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RESEARCH ARTICLE

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# POWER QUALITY ANALYSIS & CONTROL OF DIFFERENT LOADS USING SCADA

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**ABSTRACT**

In modern days, there has been large improvement in technology that has led to the control and monitoring of the systems using software such as PLC and SCADA. Both PLC and SCADA are mostly used in production, manufacturing, power generation, refining and fabrication and process industries. The main objective of the paper is to develop a system that is capable of controlling (starting, stopping) and monitoring a three phase induction Motor and household loads performance characteristics. The TCP177 HMI (touch screen) from SIEMENS has been used for monitoring as well as for control purpose. The TIA (Total Integrated Automation) Software is used for programming S7-300 PLC. The WINCC Flexible Engineering Software is used to develop the SCADA screens.

Key Words -SCADA, TIA, DCS, HMI, and PLC



## I. INTRODUCTION

Industrial control systems form the backbone of countless industries affecting nearly every basic service modern society requires. [1] The increasing number of product grades and grade changes, combined with the demand for high availability and rapid reconfiguration, emphasizes the need for flexibility in plant operation. To make this possible manufacture should be seen as intelligent resource capable of performing multiple tasks in co-operation. While the initial prerequisites are determined by process and mechanical engineers, the control systems has key role in putting the inherited potential into practice. Their prominent and increasing importance in modern life makes them an important asset. [2]

Industrial control systems have been in use since the 1960s and are often broadly categorized as Distributed Control Systems (DCS) and Supervisory Control and Data Acquisition systems (SCADA). DCS are used to control large, complex processes but typically at a single site. SCADA systems are used to control more dispersed asset. SCADA has become more advanced and complex as computer technology has advanced.

The use of SCADA systems allows high level management of the industrial process by merging data from the many distributed portions of the process. This can help enhance the robustness and reliability of the system. [1] SCADA systems, in particular, perform vital functions in national critical infrastructure systems, such as electric power distribution, oil and natural gas distribution, water and waste-water treatment and transportation systems. They are also at the core of health- care devices, weapons systems and transportation management. SCADA also have been implemented in widely distributed processes such as pipeline systems, irrigation systems, and hydro generating complex. In the power system, SCADA systems are being used for fault identification, components isolation, system restoration, breaker control, reclosure blocking, generator control, feeder switching, voltage control, load management, automated meter reading and, automatic generation control etc. [3]

## II. S7-300 Programmable Logic Controller

A programmable logic controller (PLC) or programmable controller is a digital computer used for automation of electromechanical processes, such as control of machinery on factory assembly lines, amusement rides, or light fixtures. PLCs are used in many industries and machines. Unlike general-purpose computers, the PLC is designed for multiple inputs and output arrangements, extended temperature ranges, immunity to electrical noise, and resistance to vibration and impact. Programs to control machine operation are typically stored in battery-backed-up or non-volatile memory. For our work we have used Siemens S7-300 PLC.

These are the following programming techniques to program a PLC: 1. Ladder Logic 2. Function Block Diagram (FBD) 3. Instruction List 4. Sequential Function Chart (SFC)/Style programming (STL). The **S7-300 PLC** supports two programming techniques. The techniques are Functional Block Diagram and Ladder Logic Programming. In This PLC the program written in FBD can be converted to Ladder Logic and vice-versa.

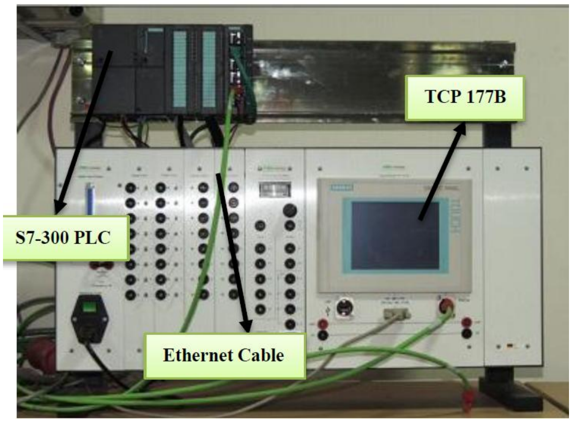


Fig: 1 S7-300 PLC with SIMATIC Panel.

## III. Totally Integrated Automation

Program is written in TIA software in FBD. This software optimizes all planning, machine and process procedures. With its intuitive user interface, its simple functions and its complete data transporting, it is extremely user-friendly. Pre-existing data and projects can be integrated effortlessly.

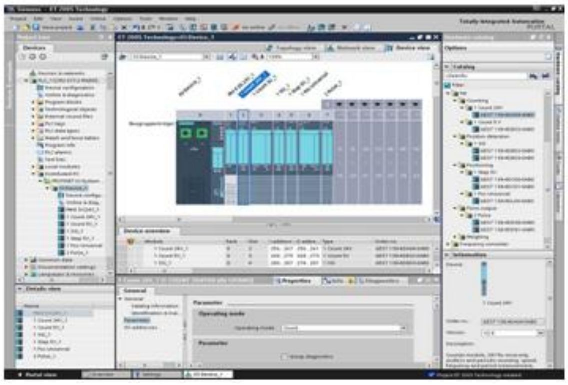

Fig: 2 TIA Software Window.

## IV. WinCC Flexible Engineering

Visualization is becoming a standard component for most of machine designs, the SIMATIC Human Machine Interface (HMI) basic panels provide touch-screen devices for basic operator control and monitoring tasks. For making screens WinCC flexible engineering software is used and it is used to configure SIMATIC TCP 177B panel.

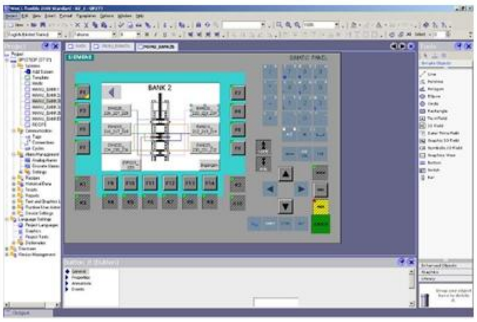

Fig: 3WinCC Flexible Engineering Software Window.


Figure: 4 Experimental Set Up for PQA

## V. Power Quality Analysis

Power quality is an issue that is becoming increasingly important to electricity consumers at all levels of usage. Sensitive power electronic equipment and non-linear loads are widely used in industrial, commercial and domestic applications leading to distortion in voltage and current waveforms. Improvement of power quality has a positive impact on sustained profitability of the distribution utility on the one hand and customer satisfaction on the other.

The analysis helps to monitor losses and also tells when to replace such appliances that are faulty and are source of loss. As an example, analysis of an office can help a company to monitor its consumptions and take necessary steps for energy saving. The analyzer used in this paper for the power quality analysis is **Janitza® Smart Meter UMG 511**. This smart meter can measure 2000 parameters and harmonics up to 63rd value.

The analysis of common household loads has been carried out. A three phase motor has been controlled and monitored. The list of analyzed loads is as follows:

1. Fluorescent Lamp
   (Bajaj® 230V, 40W)
2. Compact Fluorescent Lamp
   (Crompton & Greaves 220V-240V, 20 W)
3. Incandescent Lamp
   (Bajaj, 220-240V, 200W)
4. Electric Fan
   (Usha, 220-240V, 100W)

The following parameters have been analyzed.

1. Active Power
2. Reactive Power
3. Power Factor
4. Total Harmonic Distortion in voltage
5. Total Harmonic Distortion in current

*A: Fluorescent Lamp*

The performance of fluorescent lamp was obtained as follows:

1. Active Power Consumed

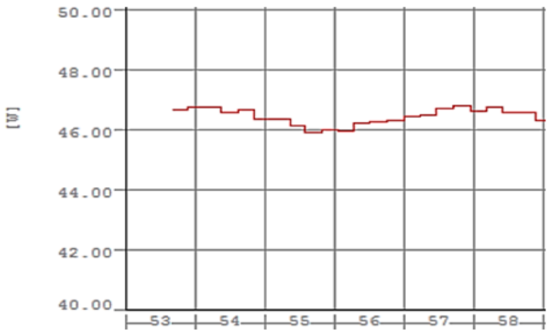


Figure: 5 Active Power vs. Time

2. Reactive Power Consumed

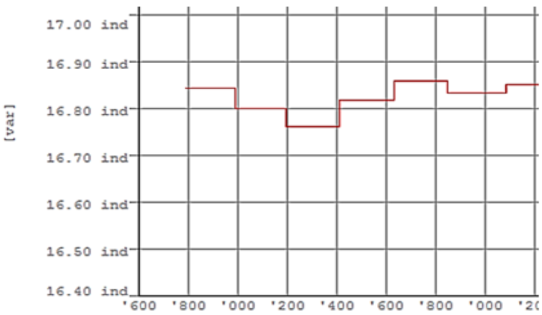


Figure: 6 Reactive Power vs. Time

3. Power Factor

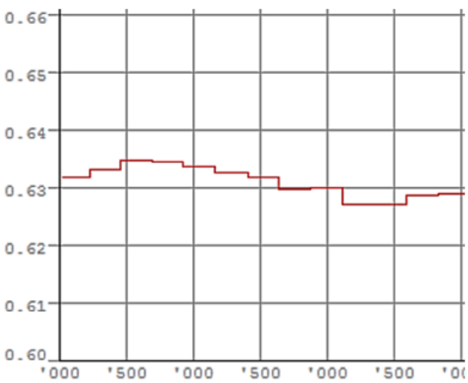


Figure: 7 Power Factor vs. Time

4. THD in voltage

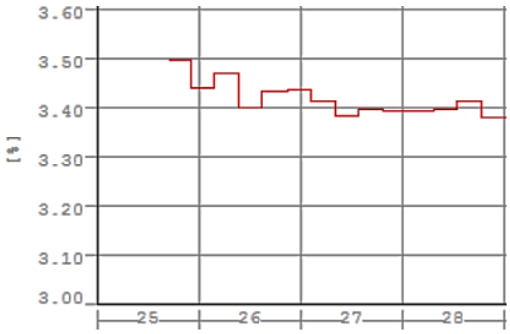


Figure: 8 THD vs. Time

5. THD in current

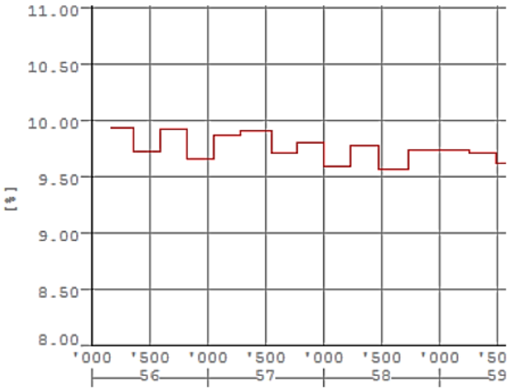


Figure: 9 THD vs. Time

*B. Compact Fluorescent Lamp Analysis*

1. Power Factor

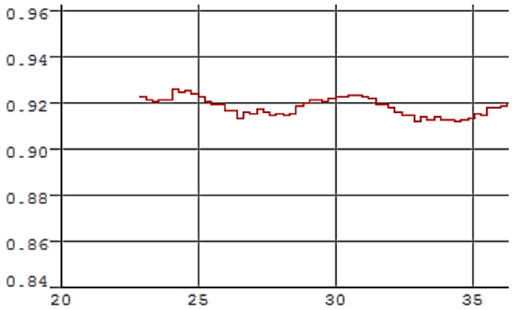


Figure: 10 Power Factor vs. Time

2. Active Power Consumed

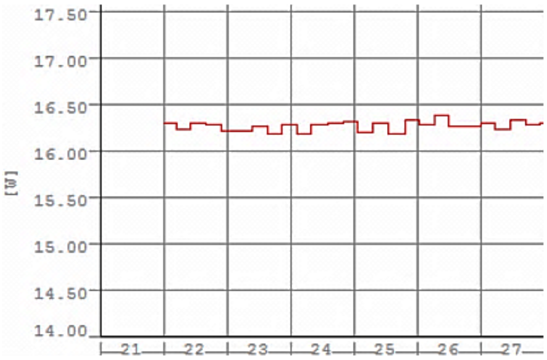


Figure: 11 Active Power vs. Time

3. Reactive Power Consumed

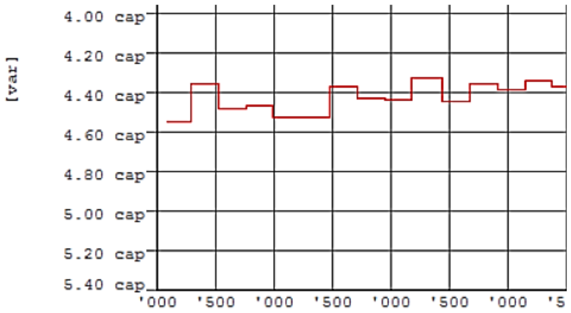


Figure: 12 Reactive Power vs. Time

4. THD in voltage

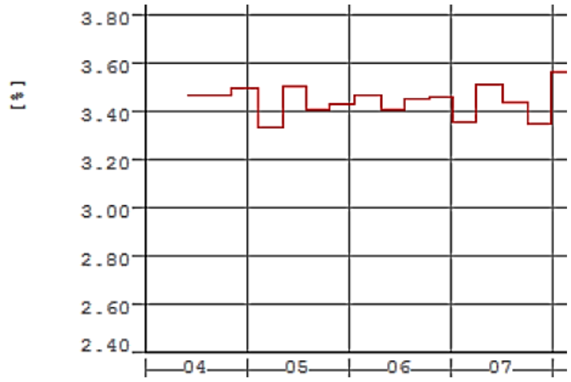


Figure: 13 THD vs. Time

5. THD in current

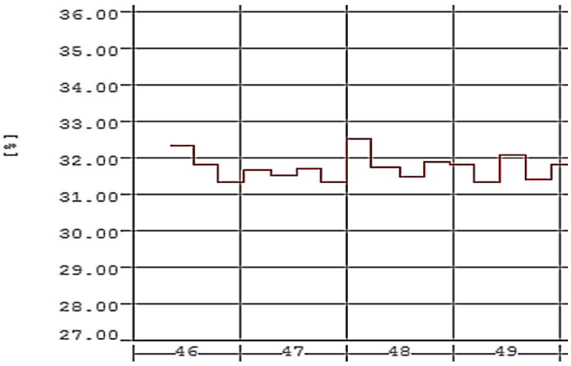


Figure: 14 THD vs. Time

C. Incandescent Lamp Analysis

1. Power Factor

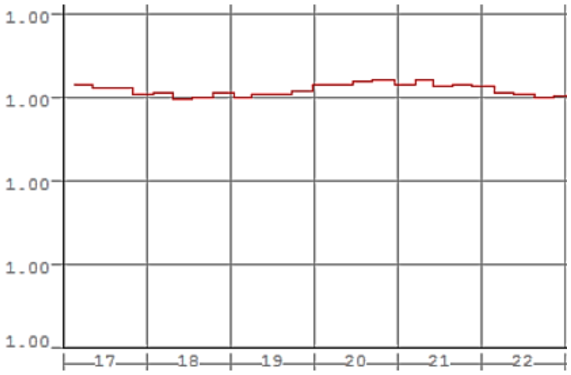


Figure: 15 Power Factor vs. Time

2. Active Power Consumed

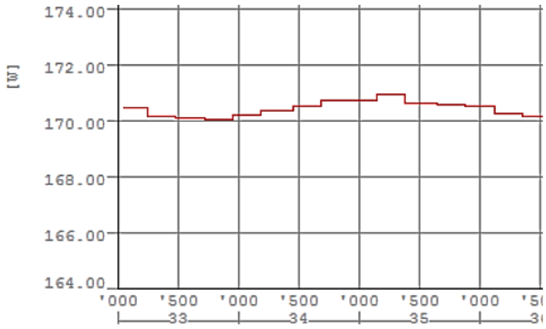

Figure: 16 Active Power vs. Time

3. Reactive Power Consumed

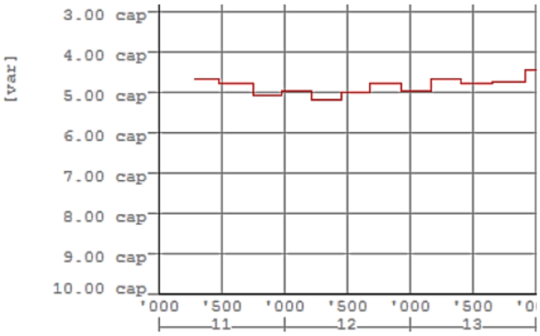

Figure: 17 Reactive Power vs. Time

4. THD in voltage

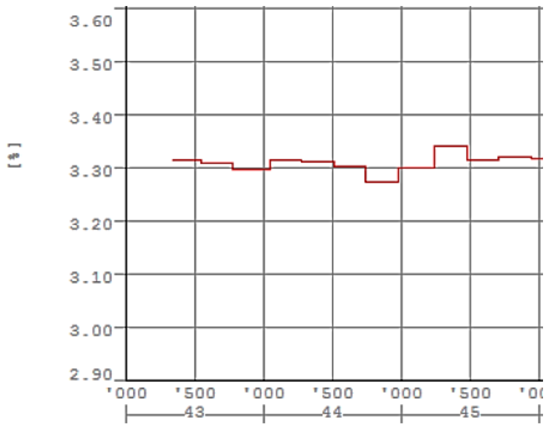

Figure: 18 THD vs. Time

5. THD in current

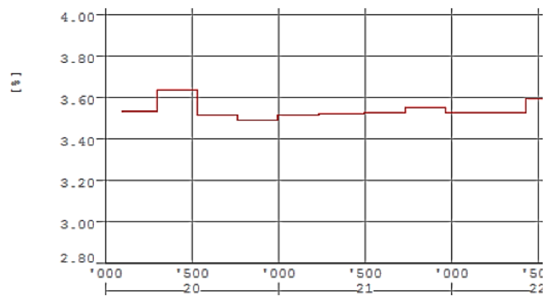

Figure: 19 THD vs. Time

Table I: Performance of Fluorescent Lamp, CFL and Incandescent Lamp

| | Power Factor | Reactive power (var) | THD in Voltage (%) | THD in Current (%) |
|---|---|---|---|---|
| Fluorescent Lamp | 0.63 | 16.8 (ind) | 3.4 | 10 |
| Compact Fluorescent Lamp | 0.92 | 4.40 (cap) | 3.4 | 32 |
| Incandescent Lamp | 1.0 | 5.0 (cap) | 3.3 | 3.6 |

It is observed that the power factor of Fluorescent Lamp, CFL and Incandescent Lamp is 0.63, 0.92 and 1.0 respectively. THD produced in current by CFL (32%) is more than that produced by Fluorescent Lamp (10%) and Incandescent Lamp. Reactive power consumed by Fluorescent Lamp is 16.8 var (ind) and by CFL is 4.40 var (cap). From active power, it is also observed that CFL is most efficient amongst the three.

*i. Electric Fan Control by Resistive Regulator*

1. Power Factor

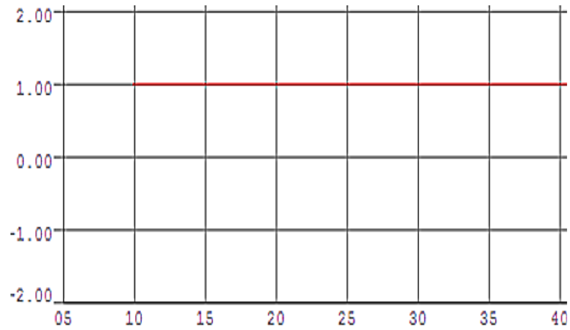

Figure: 20 Power Factor vs. Time

2. Active Power Consumed

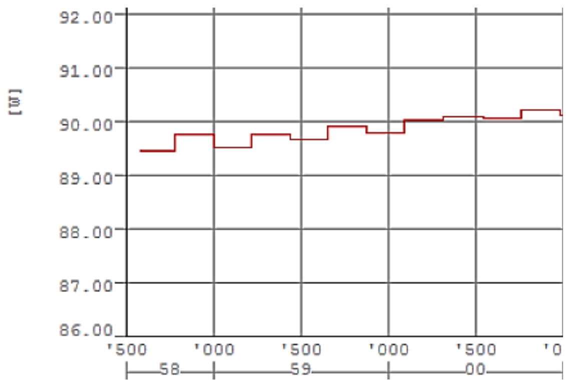

Figure: 21 Active Power vs. Time

3. Reactive Power Consumed

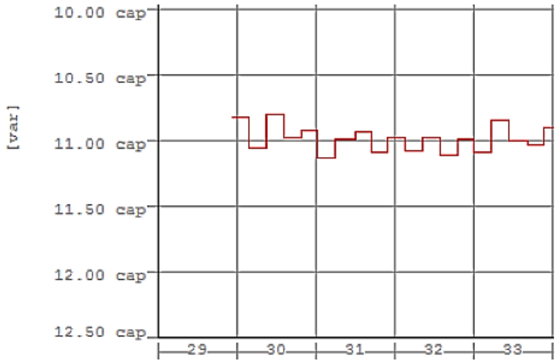


Figure: 22 Reactive Power vs. Time

4. THD in voltage

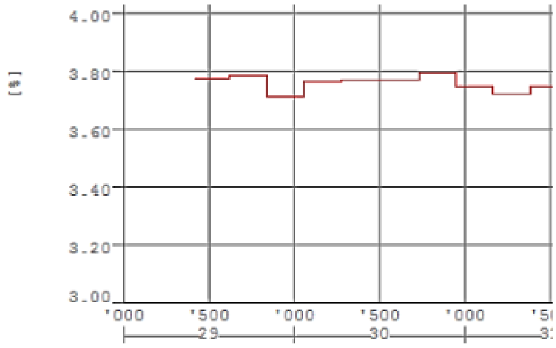


Figure: 23 THD vs. Time

5. THD in current

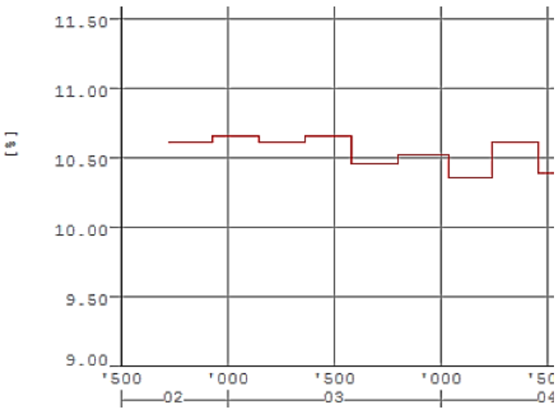


Figure: 24 THD vs. Time

ii. Electric Fan Control by Triac Regulator

1. Power Factor

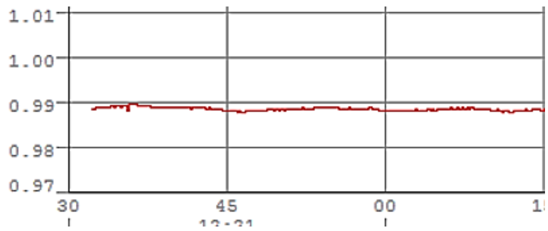


Figure: 25 Power Factor vs. Time

2. Active Power Consumed

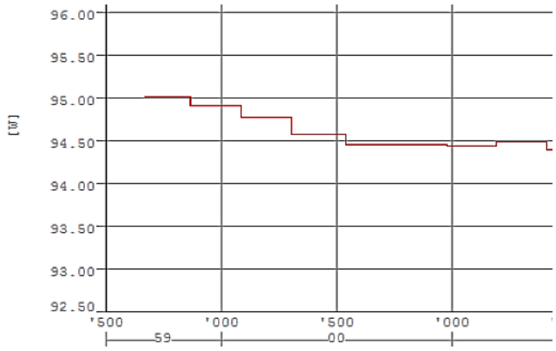


Figure: 26 Active Power vs. Time

3. Reactive Power Consumed

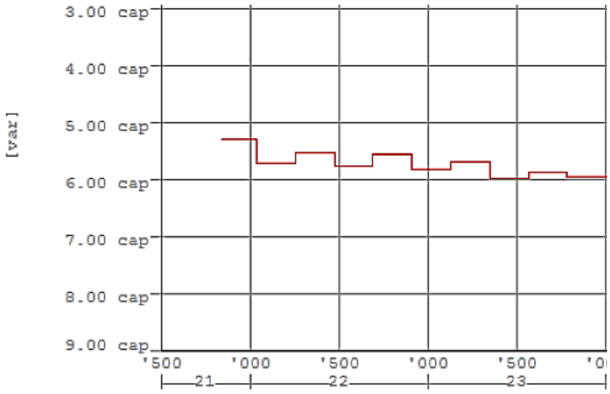


Figure: 27 Reactive Power vs. Time

4. THD in voltage

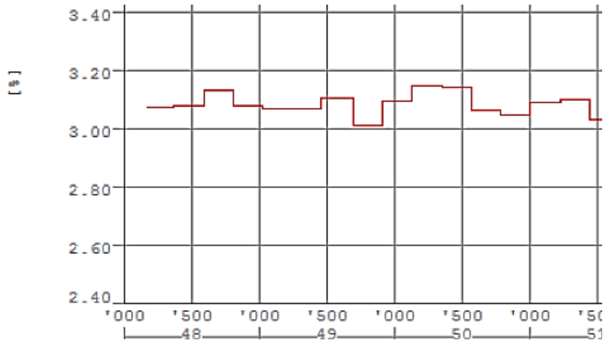


Figure: 28 THD vs. Time

5. THD in current

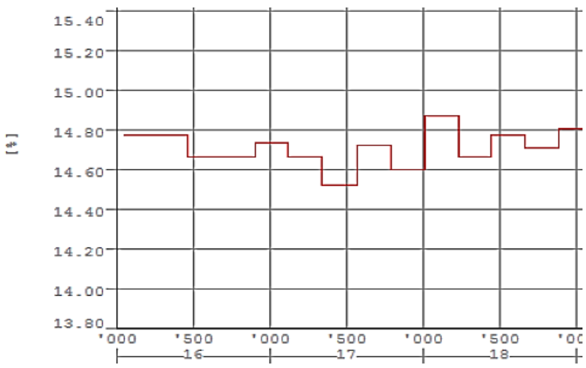


Figure: 29 THD vs. Time

**Comparison of Fan performances by resistive regulator and triac regulator**

It is found that power supplied to the fan with resistive regulator is 90 W however with triac regulator is 95 W. Resistive regulator draws 11var (cap) reactive power however triac draws 6var (cap). Total harmonic distortion produced in voltage and current by resistive regulator is 3.8% and 10.5% respectively. However THD produced by triac in voltage and current is 3.0% and 14.8% respectively. It is concluded that triac regulator is more efficient than resistive regulator.

**VI Direct Online Starting of Induction Motor using PLC & SCADA**

This method involves the direct switching polyphase stator on the supply mains. The motor takes low-power factor starting current of 5 to 7 times its full load current, depending upon its size and design. Such large current of short duration don't harm the rugged squirrel cage motor, but the high current may cause objectionable voltage drop in the power supply lines feeding the induction motor. These large voltage drop cause undesirable dip in the supply line voltage; consequently the operation of other equipment connected to the same supply line is effected considerably. A common example is the momentary dimming of lamp and tube lights in the home at the instant a refrigerator motor starts. If the supply is of sufficient power capacity and the low-power factor starting current surges don't cause objectionable voltage dips in the supply line voltage, then the direct-on-line starting should be preferred. DOL starting is sometimes used to start small water pumps, compressors, fans and conveyor belts. [4] Direct online starting of squirrel-cage induction motor is done in the SCADA Lab. The ratings and parameters of the three phase induction motor are shown in table II. First of all program is made for DOL then connection of induction motor is made with Janitza UMG smart meter. Program is loaded in S7-300 PLC with the help of Totally Integrated Automation software and stator current, power factor, and THD in stator current at No-load are observed with the help of Janitza UMG 511 smart meter.

Table II: Induction Motor parameters

| Type | 3 Phase squirrel-cage |
|---|---|
| Number of Poles | 4 |
| Rated Power | 0.75 kW |
| Rated Voltage $V_{L-L}$ | 415 V |
| Rated frequency f | 50 Hz |
| Stator Resistance R1 | 5.55 Ω |
| Rotor Resistance R2' | 8.29 Ω |
| Stator Inductance L1 | 2.2e-2 H |
| Rotor Inductance L2' | 2.2e-2 H |
| Magnetizing Inductance | 0.74 H |
| Inertia J | 0.055 kg-m^2 |

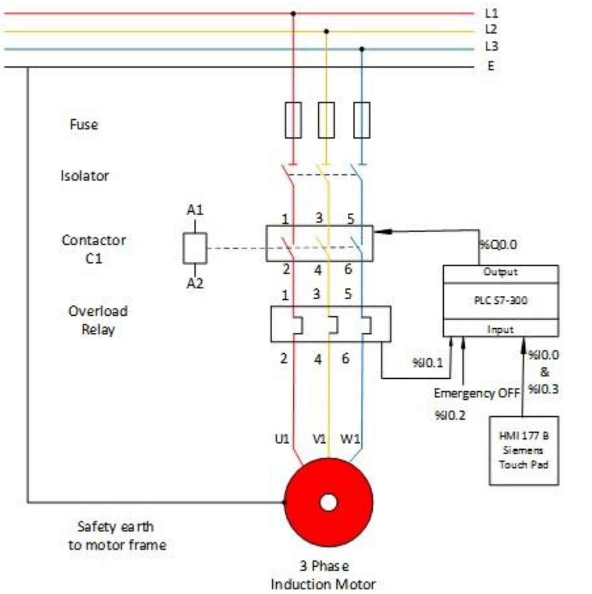


Figure: 30 Connection Diagram for Direct Online Starter

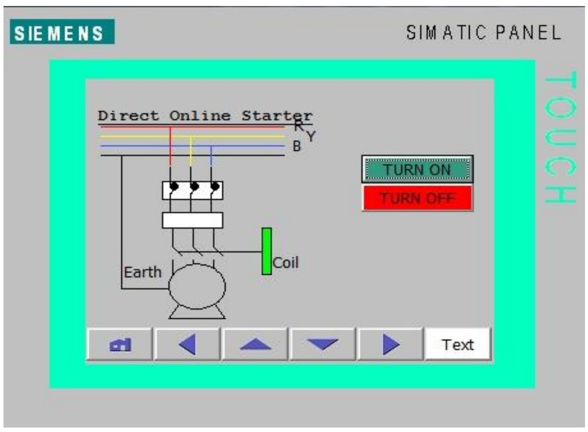


Figure: 31 HMI Screen for Direct Online Starter

SCADA Results are shown below:

1. 3-Phase Stator Current at No-Load

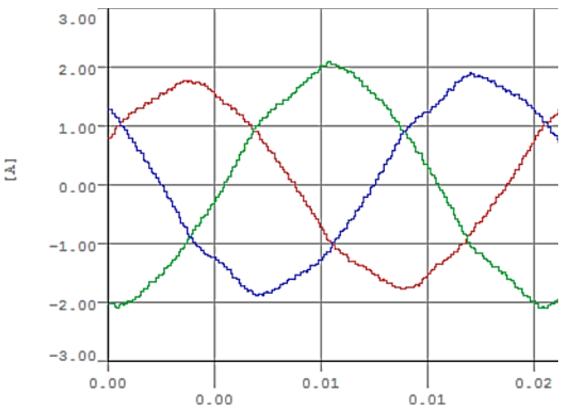


Figure: 32 Stator current at No-Load vs. Time

2. No Load Power Factor of Stator Current

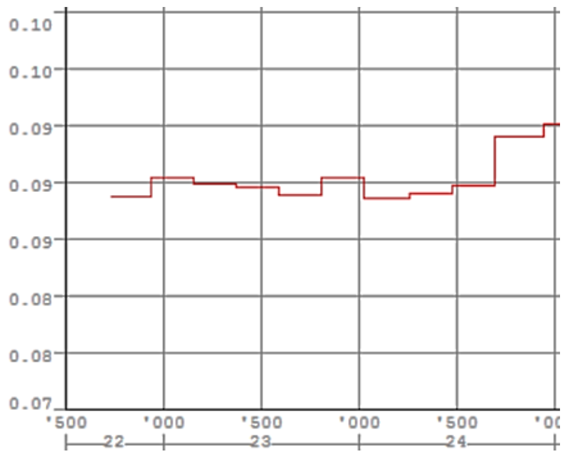


Figure: 33 No Load Power Factor Phase (A) vs. Time

3. THD in Stator Current

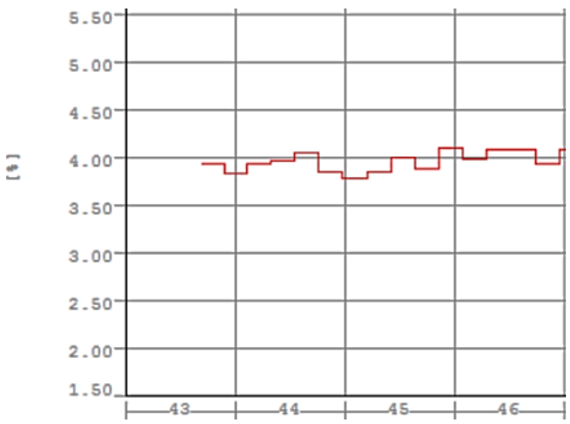


Figure: 34 THD in Stator Current Phase (A) vs. Time

## VII. Discussion

A study of hardware of Programmable Logic Controller (S7-314 CPU from Siemens) is done. The programming of this controller is done with the help of Total Integrated Automation (TIA) software. The WINCC flexible software is used to design the control screens. The Touch Panel TP 177 B (SIMATIC PANEL) is used as a Human Machine Interface. Power Quality Analysis of common household loads such as Fluorescent Tube, CFL, and Incandescent lamp was carried out. The CFL produced more THD than Fluorescent Lamp and Incandescent lamp (which produced nearly zero THD).

A fan was connected initially to a resistive speed regulator and then to a triac controlled speed regulator. It is observed that triac regulator is more efficient than resistive regulator because power output of triac regulator was more than resistive regulator. It was also observed that triac based regulator produced more THD in line current.

**Acknowledgment**

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