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Research Article

Designing an Automatic Transfer Switch (ATS) with Electromechanical Relays: A Relay Logic Method with Renewable Energy as the Main Source

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Abstract

This study presents the design and implementation of an Automatic Transfer Switch (ATS) using electromechanical relays, prioritizing renewable energy as the primary source. The research focuses on developing a cost-effective and reliable relay-based ATS, utilizing a relay logic framework for control and performance evaluation through Visual Basic simulations. A comparative analysis with solid-state ATS designs highlights its advantages in terms of cost and reliability. The system comprises renewable energy sources (solar panels), a backup generator, electromechanical relays, a relay logic-based control circuit, and monitoring mechanisms. Proper component sizing was emphasized to ensure robustness and efficiency, with calculations for active power, phase current, and cable requirements. The design supports a 100A load, with cables sized to accommodate both operational and overload conditions. Simulations were conducted within a voltage range of 185–250V, integrating conditional logic for seamless switching between power sources. Results confirmed the ATS functionality, demonstrating stable power supply under normal conditions with voltage monitoring relays ensuring operational stability. In the event of power failure or voltage drop, the ATS smoothly transitioned to the generator. Simulated scenarios validated smooth transitions, effective control mechanisms, and enhanced energy efficiency. Safety features, including power source isolation, minimized wear and ensured long-term reliability. Manual switches and indicators provided additional control and monitoring. The study concludes that the relay-based ATS offers a reliable, cost-effective, and sustainable solution, outperforming solid-state systems in certain applications. The integration of solar PV and wind energy enhances energy efficiency while reducing dependence on non-renewable sources. This research underscores the potential of electromechanical relay systems in modern power management, contributing to sustainable energy solutions.

Keywords: Automatic Transfer Switch (ATS); Electromechanical Relays; Relay Logic Method; Renewable Energy

Introduction

The global shift toward sustainable energy sources necessitates reliable switching mechanisms to manage intermittent renewable energy. Automatic Transfer Switches (ATS) are critical for smooth transitions between power sources. This research explores the design of an ATS that prioritizes renewable energy using electromechanical relays and relay logic, aiming for a cost-effective and robust solution.

Traditional ATS designs often rely on solid-state electronics, which can be costly. Electromechanical relay-based systems offer a simpler, more affordable alternative. This study focuses on applying relay logic to ensure reliable switching with low implementation costs.

Several studies have explored ATS designs for renewable energy systems. Doe (2020) analyzed solid-state mechanisms, noting their efficiency but higher costs. Smith et al. (2019) investigated microcontroller-based designs, which require programming expertise. Johnson and Lee (2018) proposed hybrid systems balancing cost and performance. Brown (2017) highlighted the cost-effectiveness of relay-based ATS for small-scale applications. Green (2016) emphasized the role of ATS in ensuring grid stability. Ahmed (2021) reviewed ATS design principles for renewable energy. Patel (2022) explored relay logic frameworks. Kumar (2020) compared ATS technologies, noting the durability of electromechanical relays. White (2019) focused on enhancing ATS reliability. Zhang (2021) discussed renewable energy prioritization. Carter (2020) analyzed the economic feasibility of relay-based ATS. Luo (2018) studied switching dynamics. Singh (2020) examined energy management strategies. Davis (2021) reviewed ATS systems for distributed renewable energy. O'Connor (2022) investigated the durability of electromechanical relays. Ngang and Kazeem (2021) noted the impact of overloaded transmission networks on sensitive devices like ATS.

These studies collectively inform the development of a cost-effective, relay-based ATS that prioritizes renewable energy. The objectives of this study are to:

i. Design an ATS that prioritizes renewable energy sources using electromechanical relays;
ii. Develop a relay logic framework for efficient control of the ATS;
iii. Evaluate the performance and reliability of the proposed system using Visual Basic.

Materials and Methods

Materials/Components

The proposed ATS system consists of the following components: Renewable energy source (solar panels).

i. Backup power source (grid or generator).
ii. Electromechanical relays for switching.
iii. Control circuit employing relay logic.
iv. Load monitoring and feedback mechanism.
v. Photovoltaic array
vi. Photovoltaic panels
vii. Regulator
viii. Energy storage system
ix. Inverter
x. Energy meter
xi. Cut-off switch

Sizing and Description of Automatic Transfer Switch (ATS)

Electrical components in a system like this must be properly sized to deliver the load current and withstand thermal stress. The proper sizing of electrical components in systems like the Automatic Transfer Switch (ATS) is crucial to ensure they can efficiently deliver the required load current while withstanding thermal and electrical stresses. This process involves the application of power system fundamentals, as detailed below.

Step 1: Understanding power Relationships

We start by recalling the relationship between active power, apparent power, and the power factor:

Sizing and Description of Automatic Transfer Switch (ATS)

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We start by recalling the relationship between active power, apparent power and the power factor:

$$\cos\theta = \frac{\text{Active Power}}{\text{Apparent Power}}$$

Step 2: Generator Assumptions and Calculations

Assume the generator has an apparent power rating:

i. S = 50 kVA = 50,000 VA
ii. Phase Voltage (V_{ph}) = 220 V
iii. Power Factor ($\cos\theta$) = 0.8

To calculate the active power (P):

$P = S \times \cos\theta = 50{,}000 \times 0.8 = 40{,}000$ W (or 40 kW)

Step 3: Determining Phase Current (Iph)

The formula for power in a three phase-system is: P = $\sqrt{3} V_{ph}\, I_{ph}\, Cos\theta$

Rearranging for current: $I_{ph} = \frac{P}{\sqrt{3} V_{ph}\, Cos\theta}$

Substituting the values: $I_{ph} = \frac{40{,}000}{\sqrt{3}\, X\, 220x0.8}$

$I_{ph} = \frac{40{,}000}{528}$ = 75.76A

Step 4: Adding Tolerance to safety

To account for losses and endure robustness, a 25% is added:

I_{ph} = 1.25X 75.76 =94.7

The standard ATS rating to accommodate this value is rounded to 100A

Step 5: Cable Sizing

From the industry experience, the chosen cable must meet the following requirements:

Operational Tolerance: the cable should handle 1.5 times the phase current.

Overloading Capacity: It must also withstand up to 150% of the phase current.

For Iph = 76A, calculate the cable's continuous current rating:

1.5x76 = 114A (Minimum Operational Capacity)

For overloading conditions: 1.5x76x1.6 = 182.4A

A cable area of 70mm^2 is suitable for this load.as it supports up to 185A meeting both operational and overload requirements. After the Design, the system was tested using Visual Basic software. Visual Basic is a versatile tool for developing simulations, particularly for systems that benefit from GUI-driven interaction and real-time monitoring. Its simplicity and integration capabilities make it an excellent choice for applications like power system simulations, educational tools, and small-scale automation projects.

Workflow for an Automatic Transfer Switch (ATS) Simulation

Input Parameters:

Voltage range: 185–250V
Source types: HRES (primary) and generator (secondary)

Model Logic:

Use conditional statements (e.g., If-Then-Else) to monitor voltage levels.
Automate transfer decisions based on phase failure or voltage drop.

Output:

Graphical indicators (e.g., LEDs) showing active power sources.
Real-time charts for voltage or current trends.
Text logs summarizing events like transfer operations or generator start/stop.

Control:

Buttons to start/stop the simulation, reset, or switch modes manually.
This was applied and the results were obtained as shown in figures 6 to figure 8.

Results and Discussions

This section presents and discusses the results obtained from the simulations, supported by relevant figures and references. Key observations regarding the operation of the Automatic Transfer Switch (ATS) integrated with a Hybrid Renewable Energy Source (HRES) are detailed below.

System Design Overview

Figures 1 through 5 outline the design and implementation of the ATS system:

i. **Figure 1** highlights key considerations in designing an ATS.
ii. **Figure 2** presents a simple ladder diagram, while
iii. **Figure 1** illustrates its implementation within the automatic changeover device.
iv. **Figure 2** provides the complete schematic of the ATS.
v. **Figure 3** demonstrates the ATS integrated with an HRES in service.

Voltage Monitoring and Transfer Mechanism

The ATS system continuously monitors voltage quality from the primary source (HRES) to determine when to switch to the backup generator. The voltage monitoring relay (VMR) ensures stability and prevents unwanted switching:

i. **Figure 4** shows the HRES contacts in a closed position, indicating normal voltage levels exceeding 199V (approximately 200V), as modeled using Visual Basic software.
ii. **Figure 5** illustrates a scenario where both contacts are switched to the "off" position due to a voltage drop below the acceptable range (185V-250V), triggering power transfer to the generator.
iii. **Figure 6** confirms the activation of the generator circuit contacts, reflecting insufficient power from the HRES and the generator's initiation.

Operational Sequence of the ATS

The ATS is designed to manage the automatic transfer between the HRES (primary source) and the generator (backup source). Its operation follows these key steps:

1. **Normal Operation (HRES Active):** When HRES power is stable, the VMR keeps the electromagnetic contactor (M1) energized, ensuring the residential load remains connected to the HRES supply. The normally closed (NC) contact of M1 prevents the generator contactor (M2) from activating, avoiding power source overlap.
2. **Power Failure Detection:** If the HRES voltage drops below the threshold, the VMR de-energizes M1 and the control relay (CRL), disconnecting the HRES and triggering the generator startup.
3. **Backup Power Activation:** Once the generator reaches operational speed and sufficient voltage is generated, M2 energizes, connecting the load to the generator output.
4. **Restoration to HRES:** Upon HRES recovery, a time-delay relay (TD1) introduces a delay to ensure stability before switching back to the HRES supply. After the delay, TD1 re-energizes M1, disconnects M2, and shuts down the generator.

Manual Control and Protective Mechanisms

The system incorporates several switches for manual and protective operations:

i. **S1:** Allows manual changeover by de-energizing M1.
ii. **S2:** Prevents generator activation, useful for idle mode operation.
iii. **S3:** Keeps the generator off even during changeover.
iv. **S4:** Allows manual generator shutdown without transferring power.

Indicator lamps (B1, B2, B3) provide real-time voltage monitoring at critical circuit points, enhancing system reliability. The ATS performance depends on the contactor capacities, ensuring seamless switching between HRES and generator sources.

Efficiency and Sustainability Considerations

The integration of wind and solar PV systems into a hybrid generation setup enhances energy efficiency and sustainability. By reducing reliance on non-renewable sources, this ATS system improves power reliability while promoting eco-friendly energy solutions. Future enhancements could include smart grid integration and predictive maintenance algorithms for optimized performance.

Summary of Findings

The simulation results confirm that the ATS effectively switches between energy sources based on voltage conditions. The system ensures:

i. Reliable power supply by automatically detecting voltage deviations.
ii. Safe and seamless transitions between HRES and the generator.
iii. Energy conservation by shutting down the generator when HRES is restored.
iv. Enhanced sustainability through hybrid renewable integration.

This study demonstrates the viability of an ATS-controlled HRES setup for stable and uninterrupted power supply, making it a promising solution for residential and commercial applications.

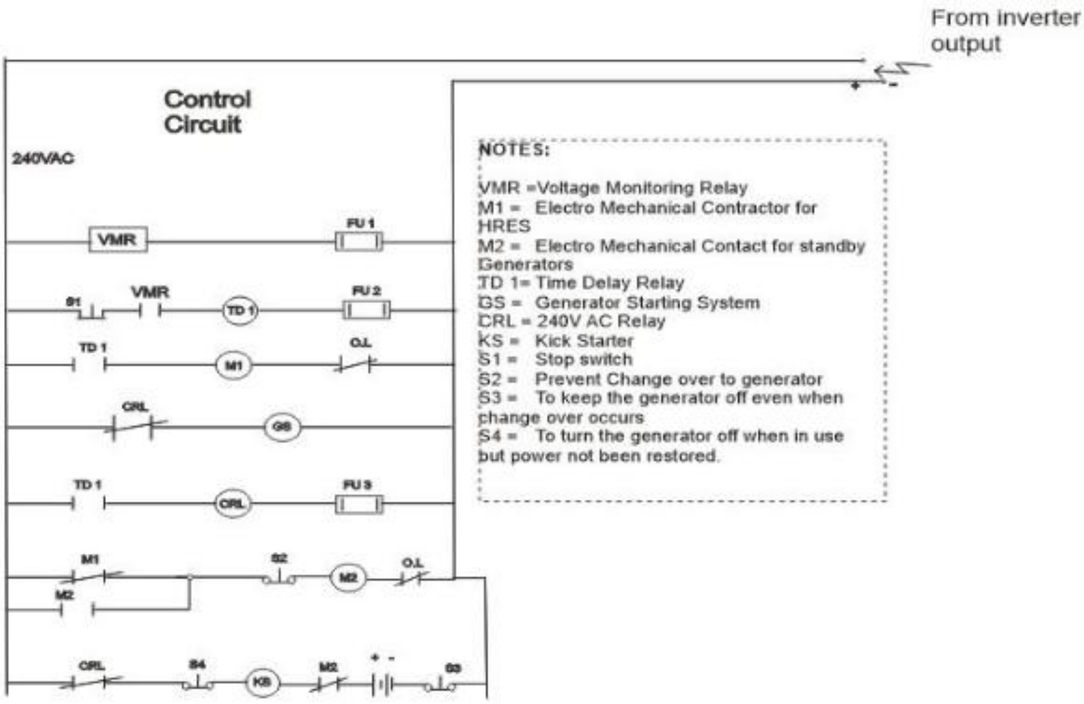

Figure.1: Example of a ladder diagram

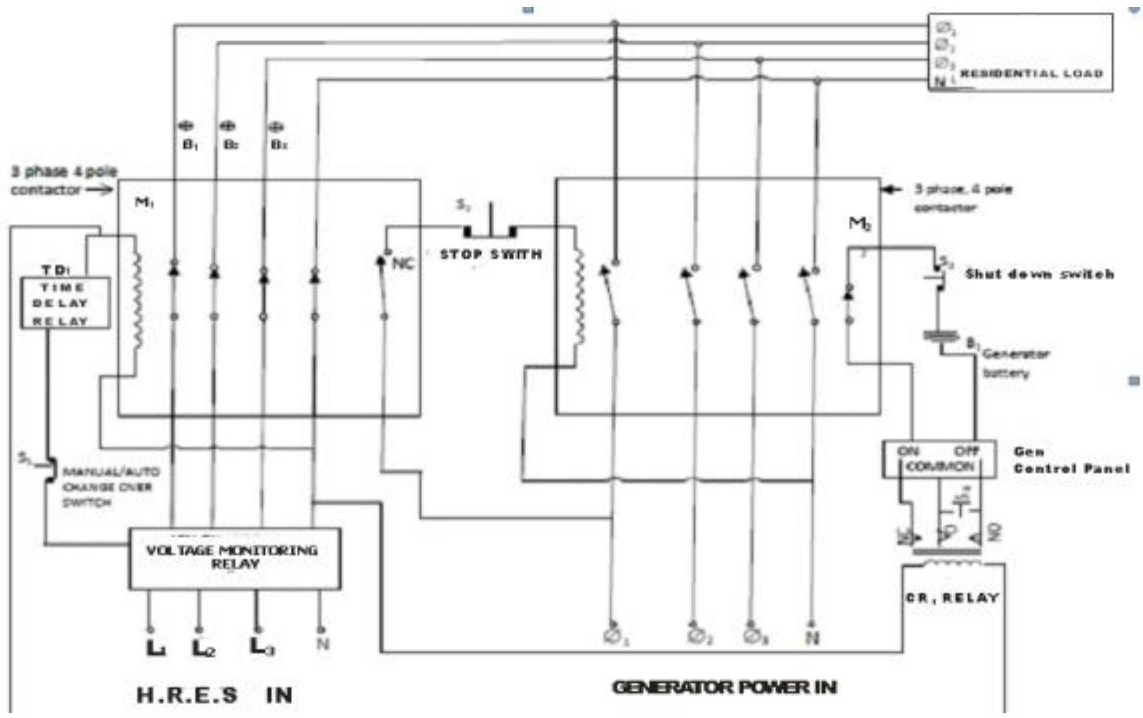

Figure. 2: Single line diagram of Automatic Transfer Switch (ATS)

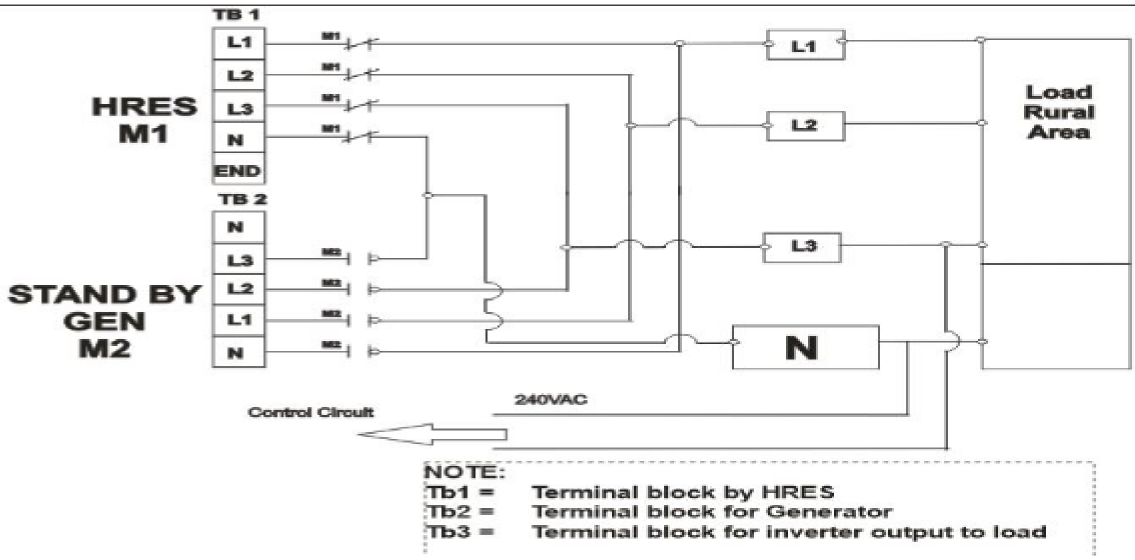

Figure. 3: Automatic Transfer Switch showing Renewable Energy Source

Simulation of Automatic Transfer Switch

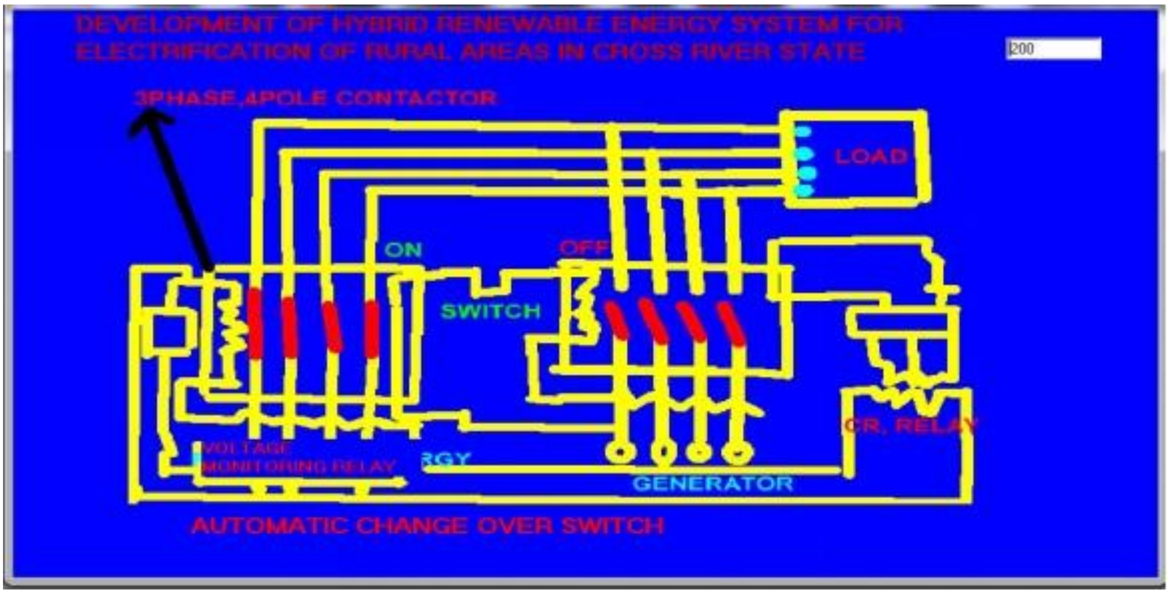

Figure. 4: Normal condition showing optimal voltage >200V)

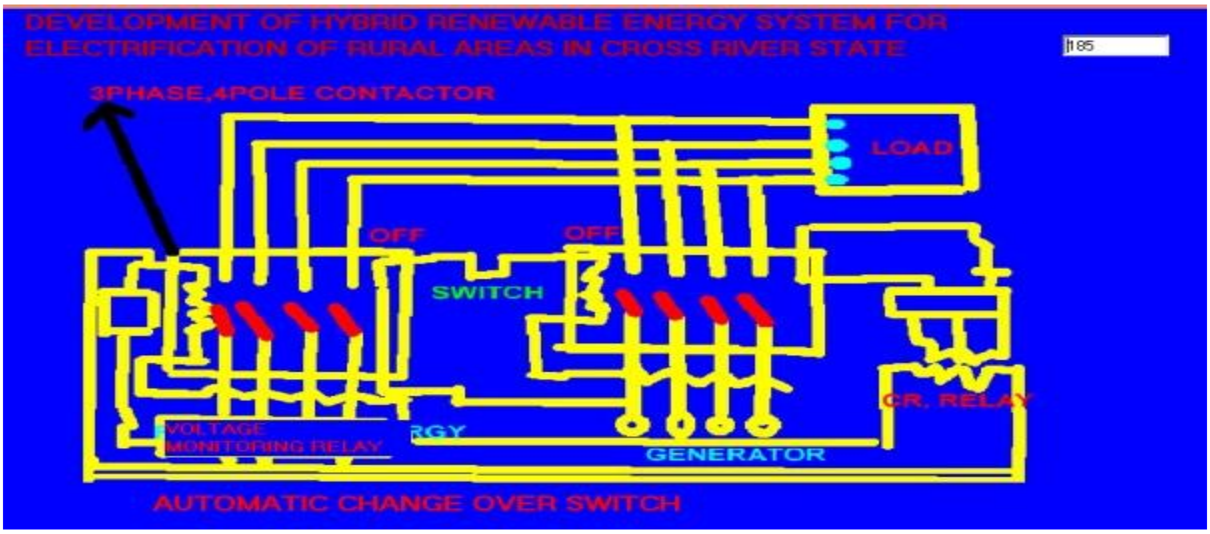

Figure 5: Open circuit condition due to low voltage

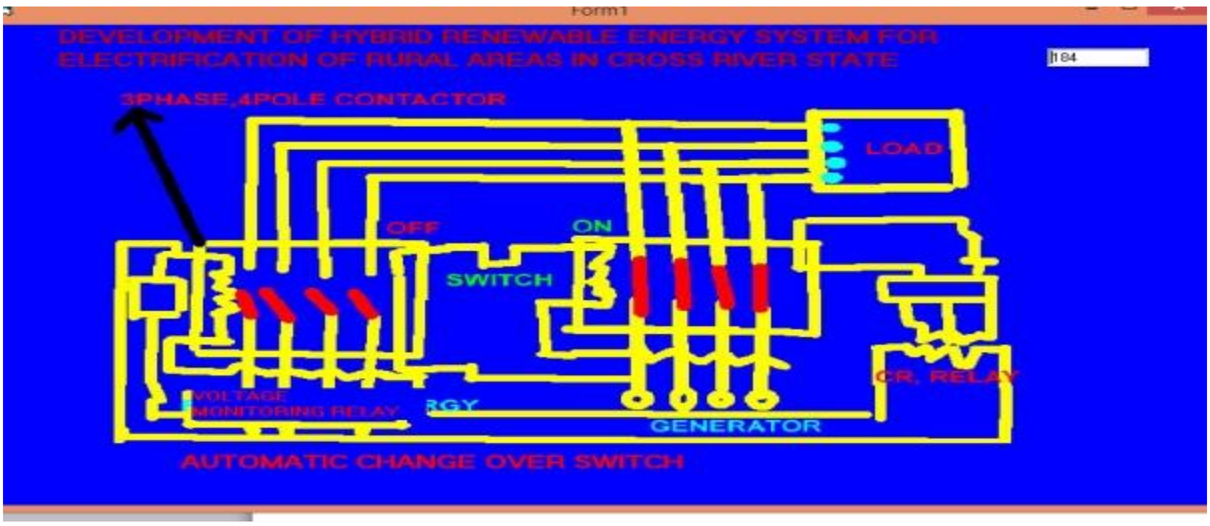

Figure 6: Energised condition showing Generator breaker closed.

The system performance was evaluated satisfactorily using Visual Basic software.

Conclusion

To design and implement a relay-based Automatic Transfer Switch (ATS) is feasible as it has demonstrated reliability and cost-effectiveness in integrating renewable energy into power systems. Using relay logic, the system efficiently manages power transfer between primary and backup sources, ensuring continuous supply under varying voltage conditions. Electromechanical relays provide a simple, economical alternative to solid-state designs, enabling seamless transfers, voltage monitoring, and safety.

Simulation and testing validated the system's performance, confirming its ability to detect voltage drops, switch to backup power, and deactivate the generator upon primary source restoration. Proper component sizing and hybrid solar-wind integration enhanced efficiency and sustainability.

Overall, the relay-based ATS is a practical and scalable solution for power management. Future improvements could enhance automation and incorporate additional renewable sources to further improve reliability and adaptability.

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