DOI : https://dx.doi.org/10.26808/rs.re.v3i6.02
International Journal of Research in Engineering & Science ISSN:(P) 2572-4274 (O) 2572-4304
Available online on http://rspublication.com/IJRES/IJRE.html volume 3 Issue 6 Nov.-Dec 2019

Ladder diagram based Design of an automatic Change over switch for rural Areas using Renewable Energy Source.

Ngang, N.B[1], ,E.N.C. Okafor[2],D. Nnadi[3]
Department of Electrical /Electronic Engineering,
Enugu State University of Science and Technology, Enugu.
Corresponding Author:nbngang@gmail.com,Tel: 2348029662752

Abstract

There are major challenges when using renewable energy for power supply.When it is cloudy usually after rain, solar production is low yet there is need to use power when the demand for power is required; weather conditions can be a problem at that period.An Automatic Transfer Switch (ATS) for a single phase power generator has been designed to enable the automatic operation and transfer of power supply between a primary source of power supply and a secondary source (power generator). Clean and environmental energy sources campaign associated with their availability at almost zero cost have resulted in the increase of Renewable energy use throughout the world. In Nigeria and specifically in most parts of the country, Solar Energy constitutes a tremendous resource. When it is cloudy usually after rain we usually experience lowsunlight; hence there is need to maintain continuity of power supply switching automatically to the stand by source. The primary power source is the Solar PV system and the generator is the secondary. This research work provided the means to transfer power in a safe manner using relay logic technique. When solar production is low (below 200V), the system switches to the diesel or petrol system until it detects voltage within the allowable limits from the Inverter and switch back to HRES. The design is simulated using visual basic to validate the performance of this work. Contacts of HRES opened when voltage falls below 185V.Contacts of generator circuit closes when voltage is below normal 185-250Vac.

Key words: Automatic transfer Switch (ATS), Photovoltaic system (PV), Relay Logic,LadderDiagramand HRES.

1. Introduction

Over the years, Renewable Energy sources market share has kept increasing. From 2014 to 2015, the global capacity was increased by *50GW* [1]. In Africa Solar Energy has seen a market boom. Due to high cost of fossil fuel [2], most households purchase a system capacity which is below their load requirement as result the storage batteries are usually not fully charged during the day.From the observation made on Solar PV system installations of some families in the town of Ugep, which is located in the south eastern parts of Nigeria, the solar energy is used to power few lighting systems (bulbs) and only basic appliances such as TV, Radio, Decoders, though other appliances are found but not used at all. In most cases during evening time or during a rainy day, the system couldn't power its specified loads for 1 hour without fall of voltage. In Uganda, the Solar Home Systems market is regarded as one of the biggest areas for commercially driven Solar PV business and has been considered for the past few years to have a high potential [2]. Nigerians have started implementing this technology. This shows the change in the Solar PV market pattern which was dominating by Institutional

DOI : https://dx.doi.org/10.26808/rs.re.v3i6.02
International Journal of Research in Engineering & Science ISSN:(P) 2572-4274 (O) 2572-4304
Available online on http://rspublication.com/IJRES/IJRE.html volume 3 Issue 6 Nov.-Dec 2019

PV segment (rural health clinics) and Telecommunications/ Tourism segment, based on 2009 research [3].

For Urban customers (Lagos and Abuja), solar companies provide equipment such as Solar PCU (Power Conditioning Unit), a device of multiple features (ATS included), hence expensive and not in the reach of most households. Solar PCU has the capability of charging battery and powering loads using Grid power. Yet, besides reliable electricity supply, households seek to minimize the Grid power consumption while purchasing Solar Home System.

ATS available on the local market dedicated to household' use have been designed and manufactured for Generators use as secondary power source. In the Solar Industry, ATS is a subsystem of Solar PCU. Though it is advantageous for some system capacity and countries with advanced power billing system, Solar PCU remains not relevant for most rural communities due to lack of funds.During site assessment prior to installation one has to consider a good mounting position; it is recommended a tilt from 5 to 15° to allow easy cleaning of modules by rain water [4]. Considering load estimation method to be used in the design, note that total Energy consumed by all appliances is calculated based on the average hours each one is used in a single day [4-5]. This gives Kilowatt hours or Units consumed.

2. MATERIALS AND METHODS

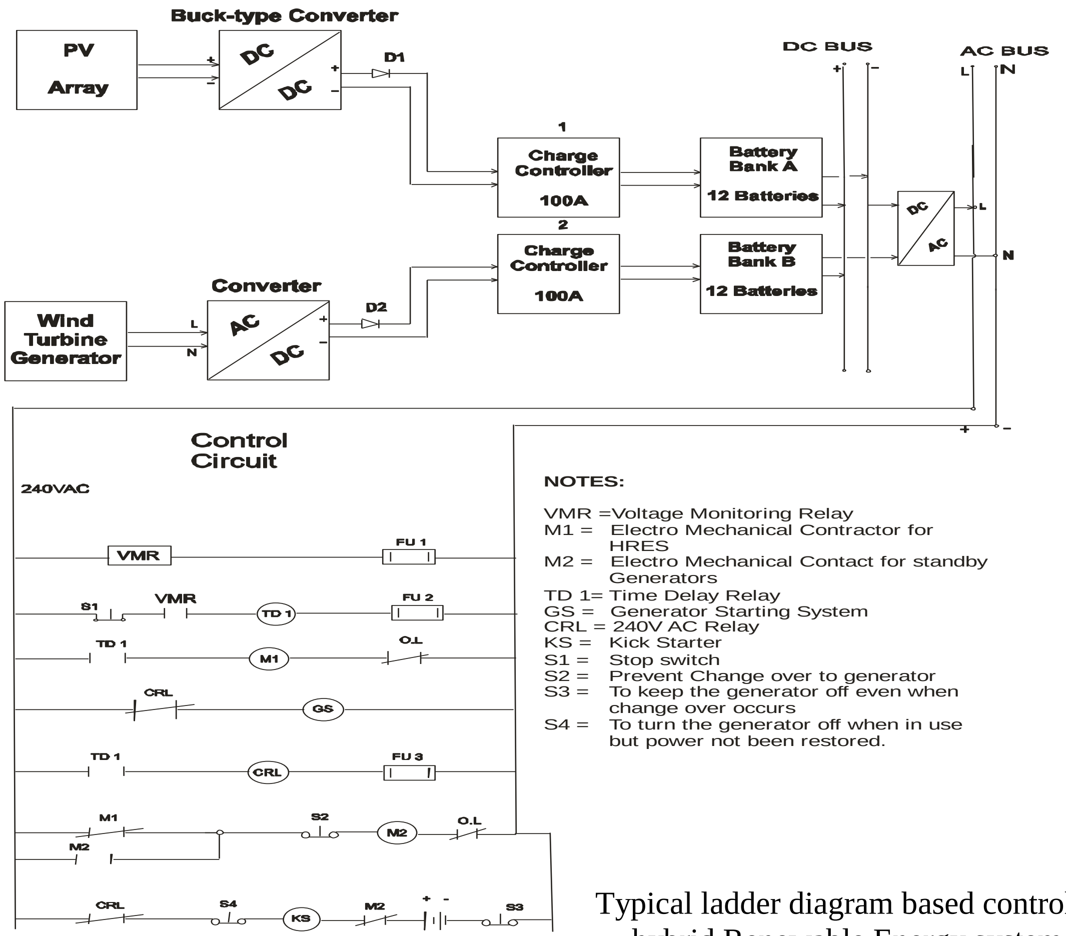

Fig.1 Typical ladder diagram based control of hybrid Renewable Energy system.

2.0 COMPONENTS DESCRIPTION

The A.C voltage monitoring and control circuit are designed and constructed. This was achieved by using voltage monitoring relay (VMR) as a primary component of the power sensing and control circuit; which is used for measuring and comparing the voltage level of the utility supply with a set voltage tolerance range (185-250V A.C) while a 12A miniature circuit breaker will act as a switch to the power supply from the public utility end of the AT

- PV Array PV modules
- Charge controller
- Battery Bank
- Inverter
- Power meter
- Disconnect Switch

PV Panel

It consists of solar cells made of semiconductors materials and connected in series. The combination of cells gives a Panel and the combination of many panels form an Array.

Charge Controller

As it called, it controls or regulates the flow of current and voltage into the battery. It is connected between the panels and the battery, and rated in terms of maximum Amps and voltage it is meant to handle.

Batteries

They are used for energy storage.

Solar PV systems require the use of deep cycle batteries i.e. which can regularly deeply get discharged using most of its capacity and quickly get charged. Solar battery can be discharge up to 20%, however for the best lifespan, it is recommended to keep the average cycle at about 45%.

In contrast, a standard battery (car battery) is designed to deliver short, high-current burst for the starting of the engine.

Though they are all lead-acid batteries i.e. consists of Sulphuric acid and plates made up of leads/

Inverter

It converts DC into AC electricity. They are categorized in three major types:

- String Inverters: PV modules are connected in series circuit before connection to this type of Inverter. It is the most affordable, can be coupled with charge controller, storage system.
- Micro-inverters: this inverter is installed on every PV module that composes the array. The output of the Micro-inverters is connected in parallel to the loads. It is the most expensive, as the DC output of each panel is directly converted to AC, there is no storage system in with this type of Inverter.
- Power optimizer systems: this is a hybrid system of the above two types. There is a Central String inverter where by the module are not connected directly to it but through an Individual power optimizer installed on each panel.

3.0 Switching Methods

There are typical two methods for power switching mechanism: Manuel Switching and automatic switching mode. The firstrequires an operator to physically flip a switch to transfer loads to the secondary source. Automatic switching happens when there is a change in operating parameters after sensing that the primary source has lost or gained power. An ATS is an electrical/electronic switch that senses when the primary power source is interrupted and automatically shifts loads to the secondary source, of course, as long as the later one parameters (voltage & frequency) are within prescribed limits [6].A typical AT follows the following steps: The normal power source fails, When power of the alternative source is

DOI : https://dx.doi.org/10.26808/rs.re.v3i6.02
International Journal of Research in Engineering & Science ISSN:(P) 2572-4274 (O) 2572-4304
Available online on http://rspublication.com/IJRES/IJRE.html volume 3 Issue 6 Nov.-Dec 2019

stable and beyond the prescribed voltage (220-230V) and frequency tolerances (±2% of 50Hz), loads are shifted to the secondary source. When the primary source is restored within prescribed limits and for a minimum time, the loads are shifted back from the secondary to the main source. In this design, the primary source is the Hybrid Renewable Energy Source while the stand by source is the diesel generator.

Most of the available ATS for home use are designed for the use of Generator as the secondary power source.The work done by a research estimated the average electric power consumption for a Ugandan house as 93.6kWh [7].This gives a clue on how on how the average daily energy can be calculated. Over time, automation of electrical power supply has become so vital as the rate of power outage is predominantly high [8].According to [9] and [10], all automatic transfer switches for generators consist of three parts namely:

- Contacts to connect and disconnect the load to source of power
- A transfer mechanism to move the contacts from one source to another
- An intelligent or logic control unit to constantly monitor the condition of the power sources and so provide the brain necessary for switching and related circuit to operate correctly

Home ATS Design

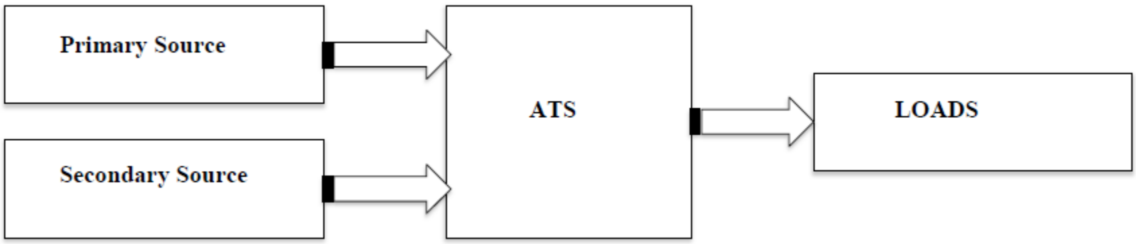

Fig. 2: ATS Design Consideration

3.1 Sizing and description of Automatic Changeover System.

(i) Sizing the Automatic Power Changeover Electrical Requirements

Electrical components in a system like this must be properly sized to deliver the load current and withstand thermal stress.

We will start doing this by using power fundamental equations and formulae.

Recall that COS θ = (Active power (kW))/(Apparent power (kVA))

Assume the rating of the generator to be Apparent power (Generator rating) 50kVA = 50,000VA

Phase voltage, V_{ph} = 220V, Cos θ = 0.8

Hence, active power (kW), = P = 0.8x50,000= 40KW

We know that P = 3Vph Iph COS θ (Power per phase

Iph = P/(3Vph COS θ) = 40,000/(3 x 220 x 0.8) = 40,000/(528)

Iph = 75.76 A.

To compensate for the losses, a tolerance of 25% is added.

This gives 1.25 x 75.76A. = 94.7A, the standard one is 100Amps to withstand stress and surge the current per phase is 75.76A.≅ 76A, the chosen power cable should be 1.5 times the current. From experience, in the industry, the operating conditions and the frequency of switching as well as the environment will be considered.

The power cable should withstand continually a current magnitude of at last 150% of the phase current. This amounts to 2.4 x 76A rounded to the next higher value.

2.4 x 76A = 182.4A. This can withstand excessive overloading. Cable area in mm^2 equal to $70mm^2$ this will withstand 185 A.The information on cable sizing is obtained from www.electrical technology.com. The cable size that can withstand or carry a current magnitude of 182.4A is $70mm^2$

DOI : https://dx.doi.org/10.26808/rs.re.v3i6.02
International Journal of Research in Engineering & Science ISSN:(P) 2572-4274 (O) 2572-4304
Available online on http://rspublication.com/IJRES/IJRE.html volume 3 Issue 6 Nov.-Dec 2019

(ii)Description of Automatic Change over System

The automatic power changeover is designed to select between two sources of supply making one source the primary or normal feeder, while the other source is secondary source or emergency feeder. In this design, the RES is the primary source while the generator is the secondary source. The agent monitors the quality of voltage from the primary source and checks if there is phase failure or out of tolerance (185-250Vac). If the parameters are not balanced or within normal range, it will transfer or change over to the standby generator starting it automatically,also switching it off automatically as soon as the conditions remain normal. The schematic diagram in Figure 6 shows the circuit when the HRE power source is ready and available. If the voltage across the phases is normal the voltage monitoring relay connects the contacts of the electromagnetic contactor (3-phase 4 pole type), M1. The output of this contactor feeds the residential load. Simultaneously, it completes the circuit of M1 coil via a time delay relay TD1. M1 has an additional "normally closed" contact (NC) in it. This contact opens when M1 is energized and also controls the voltage to the coil of M2. Anytime this contact is open, M2 which controls the generator output stays de-energized. This is like an interlock separating the generator output from the load, thus, preventing superimposition of two sources. Again, the signal from TD1 is used to energize a 220V control relay (CRL) which controls the generator starting system. As long as CRL is energized, the generator is made to stay in the off position. Thus, with normal power supply from HRES, the generator remains off and only the HRES supply is connected to the load. If however, a phase failure or complete power failure occurs in the HRES feeder, the intelligent agent (VMR) will cut off power thus de-energizing M1 and CRL. When this occurs, the normally close contact of M1 closes, connecting the coils of M2 to the generator output. Consequently, HRES circuit is disconnected from the load. M2 is yet to be energized since the generator is yet to start. However, the time for which this occurs is small as CRL, once de-energized, links the generator starter to the battery causing the generator to crank and start. Once it has run up to speed and has built up sufficient voltage, M2 becomes energized (since its coil is energized by the generator output). This cause M2 to activate and connects the load to the generator output, thus, restoring power automatically. The normally closed contact of M2 is used to disconnect the battery from the starter to prevent it from engaging when the generator is running figure

As soon as power is restored, the time delay relay TD1 prevents change over back to HRES from happening until after predetermined time. This time is kept to ensure that the HRES mains power supply is stable. Once the delay time elapses, TD1 energizes M1 and CRL at the same time. This causes the normally close contact of M1 to open and thus de-energizing M2 and disconnecting the load from the generator supply. At the same time, M1 being energized connects the load to HRES supply. In the same vein, CRL turns off the generator ignition.

The function of S1 is to make a manual change over when pushed open. This is achieved by disconnecting power from the coil of M1 thus de-energizing it.

S2 is used to prevent changeover to generator by disenabling M2. This operating condition is usually done when the generator is started to run on idle mode to steam the generator engine.
S3 is used to keep the generator off even when changeover takes place.

The function of S4 is to turn the generator off when in use but power has not been transferred. It is not a push and hold switch. B1, B2 B3 are indicator lamps used to monitor the presence of output voltage in the power circuit. The changeover rating depends on the rating of the contactors.

DOI : https://dx.doi.org/10.26808/rs.re.v3i6.02
International Journal of Research in Engineering & Science ISSN:(P) 2572-4274 (O) 2572-4304
Available online on http://rspublication.com/IJRES/IJRE.html volume 3 Issue 6 Nov.-Dec 2019

A grouping of Wind and PV energy system into a hybrid generation system could increase the efficiency by increasing their overall energy output, thereby reducing the energy storage requirement. This makes system less costly and more reliable as compared to individual energy system.

3.2 Ladder Diagrams

Ladder diagrams are specialized schematics commonly used to document industrial control logic systems. They are called *"ladder"* diagrams because they resemble *a* ladder, with two vertical rails (supply power) and as many "rungs" (horizontal lines) as there are control circuits to represent.adder diagrams are specialized schematics commonly used to document industrial control logic systems. They are called "ladder" diagrams because they resemble a ladder, with two vertical rails (supply power) and as many "rungs" (horizontal lines) as there are control circuits to represent. If we wanted to draw a simple ladder diagram showing a lamp that is controlled by a hand switch, it would look like

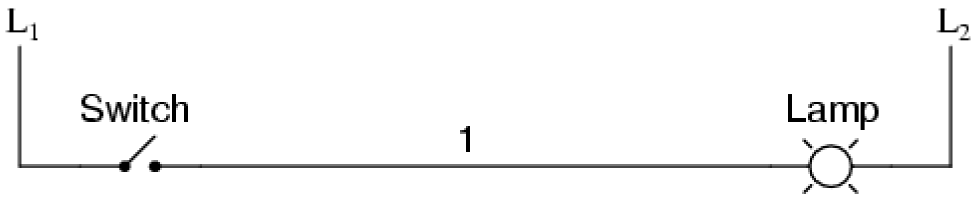

Fig. 3: Illustration of simple ladder diagram

The "L_1" and "L_2" designations refer to the two poles of a 220 VAC supply unless otherwise noted. L_1 is the "hot" conductor, and L_2 is the grounded ("neutral") conductor. There are different arrangements of automatic changeover switch, one is as shown below This work is about using ladder diagram to interpret the working and control of an Automatic Changeover device utilizing a voltage monitoring relay in the circuit of the primary source

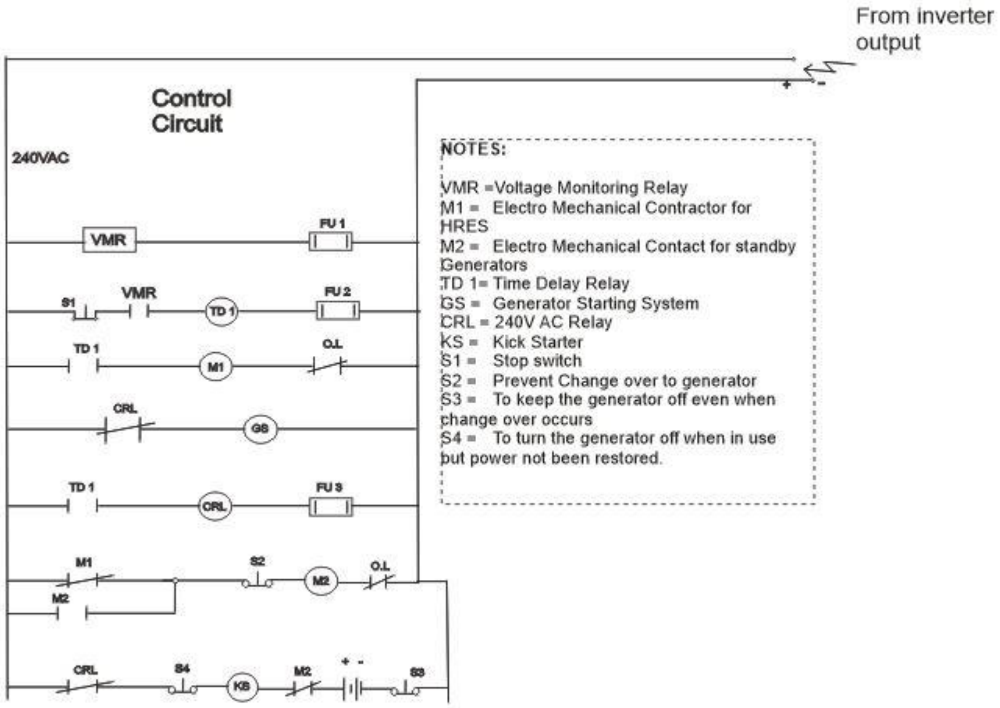

Fig.4: ladder diagram implemented in the automatic changeover device of fig 5.

DOI : https://dx.doi.org/10.26808/rs.re.v3i6.02
International Journal of Research in Engineering & Science ISSN:(P) 2572-4274 (O) 2572-4304
Available online on http://rspublication.com/IJRES/IJRE.html volume 3 Issue 6 Nov.-Dec 2019

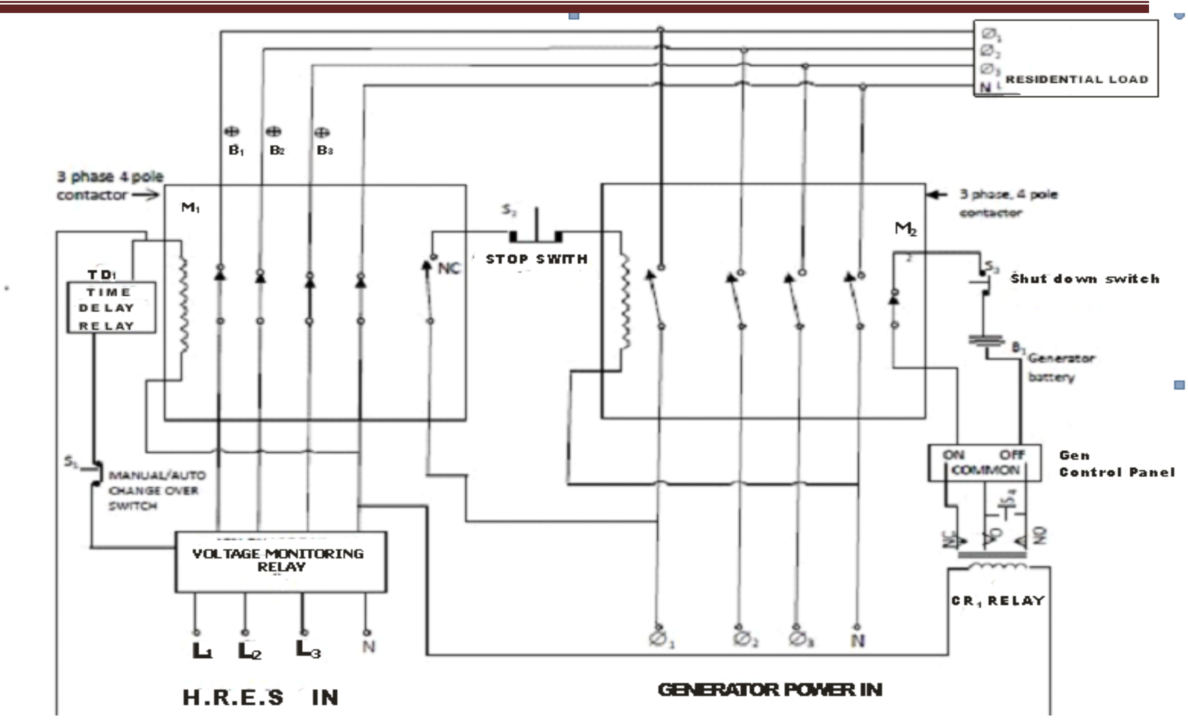

Fig. 5: Complete schematic diagram of Automatic Changeover Device

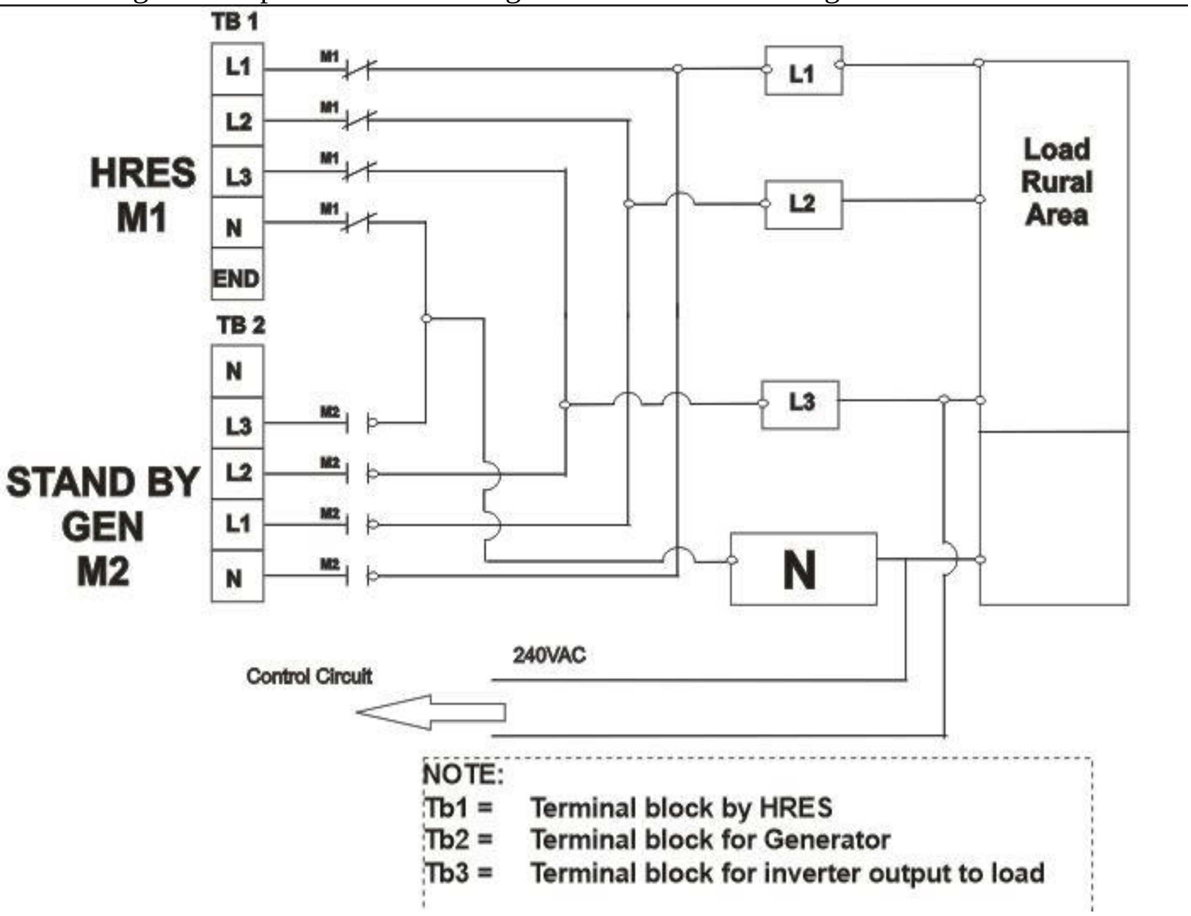

Fig. 6: Automatic changeover with HRES In service.

DOI : https://dx.doi.org/10.26808/rs.re.v3i6.02
International Journal of Research in Engineering & Science ISSN:(P) 2572-4274 (O) 2572-4304
Available online on http://rspublication.com/IJRES/IJRE.html volume 3 Issue 6 Nov.-Dec 2019

4.0 Simulation of Automatic Changeover device

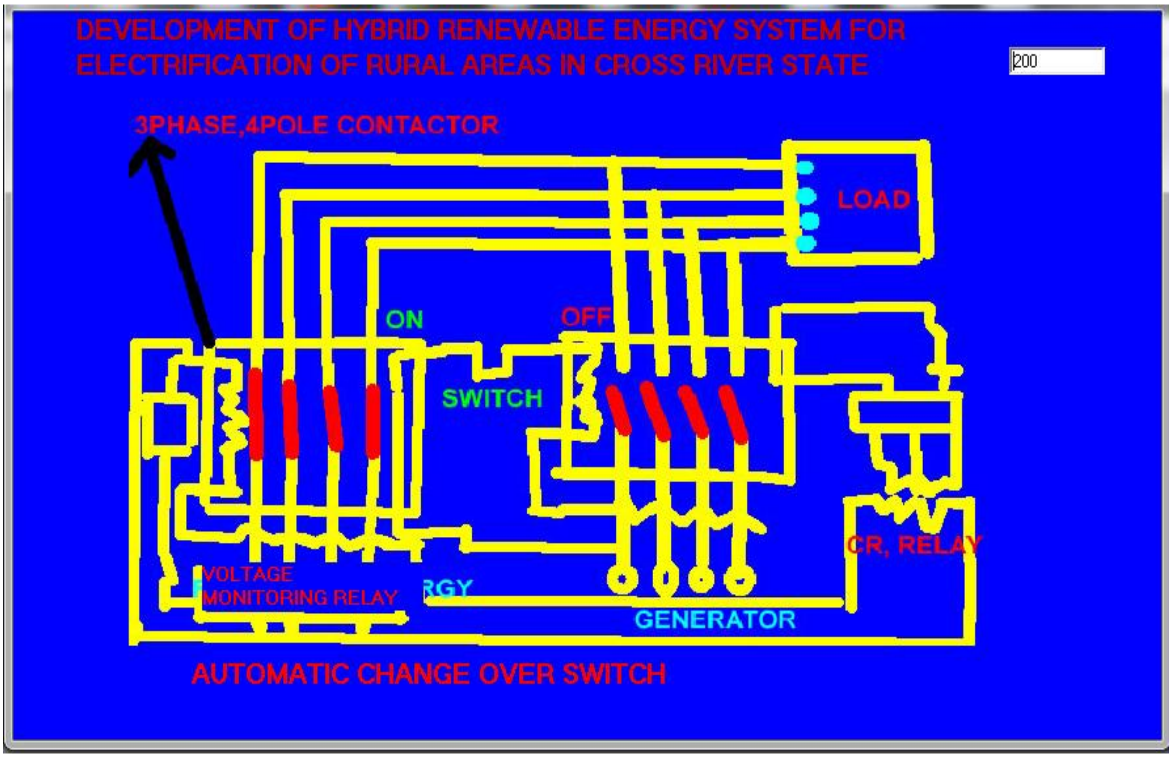

Fig. 7: Contacts of the HRES are closed meaning voltage is normal above 199 volts(200V)

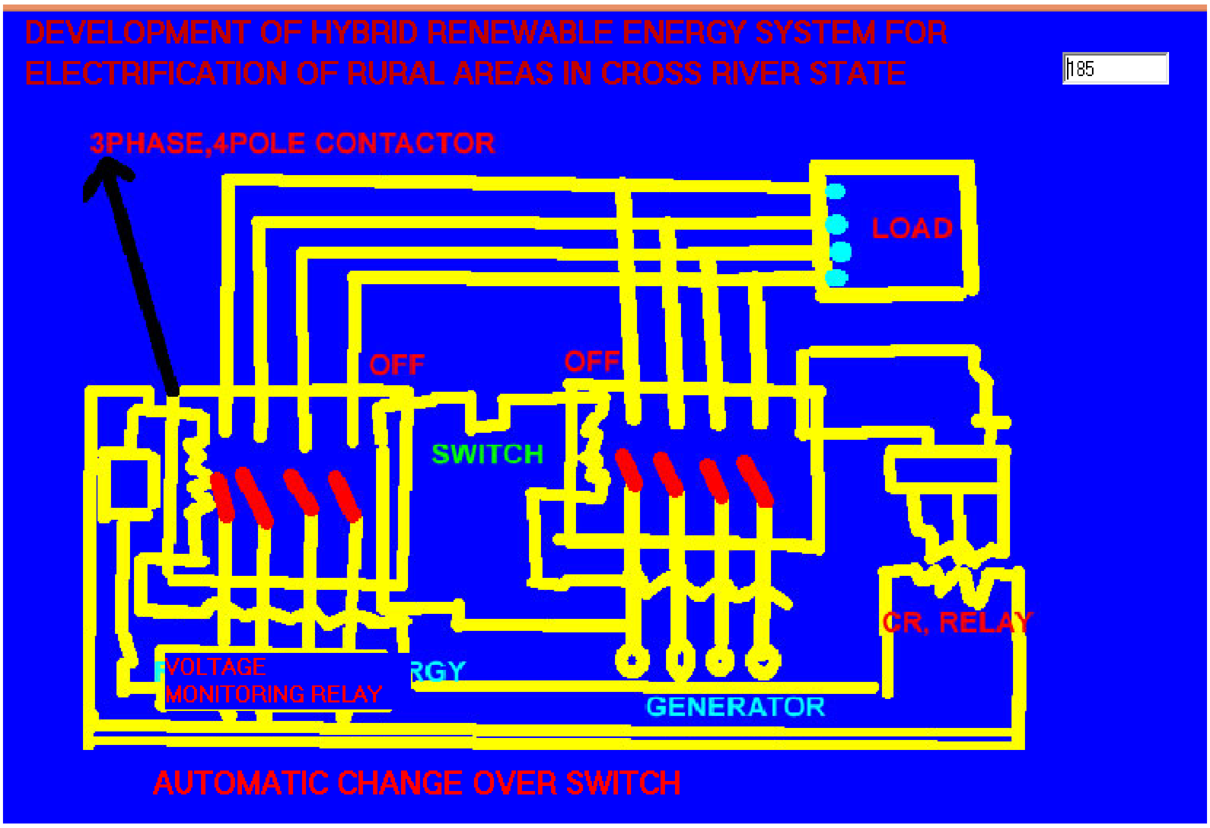

Fig.8: Both contacts are on off position voltage level below normal range ready to transfer to Generator.

DOI : https://dx.doi.org/10.26808/rs.re.v3i6.02
International Journal of Research in Engineering & Science ISSN:(P) 2572-4274 (O) 2572-4304
Available online on http://rspublication.com/IJRES/IJRE.html volume 3 Issue 6 Nov.-Dec 2019

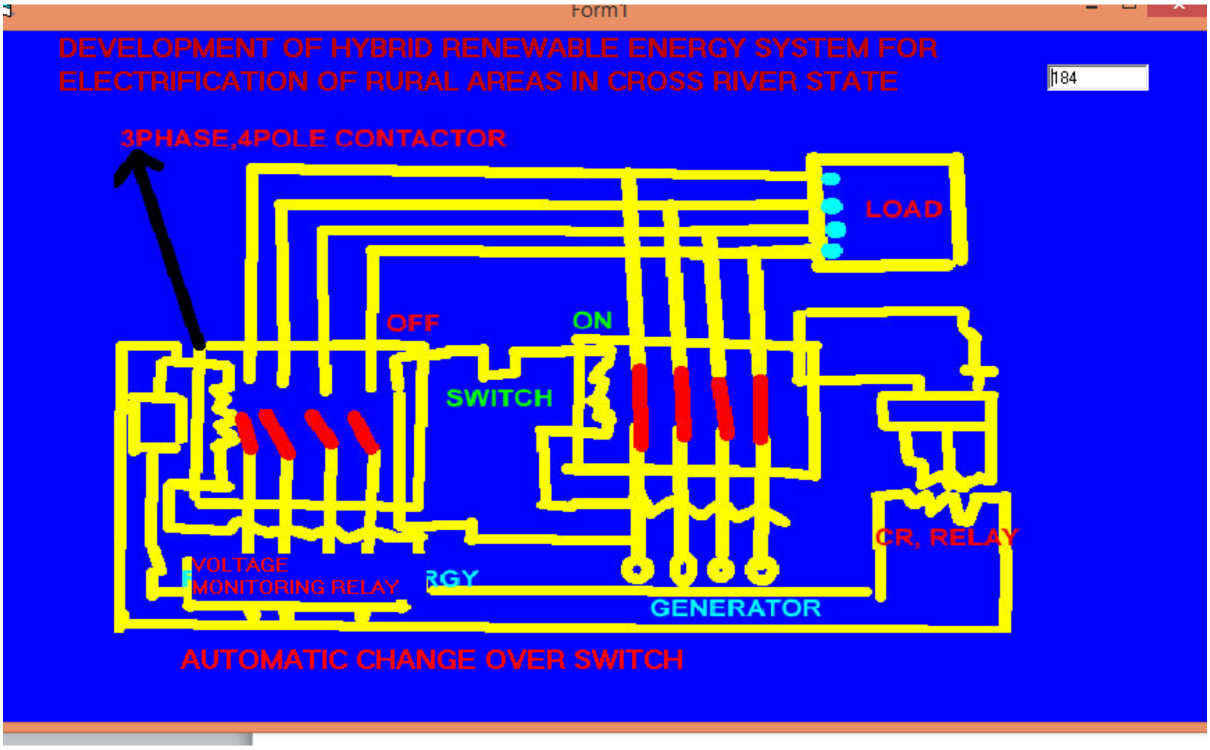

Fig. 9: Contacts of generator circuit have been closed due to low output from HRES.

4.1 Results and discussions

The simulation of Automatic Changeover Switch was performed using Visual Basic The mechanism opened and closed as designed under relay Logic control. The agent monitors the quality of voltage from the primary source and checks if there is phase failure or out of tolerance (185-250Vac). If the parameters are not balanced or within normal range, it will transfer or change over to the standby generator by starting it automatically, also switching it off automatically as soon as the conditions returns to normal.

5. Conclusion

Automatic changeover device having generator starting device/shut down facility has been implemented to help reduce manual labour. Electricians in charge of maintaining this system will find it useful due to the fact that the system is robust and user-friendly.I have included overload protection in the power circuit as a means protection as an improvement to the work of [8]. I recommend the introduction of microcontroller in future work of this type to make it fast in operation.

References

[1]. J. L. Sawin, K. Seyboth, and F. Sverrisson, *Renewables 2016: Global Status Report*. 2016.
[2]. M. Assessment, O. F. Modern, O. F. F. Grid, and L. Systems, "Produced for Lighting Africa," 2014
[3]. U. E. Hansen, "Review of Solar PV market development in East Africa UNEP RisøCentre Technical University of Denmark," no. 12, pp. 1–22, 2014.
[4]. REA, "Rural Electrification Strategy and Plan 2013-2022," 2013.
[5]. P. Mohantyet *al.*, *PV System Design for Off-Grid Applications PV System Design for Off-Grid Applications*, no. September. 2015.
[6]. A. D. Bank, *Handbook for Rooftop Solar Development in Asia*.

[7]. J. Gwamuri, "Design of PV Solar Home System for Use in Urban," no. October 2014.
[8].1. M.S Ahmed, A.S Mohammed and O.B. Agusiobo, "Development of a Single phase Automatic Change-Over Switch
[9]. ATS-01 Ver1.0, Automatic transfer switch control unit operator's manual: retrieved on December17, 2009.
[10]. A. S. Hassan, I. Adabara, and A. Ronald, "Design and Implementation of an Automatic Power Supply from Four Different Source Using Microcontroller," vol. 4, no. 5, pp. 40–46, 2017.