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Proficient Model of Monitoring and Controlling of Low Voltage Distribution Smart Feeder Protection System Using IoT

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ABSTRACT

Smart feeder is a developing power distribution network that is embedded with a blend of different kinds of energy distribution sources, as sustainable energy sources, united heat and power, and scattered energy assets. The smart feeder system, being an intermediary component for the distribution of energy to the local transformer, protects against the event of any fault, turns into a necessity in the power systems. This research work presents an advancement in monitoring and controlling the Low Voltage (LV) Smart Feeder system using the Internet of Things (IoT). The absence of data at the base feeder, the electricity administration network's status has been distinguished as the significant obstruction to its successful monitoring and control of the electrical distribution system. To tackle the issues in the recent smart feeder controlling and monitoring, authors have designed a smart feeder controlling and monitoring framework dependent on energy IoT utilizing the IoT innovations. The framework acknowledged continuous observation of feeder system devices and working conditions, information knowledge examination, alert linkage, and visual showcase. It helps backing to feeder operation and maintenance improved the activity and the intelligent smart feeder's management level. In this research work, a smart feeder protection system has been proposed with the IoT based monitoring and controlling of Voltage, Current, and Temperature (V, I, and T) of the system.

Key words: Smart Feeder, Smart Grid, PhotoMOS, Protection System, Microcontroller, IoT.

1. INTRODUCTION

Smart feeder system performance and constant electricity distribution to the consumers are one of the significant problems nowadays. Therefore, fast safety and protection plans must be effective enough to conquer issues within a short period [1-3]. Thereafter, the Smart grid technologies have grown and Internet of Things (IoT) innovation has been broadly utilized in the grid distribution network and naturally incorporated with the power innovation, which significantly improves the grid distribution's intelligence degree. In any case, at the current stage in the smart grid network, the degree of setting up intelligent feeder data monitoring in joins smart feeder and understanding the general controlling, monitoring, and the understanding of feeder hardware and operation status should be improved [4-5].

The Internet of Thing (IoT) technologies provides two-way communication systems between the electricity provider and consumer. As an idea, the smart grid is a combination of power generation, transmission, and distribution network improved by advanced digital control, monitoring, and broadcast communications abilities [6]. IoT allows effective data execution and working at all stages. IoT is the update of mobile, home, and implanted applications to be essential for a system of associated physical devices with sensors that both import and export information. The devices, utilizing embedded sensors, assemble information about nature in which they are working and how they are being utilized.The sensors are incorporated into each physical device, from electrical machines to lights to cell phones and tablets to scanner tags on non-electrical things. At that point, the devices share the information progressively about their operational state through the cloud to an IoT stage where there is an all-inclusive language by which all IoT gadgets impart. The accumulated information is then dumped or coordinated, and information investigation is performed.

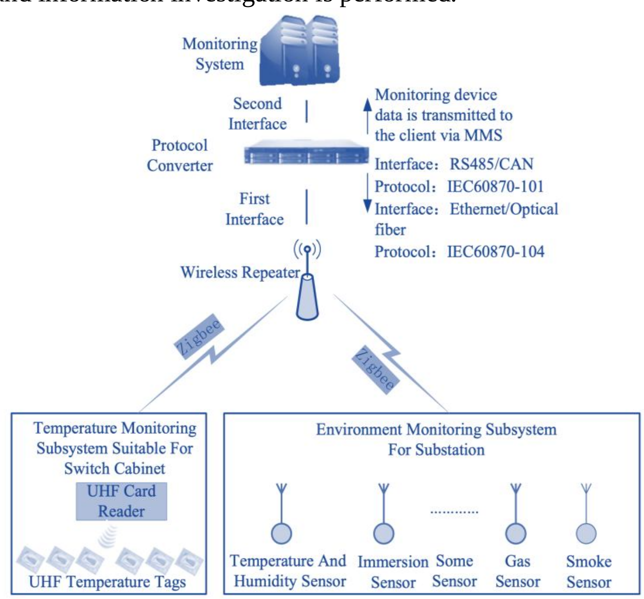


Figure 1: Feeder Monitoring architecture diagram [6].

In the early 80s, the IoT was introduced to refrigerator appliances to check if their drink is available. Constantly 2013, the IoT had developed into a system utilizing different technology, extending from the Internet to wireless communication and from Micro-Electromechanical Systems (MEMS) to embedded systems [7]. The customary automation (counting the computerization of structures and homes), wireless sensor systems, GPS, control frameworks, and others all help the IoT [8]. The IoT systems can be interconnected with any other devices, privacy, and security of the system are the main advantages [9].

Residential users regularly get the power from overhead or underground feeders exuding from utility-substations. The LV distribution smart feeder overcurrent protection and monitoring system is a key apparatus for power distribution utility to make the power system sound solid, sheltered, and effective without contributing a lot [10]. There are four types of LV distribution feeder systems used: Ring main, Meshed system, Radial, Parallel Feeders [11]. In this proposed low voltage feeders exuding from a substation are observed by microcontrollers, relay circuits, and a circuit breaker, which will open when a fault is identified. Programmed microcontroller circuit recloses were also introduced to additionally isolate the feeder in this way, limiting the effect of faults.

This paper has been organized as follows. Section 2 introduces the proposed model of smart feeder protection. Section 3 presents the microcontroller and IoT application in smart distribution feeder structure construction. Section 4 has the hardware and software implementation of the protection system. Section 5analyses the results of this designed protection system. Finally, Section 6concludes the work and recommends the future aspects.

2. PROPOSED MODEL OF SMART FEEDER PROTECTION WITH IOT APPLICATIONS

In the power system, it is common for the feeders to experience operational contortion or faults inferable from the presentation to a few encompassing conditions. In a Smart feeder system, the microcontroller-based PhotoMOS relay circuits are liable for the detection of the over-values (voltage, current, resistance, or reactance), list the fault parameters, and further, convey the fault data to IoT based developed administrative control frameworks to distinguish the fault area [12].

In that circumstance, fusing a microcontroller-based PhotoMOS relay that gives numerous desirable advantages, for example, accurate tripping, less disturbance, and enhanced fault parameter to the resulting framework appear to be proper. A PhotoMOS Solid State Relay is an electronic switch that works on ‘photo-voltaic’ impacts to switch High voltage/current using low power circuits utilizing. For fast switching, MOS innovation is applied to its control terminals [13]. To associate an SSR with a microcontroller, it needs a driving circuit shown in Fig. 2.

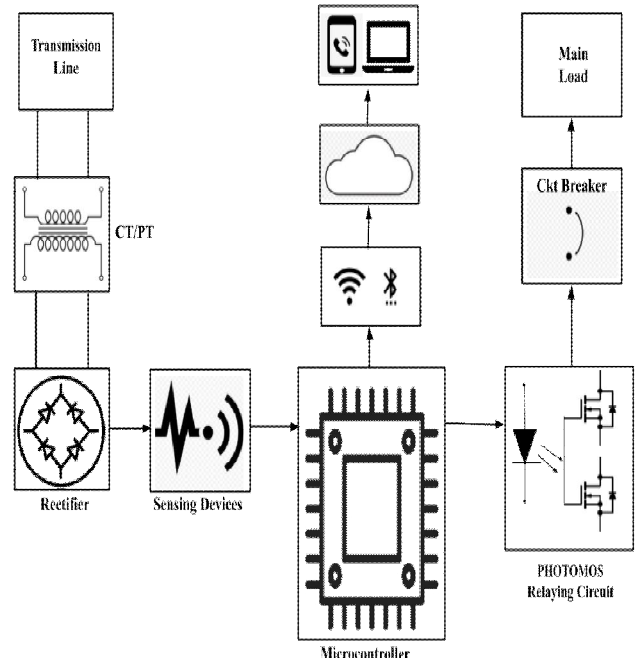


Figure 2: Proposed model of the Feeder Protection system.

In Fig. 2, an effective LV distribution smart feeder protection system has been proposed using an IoT based microcontroller & solid-state relay circuit in operation [14]. The proposed model embodies the benefits of a microcontroller-based solid-state relay circuit inside the general system that comprises of other structure squares, for example, step-down transformer (6 V), rectification assembly, sensing devices for transduction, and an automation microcontroller to enable the operation of the circuit breaker.

With the assistance of a rectifying circuit, for example, a bridge rectifier is associated in series to convert the feeder voltage from 220 V AC supply to a 6 V DC. This DC supply connected with sensing devices to observe the circuit's abnormalities and provide information to microcontroller circuit units [15]. Any change in AC voltage can bring a power cut or a weak signal to affect the DC voltage that a microcontroller experiences change. Thereafter, such changes are logically evaluated if the feeder still can supply electricity without electrical distortions [16].

When the distorted values rise above the system's predetermined threshold values, the microcontroller sends an immediate signal to the PhotoMOS relay protection system connected with microcontrollers pins through MOSFET's driver switching [17]. The Microcontroller circuit connected with the IoT cloud services to send an immediate alert signal to the live monitoring system, then the PhotoMOS relay protection system sends an immediate signal to the circuit breaker to break the system so no current and voltage can flow through the circuit and assures electrical equipment remains safe.

3. MICROCONTROLLER AND IOT ASPECTS IN LOW VOLTAGE (LV) SMART FEEDER SYSTEM

The LVdistribution smart feederframework conveys power from the transmission network and carries it to consumers [18]. The smart feeder system, being an intermediary element for the distribution of power to the regional transformer. In the power system, electricity conveyance is considered the end-stage power distribution to the consumers [19].

The IoT applications for smart feeder systems are one of them for more accurate and precise ways of monitoring and controlling the smart grid systems [20]. In smart feeders, IoT systems are programmed using microcontrollers; these programming systems are designed to process automatically [21]. The enormous part of introduced limits in the Medium Voltage (MV) and Low Voltage (LV) dissemination network stayed without legitimate monitoring, control, and outside the typical Supervisory Control and Data Acquisition (SCADA) utility frameworks, as shown in Fig. 1 and Fig. 3. But these days, all-electric systems are moving towards automation [22]. These automation systems are a combination of power system, control system, and mechanical system controlled by an IoT based microcontroller system. Microcontroller systems are more efficient and flexible [23]. Using microcontroller and IoT systems, authors canget live data of feeder lines voltage, current, and temperature to monitor and control them accordingly [24]. If the feeder line voltage and current increases above or lower to the threshold value the IoT system sends an immediate signal of alert in this research work.

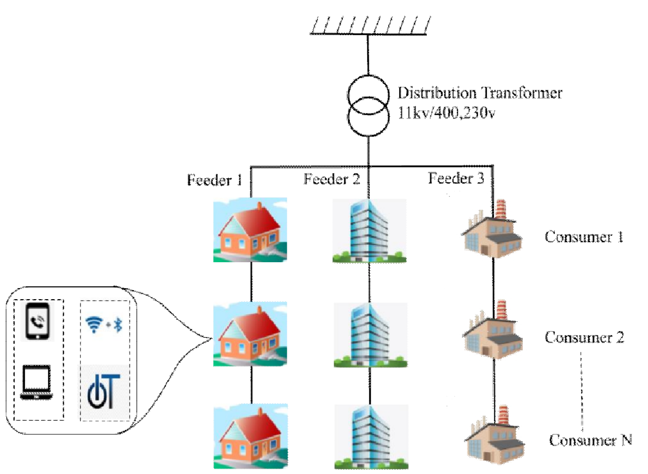


Figure 3: LV Smart Feeder Block Design.

With the power stations, it is necessary to decrease the transmission losses in overhead lines for that produced electricity has to be stepped up to a higher level so the power losses in produced electricity transmission will be less and make it increasingly productive [25]. To make transmission voltage progressively usable for the consumer's transmitted line voltage has to be stepped down. The transmission electrical cables will enter a dispersion substation where the voltage will be stepped down to low voltage levels; then,it will be appropriated for use by industries, businesses, and residential consumers, as shown in Fig. 3 [26]. Power reliability assessment is the most significant parameter to take opportune healing measures to give continuous and safe power supply to end consumers.

4. HARDWARE & SOFTWARE IMPLEMENTATION OF THE PROTECTION SYSTEM

The architecture of the smart feeder monitoring and controlling system is shown in Fig. 1. The framework's general architecture comprises two interfaces: the primary interface is the interface between the observing device (wireless repeater) and the protocol converter [27]. The subsequent interface is the interface between the convention converter and the brought together access passage. This part incorporates the transmission method of the energy network and the open system shown in Fig. 4. The power network embraces the standard interface convention of the energy framework, and the open system adheres to the norm of the open system. The primary interface: the correspondence protocol indicates the interface between the monitoring and the convention converter to meet the correspondence necessities between the monitoring device and the convention converter [28]. The secondary interface: the correspondence protocol indicates the interface between the convention converter and the system level brought together the access door. This part chiefly keeps the force business-standard IEC 61850 and IEC 60870-1-104 [29]. The transmission of the open system receives the open system's correspondence-convention, which can get to the common information base through the protected admittance stage shown in Fig. 5. [30]. Every subsystem can screen every application scene autonomously and can likewise cooperate.

The smart feeder condition observing subsystem is chiefly made out of sensors of different capacities, such as voltage, current, and temperature sensors for checking the voltage, current, and live temperature values of the protection system. Ultra-High Frequency (UHF) temperature checking subsystem comprises UHF temperature labels and UHF per user. The UHF temperature labels incorporate RFID and detecting capacities, sensors, and their estimation circuits utilize wireless energy transmission to provide power and afterward measure temperature and store information [31].

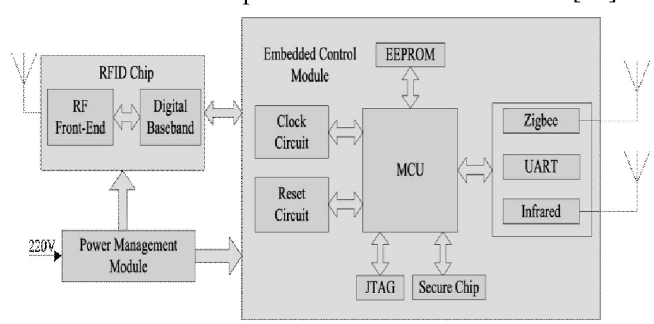


Figure 4: Hardware for sensor devices [27].

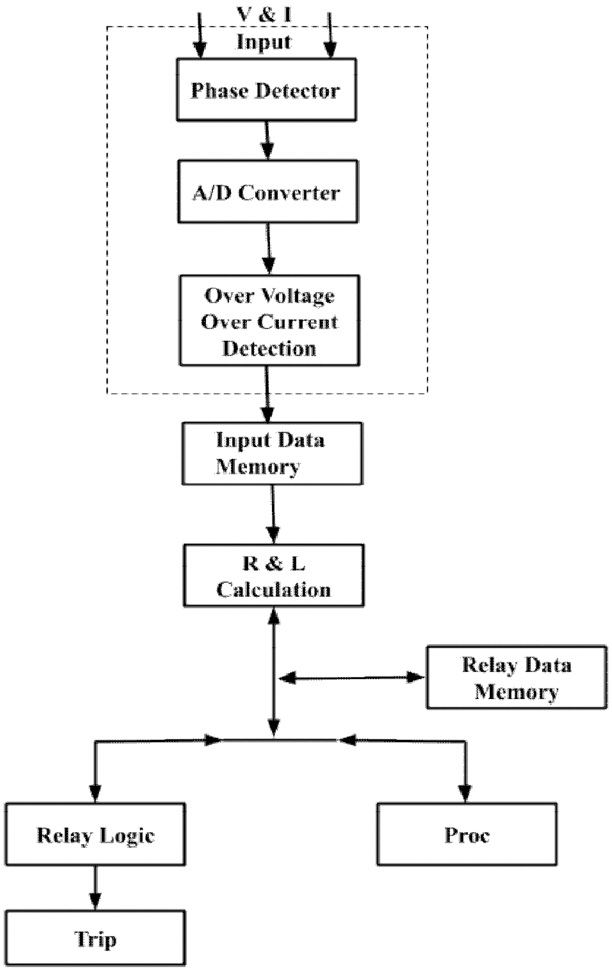


Figure 5: Relay interfacing with the microcontroller block diagram.

With the help of all the sensors connected, authors can have all the data to control the system software shown in Fig. 6. The microcontroller circuit handles the gathered system information, and the protocol converter receives the direct command from the microcontroller circuit [32]. This paper aims to implement the software design for a feeder system to monitor and control (V, I, and T).

To implement a protection system, software should have the following functions: System should receive the data from wireless receiver, The monitoring data of the system is communicated by SMS and the users, and the convention converter alludes to the IEC61850 standard, Sending the downlink orders of the SMS users to monitor, information gathering with microcontroller capacities, sensor demonstration, setting up the threshold value of the system (V, I, and T) [33]. In this system, the alarm function has been set up with the system's software's help. In the case of overvaluing the quantity immediate alarm system can be activated, and to manage all the device equipment management systems has been set up.

```
function _class(name){
  return document.getElementsByClassName(name);
}

let tabPanes = _class("tab-header")[0].getElementsByTagName("div");

for(let i=0;i<tabPanes.length;i++){
  tabPanes[i].addEventListener("click",function(){
    _class("tab-header")[0].getElementsByClassName("active")[0].classList.remove("active");
    tabPanes[i].classList.add("active");

    _class("tab-indicator")[0].style.top = `calc(80px + ${i*50}px)`;

    _class("tab-content")[0].getElementsByClassName("active")[0].classList.remove("active");
    _class("tab-content")[0].getElementsByTagName("div")[i].classList.add("active");

  });
}
```

(a)

```
$('form.form-voltage').submit(function(e){
    e.preventDefault();
    var voltage = Math.floor(Math.random() * 250) + 1;
    var current = Math.floor(Math.random() * 10) + 1;
    var temperature = Math.floor(Math.random() * 150) + 1;
    console.log(voltage, current, temperature);
    if(voltage > 230 || current > 5 || temperature > 100){
        $('span.voltage-message').addClass('error').remove('success').html('<br>Alert! Feeder is in
            Danger! <br><br>Voltage = '+voltage+' V ; <br><br>Current = '+current+' A ; <br><br>
            Temperature = '+temperature+' C');
    }
    else{
        if(voltage < 230 || current < 5 || temperature < 100){
            $('span.voltage-message').addClass('error').remove('success').html('<br>Alert! Feeder is in
                Danger! <br><br>Coltage = '+voltage+' V ; <br><br>Current = '+current+' A ; <br><br>
                Temperature = '+temperature+' C');
        }
        else{
            $('span.voltage-message').addClass('success').remove('error').html('<br>Alert! Feeder is in
                Safe! <br><br>Voltage = '+voltage+' V ; <br><br>Current = '+current+' A ; <br><br>
                Temperature = '+temperature+' C');
        }
    }
});
```

(b)

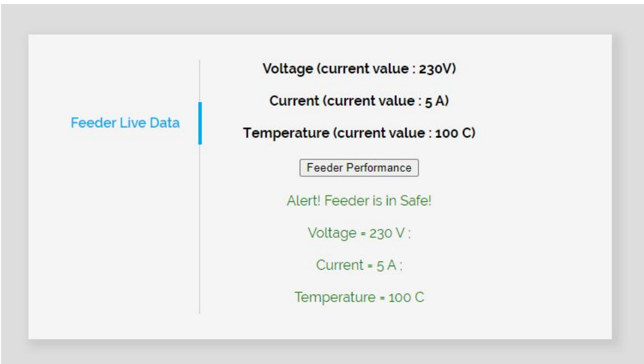
```
<!DOCTYPE html>
<html>
<head>
    <title></title>
  <meta name="viewport" content="width=device-width, initial-scale=1">
    <link rel="stylesheet" type="text/css" href="style.css">
</head>
<body>
    <div class="tabs">
        <div class="tab-header">
            <div class="active">
                <i class="fa fa-code"></i> Feeder Live Data
            </div>
        </div>
        <div class="tab-indicator"></div>
        <div class="tab-content">
            <div class="active" style="padding-left: 50px; margin-top: -20px;">
                <h4>Voltage (current value : 230V) <br><br> Current (current value : 5 A) <br><br> Temperature (current value : 100
                C)</h4>
                <p>
                    <form class="form-voltage">
                        <input type="submit" name="voltage-button" value="Feeder Performance">
                    </form>
                    <span class="voltage-message" style="padding-top: 20px;"></span>
                </p>
            </div>
        </div>
    </div>
    <script src="https://ajax.googleapis.com/ajax/libs/jquery/3.5.1/jquery.min.js"></script>
    <script type="text/javascript" src="script.js"></script>
</body>
</html>
```

(c)

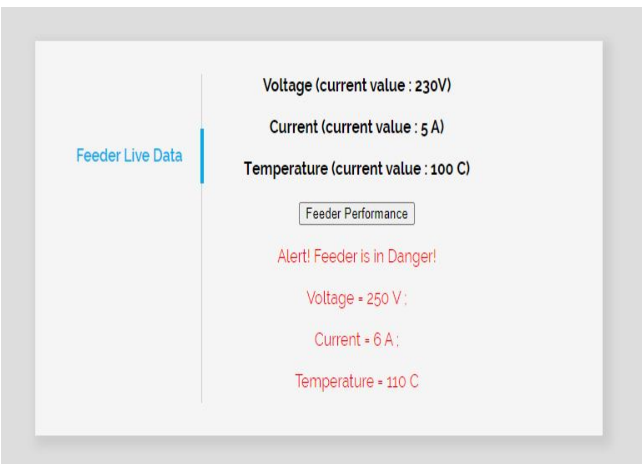
Figure 6: Software implementation of IoT protection systems.

5. RESULTS AND ANALYSIS

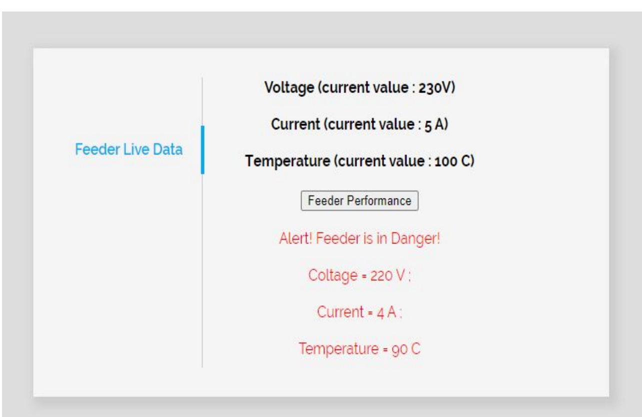
The developed software system for LV smart feeder systems have been shown in Fig. 6 and Fig. 7. The results of the monitoring and analysis of dynamic LV feeders utilizing IoT and Microcontroller show that if the overcurrent value increases or decreases from the cut-off value in the developed IoT system sends the immediate signal as shown in Fig. 7.



(a) Normal Operation



(b) Fault Condition



(c) Fault Condition

Figure 7. IoT Based live monitoring and alert system for LV smart feeder.

In this research work relay, cut-off time and overcurrent parameters have been calculated with IoT-based developed software, as shown in Fig. 5 and Fig 6. The achieved results show the significant monitoring and controlling results over the traditional circuit protection. We have recorded and shown that the IoT system can capture the slightest fault or value change in the system, and an alert signal will be sent immediately to resolve the system's fault. It is commonly a decent practice to adjust down to the closest incentive to give extra headroom. Overall, to protect the LV feeder system, three IoT system tests have been conducted based on the results proposed circuit of IoT, and the microcontroller-based system shows very positive results for future research work. These results show the alert signal time and overcurrent values.

6. CONCLUSION AND FUTURE WORKS

In this research work, a unique IoT based monitoring and controlling framework has been created by utilizing open source programming, measured, simulations, and ease parts. With this framework, system data can be gained from various sensors and observed in different conditions, such as LCD, PC, cell phones, and tablets persistently. This workalso furnishes that microcontroller-based LV feeders' performance using a solid-state relay is very significant for the electrical distribution system. The created system has been tested on a model LV smart feeder. It was seen that the information collection, count operations, and output signals as per the cut-off esteems, administration life, the executives, recording tasks, and warning frameworks were working without an error. Subsequently, this framework gives a minimal effort option compared to significant expense proficient checking frameworks [34]. The design and implementation of the IoT based system of a disturbed electric system utilizing a microcontroller and software-based defensive system given. Because of the utilization of semiconductor devices in the protection system, arc less fast switching of the system is conceivable. The effectiveness, unwavering quality, and lifetime of the insurance unit increments.

With an electric system's safety against overcurrent, under-voltage, earth fault, and temperature, a strong IoT-based system is presently unveiled. However, it is suggested that different methodologies ought to be utilized to supplement this methodology [35]. The assurance of the power network framework is a fundamental and unavoidable procedure to guarantee the LV Feeder's security since the faults are inescapable. This developed IoT system is capable of performing in any difficult condition for LV smart feeder protection.

The proposed model can further be utilized to monitor and control relaying circuits pertaining to the IoT based smart feeder protection circuits for system performance analysis. The compatibility of available SSRs with the IoT system and real comparison in all the aspects would be a challenge and a field of further research in this area.

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