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Design of a feedback for fault localization in a DC micro-grid using Siemens TIA Portal and Proteus Professional

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Abstract- Direct-current (DC) micro-grids have gained significant relevance in modern power architectures due to their high efficiency, renewable-energy compatibility, and seamless integration with distributed energy resources. However, despite these benefits, the susceptibility of DC systems to rapid fault propagation poses critical operational risks. Effective and intelligent fault-localization mechanisms are therefore essential to minimize damage, reduce downtime, and ensure grid reliability. This study presents the design and simulation of a feedback-based fault localization system for a DC microgrid using Siemens TIA Portal for automation logic development and Proteus Professional for electronic circuit modelling. The method detects abnormal variations in current and voltage along the grid, automatically determining fault location and generating corrective feedback signals for appropriate protection response. Simulation results demonstrate that the system accurately identifies faulted segments in real time and triggers isolation feedback, thereby maintaining system stability and preserving healthy network zones. The developed approach offers a low-cost, scalable, and flexible solution suitable for industrial micro-grids, renewable-driven installations, and DC power distribution networks. Future research may involve hardware prototyping, integration of intelligent diagnostic algorithms, and evaluation under varying load and renewable input conditions.

Keywords: automation and control, DC micro-grid, distributed energy systems, fault localization, feedback control, Proteus Professional, Siemens TIA Portal.

I. INTRODUCTION

The increasing demand for efficient, flexible, and resilient power systems has led to a surge in interest in microgrids localized energy systems capable of integrating distributed energy resources (DERs) and operating in either grid-connected or islanded mode. Among the different configurations, a direct-current microgrid (DC-MG) presents significant advantages over traditional alternating-current (AC) systems, including simplified conversion stages, improved efficiency, and better compatibility with a growing fraction of DC loads and renewable DERs (Ali et. al, 2021; Liu, Zhang and Rizzoni, 2018).

Amadi et al. (2025) described a DC microgrid as a network that includes DC power components, such as a DC voltage or current source and its associated circuitry. In their study, the DC microgrid consists of six solar PV arrays, with each array featuring 32 solar panels rated at 12V, arranged in an 8x4 configuration (8 columns and 4 rows). As a result, each PV array generates a total voltage of 72V. These arrays are connected to individual contactors (MCB1-6). The DC grid is equipped for fault detection through smart electronics that include an Arduino Nano microcontroller, a WCS1600 current sensor, and an LCD display. Fault detection and localization are further enhanced by integrating a Simatic S7-1200 CPU 1214C PLC into the system, which has a sensing range of 200A.

However, these benefits come with protection challenges unique to DC-MGs. In particular, fault events such as short-circuits or ground faults can trigger extremely large surge currents because the absence of zero-crossing in DC makes interruption more difficult and fault currents rise quickly (Ali et al., 2021; Modu et al., 2023). As a result, ensuring timely and accurate fault detection, localization, and isolation is essential to prevent equipment damage, minimize downtime, and preserve the reliability of the DC-MG (Ali et al., 2021).

The study "Multi-Objective Optimization of Micro-grid Design with Hybrid Renewable Energy Sources for a Sustainable Environment" effectively highlights the potential of hybrid energy systems to deliver reliable, cost-effective, and environmentally friendly electricity. By integrating solar power, wind energy, battery storage, and optional diesel generation, the research creates a balanced framework that addresses the conflicting goals of minimizing costs, reducing emissions, and ensuring system reliability (Uche-Ibe, Amadi, and Ijeoma, 2026).

In response to these challenges, a variety of fault-management strategies have been explored, ranging from over-current detection to advanced signal-processing and differential protection schemes (Modu et al., 2023; Kant et al., 2023). Yet many of these approaches face limitations: standard over-current relays may mis-coordinate under high fault currents; conventional distance-based methods are often inapplicable in low-impedance, short-span DC networks; and high-speed fault localization remains nontrivial, especially when aiming for selective isolation of only the faulted segment without disturbing healthy parts (Ali et al., 2021; Modu et al., 2023).

Amadi et al. (2025) explained that a DC microgrid is a network comprising DC power components, such as a DC voltage/current source and its accompanying circuitry. In this work, a DC grid comprises six solar PV arrays, with each array consisting of 32 12V panels arranged in an 8x4 configuration (8 columns, 4 rows). Thus, each PV array has a total voltage of 72V. These PV arrays are connected to individual contactors (MCB1-6). This DC grid was capable of fault detection through the use of smart electronics comprising an Arduino Nano microcontroller, a WCS1600 current sensor, and an LCD. Fault detection and localization were accomplished by integrating a Simatic S7-1200 CPU 1214C PLC into the system, with a sensing range of 200A

In this context, the present study proposes a fault-localisation feedback mechanism for a DC microgrid, implemented through simulation and automation tools namely Siemens TIA Portal (for control logic design) and Proteus Professional (for electronic circuit simulation). By leveraging these platforms, the research aims to develop and validate a feedback scheme that can detect, locate, and signal faults in real time, thereby enhancing the fault-tolerance, safety, and operational continuity of DC microgrids. The rest of the paper is structured as follows: first, a review of related work on fault detection and localization in DC microgrids; then the design methodology for the feedback system; followed by simulation setup and results; and finally a discussion and conclusion highlighting the contributions and potential future improvements. The demand for electrical power is rapidly increasing in emerging economies, resulting in more complex power system networks (Okosi, Amadi, and Ijeoma, 2025). Electrical power systems are designed to deliver consistent and reliable voltage to end users (Amadi et al., 2025). By focusing on localized energy systems, adopting renewable technologies, improving energy efficiency, and promoting inclusive policies, we can create a world where energy access is considered a fundamental right rather than a privilege (Ijeoma, 2025).

Chen et al., (2022) developed a system for protecting grid-connected AC micro-grids from short-circuit faults. The system relies on a microcontroller, the dsPIC33FJ32GP204, which enables quick detection and regional location. The PSCAD model was used to create the short-circuit fault simulation model, and Proteus is used to import various fault waveforms produced by the simulation. The protection system that was built was utilized to convert the wavelet energy spectrum of various fault waveforms that were produced through simulation. Subsequently, circuit breakers received the appropriate control signal. Based on the findings of the simulation, the control system was able to identify the fault region of microgrid short circuits and provide a selected protection signal in a timely and accurate manner.

Reza et al., (2021) examined different prediction and localization techniques, along with their benefits, drawbacks, technical reports, and patents in traditional distribution networks, micro-grids, and smart grids. A current review of fault location and distance measurement techniques that take into account various network types (AC/DC), the presence of distributed generation (DG), communication and automation standards, synchronous and asynchronous measurement, magnetic measurement, and state estimation-based techniques were all included in their study.

A novel, quick, and precise technique for fault identification, localization, and classification on multi-terminal direct current (MTDC) distribution networks linked to solar distributed generation and loads was presented by Mostafa and Navid (2021). A circuit kit was linked to the network using this technique. The process of fault detection involved measuring the linked kits' current and the traveling waves of the fault current, then applying the results to a mathematical morphological filter within the fault time. Using circuit equations, current calculations, and a mathematical morphological filter, identify the kind and location of defects. Disturbances in the DC distribution network were classified as DC series and ground faults. The suggested approach was put to the test in a solar DC network that was linked to numerous flaws in solar resources and energy storage.

The outcomes demonstrate the applicability of the suggested approach. The suggested fault location and classification strategy has several advantages over traditional methods, chief among them being its increased speed and accuracy. In the worst scenario, the fault location error of the algorithm provided is less than 6.5 percent. This technique performs exceptionally well in high impedance faults and is resistant against changes in sampling frequency (0.5-50 KHz) and fault resistance (0.005-120 Ohm).

A report on a fault detection and location strategy for DC micro-grids was presented by Sharif et al. (2022). Recurrent Neural Networks (RNNs) were employed in their method to find faults in DC micro-grids due to advancements in Artificial Intelligence (AI) and the appropriate performance of smart protection systems in AC micro-grids. This method measured the main bus voltage and feeder current to locate and detect faults. Additionally, the effectiveness of the suggested approach was evaluated for both the micro-grid's islanded and grid-connected operating modes. The outcome verified the suggested scheme's effectiveness. RNNs and DC microgrid simulation were designed using MATLAB and DIgSILENT, respectively.

A short-circuit fault protection system for grid-connected AC micro-grid is designed based on dsPIC33FJ32GP204 microcontroller in the work of Chen et al., (2022). The PSCAD model was used to create the short-circuit fault simulation, and Proteus was used to import several fault waveforms produced by the simulation. The protection system that was built was utilized to convert the wavelet energy spectrum of various fault waveforms that were produced through simulation. Subsequently, circuit breakers received the appropriate control signal. The outcomes of the simulation demonstrated that the control system could identify the fault location causing micro-grid short circuits rapidly and precisely, as well as generate a selective protection signal.

A work on decentralized sensor fault-tolerant control of DC micro-grids using the attracting ellipsoid approach was given by Soliman et al., (2023). This research established a new passive fault-tolerant control technique for DC-islanded micro-grids with sensor failures. The recommended method was applied to keep the system stable when there were defects, like malfunctioning actuators and sensors, as well as component failures. When the defect was not identified at all, or when the fault was not fully understood and some of its ambiguity was misinterpreted as uncertainty about the dynamics of the system after the fault, the recommended control worked well.

With respect to linear matrix inequalities (LMIs) and the attractive ellipsoid technique, the design was based on a derived sufficient condition. The state trajectories were brought into a compact region, which included the origin (an ellipsoid with minimum volume), using the ellipsoidal stabilization technique. Lastly, computational research was done on a DC micro-grid system to evaluate the viability of the suggested fault-tolerant control strategy. The simulation findings showed that the suggested control method could greatly improve the dependability and effectiveness of DC micro-grid systems when compared to earlier research.

The fault current characteristics in Huiyin and Zhenyu (2023) were examined using a fault RLC equivalent circuit. The characteristics at various fault location points were then examined using an independent DC micro-grid model made up of a PV generation unit, an energy storage unit, and a load unit. By merging the present abrupt change direction with the improved current change rate, a fault detection technique was created. With a bus voltage of 400 V, a DC micro-grid model was constructed and simulated using Matlab/Simulink. The results of the simulation demonstrated that the suggested method could identify and isolate short circuits in buses and units in less than two milliseconds, guaranteeing the system's proper operation. This capability had some reference value for low-voltage DC micro-grid fault protection at independent operation sites.

A paper on a hybrid AC/DC micro-grid based on solar and wind renewable energies was presented by Jasim et al., (2023) with the aim of reducing the number of DC/AC/DC power conversion operations. They observed that MG instability increases with increased penetration rates of renewable energy. By keeping levels of production and consumption in balance, this volatility could be lessened. In order to handle coordinated power flowing over both AC and DC lines and to achieve system stability under variable generation, load, and fault conditions, coordination control was developed in this work. In a synchronous reference frame, the MG implemented a bidirectional main converter that was managed by a digital proportional resonant (PR) current controller.

Due to its high gain at the resonant frequency, the PR controller reduced harmonics by acting as a digital filter with infinite impulse response (IIR) characteristics. In addition, the applied PR controller had no steady state error, was simple to set up, could adjust to variations in grid frequency, and swiftly followed the reference signal. Additionally, a maximum power point tracker (MPPT) setup boost converter was used to support the solar photovoltaic (PV) based distribution generation (DG) in order to collect the greatest amount of power. They noticed that power electronic converters may encounter excessive current during short circuit faults as a result of the use of converter-connected DG units in MGs. Since fault detection enables the system to swiftly isolate and recover from defects, it is essential to the control and operation of MG.

Because artificial neural networks (ANNs) are accurate, fast, and robust, this research developed an intelligent online fault detection, diagnosis, and localization information system for hybrid low-voltage AC/DC MGs. A more dependable MG was produced as a result of the suggested scheme's ability to quickly identify issues with the AC bus. The neural network was trained on a variety of short circuit faults in order to verify its validity. The MG's performance was assessed with the use of MATLAB software. The simulation findings indicated that the suggested control strategy maintains the dynamic stability of the MG, met the load demand, and achieved energy balance as well as properly predicts faults.

Components of an Electrical Grid

The following are components of an electrical grid:

- Generation
- Transmission
- Substation
- Distribution

Generation

The process of producing electric power from primary energy sources, usually at power plants, is known as electricity generation. These include, but are not limited to, electromechanical generators powered by heat engines, wind, or water kinetic energy are typically used for this. Geothermal energy and solar photovoltaic are other energy sources. The production of the grid is the total power output of its generators, which is commonly expressed in gigawatts (GW). (Reza et al., 2021).

Transmission

The bulk transfer of electrical energy from a generating site to an electrical substation, which is connected to the distribution system, is known as electric power transmission. This is accomplished by a network of interconnected wires. (Yang et al., 2016). The local wire connecting high-voltage substations to customers is not the same as this networked system of connections. The transmission system is capable of long distances since power is frequently generated distant from its consumption point. Higher voltages and lower currents result in greater transmission efficiency for a given power. As a result, for customer distribution, voltages are stepped down at local substations and up at the generating station.

(Bhargav et al., 2019).

Three-phase transmission is most common. Because the neutral and ground wires are shared, three-phase systems may provide far more power for a given piece of cable than single-phase systems can. In addition, three-phase motors and generators have higher efficiency than single-phase ones. However, resistive losses, which depend on distance and follow a square rule for current, are one of the primary losses for conventional conductors. There can be a 1-4% loss in high voltage AC transmission cables for every 100 miles. (Abdali et al., 2019). However, high-voltage direct current can have half the losses of AC. Over very long distances, these efficiencies can offset the additional cost of the required AC/DC converter stations at each end (Hare et al., 2016).

Repetitive paths abound in complicated transmission networks. The geology and available land frequently dictate the physical arrangement. The majority of transmission grids give the same level of dependability as more intricate mesh networks. Redundancy permits line breakdowns and just reroutes power until repairs are made. (Chen et al., 2016).

Substation

Although substations can be used for a wide range of tasks, they typically step up and step down voltage to change it from low to high. The voltage may change multiple times between the generator and the final user. (Makkieh et al., 2020).

The three main types of substations, by function, are:

1. **Step-up substation:** These use transformers to raise the voltage coming from the generators and power plants so that power can be transmitted long distances more efficiently, with smaller currents (Javed and Chen, 2020).
2. **Step-down substation:** These transformers lower the voltage coming from the transmission lines, which can be used in industry or sent to a distribution substation (Kokoszka et al., 2023).
3. **Distribution substation:** These transform the voltage lower again for the distribution to end users (Lin et al., 2021).
4. Aside from transformers, other major components or functions of substations include:
5. **Circuit breakers:** Used to automatically break a circuit and isolate a fault in the system.
6. **Switches:** To control the flow of electricity, and isolate equipment.
7. **The substation busbar:** Typically, a set of three conductors, one for each phase of current. The substation is organized around the buses, and they are connected to incoming lines, transformers, protection equipment, switches, and the outgoing lines (Bayati et al., 2021).
8. Lightning arresters
9. Capacitors for power factor correction
10. Synchronous condensers for power factor correction and grid stability.

Distribution

The last phase of power delivery is distribution, which transports electricity from the transmission system to specific users (Wang et al., 2023). Substations lower the transmission voltage to a medium voltage of between 2kV and 35kV when they are connected to the transmission system. This medium voltage power is transported by primary distribution lines to distribution transformers situated close to the customer's property. Once more, distribution transformers reduce the voltage to the voltage used. Clients that require much more power might be directly connected to either the sub-transmission level or the main distribution level. Distribution networks can be classified as either a network or radial (Kant et al., 2023).

There are different sizes of electrical networks that can cover entire continents or nations. Micro-grids, wide area synchronous grids, and super grids range in size from tiny to enormous. The majority of the time, grids is synchronous, which means that all distribution zones use synchronized three-phase AC frequencies to operate (such that voltage swings occur at almost the same time). This makes it possible for AC power to be transmitted throughout the region, linking a sizable number of electricity producers and consumers and maybe opening the door to redundant generation and more efficient electricity markets. As part of the delivery of electricity, the combined transmission and distribution network is referred to as the "power grid" in North America, or simply "the grid." The network is referred to as the National Grid in the UK, India, Tanzania, Myanmar, Malaysia, New Zealand, and Nigeria. (Hussain et al., 2020).

Despite the fact that electrical grids are widely used, 1.4 billion people globally did not have access to one as of 2016. The population with access to grid electricity is expanding, together with the rate of electrification. In 2017, there were about 840 million people without grid power (mainly in Africa), making up about 11% of the world's population. In 2010, there were 1.2 billion people without grid electricity (Somasekar et al., 2020).

A microgrid is a novel system that supplies the required thermal and electrical energy. It is a tiny grid system that combines customer loads with dispersed power sources (Shuai et al., 2019). A microgrid is a small grid that is typically included in the wide-area synchronous regional grid. Types of grids that can disconnect and function independently, arranged according to size. When there are disruptions to the main grid, it can act in this manner (Küçüker & Korkmaz, 2019). Islanding is the term for this, and it could continue endlessly on its own resources. Microgrids usually use distributed generators and a lower voltage distribution network than larger grids. In remote locations, micro-grids can not only be less expensive to install but also more resilient. Power electronics are used to regulate and convert energy in micro-grids (Xu et al., 2019).

Micro-grids are highly interconnected and controllable systems that comprise generators, loads, energy storage devices, and control devices (Zheng et al., 2020). The primary energy source for a micro-grid is renewable energy, which is transformed into electricity and heat for production and living through the use of micro gas turbines, internal combustion engines, fuel cells, solar cells, wind turbines, and other devices (Li et al., 2019; Huang et al., 2019). Customers directly benefit from micro-grids, which also lower line construction costs and provide a more affordable and dependable power supply (Wang et al., 2011).

Microgrids have two modes of operation: grid connection and islanding. Within the microgrid, there are several dispersed power sources. The many operating modes and distributed power regulation techniques in the microgrid make fault identification more challenging in the event of a short-circuit problem (Muhammad et al., 2020). The micro-grid can employ distributed generation technologies flexibly and effectively to guarantee the quality of the power supply at the point of common coupling in the event that the external distribution network fails. In this scenario, the microgrid can enter islanding mode and self-power using distributed power sources.

Technological or meteorological changes, human mistakes, physical damage to equipment, and numerous other factors can all be blamed for power system failures. Since these main faults have the potential to cause a chain reaction of secondary and tertiary failures, identifying these faults in the system is the first and most important step in crisis mitigation in the grid. It's critical to comprehend the grid's structure and network in order to comprehend how these breakdowns start and spread.

As per Matthieu et al., (2020), fault localization ascertains the type of fault and its possible location, while fault detection determines the incidence of a fault. Fault localization is one of the main responsibilities of power system operators. The defect may cause issues such as service disruptions, network instability, and device damage, all of which would lower the dependability of the network. As a result, both electrical companies and their customers suffer financial losses.

Traditional fault localization techniques in distribution network feeders are ineffective, especially when the network's geographic dispersion is large. It takes time and money to cover a large region, both in terms of the equipment and labour needed. As a result, in distribution networks, automatically identifying and promptly locating faults is crucial. Benefits of automatic fault location and prediction include time and human resource savings, improved system preparedness for power maintenance, future schedule modification, and improved economic aspects. These elements raise customer satisfaction and raise the system's dependability indices (Dashti, 2021).

In order to use past fault occurrences as a reference, fault detection establishes that the types of defects, or classes of faults, are well-defined and have previously occurred. In the grid, there are numerous primary fault detection symptoms that are linked to various latencies and reporting times. If a primary defect is found and reported within those parameters, it can stop more serious failures. A crucial factor is, among other things, the analysis of the imbalance between supply and demand.

A demand-supply imbalance brought on by fluctuating customer demands has always been a contributing reason to some of the previous grid failures. For most power systems, predicting the electricity demand is of importance and has been the subject of numerous research articles. The fulfilment of numerous requirements commonly referred to as "power quality," whose parameters are intimately related to one another, is necessary for the regular and controlled operation of a grid. The phrase "power quality" refers to the examination of electrical power in terms of voltage, frequency, and the lack of any electrical noise from perfect sine waves, such as flicker, transient voltage, or harmonic distortion.

To improve the prediction model's realism, it is crucial to record and utilize the information about these parameters' variances. Because the impacts are connected, every change in one of them must be offset by a change in the other. If these deviations are not addressed or corrected for, the grid may become unstable. For instance, for every drop in grid frequency, the generators' generating capacity needs to be raised by 5%. Based on past fault occurrences of the same class, classification-based techniques are taught to identify patterns in the process measurements. Patterns are regularities in the data or features of the data. Patterns in the process measurements for a particular class of defect in industrial systems can vary from fault occurrence to fault occurrence. (Matthieu et al., 2020).

A microgrid, as defined by Reddipalli et al. (2019), is a medium- or low-voltage distribution network made up of loads, storage devices, and renewable energy sources. It can be linked to the AC grid and run on hybrid or AC/DC power.

II. MATERIALS AND METHOD

Siemens S7-1200 1214C-DC/DC/DC PLC

The S7-1200 series is a programmable logic controller developed by Siemens. For the purpose of this work, the 1214C-DC/DC/DC model is chosen. Equipped with a compact high-performance CPU, 24 integral input/outputs expandable by: 1 signal board (SB) or communication board (CB), 8 signal modules (SM) and a maximum of 3 communication modules (CM).

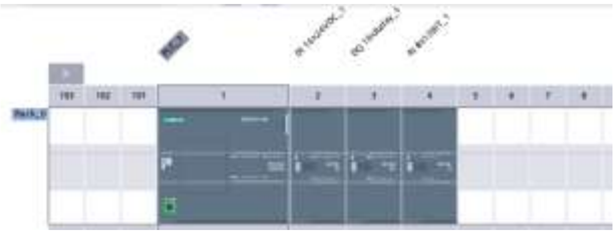

Figure 1: Simantic S7-1200 CPU1214C and IO Cards

The model number, CPU1214C DC/DC/DC, signifies:

1. **CPU:** This indicates it's a central processing unit for the S7-1200 series.
2. **1214:** Specific model number within the S7-1200 series.
3. **C:** Indicates the specific version or revision of the CPU.

4. **DC/DC/DC:** This specifies the type of power supply it accepts. In this case, it accepts a DC voltage input for all three power supply connections: CPU, inputs/outputs, and backplane.

The S7-1200 series is designed for smaller automation applications, offering a compact and modular design suitable for a range of industrial automation tasks. It supports various communication options, including PROFINET for industrial Ethernet communication. Programming is typically done using Siemens' TIA Portal (Totally Integrated Automation) software.

The compact CPU 1214C has 3 device versions with different power supply and control voltages, integrated power supply either as a wide-range AC or DC power supply (85 to 264 V AC or 24 V DC). It is also equipped with an integrated 24V encoder/load current supply for direct connection of sensors and encoders. With 400 mA, the output current can also be used as a load power supply. This PLC has 14 integrated digital inputs 24 V DC (current sinking/current sourcing (IEC type 1 current sinking)), and 10 integrated digital outputs, either 24 V DC or relay. It is also equipped with 2 integrated analog inputs, 0 to 10 V.

The following are some of the additional features of the S7-1214C-DC/DC/DC:

1. Pulse outputs (PTO) with a frequency of up to 100 kHz.
2. Pulse-width modulated outputs (PWM) with a frequency of up to 100 kHz.
3. Integrated Ethernet interface (TCP/IP native, ISO-on-TCP).
4. 6 fast counters (3 with max. 100 kHz; 3 with max. 30 kHz), with parameterizable enable and reset inputs, can be used simultaneously as up and down counters with 2 separate inputs or for connecting incremental encoders.
5. Expansion by additional communication interfaces, e.g. RS485 or RS232.
6. Expansion by analog or digital signals directly on the CPU via signal board (with retention of CPU mounting dimensions).
7. Expansion by a wide range of analog and digital input and output signals via signal modules.
8. Memory expansion (SIMATIC Memory Card).
9. PID controller with auto-tuning functionality.
10. Integral real-time clock.
11. Interrupt inputs: For extremely fast response to rising or falling edges of process signals.
12. Removable terminals on all modules.

Simulator (optional): For simulating the integrated inputs and for testing the user program.
The STEP 7 Basic programming package permits complete programming of all S7-1200 controllers and the associated I/O.

Software Design

- Siemens TIA (Totally Integrated Automation) Portal

Siemens TIA (Totally Integrated Automation) Portal is a software platform developed by Siemens for programming and configuring automation systems. It is a unified engineering environment that integrates various automation tools into a single software suite, providing engineers with a comprehensive set of tools for designing, programming, commissioning, and maintaining automation systems.

Key Features and Components of TIA Portal:

1. **Integrated Engineering:** TIA Portal integrates various engineering tools into a single framework, allowing seamless communication and data exchange between different components of an automation project.
2. **Programming Languages:** It supports multiple programming languages including ladder logic (LAD), function block diagram (FBD), structured text (ST), and Sequential Function Chart (SFC). This versatility allows programmers to choose the best language for their application.
3. **PLC Programming:** TIA Portal is used for programming Siemens PLCs (Programmable Logic Controllers), including the popular S7-1200 and S7-1500 series, as well as older PLC models like S7-300 and S7-400.
4. **HMI (Human-Machine Interface):** It includes tools for designing and configuring HMI panels and interfaces. Engineers can create graphical

user interfaces (GUIs) that operators use to monitor and control industrial processes.

5. **Motion Control:** TIA Portal provides tools for configuring and programming motion control systems, including drives, motors, and advanced motion control functions.
6. **Safety Integrated:** It supports safety functions and integrated safety technology, allowing engineers to design safety systems within the same environment as the standard automation system.
7. **Simulation and Testing:** TIA Portal includes simulation tools that allow engineers to test and validate their programs before deployment. This helps reduce commissioning time and minimize errors during startup.
8. **Device Configuration:** Engineers can configure and parameterize devices such as PLCs, HMIs, and drives directly within TIA Portal, streamlining the setup process.
9. **Scalability:** TIA Portal is scalable, supporting both small-scale applications (like machine automation) and large-scale automation projects (like entire production lines or plants).
10. **Openness and Compatibility:** It supports communication protocols like PROFINET, PROFIBUS, and Ethernet/IP, ensuring compatibility with a wide range of industrial equipment and devices.

TIA Portal's unified approach to automation engineering simplifies project management, reduces engineering time, and improves overall system efficiency. It is widely used in various industries including manufacturing, automotive, food and beverage, and more, where reliable and efficient automation solutions are critical.

In this work, the TIA portal alongside Simatic s7-plcsim v15 is used solely for PLC programming and simulation. Ladder logic programming is used in writing the intelligence. The intelligence is built such that when the current in A0, which corresponds to total current across PV array1, exceeds 200A, MCB 1 is disconnected as this current exceeds the maximum that could be supplied by the PV array1 thus, a fault is present in the system. The same process is applied across MCB2 which bears the contact for PV array2, MCB3-PV array3, MCB4-PV array4, MCB5-PV array5, MCB6-PV array6. While a fault may be detected at PV array1, MCB7, which is connected to the node at which PV arrays 1 and 2 merge, maintains contact and is only disconnected when a fault is detected in PV array1 and 2. The same applies of MCB8 and MCB9 which are connected to the merging nodes of PV array 3 and 4, and PV array 4 and 6, respectively.

III. RESULTS AND DISCUSSION

Fault Detection and Localization Simulation on TIA Portal Simulation

On the TIA portal, the ladder logic program is first compiled before simulation. Conversion of the data from the analog sensors (WCS current sensors) is done using the Norm_X and Scale_X conversion functions. With Norm_X used in converting the raw analog values of 0-27648 to a range of 0-1. The Scale_X function then converts this value to real usable values within the sensing range of the current sensor (0-500A). Less-than or equal-to conditions are then applied to all six scaled outputs and a contactor (MCB) is connected. With PV array 1 connected to current sensor 1 and MCB-1, PV array 2 to current sensor 2 and MCB-2, till PV array 6 connected to current sensor 3 and MCB-6.

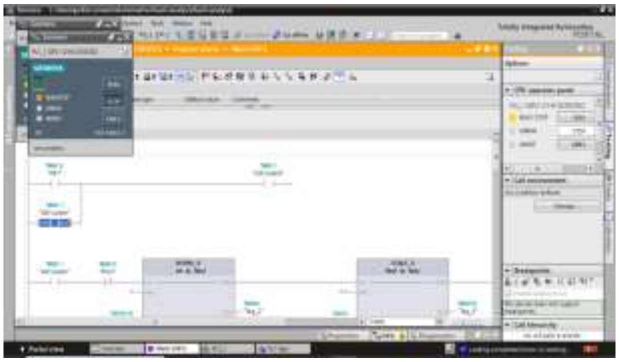

Figure 2: Tia Portal Showing Simulation Online Before Being Run

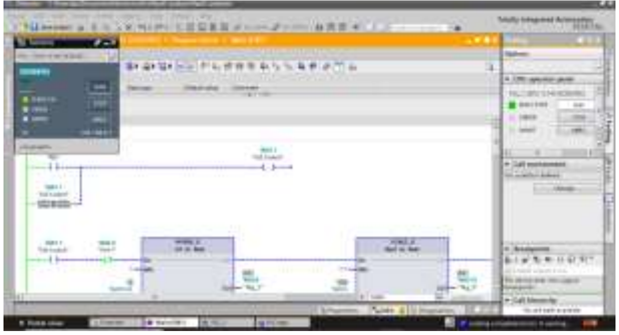

Figure 3: TIA Portal Showing Simulation Running without supply breaker (PB1) toggled to 1

Figure 4 shows the fault detected in PV arrays 1 and 2 and the consequent localization of the identified fault. It is observed that as a result of the identified fault (current at PV array 1 and 2 are 262.23A and 200.42A respectively, exceeding 200A), the MCBs 1 and 2 are switched to NO while other MCBs are NC, allowing for the flow of current on other lines on the network which were not affected by this fault.

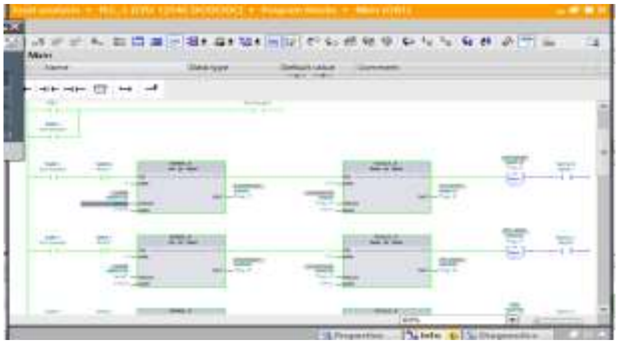

Figure 4: Simulation showing fault detected at PV Arrays 1 and 2

Table 1: Fault Detected at PV Array 3 and 4

PV Array	Current Value	Report
1	262.33A	Fault Detected. Current >200A
2	200.42A	Fault Detected. Current >200A
3	79..8A	No fault Detected. Current <200A
4	107.26A	No fault Detected. Current <200A
5	172.02A	No fault Detected. Current <200A
6	199.09A	No fault Detected. Current <200A

Fault Detected at PV Array 3 and 4

Figure 5 shows fault detected in PV arrays 3 and 4 and consequent localization of the identified fault. It is observed that as a result of the identified fault (current at PV array 3 and 4 are 235.09A and 307.43A respectively, exceeding 200A), the MCBs 3 and 4 are switched to NO while other MCBs are NC, allowing for the flow of current on other lines on the network which were not affected by this fault. Thus, a fault in PV Arrays 3 and 4 will in no way distort the operation of the grid as shown in Figure 4.8, where only the common node of PV 3 and 4 is isolated while other PV arrays feed the output rung.

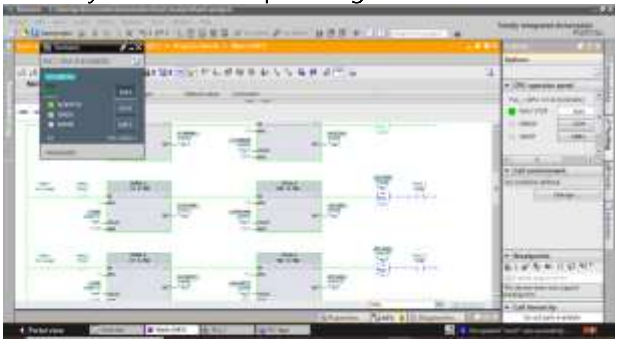

Figure 5: Simulation showing fault detected at PV Arrays 3 and 4

Table 2: Fault Detected at PV Arrays 3 and 4

PV Array	Current Value	Report
1	72.33A	No fault Detected. Current <200A
2	90.42A	No fault Detected. Current <200A
3	235.09A	Fault Detected. Current >200A
4	307.43A	Fault Detected. Current >200A
5	172.02A	No fault Detected. Current <200A
6	199.09A	No fault Detected. Current <200A

Fault Detected at PV Array 3 and 4

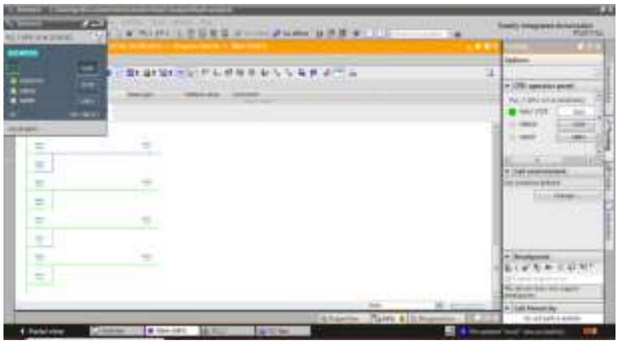

Figure 6: Simulation Showing Grid DC Output with PV Array 3 and 4 Isolated

IV. CONCLUSION

The design and simulation of a feedback-based fault localization system for a DC micro-grid using Siemens TIA Portal and Proteus Professional has been successfully achieved. The work demonstrates that effective protection in a DC micro-environment is attainable through real-time monitoring and automated response signalling. By detecting abnormal current and voltage deviations and accurately identifying the faulted line segment, the developed system enhances operational stability and mitigates equipment damage, downtime, and energy loss.

Furthermore, the integration of automation logic with a circuit simulation platform allowed efficient validation of system performance under different fault scenarios. Results indicate that the proposed architecture provides quick fault detection, selective isolation capability, and stability preservation for healthy sections of the microgrid, all of which are essential for continuity of power delivery in renewable-integrated DC networks. Overall, this research provides a scalable and cost-effective foundation for modern DC micro-grid protection schemes. With further development such as hardware implementation, adaptive intelligence, or communication-assisted protection, the system could be expanded into a fully autonomous real-world deployment suitable for industrial, commercial, and distributed power infrastructures.

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