International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 07 Issue: 06 | June 2020 www.irjet.net p-ISSN: 2395-0072

Design and Implementation of a Microcontroller-Based Automatic Changeover System for Transformers in Power Stations

Kibet Fridah Jerobon[1], Mutuku Joseph Ndisya[2], Ominde Calvine Fundi[3]

[1]Student, Department of Physics, College of Pure and Applied Sciences, Nairobi, Kenya
[2]Professor, Department of Physics, College of Pure and Applied Sciences, Nairobi, Kenya
[3]Doctor, Department of Physics, College of Pure and Applied Sciences, Nairobi, Kenya

---***---

Abstract - *This research project seeks to design and construct a programmable microcontroller-based automatic changeover system to ensure an efficient and continuous uninterrupted power supply to industrial plants and residential areas. The circuit incorporates two transformers connected independently to specific loads. Current sensors are connected to the transformers to check for current availability and the input fed to Arduino ATmega2560 microcontroller. A feedback loop is also created by connecting the loads to the microcontroller to monitor load variations. Using the transformer and load inputs, the microcontroller instructs the relays to switch between the loads according to the specified transformer capacities and availabilities. Load shedding and load sharing are also executed by the microcontroller and the status of the transformers and loads displayed on an LCD display. Two sets of data were obtained; one showed the effects of load variations on transformer performance before and after the changeover, and the other showed the results for when the designed microcontroller based changeover system was implemented. The results showed that whenever a load was applied on the secondary side of the transformer, the secondary current increased together with the primary current. It was also found that for two operational transformers, the changeover process does not require any time-lapse. Using a program algorithm, load shedding and load sharing are achieved through the microcontroller. Measured current, time and resistance variables were plotted and analyzed graphically using Minitab. Proteus ver. 8.6 software was also used to simulate the circuit, and the results presented graphically.*

Key Words*: *Automatic changeover system, Liquid crystal display (LCD), Load shedding, Load sharing, Microcontroller, Relays

1. INTRODUCTION

This In Kenya, power consumption has relatively increased over the years. A lot of areas have gained access to electricity which has led to vast growth and development. With the increased demand for electricity, industrialization has been promoted. This has led to the development of schemes that boost the economy of the country and has, in turn, increased the demand for continuous and uninterrupted power supply. This includes the development of high technology and the implementation of complex types of equipment that are fully dependent on electrical power. To meet these demands, different schemes which essentially need two or more sources of supply to the bus bar system are required. Both the equipment and methods used to effect the changeover of the supply are exposed to challenges that include inefficiency and cost [3].

The supply of uninterrupted electricity calls for the introduction of alternative power sources and the automation of power generation techniques [1]. Automation of electrical power which mainly involves the use of advanced technology mostly implies the incorporation of automatic circuit systems that will help in eliminating time wastage, overloading of the electrical equipment and components used through monitoring. However, with the introduction of alternative power sources, constraints of switching both smoothly and timely between the alternative sources and the mains supply are brought forth, in case of a power interruption [4].

The provision of alternative power source in the power stations has no doubt brought relief in the availability of power but not without a supervisory challenge associated with manual operation of the changeover [9]. Therefore, for quick changeover, automation processes should be emphasized especially in industries that require uninterrupted power supply such as hospitals and security agencies [10]. An automatic transfer switch is very necessary for the operation of these electrical systems as it allows the transfer of loads between power sources without physical intervention [2].

With an automatic changeover system, the changeover occurs almost instantly because the electrically connected relays and interlocks monitor all the conditions of the changeover. This package is economical in terms of space, reduced time for system design and troubleshooting and lesser number of failures, ensuring efficient continuous power supply to industries and even households. The use of microcontrollers to operate and communicate between different circuits of the substation, in this case, has become essential for quick fault detection and changing over [5]. It can also fulfil data acquisition, equipment control, measurement and parameters adjustment, which play an important role in improving the economic benefits, safety and the reliability of power grid operation [8]. In addition, it also improves dispatcher communication, modernization and automation enhancement during electric power dispatch and the efficiency and level of dispatch.

As much as the automatic changeover systems are reliable and efficient, they also suffer some setbacks that if not eliminated, may cause further damage to the whole power grid. These setbacks include the overloading of transformers after switching. Overloading can be reduced or eliminated by combining the automatic changeover switch with a gradual or sequential loading of the transformer and the switched feeders [7]. This sequential loading ensures the step by step loading of the feeders to maintain power supply stability in case of transformer overloading occurs. The combined function of the automatic changeover system and the sequential loader is critical in areas and industries that require an uninterrupted power supply for continuous operation.

This research paper utilizes the combination of a microcontroller and the load shedding and sharing features to detect transformer failures, prevent transformer overloading, and to ensure a continuous and uninterrupted supply of power to the consumers. This, in turn, ensures system stability and durability. The design incorporates Arduino ATmega2560 microcontroller, current sensors, Liquid crystal display (LCD) and relays to switch between loads during load variations.

2. DESIGN, METHODOLOGY AND ANALYSIS

2.1 The working Principle

The design of the automatic changeover system starts with the detection of voltage/current from the two transformers using a voltage/ current sensor circuit, as shown in Fig- 1.

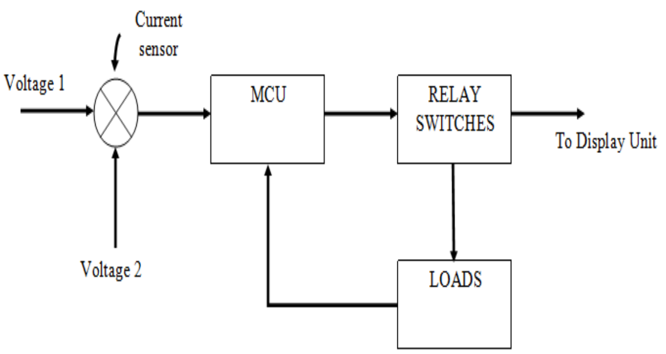


Fig -1: The design of the automatic changeover system

The output of the voltage comparator/sensor is fed to the microcontroller unit (MCU) which then gave instructions to the relay switches to either isolate the defective transformer or not to isolate it. If there is the presence of current from both transformers, the microcontroller instructs the respective relays to either open or close the loads. Current variations are recorded as they occur. If no voltage is input to the microcontroller, it implies that the transformer does not have any input and therefore shows a cause for failure.

A feedback mechanism is also included in the system to monitor and record load current values to determine if the transformers can support the demand. In this case, current sensors from the loads are connected as inputs to the microcontroller. The changeover system is effected using the following modules, as shown in the block diagram:

i. The voltage sensor module
ii. Design of the Control system
iii. Design of the automatic changeover circuit
iv. LCD display module

2.1.1 Voltage Sensor Module

The voltage sensor circuit is required for constant monitoring of input current, and voltages from the transformers must be done. The circuit setup is as shown in Fig.-2.

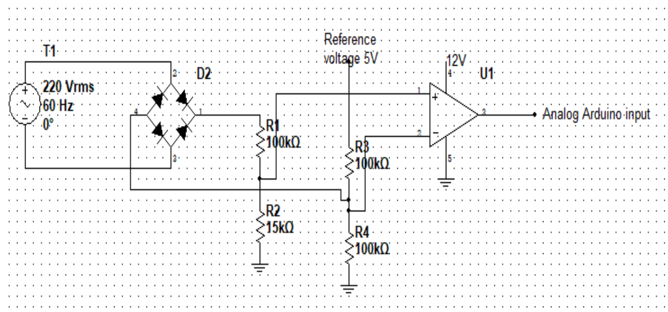


Fig -2: Voltage detector circuit using an IC comparator

The voltage detection circuit includes resistors, a full-wave bridge rectifier and an IC comparator. The mains line is connected through two resistors to the positive pin of the IC and a reference voltage of 5 V connected to the negative pin. To calculate the voltage across, R_2, equation 1 was used.

$$V_{R2} = \frac{R2}{R1+R2} V^{+} \qquad (1)$$

Where V_{R2} is the voltage across R_2, V^+ is the unregulated voltage, R1=100 kΩ, R2=15 kΩ.

The output voltage of the rectifier was calculated using equation 2.

$$Vo = \frac{2\times\sqrt{2}\times Vrms}{\pi} \qquad (2)$$

2.1.2 Design of the Control system

ATmega2560 Arduino microcontroller is used to implement automation in the changeover system. The block diagram showing the operation of the control circuit is as shown in Fig -3.

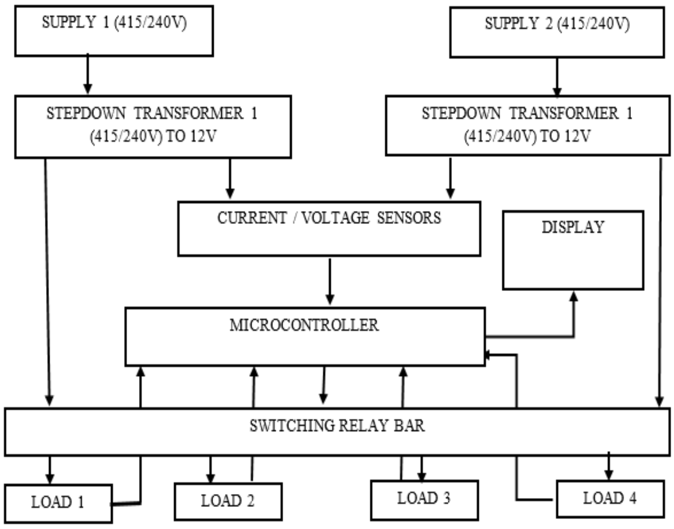


Fig -3: Schematic diagram of the microcontroller-based changeover system

Using the Arduino software, C programming language was used to write the program into the microcontroller in order to run the hardware of the system. In addition, the system provided for load shedding and load sharing features, such that, when one of the transformers failed, the respective loads were connected to the existing functional transformer with priority. The microcontroller continuously compared load currents to the transformer input currents. Therefore, whenever the load exceeded the allocated transformer load capacity, the microcontroller instructed the relays to close or open in order to shed/isolate that particular load.

2.1.3 Design of the Automatic Changeover Circuit

This circuit requires two 220V/12VAC transformers connected in parallel. Four loads of different capacities are also connected in the circuit, with each transformer being allocated two loads as per their load capacity, as shown in Fig -4.

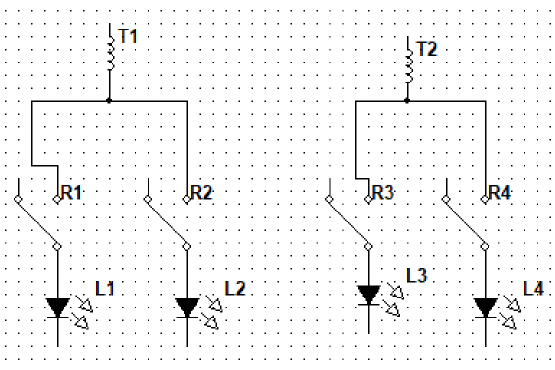


Fig -4: Line to load connection through relay switching

Relays R1 and R2 are used to control the loads for T1, while relays R3 and R4 are used to control loads for T2. When there is no current from both transformers, all the relays remain at the normally closed (NC). When both T1 and T2 have current, relays R1, R2, R3 and R4 move the contact to the normally open (NO) and loads L1, L2, L3 and L4 light consecutively. When only T1 has current, then only relays R1 and R2 remain at the NO. To effect the load shedding feature, each load is connected to each transformer through independent relays. Therefore if only T1 has current, then the relays open and close accordingly to switch on the prioritized loads.

2.1.3 The LCD display module

The Liquid crystal display indicates the status of the connected transformers together with the current drawn by each load connected in the system. So, if transformers T1 and T2 are functional or not, then the loads connected are indicated together with those not connected in the system.

2.2 Simulation/Results

2.2.1 Simulation

The simulation of the microcontroller-based changeover system is done using PROTEUS ver. 8.6, as shown in the circuit in Fig -5.

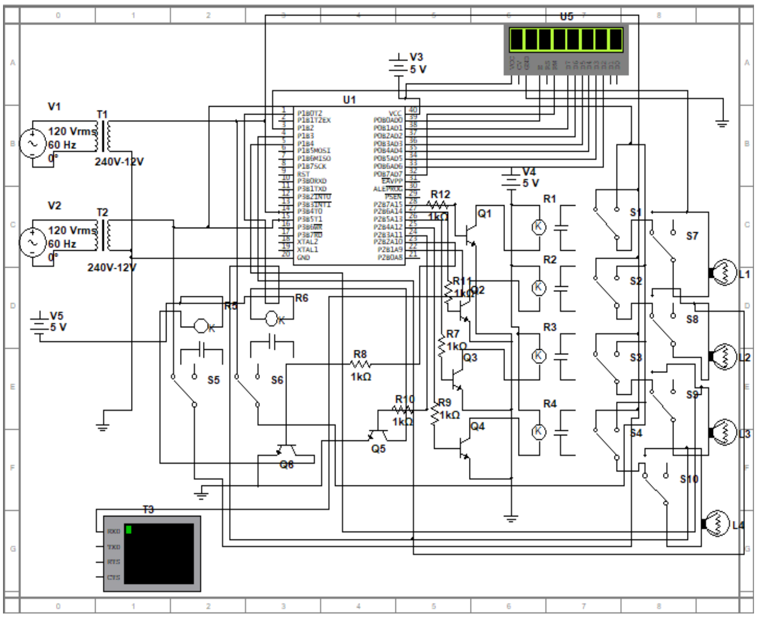


Fig -5: Simulation circuit diagram of the microcontroller-based changeover system

Two input currents, I_1 from transformer T1 and I_2 from transformer T2 are fed to the microcontroller through the current/voltage sensor. The microcontroller compares currents I_1 and I_2 to the current capacities specified in the program algorithm before the loads are switched. Four input currents from L1, L2, L3 and L4 are also fed into the microcontroller to provide a feedback loop to the system. The algorithm used in the program is based on the continuous comparison of the input currents from the two transformers and the currents consumed by the loads to determine the load shedding and load sharing schedule. A display is connected to the microcontroller to show the real-time status of Transformer T1 and Transformer T2 and load currents of L1, L2, L3 and L4 equivalents to the transformer capacity specified in the program.

2.2.2 The testing Results and Discussions

For the full implementation of the system, Fig -6 is used to illustrate the flow of the entire circuit. T1L1, T2L1, T1L2, T2L2, T1L3, T2L3, T1L4 and T2L4 represent relays 1 to 8 respectively with all the transformers connected through the relays to loads 1 to 4 as shown.

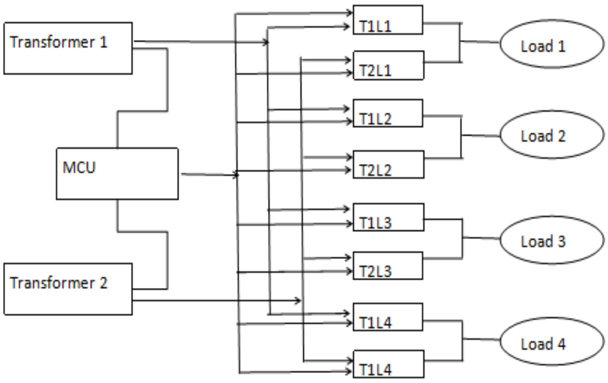


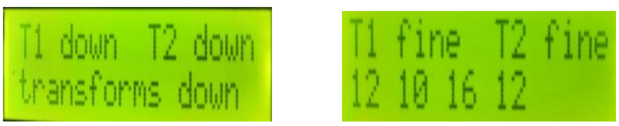
Fig -6: Block diagram of the testing microcontroller system

The microcontroller constantly compares the inputs from the transformer and the loads and instructs relays 1 to 8 on which loads to close and open. This system ensures that whenever there is a power interruption either due to failures of transformers T1 or T2, all the loads remain ON. The status of the transformers, relays and loads is observed and recorded in Table 1.

Table -1: Automatic changeover results for transformers T1 and T2 and loads L1, L2, L3 and L4

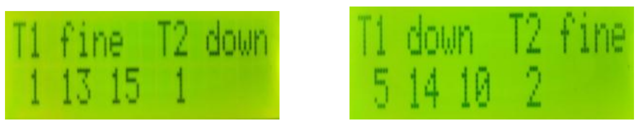
Status of Transformers		Relays							Loads				
T1	**T2**	**R1**	**R2**	**R3**	**R4**	**R5**	**R6**	**R7**	**R8**	**L1**	**L2**	**L3**	**L4**
ON	ON	ON	OFF	ON	OFF	OFF	ON	OFF	ON	ON	ON	ON	ON
OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	ON	ON	ON	ON
ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	ON	ON	ON
OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF

For effective transformer changeover, load shedding and load sharing features included in the changeover ensures that only the loads within the specified transformer capacity in the algorithm are switched on. The display shows the status of the transformers and the loads during the changeover process, as in Fig 7 and Fig 8. That is, which transformer between T1 and T2 is active and which loads are switched on. Since the load prioritization criteria follow L2, L3, L1 and L4 consecutively, load shedding and sharing are effected and active loads shown on the display.



(a) (b)

Fig -7: LCD Display showing the status of transformer 1 and 2 when both have failed and when both are working properly together with the load values of L1, L2, L3 and L4.



(a) (b)

Fig -8: LCD display of the status of T1 and T2 when one failed and the respective active loads.

The experiment is purposed to verify the capability of the designed system to switch over the supply source of the loads from Transformer T1 to Transformer T2 and vice-versa (Hashanah, 2018). Fig 7 (a) shows when both T1 and T2 are down which implies both transformers failed or were disconnected while Fig 7 (b) shows both T1 and T2 being fine which implies both transformers are functional and loads L1, L2, L3 and L4 are 12 mA, 10 mA, 16 mA and 12 mA respectively.

In the case where all transformers are functional, and the loads exceeded the transformer capacity, the prioritization criteria is implemented to effect load shedding and load sharing and therefore preventing transformer overloading.

Fig 8 (a) and (b) shows the results when one of the transformers is ON, and the other is OFF together with the connected loads. When only one transformer is ON, some loads are shed, and the display indicates the active loads. Fig 8 (a) shows L1, L2, L3 and L4 as 1, 13, 14 and 1 milliAmperes respectively implying only L2 and L3 are active while L1 and L4 are shed according to the prioritization criteria.

Fig 8 (b) shows loads L1, L2 and L3 being active while L4 is shed. The prioritization criteria is dictated by the algorithm such that L2 then L3 then L2 then L4 are connected in that order. The switching time of the changeover system is very negligible, making the system efficient. This is because no downtime is needed for either of the transformers during the changeover since the AC current/voltage is of the same frequency.

3. CONCLUSION

The project proposes the design and development of an automatic microcontroller based changeover system for power in industrial and residential areas in case the power supply system experiences faults. The designed system utilizes the microcontroller unit to instruct and control the switching relays and to display the real-time results during the changeover process. From the simulated system, the results showed that the automatic control system enabled an efficient system through the reduction of time-lapse during switching. It also reduces power instabilities through the implementation of load shedding and load sharing.

ACKNOWLEDGEMENT

My sincere appreciation goes to my supervisors Prof. Mutuku Joseph and Dr. Ominde Calvine for their support during each stage of my research. They gave me all the support, directions and guidelines I needed to carry out my research work. I would also like to appreciate Jomo Kenyatta University of Agriculture and Technology for funding the research and providing the necessary facilities and equipment needed. I am also thankful to my colleagues and family for providing the necessary moral support that saw me achieve these heights in my research work. Finally, I thank the Almighty God for his faithfulness.

REFERENCES

[1] M. Ahmed, and A. Mohamed, "Development of a Single Phase Automatic Changeover Switch," Au Journal Of Technicial Report, , 2006, pp. 68-74.

[2] A. Amadi, A. Umeogamba, C. Ogbuka, C. Nwosu, I. Chinaeke, and M. Odo, "A 5KVA Automatic Transfer Switch with Overload, Short Circuit Protection and Generator Stop Functions." 2019 IEES 1st International Conference On Mechatronics, Automation And Cyber-Physical Computer System, 2019, pp.69-81.

[3] C. Amuzuvi, and E. Addo, "A Microcontroller-Based Automatic Transfer Switching System for a Standby Electric Generator," Ghana Mining Journal, 2015, pp. 18-36.

[4] L. Ezema, and B. Peter, "Design of Automatic Change Over Switch with Generator Control Mechanism," Natural And Applied Sciences, 2012, pp.125-130.

[5] T. Ilomuanya, and I. Okpala, "Implementation of the Designed Automatic Changeover System for the Department of Physics," International Journal of New Technology and Research, 2016, pp. 130-136.

[6] R. Hasanah, S. Soeprapto, and P. Adi, "Arduino-based Automatic Transfer Switch for Domestic Emergency Power Generator-Set," Advanced Information Management, Communicates, Electronic and Automation Control Conference, 2018, pp. 742-746.

[7] E. Idoko, P. Udenze, F. Ikule, "Design and Implementation of Three Phases Automatic Changeover Switch," International Journal of Advanced Engineering Research and Technology (IJAERT), 2018, pp. 435-439.

[8] L. Shuangshuang, J. Baochen, W. Xiaoli, and D. Lubei, "Research and Application of SCADA Systems for a Microgrid," MPDI Technologies, 2017, pp. 5-12.

[9] C. Obasi, B. Olufemi, J. John, O. Victor, and O. Chiedu, "Design and Implementation of Microcontroller Based Programmable Power Changeover," Computer Engineering And Intelligent Systems, 2015, pp. 38-50.

[10] C. Rockis, And A. Mazur, "Electrical Motor Controls" New York: American Technical Publisher, 2001, pp.138-163.