

Application Of An Automatic Three-Phase Power Supply Phase Selector In The Medical Ventilator

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Abstract

The Three Phase Power Supply Phase Selector device is critical for the operation of all medical equipment, particularly medical ventilators. Because of COVID 19, the need for ventilators has increased significantly. However, hospitals in rural areas are experiencing single-phase failure and low voltage in distribution lines, which causes interruptions in ventilator operation. This paper proposes an automatic Three Phase Power Supply Phase Chooser with a Programmable Logic Controller (PLC) to keep all medical ventilators running without disruption, especially in the occurrence of single-phase failure. During a phase failure, the proposed system automatically connects the ventilator to the another available phase in a very short period. The PLC detects the restoration of the phase of the single-phase supply and automatically reconnects the ventilator to the restored phase. It also aids in maintaining an uninterrupted power supply to critical single-phase medical appliances. It also protects sensitive single-phase medical equipment from damage and burnout. This system can be used in a variety of locations where critical single-phase medical equipment must operate continuously and without disruption. The key benefit of this controller is that it is reliable, easily programmable, and flexible.

Keywords: PLC, Phase Changer, Power, Phase chooser, Power system, Voltage collapse, Power instability, outages

INTRODUCTION

Many electrical consumers fed with three-phase electrical supply system, but only single phase is connected to many individual loads. In distribution transformer, sometimes it is happened that one of the three phases gets blown out due to faults in the feeder or tree branches falling on the overhead line or insulation failure or other reasons. In that case consumer load connected to faulty phases gets interrupted. This controller helps that the load connected to the faulty phase is temporarily connected to other available phase of three phase supply. This phase selector technology which connects load with the available phase temporarily until the faulty phase gets restored. However, the controller system focuses on the design of an R Y B phase selector using PLC. The flexibility of the controller system is increased because it does not require any micro controllers, hardware interfaces to connect all industrial sensors, actuators, relays, switches with the microcontrollers. PLC is created in accordance with the IEC specifications which are typically at a range of current/voltages. Additional hardware setup is not needed to connect all inputs and outputs with PLC. This controller helps that the loads connected to the phase in industry/hospitals etc. can be temporarily connected to one of the other two working phases. The controller connects the load to the available phase automatically and restore to the actual phase when the failure phase are restored. Human intervention is reduced in this system; hence it increases the flexibility in the process control. Ephrem Ryan Alphonsus et.al concludes that the PLCs can be used for many applications whether it is of simple or complicated control system [1]. Nowadays, many of the control logic are being executed by the PLCs. According to Ofualagba G et.al [5], an intelligent control circuit is essential for careful and smooth selection channel at particular time to feed power to the single phase load without notice of outage. According to Vipula Tippa et.al [4], the importance of the power supply phase selector is predominant in case of operations and emergency treatment in hospital. Hence the automatic phase selector is essential to operate single phase essential loads without interruption.

RELATED WORKS

F. U. Nweke et al. [2] have designed the Automatic three phase power system selector with comparator unit could results complication in the circuit connections as well as separate protection system needed to protect the ICs, capacitors, resistors etc. against sudden increase in voltage in the distribution grid. Namita R. Chavan et al. [3] have implemented the Automatic active phase selector with arduino unit which may need extra hardware arrangement to connect the power circuit load with arduino. Ofualagba G et al. [5] have demonstrated Automatic Phase Selector and Changeover Switch for 3-phase supply with ATmega

microcontroller, since Due to the fact that PLCs are intended to connect to industrial-grade sensors, actuators, and communication modules, they have current and voltage ratings that are frequently incompatible with microcontrollers without additional hardware. Hence the main reason for designing the automatic R Y B phase selector using PLC is ruggedness; additional hardware setup is not required to connect the power circuit components with PLC.

NECESSITY OF AUTOMATIC PHASE SELECTOR

In rural areas, the primary problem of the consumers is single phase failure and low voltage in distribution lines. This single phase failure may be due to tree branches falling on the distribution lines or insulation failure or conducting path failure. The low voltage of phases may be due to the fuse burnout in the primary side of the distribution transformer. Hence the essential load connected to such phase does not receive power; it is inoperative until the failure phase gets restored. During earlier days, phase selector switch which performs manual switching of load to available phase. When the failure phase gets restored, the consumer should change manual switch to the original phase, if it is not so, this creates load unbalancing in the distribution transformer. By implementing automatic phase selector, the load is automatically connected where the phase voltage is available. Also it reconnects the load to their own phase, when the failure phase gets restored.

DESIGN OF METHODOLOGY AND IMPLEMENTATION

An electronic device called a PLC is used in industrial control systems and other systems where a greater level of system dependability is required. Initially designed to replace the hardwired relays, timers, and counters used in industry automation, it is now utilised by all forms of production processes, including robots.

PLC operated machines and equipment are now found in every factory. PLC were first used for control by many engineers because of their robustness and capacity to tolerate harsh environments. It excels in producing outputs to specified inputs in the real-time operating system in a very short amount of time. PLCs can generally be considered to be superior to microcontrollers. I/O modules, a power supply, and a processing module make up the majority of it. The RAM and CPU make up the processing module. The CPU also has a microprocessor and communication networks in addition to a programming interface (USB, Ethernet, or RS232). The I/O modules are typically independent from the processor, just as the power supply is. I/O modules come in several varieties, such as digital (on/off), analogue (changing with time), and special modules like quick timers and counters. The input/output modules are linked to the input/output devices. While PLCs are built to connect with sensors, actuators, and communication modules, microcontrollers require additional hardware to do so. Ethernet and a number of RS- serial series, including RS-232 and RS-485, are often compatible with PLCs for communication. Now that the internet of things has arrived, PLC devices may send and receive data using wireless communication interfaces. The PLC must be programmed with minimal technical skills. Diagnosing and resolving issues is fairly simple. The HMI display panel that comes standard with modern PLC systems facilitates monitoring without the need for extra hardware.

Under normal operation, when all the three phases are available with rated voltage, the entire essential loads are connected to their respective phases. The objective of the system is that when there is any single phase failure, that corresponding load would be connected to other available phase within a very short time. This can be done by PLC effectively to increase the reliability of the utility load system. Figure 1 shows the input side connection setup of the PLC. Three step-down transformers 230/12 V are connected to each phase from the utility supply and are used by the PLC-based automated phase selector to detect or sense the available phase voltage. With these transformers, the phase voltage is reduced from 230 VAC to 12 VAC. 12 V AC voltages are changed into 12 V DC voltages using the WOM bridge rectifier. These transformers step down the phase voltage from 230 V AC to 12 V AC. The WOM bridge rectifier is used to convert the 12 V AC into 12 V DC voltages. Three 1000 μ F capacitor is connected across each 12 V circuit to convert pulsating 12 V DC into pure 12 V DC. Now the PLC can receive 24 V dc as input through the 12V relay, these three 24 V DC input is given to the input terminals (I0.7, I0.8, I0.9) of the PLC, this helps to sense the availability phases by PLC. The 12 V DC relay is used in each phase circuit to provide better electrical isolation between power circuit and PLC. This setup can easily measure the phase voltage of each phase, hence the controller is able to rightly connect the load to the healthy voltage phase. When the failure phase gets restored, then the corresponding load would be connected back to their original phase to avoid load unbalance in the distribution line.

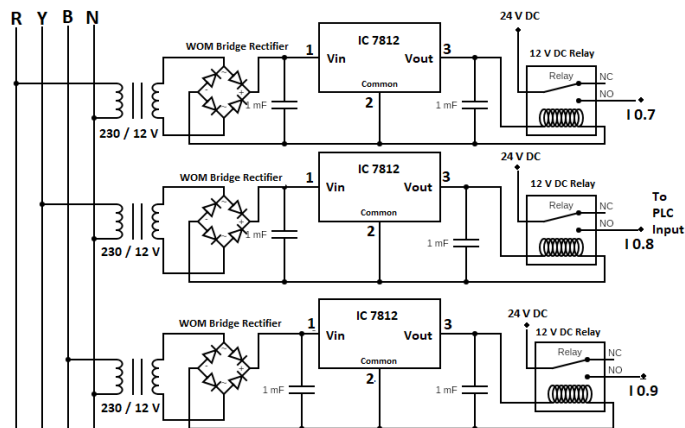


Figure 1. Input side Power circuit

After a complete investigation to design the controller, the required inputs and outputs were identified, Table I describes the description of each input of the PLC. Table II describes the description of each output of the PLC.

Table 1. Input Description

PLC Input	Description
I 0.0	Green Start Push button for the controller unit
I 0.1	Red Stop Push button for the controller unit
I 0.7	R phase sensing input
I 0.8	Y phase sensing input
I 0.9	B phase sensing input

Table 2. Input Description

PLC Output	Description
Q0.0	Controller Indications
Q0.7	AC single phase supply from R phase
Q0.8	AC single phase supply from Y phase
Q0.9	AC single phase supply from B phase

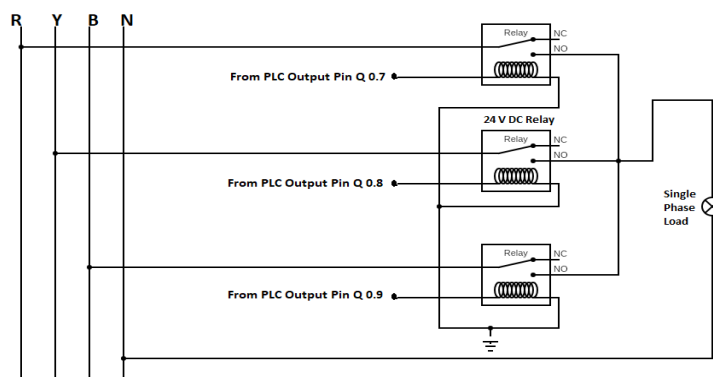


Figure 3. Output side Power Circuit

Fig.2 shows the output side connection setup of PLC. At the output part, all essential load is being connected via individual 24 V DC relay to all the three phases (The relay rating is selected based on the load rating). Based on the ladder logic programmed in the PLC, the essential load is automatically gets connected to the available phase. Hence due to single phase failure, then the respective single phase load would be disconnected and it reconnects within short time to other healthy phase of three phase supply. Again when the failed phase gets restored, then the load is automatically reconnected to their original phase within the very short period of time interval specified in the timer block.

PLC Programming

Ladder logic diagram was developed instead of hardwired electrical relays in control circuits and load. Ladder logic diagram methodology is best to do discrete controlling and interlocking. The required control circuit is programmed as relay ladder diagram in the company specific PLC software and then downloads into the PLC module. The designer can create the graphical logic expressions needed to programme a PLC with the use of ladder. A relay control circuit can be drawn similarly to how a PLC programme is written using ladder diagrams. A PLC has many “input” terminals, through which it receives “high (24 V)” and “low (0V)” logical states from sensors or switches. In this system we used three input terminals I0.7, I0.8, I0.9, through which it sense the availability of phases in three phase supply. PLC also has many output terminals, through which it send outputs “high (24 V)” and “low (0V)” signals to power the load. In this system we used three output terminals Q0.7, Q0.8, Q0.9. Interlocking feature is incorporated in the Ladder logic programming to avoid short circuit between phases during switching of load connection from one phase to another phase.

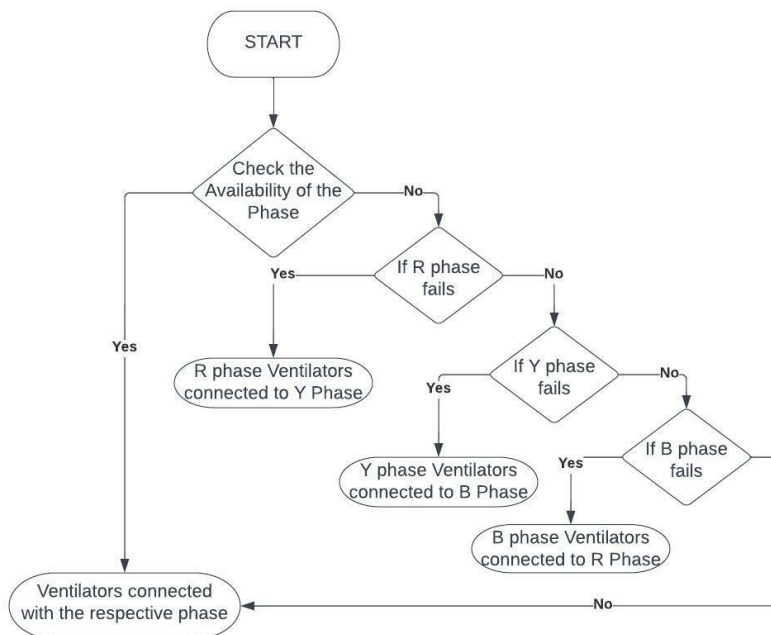


Figure 3. Sequences of Operations

Figure.3. shows the sequence of operation, initially the PLC sense the availability of all the three phases. If all the three phases are available, then the loads are connected to their respective phase of supply. If R phase is not available, then the controller switches the R phase load connection to Y phase within short period of time. If Y phase is not available, then the controller switches the Y phase load connection to B phase within short period of time. Similarly B phase gets connected to R phase during the absence of B phase supply.

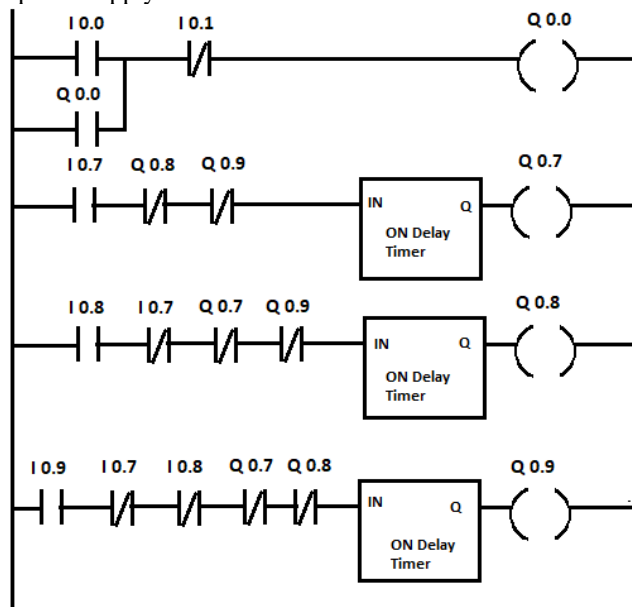


Figure 4. Ladder Logic Diagram

Figure.4. shows the ladder logic diagram of a phase selector for R phase load. The integrated controller ladder logic program can be done for the entire three individual phase load.

In the Rung 0, the input I0.0 denotes start, I0.1 denotes stop, the output Q0.0 denotes the indicator and seal-in contact Q0.0 is parallel auxiliary contact.

In the Rung 1, the Q0.7 is energized after microseconds of time delay only if the I0.7 is high, an interlocking is made with Q0.8 and Q0.9 to avoid short circuit between phases.

In the Rung 2, the Q0.8 is energized after microseconds of time delay only if the I0.8 is high, an interlocking is made with Q0.7 and Q0.9 to avoid short circuit between phases.

In the Rung 3, the Q0.9 is energized after microseconds of time delay only if the I0.9 is high, an interlocking is made with Q0.7 and Q0.8 to avoid short circuit between phases

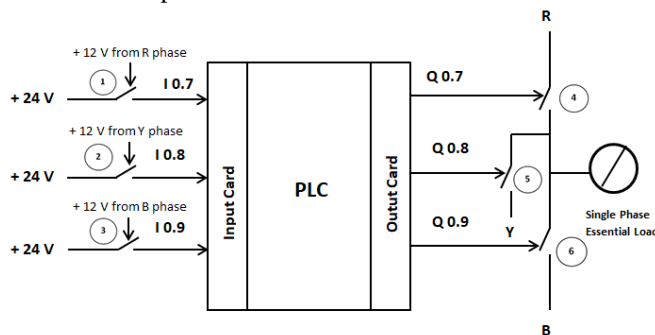


Figure 5. Hardware connection set-up

Figure 5. shows the hardware connection set-up of phase selector using PLC. The switches 1 to 3, it represents 12 V DC auxiliary relay and switches 4 to 6, it represents 24 V DC auxiliary relays. These auxiliary relays are giving better electrical isolation between PLCs and power circuit. Hence the PLC is full protected against voltage surge in the power circuit.

RESULTS AND DISCUSSION

Under normal operation, all the ventilators are connected to the respective phase of supply. If the R-phase supply fails or the R-phase voltage falls below the rated value, the ventilator connected to the R-phase supply is automatically connected to the Y phase. Similarly, if Y-phase supply is not available, then the corresponding ventilator will be automatically connected to B phase. Table 3 shows the state of transition of the ventilator connection between phases. The reconnection of loads to the other phase is done as per the order of the phase sequence R Y B. However, if the failure of a single-phase supply is restored, then the automatically corresponding load is connected back to the respective phase to avoid load unbalancing in the distribution line.

Table 3. Ventilator Load Transition

R	Y	B	R Phase Ventilator	Y Phase Ventilator	B Phase Ventilator
√	√	√	R	Y	B
×	√	√	Y	Y	B
√	×	√	R	B	B
√	√	×	R	Y	R
×	×	√	B	B	B
√	×	×	R	R	R
×	√	×	Y	Y	Y
×	×	×	NA	NA	NA

This controller can be implemented in hospital operation units, college libraries, government offices and institutes, banks, industries, and schools. Due to the failure of phase, these controllers help to operate all essential loads continuously without interruption.

Finally, by implementing this controller, the single-phase power failure effects can be resolved in rural areas during heavy wind or rainy days.

CONCLUSION

The proposed system automatically connects the medical ventilator to the available phase to ensure an uninterrupted power supply. This arrangement enables the operation of all essential single-phase medical equipment at all times in the incident of a single-phase failure in any phase. This automated system is capable of monitoring, controlling, and switching the load between three phases. We can reduce human effort, stress, and save time by implementing this system. It provides greater safety to personnel than manual switching. When the failed phase is restored, the controller automatically reconnects the

medical ventilator to the respective phase, effectively eliminating the load-unbalancing problem. Because this system allows all essential loads to operate at rated voltage, vital medical appliances cannot operate at low voltage. This system reduces downtime caused by a single-phase supply failure, thereby improving system reliability. Schneider Electric PLC M221 Logic controller TM221CE24T was used to test this controller. Furthermore, the integrated control can be programmed to perform an integrated function of phase selector and load changer.

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