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Intentional Islanding Algorithm for LVDC Microgrid-Based Disaster Resilient Power Systems

T.Venkatesh, A. Jaya Laxmi

Abstract**:** ***The combination of a low-voltage DC (LVDC) microgrid with an Intentional Islanding Algorithm (IIA) is presented in this paper to guarantee stable and reliable operation during microgrid disturbances. By isolating the LVDC network and identifying abnormal grid conditions, the proposed algorithm enables a rapid transition from islanded to grid-connected mode. Solar photovoltaic generation and battery energy storage are incorporated into the system to support sustainable energy use and maintain power balance during on-site operation. The performance of the proposed II algorithm is compared with conventional islanding detection algorithms, such as the passive islanding algorithm, the active islanding algorithm, and the hybrid islanding algorithm, using parameters including voltage stability, settling time, power balance, continuity of supply to critical loads, and power quality. A modified IEEE-recommended distribution system serves as the foundation for the LVDC microgrid model, implemented in MATLAB/Simulink. Simulation results demonstrate that the proposed IIA significantly improves system performance by reducing voltage fluctuations, accelerating system stabilisation, improving DC-link current behaviour, and ensuring uninterrupted power supply to critical loads during grid outages. These results confirm the effectiveness of the proposed approach in improving the reliability and resilience of LVDC microgrids.***

Keywords**:** ***LVDC Microgrid, Disaster Resilience, Renewable Energy Integration, Power Quality***

Nomenclature:
LVDC: Low Voltage Direct Current
IIA: Intentional Islanding Algorithm
IEEE: Institute of Electrical and Electronics Engineers
PV: Photovoltaic

I. INTRODUCTION

Natural disasters such as cyclones, floods, earthquakes, and heat waves significantly impact electric power systems [1] [2]. These disasters often cause power to go out for a time, which has a big impact on people and the economy [1]. Power plants and a lot of wires are the usual means of getting electricity to people, but they are not working well. This is due to the difficulty of protecting it and to the fact that it relies on a small number of power plants and a large amount of equipment to supply people with electricity [2]. So, people are trying to figure out how to strengthen the power system [1] [2]. Electric power systems need to withstand problems such as cyclones, floods, earthquakes, and heatwaves. Microgrid concepts and low-voltage DC distribution systems are utilized together [3, 4]. They seem like a good alternative to the usual air conditioning systems. Because they use energy more effectively, low-voltage DC systems are superior. They also have conversion stages and are easier to control. In addition, energy storage systems and energy sources are well-suited to low-voltage DC systems. The benefits of low-voltage DC microgrids include these. They are particularly useful for powering objects during disasters and emergencies [1] [3]. In these circumstances, low-voltage DC microgrids can be of great assistance. For a microgrid to operate effectively, it must detect problems in the main power grid and switch to operate on its own without interrupting power to critical loads [5] [6]. Microgrids must carry out this task. Control and detection of microgrid islanding are crucial for ensuring the microgrid's reliability [5]. There are a few ways that microgrids can detect when they need to switch to islanded operation. These ways are usually grouped into three types: methods, active methods and hybrid methods [6] [7]. These methods have some problems. They are as slow to react as possible and cannot detect everything. They can degrade power quality [7]. To fix these problems, this paper suggests a method called the Intentional Islanding Algorithm. This algorithm is made for LVDC microgrids [8]. The Intentional Islanding Algorithm aids in identifying issues, facilitates coordination of various energy sources, and maintains voltage stability when the grid is down. The Intentional Islanding Algorithm is a solution for LVDC microgrids. The proposed strategy is contrasted with techniques like passive and active islanding [6, 7]. We also examine islanding techniques, which combine these approaches. This comparison shows that the proposed approach works better when things go wrong, such as during a disaster. When things are out of the ordinary, we want to see how well the proposed strategy works.

II. LVDC DISTRIBUTION SYSTEM

In the 1920s, the first secondary voltage AC networks were constructed to improve city operations. Some ideas for connecting solar panels and wind turbines to secondary distribution networks are provided in IEEE standard 1547.6-2011 [9]. As depicted

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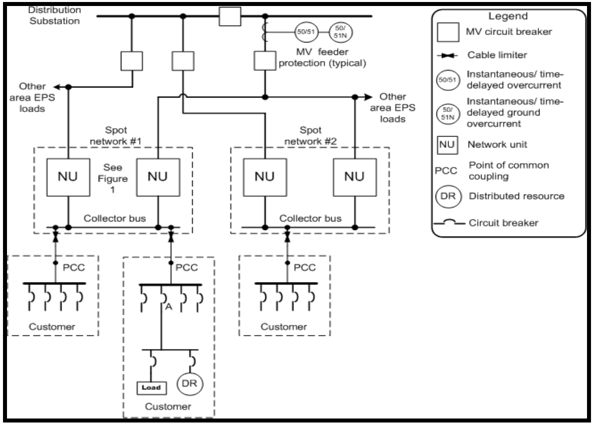
*Correspondence Author(s)
T.Venkatesh*, Research Scholar at JNTUHCHE and Faculty Member, University College of Engineering and Technology for Women, Kakatiya University-Wrangal, Hyderabad (Telangana), India. Email ID: thoorpativenkatesh@kakatiya.ac.in, ORCID ID: 0009-0003-7859-4830
Dr. A. Jaya Laxmi, Department of Electrical Engineering, Jawaharlal Nehru Technological University, Hyderabad (Telangana), India. Email ID: aj11994@jntuh.ac.in, ORCID ID: 0000-0002-6515-4401

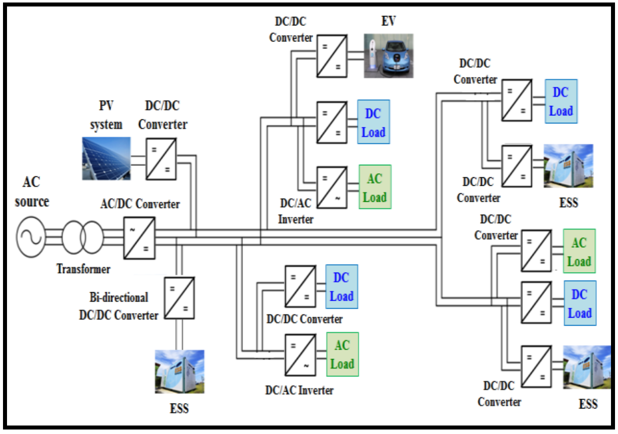
in Figure 1, this standard is crucial to the DC-voltage prototype system we are discussing. This direct-current voltage prototype system is still based on secondary-voltage AC networks [10].



[Fig.1: IEEE Std. 1547.6-2011 for Electric Power Systems, Secondary Distribution Network, and Secondary Resources]

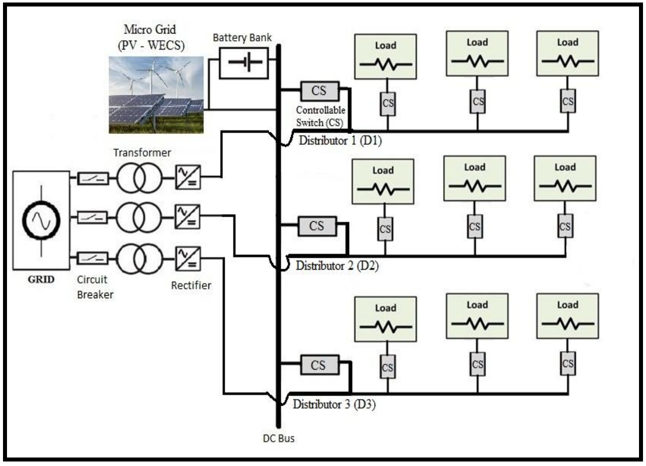
We are seeing more things that use direct current, such as computers, televisions, medical equipment, data centres, and communication devices. This is why direct current distribution systems are becoming popular again [11] [12]. Direct current systems are widely used in telecommunications, aircraft, boats, and data centres because they are more reliable and cost-effective than AC systems [11]. The big push to use energy sources such as solar panels and fuel cells has really accelerated the development of LVDC distribution networks. These things, like panels and electric vehicles, are mostly direct current. This is why people are working hard on distribution networks. Renewable energy sources, such as panels and fuel cells, are important. They are usually direct current. So, people are making distribution networks to help with this.

The IEEE LVDC Forum in India has suggested using a 48 V DC supply system for homes with low-power appliances, as shown in Fig. 2 [11]. LVDC microgrids are useful because they can operate when connected to the grid and when disconnected. This means the LVDC microgrids can switch between these two modes easily when grid problems arise, making the whole system more reliable and robust [12].



[Fig.2: IEEE std. Low Voltage DC (LVDC) Distribution System with a 48V]

Distributed Energy Resources can be any source at the distribution level, such as Renewable Energy Sources, Diesel Generators, Biomass, Fuel Cells, and Batteries [13]. Distributed Energy Resources are really useful. These Distributed Energy Resources can help a lot during natural disasters. We have a block diagram of the proposed prototype Low Voltage Direct Current Distribution System. It is shown in Figure 3.

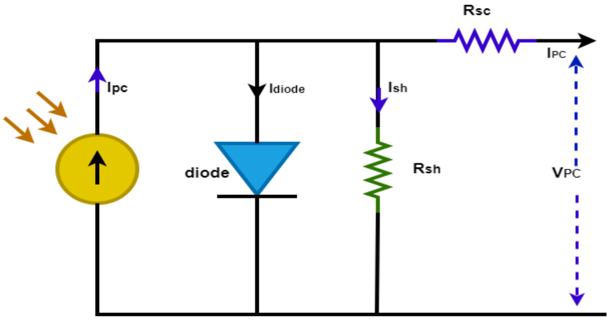


[Fig.3: Block Diagram of the Proposed Model of the Prototype LVDC Distribution System]

We have energy sources like Solar and Wind Energy Conversion Systems designed to work. These systems take the three-phase lines from the AC distribution system. Turn them into three DC distributor lines using Rectifiers. We are looking at a home that uses about 1 kW of power. So, three DC loads of 1 kW each are connected to each Feeder. There are three Feeders, F1, F2, and F3, each with three DC loads, for a total of nine DC loads on these three Feeders.

III. STANDALONE PHOTOVOLTAIC (PV) MODULE DESIGN.

A photovoltaic module converts solar energy into electrical energy [14] [15]. Parallel resistance, series resistance, and an ideal current source may be needed for PV modelling [14]. Figure 4 below illustrates a PV-equivalent circuit using a single diode [15].



[Fig.4: PV System]

Model characteristic equations are developed for solar module voltage and current.

$$I = Ipv - Is\left(\left(e^{\left(\frac{V+IRs}{\eta NsVt}\right)}\right) - 1\right) - \frac{V+IRs}{Rp} \qquad (1)$$

The electrical settings of the Solar modules are determined under optimal conditions (i.e., with a radiation level of 1000 W/m² and an ambient temperature of 25°C). Using formulations and Simulink model features, PV equivalent circuits are constructed with varying qualities [16]. Examining the solar panel model ND-1240Q2. The panel's parameters are listed in Table 1.

Table I: Solar System Parameters

PV Panel Parameters	Rated Value
V_{oc} Voltage at Open Circuit	37.5v
I_{sc}, current obtained at short circuit	8.61 a
Maximum Power Pmax	240w
Voltage at Maximum Power	30.2v
Current at Maximum power	7.95 a

IV. LVDC MICROGRID ARCHITECTURE

The proposed LVDC microgrid consists of a utility grid interface, photovoltaic arrays, battery energy storage, DC loads, and a centralised LVDC bus rated at 400 V [17] [18]. Power electronic converters are used to interface DERs and storage units with the DC bus [17]. Critical loads such as communication systems, healthcare facilities, and disaster response centres are prioritised during islanded operation, while non-critical loads may be curtailed if necessary [17] [18]. The LVDC system is modelled on a modified IEEE-recommended DER interconnection test system. Compared to AC systems, DC distribution reduces the number of power-conversion stages, improves efficiency, and simplifies control and protection schemes, making it particularly suitable for disaster-resilient microgrid applications. For the datasheet of the 240-watt PV module, you should explain how the research was conducted, including the research design, research procedures (in the form of algorithms, pseudocode, or other), how to acquire the data, and how to perform any tests. References should support the description of the course of research so that the explanation can be accepted scientifically [17] [18].

V. CONVENTIONAL ISLANDING ALGORITHMS

A. Passive Methods

Islanding detection techniques that work by keeping an eye on system parameters like voltage, current, and frequency [19]. These methods are easy to use and relatively inexpensive. However, the islanding detection techniques have a problem. They often fail to detect islanding, and they are slow to respond. This means that when islanding occurs, the voltage can change significantly [19].

B. Active Methods

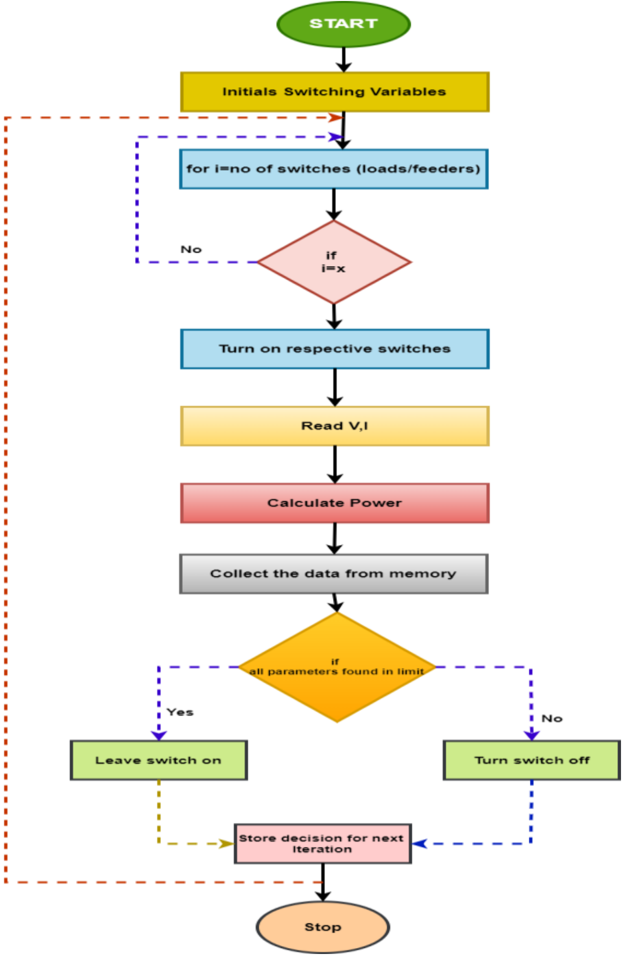
When we use islanding methods, we introduce small perturbations into the system and observe its response to determine whether islanding is occurring [20]. This way, we can accurately detect islanding. However, the things we add to the system to do this can actually worsen power quality. Causes problems when everything is working normally.

C. Hybrid Methods

Hybrid islanding techniques use both active methods to reduce the areas where detection cannot occur and to speed up the detection process [21]. However, these techniques have some problems. They are complicated, and there are still some issues with the quality of the leftover power. These are the limitations of hybrid islanding techniques.

VI. PROPOSED INTENTIONAL ISLANDING ALGORITHM

The Intentional Islanding Algorithm is designed to help the system switch quickly and smoothly from connected to the grid to islanded operation [22] [23]. This algorithm always monitors the grid's voltage. The flow of power. If it detects something is wrong with the grid, such as a problem or a power outage, it intentionally separates the LVDC microgrid from the grid. When the system is working on its own, it uses a team effort to control energy from panels, wind, and batteries to keep voltage stable and power balanced in the Intentional Islanding Algorithm. Battery energy storage gives us the power we need away when things get unstable. On the other hand, renewable energy sources provide a steady power supply [22] [23]. The proposed IIA ensures that the power supply remains uninterrupted and the voltage is always at the required level. This means critical loads get the power they need without interruption. Power quality is also improved with the proposed IIA.



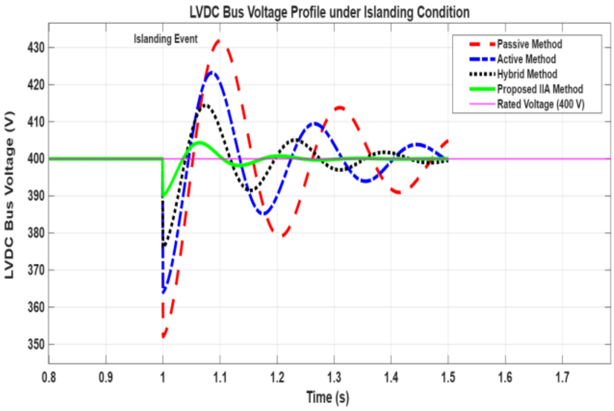
[Fig.5: Proposed IIA Flow Chart]

VII. SIMULATION RESULTS AND DISCUSSION

Figure 3 was developed in MATLAB/SIMULINK to compare the performance of the proposed IIA with conventional algorithms, including the passive islanding algorithm, the active islanding algorithm, and the hybrid islanding algorithm.

A. Comparison of LVDC Bus Voltage Profile

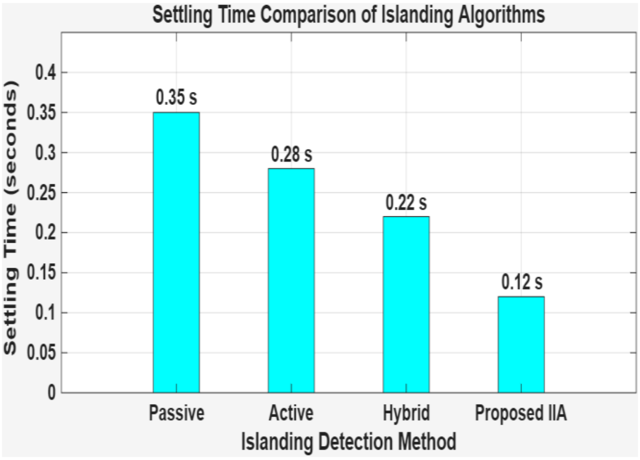
The simulation results show that the passive islanding algorithm induces large voltage changes and that the oscillations persist for a long time. The active and hybrid islanding algorithms perform a little better, but the voltage remains unstable, as shown in Figure 6. On the other hand, the proposed IIA keeps the LVDC bus voltage very close to 400 V, as it should be, and it varies only slightly. It also settles quickly, which means the IIA is very good at keeping the voltage stable. The IIA produces small voltage changes, and the voltage stabilises very quickly.



[Fig.6: LVDC Bus Voltage Profile]

B. Settling Time Comparison

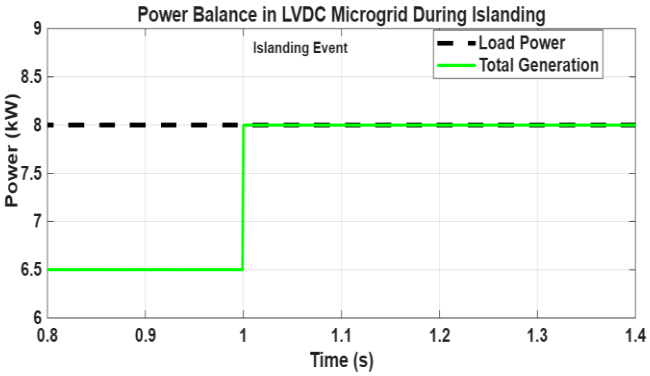
The settling time (0.12 s) of the proposed IIA is very low compared to conventional Islanding algorithms such as passive Islanding (0.35s), Active Islanding (0.28s), and Hybrid Islanding (0.22 s), as shown in Figure 7. These algorithms take time to stabilise because they detect things late and oscillate frequently. The proposed IIA becomes stable very quickly after the islanding happens compared to conventional Islanding algorithms.



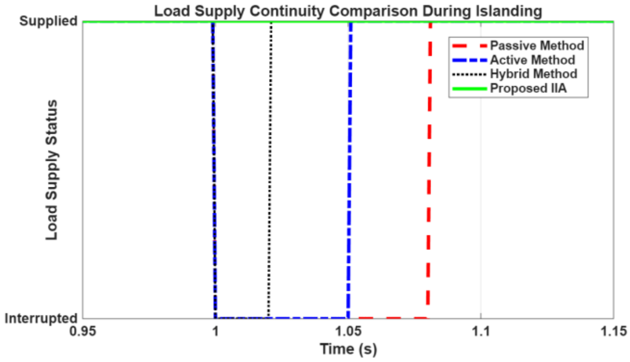
[Fig.7: Comparison of Settling Time]

C. Power Balance and Load Supply Continuity

When the power system is operating on its own, the new IIA system ensures that power is shared properly among the panels, wind turbines, and battery systems. The important things that need power do not lose it. With the old ways, they do lose power for a little while because the control system is too slow. The IIA system helps the solar panels, wind turbines and battery systems work better.



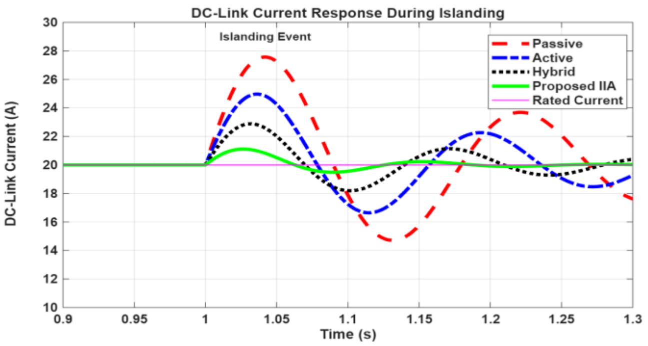
[Fig.8: Comparison of Settling Time]



[Fig.9: Comparison of Settling Time]

D. Comparison of DC-Link Current

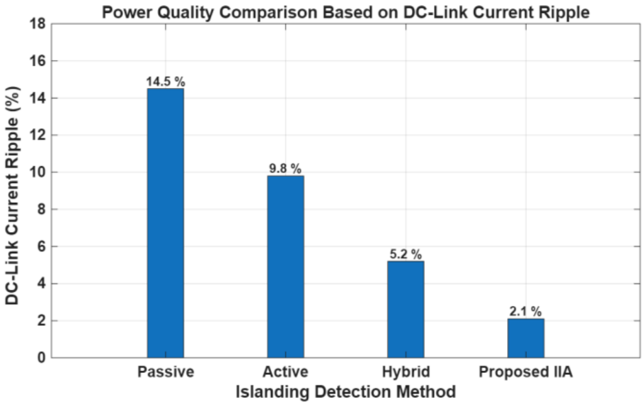
Figure 10 shows the DC-link current response of different islanding algorithms. It is noted that the conventional passive islanding algorithm exhibits the largest oscillations and the greatest deviation from the rated current during islanding, indicating slower stabilisation and poorer dynamic performance. The active islanding algorithm shows improved response compared to the passive approach, but it still exhibits noticeable overshoot and oscillatory behaviour. The hybrid islanding algorithm shows reduced oscillations and faster convergence toward the rated current. The **p**roposed IIA provides the most stable response with less overshoot and a rapid settling time, closely tracking the rated current. This shows that the proposed IIA significantly improves DC-link current stability during islanding conditions compared to conventional algorithms.



[Fig.10: Comparison of DC-Link Current]

E. Comparison of Power Quality

Figure 11 shows the comparative power quality performance of various islanding algorithms. It is noted that the passive islanding algorithm yields the highest ripple of 14.5%, indicating poor power quality under islanding conditions. The active islanding algorithm shows better performance than the passive islanding algorithm, with a ripple of 9.8%, and the hybrid islanding algorithm gives a ripple of 5.2%. The proposed IIA achieves the lowest ripple of 2.1% and demonstrates superior performance in improving power quality.



[Fig.11: Comparison of Power Quality]

VIII. CONCLUSION

This work describes integrating an LVDC microgrid into the Intentional Islanding Algorithm (IIA) to improve system performance during islanding events. The simulation results show that the proposed IIA achieves superior performance in terms of voltage stability, settling time, and power quality compared with conventional islanding algorithms, including the passive islanding algorithm, the active islanding algorithm, and the hybrid islanding algorithm. The proposed algorithm also supplies continuous, high-quality power to the loads. Hence, the combination of IIA in an LVDC microgrid can be considered an effective approach to enhance grid resilience.

DECLARATION STATEMENT

Authors of review-type articles are required to include a declaration of accountability in the article that stipulates each author's involvement. The level of detail differs; Some subjects yield articles that consist of isolated efforts that are easily voiced in detail, while other areas function as group efforts at all stages. It should be after the conclusion and before the references.

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- **Data Access Statement and Material Availability:** The adequate resources of this article are publicly accessible.
- **Author's Contributions:** The authorship of this article is contributed equally to all participating individuals.

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AUTHOR'S PROFILE

Venkatesh Thoorpati is a Research Scholar at JNTU Hyderabad and an Assistant Professor in the Electrical Engineering Department at the University College of Engineering and Technology for Women, Kakatiya University-Wrangal, Telangana State, India. He received his B.Tech. in Electrical and Electronics Engineering from Kakatiya University in 2009 and his M.Tech. in Power Electronics from JNTUH in 2013, and is currently pursuing a PhD at JNTUH. His research interests include Smart Grid Technologies, microgrids, Distributed Generation, Applications of Renewable Energy Technologies to Disaster Management, and Artificial Intelligence Applications to Power Systems.

Dr. A. Jaya Laxmi (Senior Member, IEEE) was born in Mahaboob Nagar District, Andhra Pradesh, on 07-11-1969. She completed her B.Tech. (EEE) from Osmania University College of Engineering, Hyderabad in 1991, M. Tech. (Power Systems) from REC Warangal, Andhra Pradesh, in 1996 and completed a PhD. (Power Quality) from Jawaharlal Nehru Technological University College of Engineering, Hyderabad in 2007. She worked as a Coordinator at the Centre for Energy Studies for 5 years and 6 months. She has five years of Industrial experience and 26 years of teaching experience. and presently working as a Professor at JNTUH College of Engineering, Hyderabad. She has 137 International and Indian Journals to her credit. She has 153 International and National papers published in various conferences held in India and abroad. She has authored one Book titled **"Basic Electrical Engineering"** She has worked on a Research project titled "Method and System for Providing Power Resilience During and Aftermath of Disasters Using Intentional Islanding (Centre for Disaster Management in Electrical Engineering)" with funding of Rs. 78 lakhs from TEQIP-II. Recipient of "State Awards to Meritorious Teachers-2022" from the Higher Education Department, Government of Telangana. Recipient of "AICTE Lilavati Award 2021-22" with a cash prize of Rupees one Lakh and a certificate. Recipient of"Bharat Jyothi Award", Recipient of "Best Women Faculty" for WE - Awards 2019 in Telangana Information Technology Association (TITA). Recipient of Best Paper Award.Recipient of "Outstanding Woman Educator & Scholar Award".