



Design and Implementation of Programmable Logic Controller Based Automatic Transfer Switch

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Abstract: A PLC-based automatic transfer switch (ATS) may improve production in the industry efficiency and also the household power connection. It's an electrical switch that may be used to change the load when the main power is failing to supply electricity. Manually controlled transfer switches exist. In this scenario, a switch must be thrown by an operator to take manual control of the system. Some, on the other hand, are activated automatically when the main power source fails. When a major source of electricity is no longer functioning, power from a new or used generator can be either manually or automatically transferred when utilize a transfer switch for transferring control to the on-side application. Using a programmable logic controller (PLC), we describe the implementation and design of an automatic transfer switch (ATS). The primary function of a transfer switch is to divert electricity from the main grid to a standby power supply. Single-phase and three-phase circuit breakers, Siemens Logo PLC, relays, and indicator lights are used in this system. This portable and economic system would be helpful to every domestic, industrial, factory, and academic institution.

Keywords: Indication Light, Relay, Generator, Transfer Switches, PLC, Relay

1. INTRODUCTION

It's an electrical switch that may be used to change the load when the primary source is no longer functioning to supply electricity. PLC-based automatic transfer switch (ATS) that may improve industrial production efficiency and also the household power connection. Automatic Switching has been a strong prospect for further innovations in the field of electronics. As inverters fail due to inadequate battery time, inverters are usually not considered to be the biggest option for backup supply [1]. By installing the automatic transfer

switch (ATS) for industrial generators, the key problems of turning it on/off can be avoided. The changeover switching is the key function related to a Generator set. When the main power source fails then the changeover switching is starting to work. By the simple, strong, secure, dependable connections to the hardware and software of the PLC have become the most important position [2]. Process control of tap-changers and other electrical systems like as protection and substation have all seen success with the usage of PLC [3], [4], [5].

Working Procedure

Low-level distribution systems include a variety of loads, from industrial to commercial to residential, that may be served by the same power source. Different backup sources each received additional loads, while the primary source received some more loads. An example of an interconnected system with several supply sources shown Fig.1. It may be categorized due to the significance of their role that are discussed in follows: -

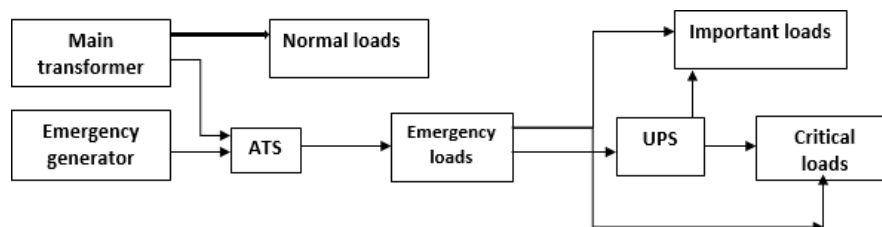


Fig.1: Distribution of loads

Normal Load: These loads only have one source of power (the main). So, when these loads will be unaffected if the primary power supply goes off.

Emergency loads: such as emergency lights and escalator access. These kinds of loads are often linked to the primary source of power. The emergency generator will provide electricity via the ATS system during a power failure until the primary source is restored.

Important loads: critical care units, as well as hospital operation. The three distinct backup sources might all be used to power these loads. The primary power source, an emergency generator, and an uninterruptible power supply serve as the three primary sources of backup power (UPS). The UPS delivers backup power via the transfer switch when the primary power supply and the emergency generator fail (TS). TS may have an automated feature. Static switches are particularly suggested in this scenario because of their quick reaction time [6].

Critical loads: Examples of this include electrical devices as well as those for control and protection. In the event of a power breakdown, this essential load will not tolerate it. As a result, the UPS is directly linked to the loads that must be protected at all costs. The UPS is an electrical device that converts AC electricity to DC voltage. There are two primary sources of AC voltage: the main generator and the backup generator. In order to charge the battery bank, an electronics converter transforms alternating current (AC) voltage into direct current (DC). The key loads are powered by a dc-to-ac converter attached to this battery bank. When both the main and emergency power fail to produce power, the battery bank will continue to supply vital loads using the DC to AC converter. In order to maintain the UPS, a manual



transfer switch is attached to the UPS. Size and cost will be determined by client needs and load priorities, therefore keep this in mind while making equipment selections.

Literature Review

This kind of platform is required to demonstrate how the main power source is switched to a backup power source or a safety generator in an automatic manner [7]. In order to better comprehend the ATS driving process, theoretical thoughts and theories are offered here. L.S. Eczema, B. Pieter, and OO Harris propose an automated switching system for connecting user loads to the output of a generator in case the main supply goes down [8]. When the mains supply is restored, the system automatically switches the loads to this new source and shuts off the generator collection. Using this method has proven to be a great success. For any situation in which a backup power source is needed, the generator characteristics that will be employed on the automated shift switch may be used. Consequently, it's essential to keep track of the peripherals that must be utilized with the automatic transfer switch. When the major source of power fails, the most common approach is to temporarily provide electricity. There must be a rapid and dependable response to any problems with the structured wiring. During a power outage, the transfer switch is used to transition the "key" power source to the "backup" power supply in order to continue providing electricity. It is generally done automatically, but may be done manually for maintenance needs.

Motivation Of This Work

A transfer switch for any power link to a home is required by the NEC. The only secure way to directly connect a generator to the home is to use an automatic transfer switch. An automatic transfer switch separates the transmission lines from the house. This avoids back-feed, which happens when the power goes back down the lines of the utility. Back Feed has the ability to trigger fires. Worse than, back-feed may electrocute people working on transmission lines. Not only a transfer switch is the most secure path to connect a generator to the house, but it is also the simplest. Particularly while on an outage, using extension cords to and from appliances can be an inconvenient and time-consuming problem. A transfer switch allows users to use the household electrical system to quickly and easily power every equipment in the residence with the generator. Some products, such as furnaces or well pumps, may also not be linked to a generator with an extension cord. Thus, during a power outage, a changeover switch is required to operate these objects.

Requirements of Hardware

This project requires a variety of different components. Each and every component of this project is described in detail below:

a. Siemens Logo PLC

Siemens has the ideal controller for basic automation tasks in the manufacturing and construction industries [10]. The modular structure of logo keeps it versatile indefinitely. Also included are built-in features that are generally incorporated in a conventional PLC as well as annual timers and stopwatches. Over 40 functions and 400 components are available for usage in applications.



b. Relay

In A relay is categorized into several types, consisting of electromagnets that are commonly seen as a switch. Definition defines that relay represents the action of moving anything from a thing to other. A signal traveling from one end of the circuit board to the other has an effect on the switching activity at that end. The same definition can be applied to this device. Therefore, a relay is a switch that electrically regulates circuits [11]. In order to turn it on or off, signals are used to initiate or break contact without the need for human involvement in this system's principal function. It is primarily used to use a low power signal to control a heavy circuit. Usually, a DC signal is used to handle high voltage- driven circuits, such as controlling AC household appliances with micro-controller DC signals. It does not produce any magnetic field when the core is not being powered, and it doesn't act as a magnet. The specification of Triger voltage and current is 5V DC and 70mA respectively. The AC and DC load current in 10A. The maximum switching of this relay is 300 operating/minute.

c. Magnetic Conductor

Magnetism contactors are a form of electrical relay that may be found in almost all electric motors [12]. They do not disconnect the appliance from the power supply in the event of a short circuit.

d. Moulded Case Circuit Breaker

In the event of an overload or a short circuit, a circuit breaker is an electrical switch that instantly controls the flow of electricity to prevent damage to the circuit. After a problem is detected, the primary goal is to halt the flow of current. An arc is formed when a high voltage or current is disturbed. Voltage and current are both related to the length of the arc, but the voltage is directly proportional to the current. There must be a means to keep the arc confined, cool it down, and extinguish it so that it can resist the voltage in the circuit once again. Vacuum, air, insulating gas, and oil are all common arc-forming media in circuit breakers. Climate change is the main factor of this component. It is reliable in Tropical, intense sunshine, heavy rain, humid. The tolerance temperature range is 00-5000 C.

Switch Mode Power Supply

SMPS are utilized in a range of applications as an efficient and dependable source of power. This is a significant contributor to their output. SMPS has advantages in terms of size, weight, cost, efficacy, and overall efficiency. It seems that this is a standard feature of modern electronic devices. It's a system in which high-frequency switching of power semiconductors is used to convert energy and regulate it [13]. The regulation in the SMPS is performed by a switching regulator. Like every electrical device, SMPS has some active and some passive components. It has both advantages and disadvantage as each of those devices. The main important side of the SMPS is low cost and high reliability. It also has high efficiency and also compact in size. It is built-in electromagnetic interference filters or EMT filters on the power and signal cables to reduce the high-frequency Electromagnetic noise.

Design and Implementation

In this ATS project main power line is interfaced by generator through Siemens LOGO PLC. When main power connection is ON then the generator will be off. There are 3 indicators for

main power line and another 3 indicators for Generator. 3 indicators mean 3 phase line of main power line and generator. If any of phase is missing then phase failure relay will indicate that which phase is missing then the phase failure is sensing the indicator. Said that, their two-phase failure is connected one is for the main power line and another is for the generator. There are two magnetic contactor and two MCCB connected for the main power line and generator. SMPS is delivering the power to the Siemens LOGO PLC. PLC has 4 outputs, two for magnetic contactor and two for 2 lamps. Magnetic contactor is used for trip the power lines disconnected from the load.



Fig.5.1: The Experimental Setup

a. Ladder Program

The ladder program, shown in figure 5.2 & 5.3, uses PC software that was preinstalled on the PLC.

In this programmed I1 sense when power is on, then it will open the output Q3 which means the gas point of the generator. After 2 seconds the starter of the generator Q4 will be on. After 3 seconds the generator will be on and it indicates Q2 and then load is on. When the power is back then I1 will be in open contact and the load is on.

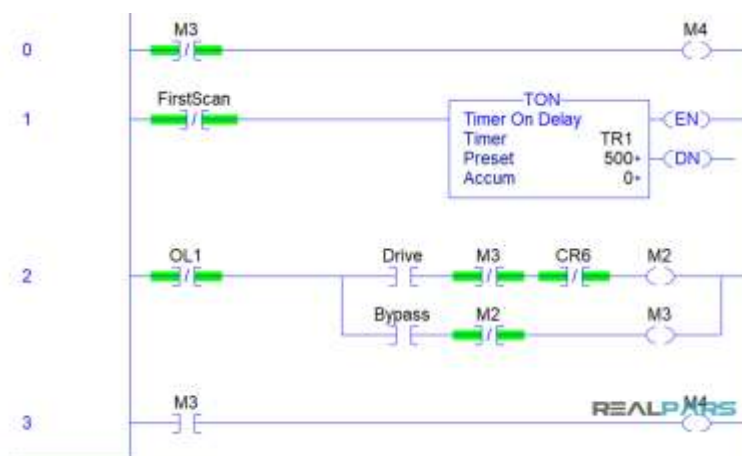


Fig.5.2: Ladder Program for Main Power

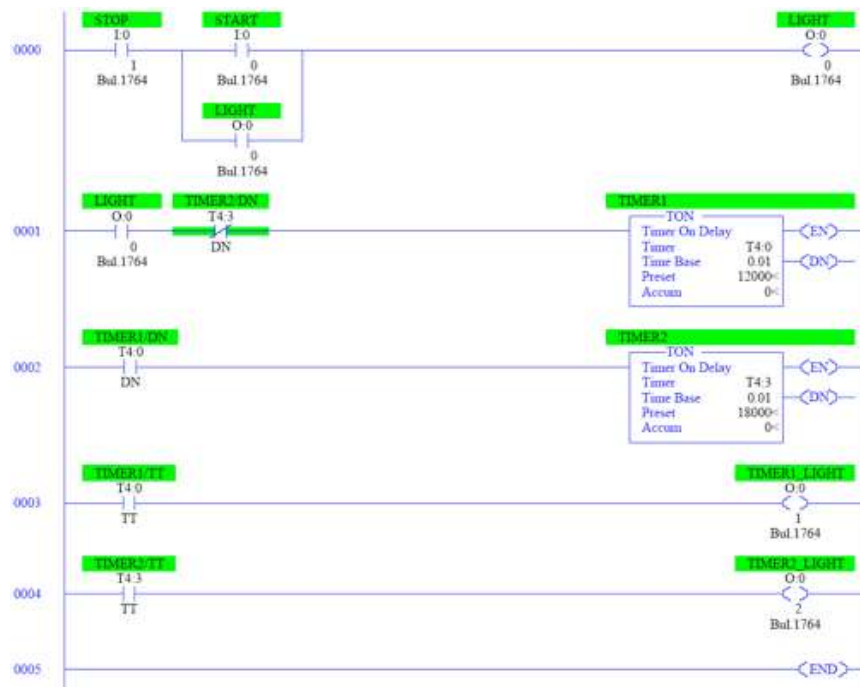


Fig.5.3: Ladder Program for Generator When Load-Shedding Occurs

b. Software programming

The ladder program for the proposed model discussed in two steps one is fault condition and other is normal condition. These two steps are discussed in below

In Fault condition:

If one of the primary source's phases isn't working,

Disconnect the main power supply immediately using the magnetic contactor (T001 is OFF).

The self-start generator (Q4 is ON) is turned on after a time delay (T1).

The relay is on (M1 is ON) which is checking for the generator output voltage.

Connect the generator via its contactor if the output voltage of the generator is rose and remained constant for a time period (T3) (T002 is ON).

Normal Situation:

If none of the phases of the main source are off,

If none of the main source phase is off and the situation remains steady for more than four hours (T4), turn off the generator using the contactor (Q2 is OFF).

Afterwards, connect the main source to the magnetic contactor (T5) and wait for a few minutes (T003 is ON).

Once the timer (T6) has expired, shut off the generators (T002 and M1 are OFF).

In table 1 shows the symbol and there working details in step by step that shown in the ladder program

step



Symbol	Details
Generator Parts	
I1	Main power on/off circuit breaker.
M1	Checking which line is active.
M1	Relay coil for generator (Gas valve on Q3)
Q3	Switching for Gas valve on.
M1	Relay coil send a signal to the PLC for on/off.
T001	PLC Timer to start self-start generator.
T001	Receive signal from PLC.
T004	Magnetic contactor for self-start generator.
Q4	Self-start generator.
Q4	Relay coil for self-start generator.
Q1	Relay coil for main line.
M2	Sensor for main line.
M2	Relay coil for sending a signal to the PLC.
T004	Timer PLC to build up generator voltage.
M1	Relay coil for send a signal to the PLC.
T002	Timer PLC to connect the generator.
M1	Relay coil for generator output supply.
T003	Magnetic contactor for generator line.
Q2	Generator output.
Main Part	
M1	Relay coil
T003	Timer PLC to disconnect main line
M1	Relay Coil for switching
T003	Magnetic conductor for main line
Q1	Main line output

Table 1: List of the ladder program symbol and their details work

c. Working Process of ATS System

It is the PLC's main objective to switch on the generator when the main power supply signal is no longer available, ensuring that both power sources are always on at the same time. Before activating a generator in the event of a power outage, the PLC waits until the main power source returns for a certain length of time before issuing a command. It also waits for a certain amount of time before resuming normal operations. The PLC holds on to the generator if the primary power supply breaks before it has been sufficiently restored [14]. There will be a NO relay and a magnetic contactor on a major electrical circuit if the main power line is turned on. This means that the generator will shut down. During a power

failure, the main power line's relay and magnetic contactor will be tripped to the NC position for 10 seconds, following which the generator's relay and magnetic contactor will be tripped to the NO position and the generator will automatically start. In the PLC, there is a built-in timer for this purpose. Relay switch and magnetic contactor switch positions will reverse after 10 seconds when power returns to the main power line and the generator. If there are any phase failures, the phase failure relay indicates where the failure is occurs. When the power line exists then the indicator of the power line indicates this.

Testing and Outcome

Fig 5.1 shows the experimental setup of the project. In this setup first 3 indicator indicates main 3phase line, and the below green indicator indicates when main line supply powers. The next 3 indicator indicates 3phase line for generator. The below green indicator indicates when load shedding occurs and generator starts to supply power. There are many equipment likes SMPS, circuit breakers, relay, magnetic conductor, PLC, main 3phase line supplier and generator.

Fig 6.a this stage the main line indicator green light is on which means the main line supply power. The switching and the main line sensing relay are on mode. For this reason, the main line magnetic conductor is on.

Fig 6.b indicates the opening of the generator gas valve when load shedding occurs. At this time PLC send a signal to the gas valve of the generator and then the gas valve is on.

Fig 6.c shows when the self-start generator is running automatically. In this step gas valve helps to starts the self- start generator and the self-start generator is on.



a. When Main Power is On



When generator gas valve is on



When self-starting generator is starting



When generator at running condition

Fig.06: The results of the experiments conducted on various types.

Fig 6.d shows when the generator at running condition and starts transmitting power. In this stage when the main power reached in stable condition then self-start generator is off and the generator is supplying power to the consumers.



For this reason, the generator 3phase line indicator is on mode. The mentioned ATS using the PLC that proposed our project are practically fulfilled the requirements. In order to keep up with demand, there are two more backups available to handle the extra load. PLC is designed to work on the factory ground floor. The house is designed to work beside the Main meter because of the power supply to the different floors through the PLC. For industry, The PLC design to work on the same space because its required installation space is not so big. It is possible to apply the switching in various ways. It depends on the sophistication of the client's power distribution structure. It can be specialized equipment in which all sub-functions are combined in "one box" or when the architecture is more complicated or if higher output is needed, it can be a device composed of sub-assemblies. It has been found so valuable and helpful for the students, to learn the actual industrial system.

2. CONCLUSION

This research identifies a wide range of challenges related to PLC-based automated transfer switches. Test models for an automated transfer switch system that improves controllability and operation speed have been used in this project to demonstrate its effectiveness. We'll be able to get rid of our outdated monitoring system with this work.

Future Scope

A transfer switch is an electromechanical system that is used either electronically or mechanically to exchange loads between two power sources. To ensure uninterrupted power supply, it offers a rapid transition between multiple power sources. Manual transfer switches need manual access, which can be flipped to restore power to a generator or power source. Automatic shift switches (ATS), on the other hand, do not need external inputs and, in the event of a power cut, will automatically flip to generator power. These switches are cost-effective and far less risky to run, providing improved reliability and protection. In industrial and commercial settings such as factories, warehouses, hospitals and schools, such switches find wide application where continuous supply is needed [12].

3. REFERENCES

1. S. R. S. S Narasimha, "Design and implementation of smart uninterruptable power supply using battery storage and photovolatic arrays," International Journal of Engineering & Technology, 2018
2. J. M. S. G. S. Daniel Zdrențu, "Experimental study platform of the automatic transfer switch used to power supplies back-up," ATEE, pp. 1-6, 2013.
3. B. P. O. H. L.S. Ezema, "DESIGN OF AUTOMATIC CHANGE OVER SWITCH WITH," SAVAP International, vol. 3, no. 3, 2012
4. Gjorgiev, Blazhe, Alexander E. David, and Giovanni Sansavini. "Cascade-risk-informed transmission expansion planning of AC electric power systems." Electric Power Systems Research (2021): 107685
5. Vamshidhar Thonti, "Circuit Digest," 11 October 2017. [Online]. Available: <https://circuitdigest.com/article/relay-working-types-operation-applications>



6. Yehorova, Victoria. "The world's main manufacturers of programmable logic controllers. Overview." (2021)
7. Romadhon, Ahmad Sahru, and Vivi Tri Widyaningrum. "Automatic Food Packaging System using Programmable Logic Controller." (2021).
8. Mhamdi, Hicham, et al. "Methodological approach for the implementation of a remote management system for large-scale irrigation." *Materials Today: Proceedings* (2021).
9. Ghantimath, Mr Amit S., and Mr Vinayak KU. "Design and Simulation of DSTATCOM using Fuzzy Logic Controller." (2021).
10. Nasriddinovna, Aslanova Gulnoz. "Automation of transformer substations of industrial enterprises with modern programmed logical controllers." *Asian Journal of Multidimensional Research* 10.9 (2021): 751-757
11. Cao, Xinhui, et al. "The Principle of Intelligent Switch Composition and Algorithm of the Built-In Electronic Voltage Transformer." *Journal of Applied Mathematics* 2021 (2021).
12. Ahammed, Md Tabil, et al. "Design of Porous Core Fiber for Terahertz Regime using Zeonex." 2021 4th International Conference on Computing and Communications Technologies (ICCCT). IEEE, 2021.