded in both scenarios, and the total shedding load for Scenario 3 is less than scenario 6. The results revealed that different options during SR can lead to different numbers of nodes to be shedded, total shedding load, and the overall system performance. Therefore, the location and size of the DER in the SDN have shown a significant impact on the overall performance in terms of load shedding, voltage profile, and overall power loss, similar to results obtained by previous studies (Hussain et al. 2019, Kawambwa and Mnyanghwalo 2023, Rhodes and Roald 2022). Voltage profile improved by almost 6.7%, and power loss reduced by almost 74%.

Table 3: Power loss and minimum voltages for service restoration scenarios

	Scenario 1	Scenario 4	Scenario 5	Scenario 6
Ploss	13.03565	7.830971	7.746795	7.546369
Qloss	7.039921	4.603934	4.552371	4.46992
Vmin	0.846271	0.900368	0.900197	0.905642

Table 4: Shedding nodes and their sizes for service restoration scenarios

SN	Scenario 2		Scenario 3		Scenario 4		Scenario 5		Scenario 6	
	Nodes	Size (kW)	Nodes	Size (kW)	Nodes	Size(kW)	Nodes	Size (kW)	Nodes	Size (kW)
1	111	4.6797	127	1.1174	110	2.6176	110	2.6176	111	4.6797
2	118	2.3851	128	3.6146	117	3.0838	111	4.6797	128	3.6146
3	121	1.5102			118	2.3851	121	1.5102		
4	125	4.2597			125	4.2597	122	0.853		
5	127	1.1174			127	1.1174	128	3.6146		
6	128	3.6146			128	3.6146				
Total size		17.5667		4.7320		17.0782		13.2751		8.2943

Conclusion and Recommendations

This study presents the SR framework in Tanzanian SDNs through the use of IoT sensors and renewable energy sources. The proposed distributed framework presented an algorithm for engaging DERs and load shedding. Since SR is a complex and an NP-hard problem with many possible solutions, the BBA metaheuristic algorithm was used to find optimal solutions. In testing the proposed algorithm, two cases were considered, the first case considered the DER integration alone and the second case considered a combination of DERs

integration and load shedding. In the first case, the results revealed that increasing the number of DERs improves power system performance. However, there should be a balance on the number of DERs since they are costly, and each network has the maximum allowable DER size. Also, the locations and sizes of DERs have a significant impact on power system performances. Therefore, for proper DERs integration for SR, optimal DERs placement should be considered. In implementing SR schemes, a combination of load shedding and DERs integration should be considered options for improved system performance.

This study involved the use of IoT sensors for collecting network information and distributed processing through the use of DCU. Implementing the proposed framework will enhance the efficiency of the power system reliability, visibility, loss reductions, and improved user satisfaction. However, for efficient implementation of the proposed solutions, power system utilities should ensure the deployment of the IoT sensors along the network, deployment of the SR management system, bidirectional power flow adoption, installation of smart switches, enforce interoperability between subsystems and enhancement of distributed processing.

Acknowledgment

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