Solar Based Controller Designing For Starting & Speed Control of Induction Motor

Muhammad Farrukh, Mairaj Qazi, Aamir Ali Lakho, Muhammad Rafique Abro

Abstract: ***This paper describes the implementation of Solar Based Controller which is designed to control the starting (inrush) current and speed of Induction Motor. The motor in starting causes I2R losses due to heavy starting (inrush) current that will overheat the engine and also may damage the motor windings. Despite the fact, many countries are currently facing the threatening problems of load shedding because of fluctuation of oil prices, faulty distribution system, ageing of equipment, and mismanagement of resources, economic & political Instability etc. This issue has been very devastating for the national economy as the industries are being adversely affected due to this severe shortfall. Accordingly, in this design, we have used solar energy to feed our system & to start (inrush) current is controlled by using Star-Delta technique. In Star-Delta technique, the first motor will run in star connection & then in the delta, and the overall process of switching is done through PLC (S7200), the line current drawn with star connection initially is decreased to one- third of starting current as compared with the windings linked directly in the delta. The speed of the motor is controlled by altering the applied frequency and voltage from the inverter to maintain different loads. The cost-effective & robust system designed was successfully experimented to implement it in industries where motors are widely operated like (Coalmines, Chemical, Textile, Cement, Sugar mills) etc.***

Keywords: ***Induction motor, Star-Delta Controller, Solar panel, Inverter, PLC S7200, ladder logic.***

I. INTRODUCTION

Induction motors are widely employed in several operational areas and industrial applications as they're simple, robust and reliable and have low production prices. The 3φ squirrel cage induction motors (SCIM) are used in more than 85% of the industrial electric motor driven systems [2]. It must be noted through Star-Delta connections harmonics, and I^2R losses can be reduced to increase efficiency [3]. Also, Industries are moving towards soft controllers like PLC (Programmable Logic Controller) rather than Relay Logic Control. A PLC is like a specialised PC. Since it is a computer, it has all the fundamental parts contained in the personal computer, a central process unit, memory and input/output interfacing [1]. It utilises a configurable memory for the storing purpose of user-defined instructions for performing particular functions like logic, arithmetic, timing, sequencing and counting [4]. PLC is programmed to sense, activate, and control industrial application. Additionally, the PLC endlessly monitors the inputs and actuates the outputs according to the control program as depicted in Fig 1.

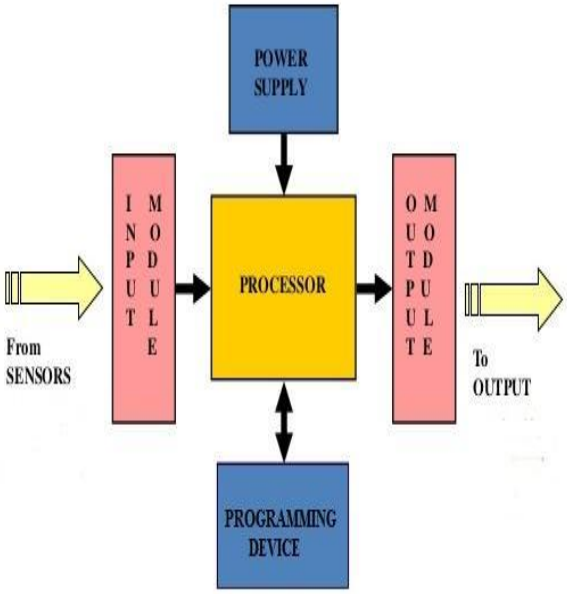

Figure 1 Basic Structure of PLC.

The implementation of the solar based controller for controlling the starting (inrush) current and speed control system for the induction motor supported programmable logic controller, and VFD technology is delineated. Star-Delta methodology is employed to control the starting (inrush) current although potentiometer also can be used to manage the speed of the SCIM. It must be noted there are many other methods to control the speed of 3-phase Induction Motor stated below:

1. Voltage/Frequency (V/F) control method [9].
2. Altering some Stator poles.
3. Adding rheostat in the stator circuit.
4. Adding rheostat on the rotor side.
5. Varying supply voltage.

PLC switches the complete system. The sun is taken into account as the prime source of energy. It's renewable, inexhaustible and environmental pollution free. So, we tend to feed our system through the solar and electrical converter or inverter to overcome today's load shading issues.

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At first, this research prototype aims to control the starting (inrush) current and speed of induction motor so that we can protect the motor from damaging and overheating and also to protect the other appliances that connected to same line. Secondly, to alter the motor speed as required by the applications to manage various process parameters at distinct loads.

II. SYSTEM SETUP

The proposed design uses a Star-Delta motor starter technique to reduce the initial inrush current whereas V/F frequency control approach is implemented to vary the speed of 3φ induction motor (SCIM) [7]. The mechanism involved in Induction motor is self-starting. During operation, a voltage is induced in the rotor as long as B-field is rotating, in result current starts to flow in the rotor.

According to Lenz Law, the rotor will begin pivoting to contradict the direction of current flow this gives torque to the motor. Finally, the motor is self-started. During this period as torque elevates, that increases current flow in the rotor. To accomplish this the stator draws a significant amount of current when the motor achieves its full speed, a substantial amount of current is drawn, and coils get warmed up, harming the motor. To overcome this problem one way is to utilise Y-Δ technique that initially decreases the supply voltage that will reduce the torque.

The Star/Delta starter consists of three contactors delta, Star & main contactors as shown in Fig 2. At initial startup, the two contractors (main & delta) are closed. AC3 contactors are used which are assessed at fifty-eight per cent of the current rating of the motor. The Star contactor is the third contactor that passes on star current when the motor is linked in star connection. It can be depicted from Table 1 star configuration has one-third current as compared to delta configuration.

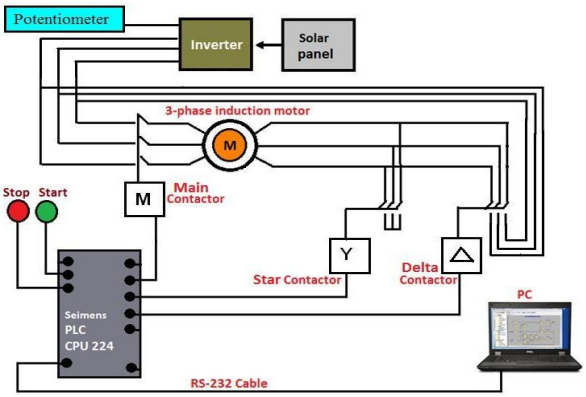

Figure 2 Star/Delta Starter Approach.

S.No	Configuration	Voltage	Current
1.	Star Connection	$V_L=\sqrt{3}V_{PH}$	$I_L=I_{PH}$
2.	Delta Connection	$V_L=V_{PH}$	$I_L=\sqrt{3}I_{PH}$

Table 1 Star-Delta (Voltages & Currents)

During operated, at first the main contractor and star contactor are turned on after some time, star contactor is turned off & a short time later delta contactor is turned on. The contactor is controlled by a timer incorporated with a starter by PLC technique. The Star/Delta is interlocked electrically as well as mechanically.

The speed of the motor is varied by the V/F frequency control approach [8]. At the point when 3φ supply is latched to the induction motor, a rotating B-field is created which moves at a synchronous speed given as:

$$Ns=(120*fs)/p \quad (1)$$

Where fs is the Frequency and p is a number of poles. On the other hand, emf induced is given by:

$$E=4.44\varphi Ktf \quad (2)$$

Where f is the frequency, t is the number of turns/phase, and K is winding constant. There is a proportional relation between frequency and speed. However, elevation influx is observed with a reduction in frequency; this situation leads to an increment in the no-load current of the motor as saturation of rotor and stator core is occurred due to large flux involved. To counter this effect flux should be kept constant and voltage must be changed. In other words, with a decrease in frequency; flux elevates in the mean-time if we decrease voltage flux will also fall causing no variation in flux and hence it remains consistent. It must be noted we have to maintain V/F as constant.

III. EXPERIMENTAL SETUP

In this research work, five solar panels are used to feed inverter for the operation of Induction motor (SCIM). The nominal Power rating of each solar panel was 100W and space (area) of 5.5m^2 approx is needed for panels. Further given Table 2 states the specific values of Photovoltaic cells. Whereas, the three-phase inverter converts DC power from the solar panel directly to AC power. A primary 3-phase inverter is consists of 3 single-phase electrical converters each connected to one of the three load terminals as depicted in Fig 3.

Figure 3 Three Phase Inverter.

Module Type	Amorphous Silicon
Nominal Power (+/- 5%)	100W
Open Circuit Voltage	96V
Short Circuit Current	1.7A
Maximum Power Voltage	70V
Maximum Power Current	1.43 A
Maximum System Voltage	600 V
Fuse Rating	3 A

Table 2 PV Cell Ratings

As stated before for controlling starting current Star-Delta technique is implemented which is switched by using PLC. Initially when Start Button is pressed a signal is to PLC input, and then PLC actuates the contactors according to the programming stored in its memory.

First, the motor is connected in Star connection; it will run in star connection for five seconds then the motor is connected in Delta connection. As illustrated in Flowchart Fig 4.

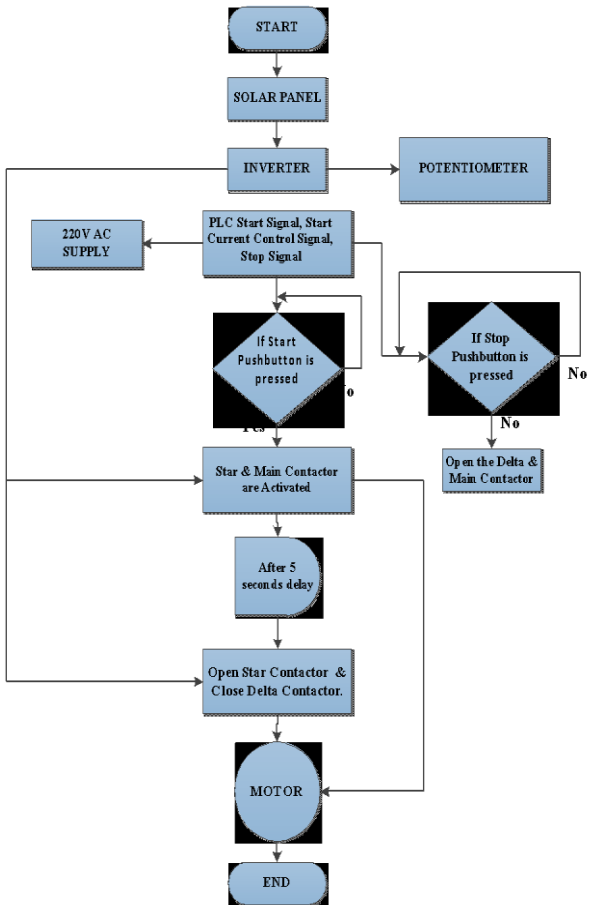

Figure 4 Flowchart of the Model.

For controlling speed, the potentiometer is used with the inverter; different applied frequency from inverter controls the rate because the speed of the motor is directly proportional to the frequency so by altering frequency we get different speeds for a different type of loads. Stop Pushbutton is used to shut down the process in an emergency at any time. The working of the design is shown in Fig 5.

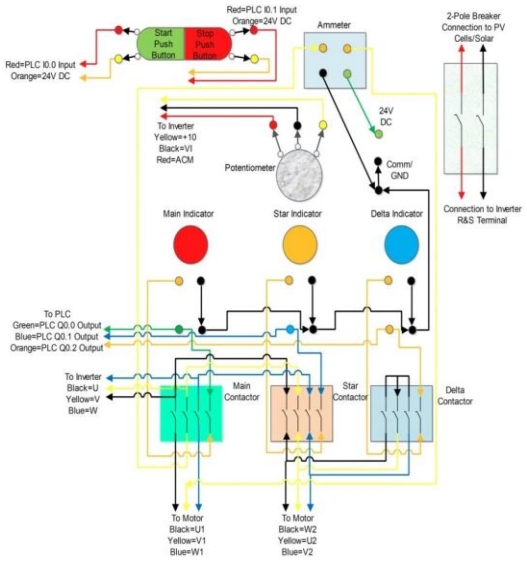

Figure 5 Schematic Diagram

PLC's are widely used in automation due to their simple wiring, flexibility and easy troubleshooting [5]. Accordingly, execution of the design is done through PLC S7200. Programming software compatible with this PLC is Step 7 Micro-Win. The interfacing of the Programmable logic controller (PLC) is depicted in Fig 6. It can be observed that I/O addresses are used for contactors efficiently. Whereas, for programming ladder logic is implemented; for Main, Star and Delta contactors PLC addresses Q0.0, Q0.1 and Q0.2 are used. Apart from that, a time of 5 seconds & Emergency button is provided to stop the process anytime as shown in Fig 6.

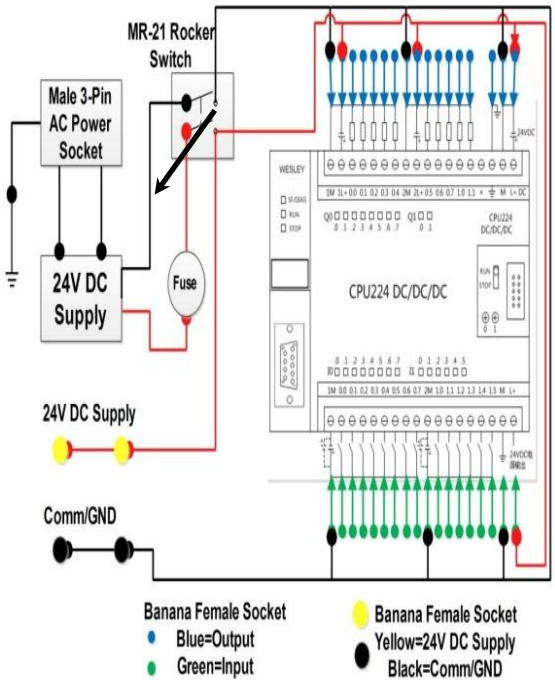

Figure 6 PLC Interfacing with System [6]

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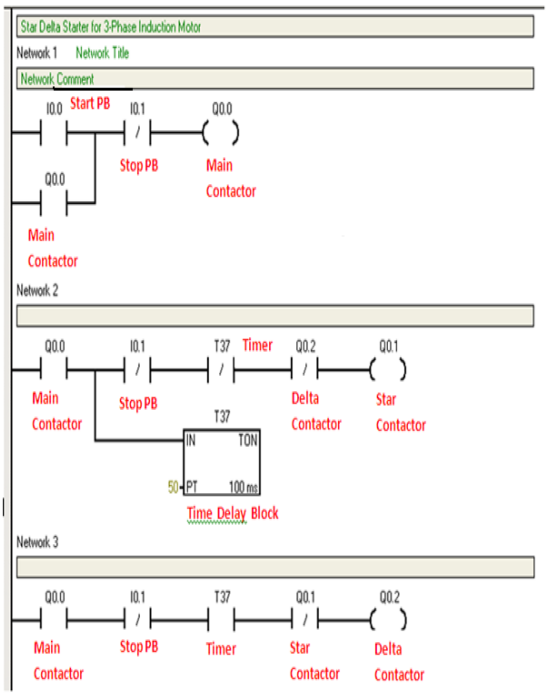

Figure 7 Ladder Programming.

IV. EXPERIMENTAL RESULTS AND ANALYSIS

The design when experimented gave a proportional relationship between Voltage versus Frequency & Voltage versus Speed. Power supply for analogue frequency is +10V fed from inverter; by changing this voltage through a potentiometer, we changed frequency for controlling speed. Potentiometer at high (e.g. 32000 value) = +10V = 50Hz= 1500rpm. When changing potentiometer position to half (e.g. 16000 value) = +5V = 25Hz = 750rpm [4]. The results are shown in Fig 8.

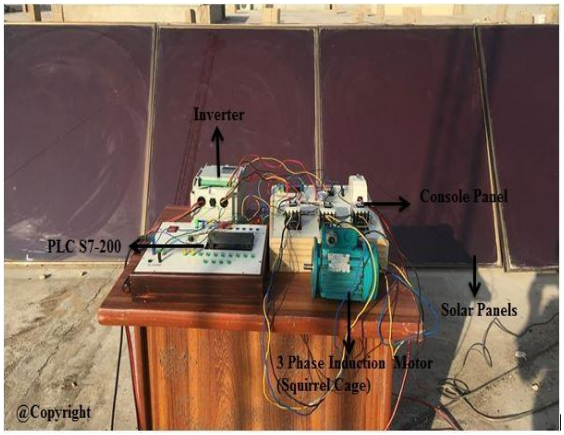

Figure 8 Systematic Implementation of Model.

S.No	Voltage (Volts)	Speed (rpm)	Frequency (Hz)
1.	1	150	5
2.	3	450	15
3.	5	750	25
4.	7	1050	35
5.	10	1500	50

Table 3 Results of Model.

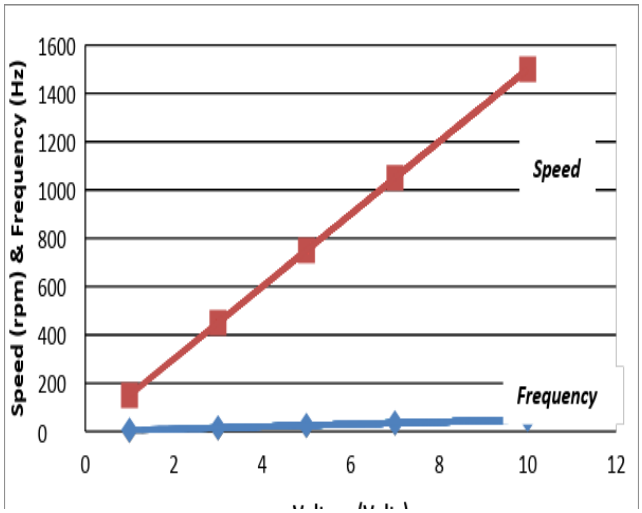

Figure 9 Voltage vs Frequency & Voltage vs Speed Analysis.

It can be observed from the above analysis that the speed of the induction motor was successfully controlled by different V/F frequency technique.

V. CONCLUSION

The proposed research successfully presented "Solar Based Controller Designing for Starting & Control of Induction Motor". Firstly, the Star/Delta techniques used gave a satisfying result in reducing the starting inrush current to protect the electric appliances connected to the same supply from a dip (voltage drop in line voltage). Secondly, the speed of the induction motor (SCIM) was controlled by the V/F frequency method. For future work the system can manage and maintained via an HMI (WinCC, LabVIEW etc.) also GSM (Global System for Mobile Communication) can be deployed enabling the engineers to get the status of the process anywhere anytime.

Concluding, the prototype was simple economic and affordable; it can be utilised in any concerned industry for presented tasks.

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