KKU Engineering Journal

https://www.tci-thaijo.org/index.php/easr/index

Published by the Faculty of Engineering, Khon Kaen University, Thailand

Design of a programmable logic controller auto power reset circuit for an FM transmitter

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Received September 2015
Accepted December 2015

Abstract

The mono-stereo controller using an audio mute clock has been used at the International Broadcasting Bureau (IBB) FM 106.6 MHz transmitter in Ulaan Baatar, Mongolia since 2010. The major problem of the FM broadcast station was from a frozen programmable logic controller, PLC, that must be manually reset and the report by the VOA listeners. A PLC auto power reset circuit was proposed and built as a mono-stereo controller to monitor the operation of the PLC. The circuit was also used to restart the PLC whenever it became frozen. A cloud router and Transmission Control Protocol/Internet Protocol (TCP/IP) to a Recommended Standard Number 232 (RS-232) converter were used to synchronize the time parameter of the PLC. From the results, this circuit improved transmitter availability and quality of the 24 hours/day broadcast program without affecting the listeners. The reliability of the cloud router is acceptable with low delay of data transfer via the internet connection between Thailand and Mongolia. The cloud router, leased by IBB from a provider that offers Internet services at speeds of up to 1000 Mb/s via a remote terminal, is used for scheduled programming and correct time synchronization of the PLC. The proposed system is very stable and there has been no incidence of a frozen PLC when connected to the Internet or when it was disconnected. Hence, the designed PLC auto power reset circuit can be used for relief of this frozen PLC problem.

Keywords: PLC auto power reset circuit, Mono-stereo controller, Programmable logic controller, TCP/IP to RS-232, Automated broadcasting network

1. Introduction

The network control and automation system for broadcasting the FM radio, called as automated broadcasting network, has been firstly used to broadcast the Voice of America's (VOA) program since 1988 [1]. The network had been used and developed to be a fully automated system for 24 hours operation. The automation broadcast radio controlled using audio mute clock for mono-stereo switching which is called the standard M circuit of mono-stereo controller to change the schedule program has been proposed by A. Pattanajakr [2]. The transmitter is located in the Mongolian National Broadcaster (MNB), Mongolia that is in the desert and restriction area. The major problem at FM station was from the frozen PLC and reported by the VOA listeners to contact number of FM 106.6 station or country representative of the IBB in Ulaan Baatar, Mongolia due to the bi-lingual programs was heard from the FM receiver. Also, it could be monitored from the recorded program stored on Remote Motoring System (RMS) [3] in Mongolia. The one problem of the causes of frozen PLC is from the instability of power system in Mongolia, especially in night time. This is because electrical loads such as; the heaters had been turned on. The frozen PLC can be only manually reset to allow the mono-stereo controller restore to the correct program.

The aim of the study is to design and build the PLC auto power reset circuit to resolve the frozen PLC. In addition, a stand-alone PLC is connected the TCP/IP to serial (RS-232) converter is used to communicate with the remote terminal. In order to connect the remote terminal to the PLC from the remote terminal from anywhere, the cloud router is used to connect the TCP/IP to serial converter to allow the remote terminal communicate with the PLC via internet. The remote terminal can synchronize time of the PLC and update broadcast program schedules of the FM transmitter that can be revised from network control center in Washington during the year. These can be implemented on the remote terminal from anywhere when the internet connection is available.

2. Experiment setup

Normally, the frozen PLC must be manually reset by operators and the problem of access to the station especially in the winter season. Then, the new design of auto power reset circuit has been proposed to resolve the problem of the frozen PLC that was occasionally happened during 2010-2013.

The designed and fabricated of the PLC auto power reset circuit was implemented in the mono-stereo controller. Also, it was installed on the transmitter rack at the IBB affiliate FM station in MNB building in 2013 for testing the proposed circuit. The proposed PLC auto power reset circuit is used to keep the FM transmitter broadcasts only one program all the time to the listeners. The cloud router with speed of 64 kB/s

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doi: 10.14456/kkuenj.2016.14

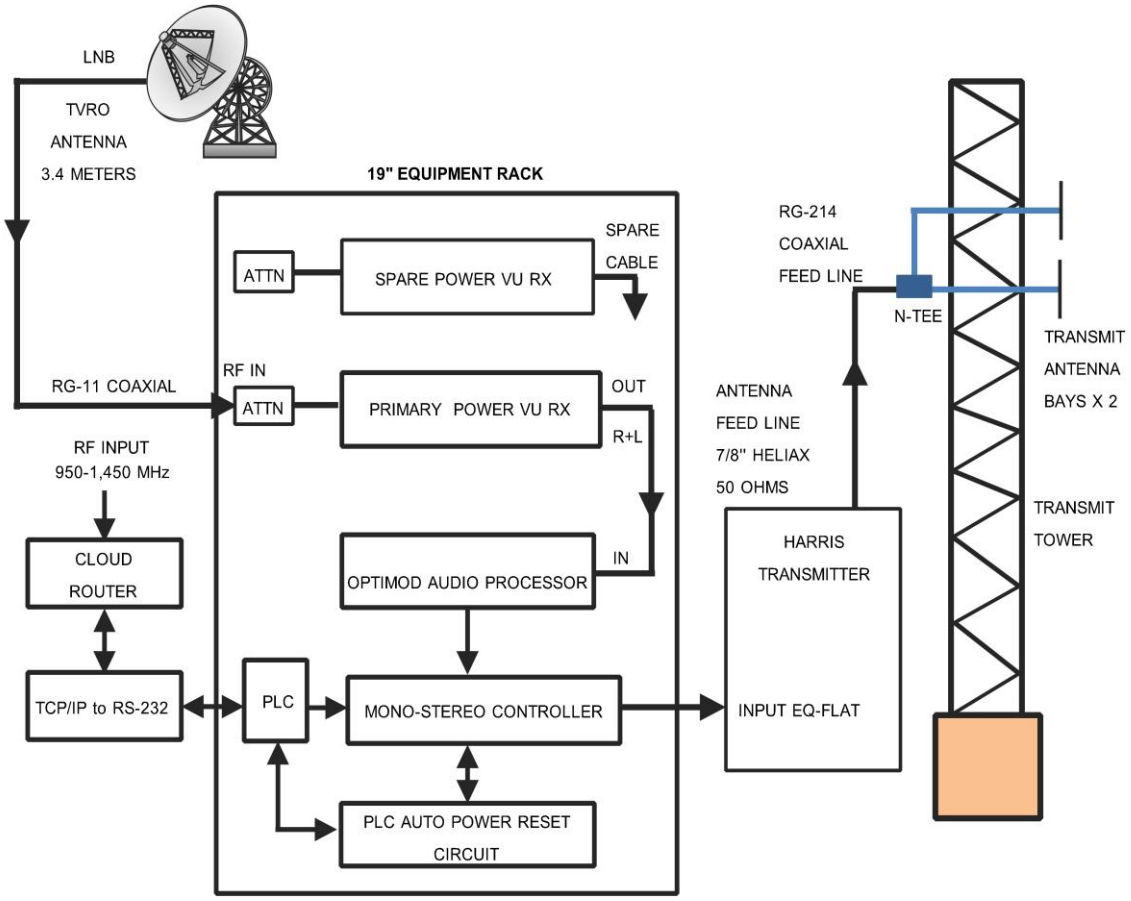

Figure 1 Simplified Diagram of Mono-Stereo Controller with the PLC auto power reset circuit and cloud router

is additional circuit that is used to allow time synchronization and update new broadcast schedules from the remote terminal. These two circuits work dependently from each other however both are used to support the FM transmitter operation. The proposed PLC auto power reset circuit and cloud router are shown in Figure 1 and the operation system of Figure 1 has been described in [2].

From Figure 1, the program that is encoded and uplinked from the IBB studio in Washington to the Asiasat-3 and by received the receiver, power Vu model 9223 which the dish is pointed to this satellite. The audio outputs of the receiver are connected to inputs of the FM optimod and one output of optimod is wired to audio sensor to generate audio mute.

The PLC auto power reset circuit that is built in the mono-stereo controller was installed on the transmitter control rack. It was tested for reliability and passed the test with good result in Thailand. The TCP/IP to serial converter and the cloud router are installed and used to provide communication with the PLC from the remote terminal for time synchronization and the broadcast schedule updated.

The remote time synchronization can be performed with the installation of the TCP/IP to RS-232 converter, model CSE-H25 from the Sollae Systems [4]. The RS-232 of the converter is connected to the serial port of the PLC while the local area network (LAN) port of the converter is connected to the LAN port of the cloud router via ethernet cable. The TCP/IP to RS-232 converter creates virtual serial port that allows the PLC to communicate with the remote terminal via internet. At the remote terminal, the ezVSP software [4] creates virtual serial port communicates with the TCP/IP to serial converter. The time synchronization and program update can be performed via the remote terminal from anywhere when the internet connection is available. The cloud router was installed and configured to communicate with the TCP/IP to RS-232 converter via the internet to the remote terminal. The ezVSP software which is free download from the Sollae Systems website has to be installed on the remote terminal and requested registration before the serial virtual port can be created.

The real time clock of PLC has an accumulated error of time that can affect the switching from stereo to mono mode. To assure the correction of the clock in the PLC, the clock on the remote terminal must be synchronized with standard time such as standard clock, Global Positioning System (GPS) clock and atomic clock from the internet. Then, the remote terminal is connected to the PLC via the cloud router before the time synchronization is performed. The PLC time after synchronization is deviated from the standard time in msec due to the delay of transferred data depending on the internet speed between Thailand and Mongolia less than 300 msec between the remote terminal and the PLC.

The cloud router that provides by cloud service provider from Thailand connected via internet from Mongolia to Thailand. The provider uses very high secured cloud server with authentication to prevent the access to the PLC from authorized person via internet.

From Figure 2, the PLC auto power reset circuit consists of the microprocessor monitor IC (MAX1232) and precision timer, LM555N. The board was built and installed in the mono-stereo controller. The new controller was tested at IBB transmitting station in Thailand for 6 months before it was replaced the old one at Mongolia in August 2013. The mini PLC from the Array model AF-10MR-E was also internally modified by removing the relay at Q_4 to reduce the noisy

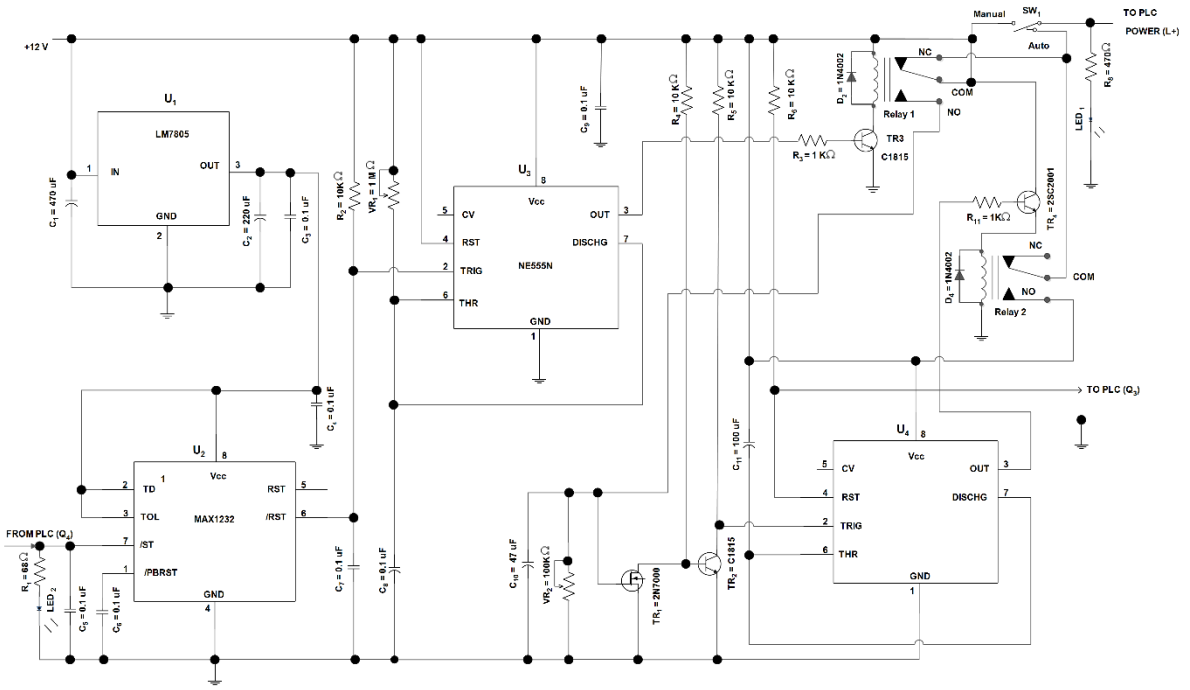

Figure 2 The circuit diagram of the PLC auto power reset

from the relay contact. Also, the new software is programmed to the PLC to generate the clock of 50 msec when it is in normal operation. Since, the IC, MAX1232 is used as watchdog timer, the clock pulse from the PLC must toggle the strobe input (pin 7) within a timeout period of 1,200 msec which is determined by time delay (TD) per electrical characteristics of the chip. The longest time delay which is 1,200 msec can correctly read the status of the PLC if it really stops working. When the PLC is frozen, the sequence of the reset takes 1 second to restart the PLC during the night or day time without manned assistance.

The regulator power supply that is used by the PLC auto power reset circuit is also built in the mono-stereo controller and externally wired via D9-type connector to the PLC. The switch 1 (SW_1) is wired to the output of the PLC (Q_1) and is switched to manual position for time synchronization by manual. The SW_1 must always be set at auto position to allow the remote terminal that can automatically synchronize the clock of the PLC. Also, it can be done by the remote terminal from Thailand transmitting station or anywhere that has internet access every 3 months.

From the circuit diagram, the U_1 is voltage regulator which is used to regulate voltage from the power supply 12 voltages to provide 5 voltages for U_2 and the U_2 is micro-processor monitor chip (MAX1232) that is used to monitor the 50 msec clock from the PLC. The U_3 is the precision timer, LM555N that is used to remove the power from the $relay_1$ when there is no clock from the PLC. The U_4 is the precision timer that is used to energize the $relay_2$ for 1.08 sec to provide 12 voltages to the PLC while is being restarted. The D_1 is redrawn as LED_2 used to monitor the 50 msec clock from the PLC and the D_3 is LED_3 and is used to monitor the mono-stereo controller when it is on stereo operation. The mono-stereo controller with 3 LEDs display is shown in Figure 3.

The prototype of the PLC auto power reset which consists of micro-processor monitor (MAX1232), two precision timers (LM555N, U_3 and U_4), voltage regulator (LM7805) and other components built on the printed circuit board as shown in Figure 4.

Due to the broadcast schedule of the VOA program are usually changed into two different seasons. One is in the summer season by the end of March and the other is at the end of October in the winter. The access to the PLC from the remote terminal is required to update the new schedule program. The TCP/IP to RS-232 converter is used to communicate between the remote terminal and the serial port of the PLC for updated the broadcast schedules.

Figure 3 The mono-stereo controller with 3 LEDs indicator

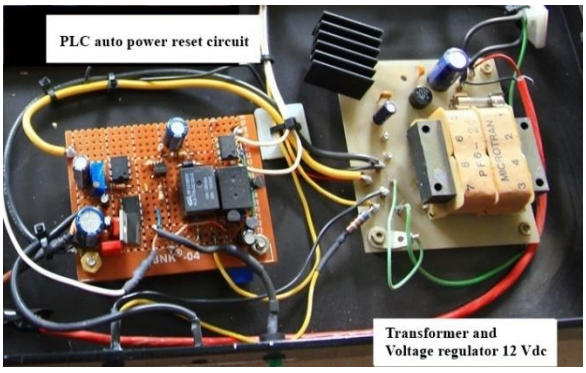

Figure 4 The image of the PLC auto power reset prototype

The broadcast schedule can be uploaded from the remote terminal via internet to overwrite the existing schedule on the PLC before the new schedule is annually changed in the end of March and October. The real system which consists of mono-stereo controller, the PLC, TCP/IP to RS-232 converter and cloud router is shown in Figure 5.

The functioning of the PLC auto power reset circuit is shown in Figure 6. The PLC in the reset circuit is used to generate the 50 msec and monitored by the reset circuit. If there is no clock from the PLC that means the PLC stops working or it is frozen, the PLC auto power reset circuit removes the power supply of the PLC for 1 second before the PLC is restarted.

3. Results and discussions

The mono-stereo controller with the built-in PLC auto power reset circuit was designed and fabricated to resolve the stop working problem of the frozen PLC without human intervention. It was tested at the IBB Thailand transmitting station for 6 months before it has been installed and broadcasted in the IBB affiliate station in Mongolia since 2013.

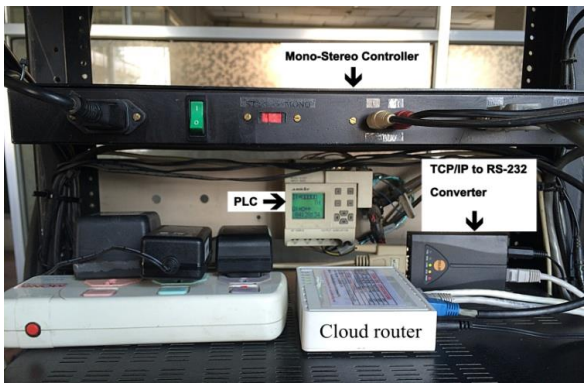

Figure 5 The mono-stereo controller, the PLC, TCP/IP to RS-232 converter and cloud router

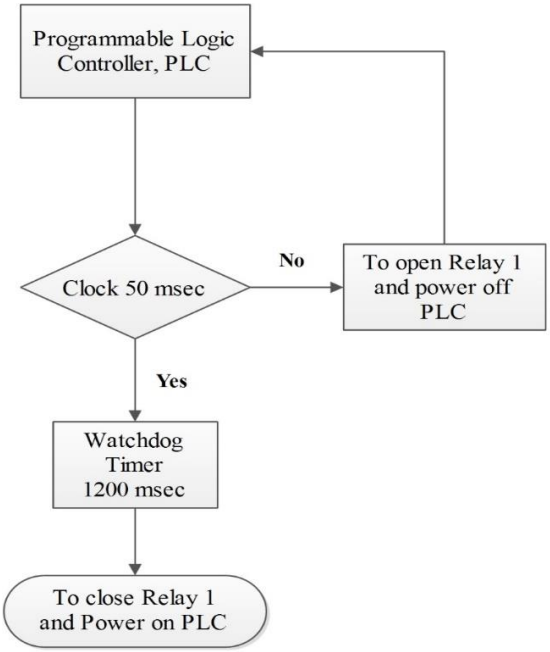

Figure 6 The procedure of PLC auto power reset circuit

From the design, whenever, the PLC is frozen, the clock pulse of 50 msec at the output of the PLC (Q_4) stops, the circuit removes the power from the PLC for 1 sec before it can be restored to operation again. The flowchart in Figure 3 shows the sequence of the clock from the PLC that is monitored by the PLC auto reset circuit that is generated from the PLC. When the 50 msec clock stops, there is logic "1" from pin 6 of timer (U_2) to trig pin 2 of timer (U_3) to initiate logic "1" to turn on the TR_1 that results contact of relay ($Relay_1$) changing from close to open state. This disconnects of the power supply to the PLC for 1 second before it is restarted. At this stage, the clock appears at the output of PLC (Q_4) again if the PLC is still working.

During the PLC is restarting, the pin 3 of timer (U_4) initiates logic "1" to turn on TR_4 that energizes the $Relay_2$ to change contact from open to close state that allows the PLC connects to the power supply during it is restarting until the clock pulse reappears at the output of PLC (Q_4) after pin 4 of timer (U_4) is reset by the output of PLC (Q_3).

From the circuit diagram, the timing of 1 second is used as time delay before the conduction of MOSFET, TR_1 and TR_2 to generate logic "1" to trig pin 2 of timer (U_4) that is used to hold the regulator 12 voltages power supply. The power supply is powered to the PLC during restarted. The time delay can be calculated from the following RC time constant formula 1 [5].

$$T_c = RC \quad (1)$$

where T_c is time constant, in second, R is resistance, in ohm and C is capacitance, in farads.

In the circuit diagram, the resistor 50 kΩ, which is variable resistor (VR_2) can be adjusted until the required time constant is achieved. The capacitor (C_{10}) is 47 µF. The precision resistor and capacitor value are used to generate this time delay. Then, the appropriated set time is 1.08 seconds that must be longer than the restarting time of the PLC. If this time delay is shorter than the restarting time of the PLC, the circuit resets the PLC again and again.

By this time delay, the circuit can hold the power supply of the PLC when it is being written new programmed from the remote terminal to the PLC with no interruption. During this time delay, the 50 msec of clock stops and then, the watchdog timer assumes the PLC is frozen. The 12 voltages supply voltage keeps the PLC from resetting until the program that it is written from the remote terminal is done. This time delay always provides the system reliability of the PLC without any affection to the transmitter since it was used at the transmitter site in 2013.

The listeners heard the two broadcast programs at the same time from the receivers. The numbers of reported problem of the two programs per year during 2010-2014 were reported by the listeners and monitored from the RMS as shown in Table 1. The problem can be found 2, 3 and 3 times/year since 2010-2012 respectively. After the installation of the PLC auto power reset circuit, it has no problem since 2013.

Table 1 The reports of the transmitter operation in bilingual programs

Observation Period	Listeners (Times)	RMS (Times)
2010	2	2
2011	3	3
2012	3	3
2013	0	0
2014	0	0

4. Conclusions

The PLC auto power reset is implemented at the IBB affiliate FM 106.6 MHz transmitter site in Ulaan Baatar, Mongolia since 2013. This proposed circuit can resolve the problem of the frozen PLC whenever it stops working without the need of human intervention to perform manually resetting at the transmitter site since it was installed. The listeners and the RMS have not been reported about the problem of the two broadcast programs problem due to the frozen PLC since 2013 until present. This circuit can also improve the transmitter reliability and quality of the on-air program that is carried 24 hours/day by the transmitter to the coverage area without affection to the listeners in Ulaan Baatar, Mongolia. The performance of the cloud router is reliable and acceptable with low delay of data transfer over the internet from Thailand to Mongolia. The schedule program and the time synchronization of the PLC can be correctly performed via the cloud router by the remote terminal. The error of the PLC time is average 5 second per day or 2.5 minutes per month and this is not caused the program schedule error. Although the PLC time error is 7 minutes from the Master Clock in Washington, the clock can still execute the PLC when the audio mute clock appears within the PLC time error. The overall of the system design is very stable and there is no problem of the frozen PLC whether it connects to the internet or not.

5. Acknowledgements

Authors would like to thank the IBB Thailand for facilitation of equipment. Also, the authors is solely responsible for its content. The conclusions and opinions expressed in this publication are solely those of the authors and do not necessarily reflect the conclusions or opinions of the Voice of America, the Broadcasting Board of Governors (BBG), or the U.S. Government.

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