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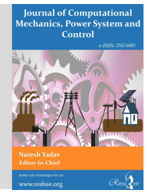

sRDOs : Substation Remote Diagnostic And Operation Solution for Distribution System Management

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Abstract: This work presents information regarding the extensive array of issues faced by both the consumers and the electric utilities in the distribution system in developing countries. Additionally, it protects the cost effectual solutions via remote monitoring, network operation, and diagnostic without compromising the reliability of the system. The utilizes transfers from the unintelligent network and manned networks to entirely unmanned smart grids, and switching activities at feeders and substations are controlled and managed remotely using the dedicated systems. The load in Load Voltage (LV) and Medium Voltage (MV) feeders is remotely monitored using the Substation Remote Diagnostic and Operation Solution (sRDOs) and distribution transformers as well as it permits the utility to disconnect non-paying consumers with completely no additional resource deployment and without suspended supply to paying consumers.

Keywords: Diagnostic, Electric Utility, Low Voltage, Medium Voltage, Remote Monitoring, System Reliability, Unmanned Smart Grids.

Nomenclature

Abbreviations	Descriptions
DS	Distribution Systems
FCSE	Fault Current Signal Energy
PMUs	Phasor Measurement Units
RF	Random Forest
HIF	High-Impedance Fault
DG	Distributed Generation
SVM	Support Vector Machine
SCADA	Supervisory Control and Data Acquisition
PQ	Power Quality
KNN	K-nearest neighbors
DN	Distribution Networks

1. Introduction

In electric power DS, the location of the rapid and precise fault can aid engineers in speedily recognizing, minimizing outage time and restoring faulted components, speeding up system restoration, and, therefore, greatly enhancing the reliability of the system [1].

If they are operated in rated conditions Distribution Transformers have a long service life. Nevertheless, if they are overloaded their life is considerably minimized, ensuing in unexpected failures and supply loss to a large number of consumers hence affecting the reliability of the system. In distribution transformers, Overloading and unsuccessful cooling of transformers are the important reasons for failure. Numerous power companies exploited the SCADA system for online monitoring of power transformers. However, extending the SCADA system for online monitoring of distribution transformers is a costly proposition [2].

For the current electric open markets, the interest in PQ on DS facilities has increased [12]. At present, PQ is concentrated for 2 most important reasons such as: initially, the high sensitivity of electronic and electric equipment; and subsequently, the service permanence requirements in serious processes like data management and control [13]. One part of the issue is associated with the continuity

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of power service. Transient and permanent faults origin power supply interruptions and fault location turn out to be a problem in the restoration process [14]. A few impedance-based techniques exploited to recognize and locate faults were proposed in [3] to resolve this issue in spite of the minimum ability of distribution facilities to put into practice it owing to their economical, operative, as well as technical implications [3].

Regarding the growth and development in the electric power infrastructure reliability, at present and in the future the world faces a significant issue [1]. The availability of the electric supply is vital for the development of the country [15]. For example, educational institutions, remote laboratories, hospitals, industries, and even other medium and small enterprises are based upon the extremely reliable power supply for the smooth running of their daily activities [11]. Hence, the outcomes of unreliable supply can affect threatening life circumstances and a lack in the development of the socio-economic.

Of course, developing countries such as Nigeria undergoes these outcomes more as electric utilities that have an extensive array of an issue to overwhelm if they are in the distribution or generation subsectors. Nevertheless, the distribution companies under their location on the power chain undergo highly varied and complicated operational and technical issues. Aforesaid issues are highly associated with the size as well as the network complexity and also the direct communication between the costumers and end users of the electricity. As the direct interface, the distribution company with the electric customers has thus burdened with the recovering/realizing duty of the revenue that drives the whole power chain [2].

For the DN, the future plan is a fully automated system i.e., a smart grid that is the combination of IT, control, "communication tools, and intelligent monitoring devices" into the system for enhanced system security and electricity supply utilization at the customer's end [9]. When a fully automated distribution grid may not probable instantaneous, the monitoring of the dangerous equipment in distribution substations has the main link in attaining this future plan [10]. This dangerous "distribution equipment is the distribution transformer" [3].

The major objective of this paper is to work on the development of a process that can evaluate the state of the key distribution network infrastructure, forecast its dynamic behavior for reliable/safe operations, and remotely cooperate with it to take a suitable decision.

2. Related Work

In 2022, MohamedAzeroual *et al.* [4] developed a technique on the basis of the multi-agent system for fault position and autonomous power restoration in the Power DS which comprises the DG. Effectual detection of fault, localization, highly protection was needed to control the system. It was from the blackout and configured them suitable subsequent to an outage. Also, this study analyzed the adopted protection technique by exploiting an open ring feeder distribution system. Moreover, the effect of the DG combination on fault position and multiple faults was identified in this article. In 2022, Diego L.C.Crespo and MiguelMoreto [5] developed a fault location approach for distribution networks. This was identified from PMUs by exploiting the synchrophasor voltages. Also, the adopted model could cope with data attained from a minimal of only 2 PMUs. By exploiting the bus admittance matrix fault point was computed beside the pre- as well as during-fault voltage phasors. In 2022, JianSun *et al.* [6] worked on an experimentation technique of a 10 kV 3-phase distribution line that was modeled. This was performed by exploiting a numerical experimentation platform. Furthermore, a fault location technique of three-phase distribution lines was designed. It was based on the criteria of the minimal mirrored FCSE. The positioning accurateness of the HIF was examined in diverse influencing factors. In 2022, Charalampos G.Arsoniadis *et al.* [7] addressed a fault position model, which was suitable and appropriate for unbalanced medium voltage overhead DS with or without distribution. The developed model uses only "synchronized voltage measurements from 2 measurement points inside the DS". The approach precisely validates the fault position for any type of short-circuit fault by using the basic bus-impedance-matrix-based fault analysis. In 2022, AliGhaem *et al.* [8] developed an ensemble learning-based technique to ascertain the type and position of faults in a smart distribution network. The utilized model was a stacking-based approach that comprises 2 important levels, each that comprises one or more independent classifiers. In the design of the developed model for the initial level, KNN multiclass SVM, and RF models were utilized.

2.1. Challenges

One of the main issues is the pressure of cost and pricing and the next one is the increasing demand and the final one is the pressure on aging infrastructure. Therefore, we understand that from the aforesaid challenges, a transition to fully automated distribution network deployment is required for electric utilities.

3. Proposed Method

To address these issues in a more economical and timely manner, a sRDOs was developed. This particular design gives the electric utility control over the customer's distribution substation feeder at the consumer's LV side. It also allows for automatic opening/interruption/isolation and closing/reconnection of the customer.

It consists of a pole-mounted sRDOs device on the consumers' LV side of the transformer, a microcontroller, and a GSM communication modem. The switching commands are sent via SMS to the relevant sRDOs device, either from a mobile phone or from a desktop with an attached modem (GSM Modem). A backup power supply ensures the sRDOs devices are always online and able to carry out isolations or reconnections on events of interruptions or power outages. The sRDOs are designed such that the device is pole mounted (pole mounting arrangement) to guarantee increased security of equipment. The design is done such that GSM communication is used with SMS commands for maximum reliability since sometimes mobile networks are unavailable yet text messages can still be delivered. There is a reply from the intelligent device for confirmation of switching operations depending on the situation at hand. In addition, there is what is called control security meaning that only preset numbers can send instructions or perform operations. Fig. 1 below shows the solution in a one-line diagram.

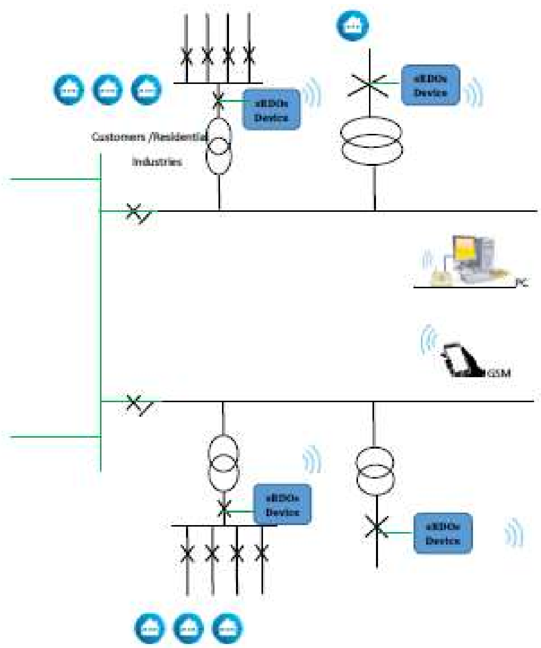

Fig.1.*Single line diagram for the deployment of sRDOs*

The specific components of the sRDOs device (that is parts in bits that made up the intelligent monitoring device) are as follows.

1) **Intelligent Feeder Pillars (IFP) -**These field devices are pole or ground-mounted intelligent feeder pillars that provide overload and short circuit protection to the distribution transformer and secondary LV circuit.
2) **sRDOs Controller-**
   This component is housed in the IFP and it is a critical part of the communication and control of the sRDOs devices at different locations in the field.
3) **Dispatch Center Control (DCC)** –It is an arrangement of a simple mobile phone operated by personnel at the base station or a personal computer (desktop with a modem) at the base station. All switching operations (isolation, interruption, reconnection, and so on) can be performed from this point. That is all opening and closing commands are remotely carried out.

When this solution is deployed, load shedding on overloaded MV and LV feeders can be achieved remotely. This also applies by extension to transformers depending on the diagnosis made at the secondary of the distribution transformer. Erring customers are automatically isolated with a single command sent to the device on the feeder pillar and this is a breakthrough because this will enhance increased safety of the technical personnel assigned to doing the disconnection. In general, this is a form of total distribution system monitoring void of complex Supervisory Control and Data Acquisition.

4. Conclusion

This intelligent sRDOs arrangement gives the electric utility a more reliable network through reliable automatic disconnection or isolation operations which can be deployed within limited periods without major changes in the distribution network configurations. The solution is simple, and user-friendly when it comes to operation therefore minimal training is required. This solution can also be worked upon in future research and upgraded to a more elaborate monitoring arrangement which can be incorporated and used for monitoring at High Voltages (HV) and Extremely High Voltages (EHV).

Compliance with Ethical Standards

Conflicts of interest: Authors declared that they have no conflict of interest.

Human participants: The conducted research follows the ethical standards and the authors ensured that they have not conducted any studies with human participants or animals.

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