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Development of PLC based Automated Spindle Testing Platform

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***Abstract*—This Automation is the process of handling various parameters of process without presence of a person. PLC, VFD and HMI are the tools to handle such parameters. Present work involves development of PLC based automated spindle testing platform through which data can be monitored at any instance, generates accurate and precise testing report in required format with minimum involvement of human efforts. The monitoring and controlling of a spindle specimen based on PLC, HMI and VFD technology control panel described here. PLC proves an effective tool in industrial control of drives and data acquisition system. The platform should be used by many spindle manufacturing industries as it gives more accurate spindle testing report and saves lot of energy. By analyzing this report spindle life can be increased.**

Keywords— Automation, Data Acquisition, Mechatronics, Programmable Logic Devices, Temperature Measurement, Variable Speed Drives, Vibration Measurement etc.

I. INTRODUCTION

Even though many new manufacturing processes are introduced over the last decades, main heart of manufacturing processes have remained dominant in the metal working industry. Over decades, the basic principles of metal cutting and main mechanical components of the machine tools remained same. Same as years ago, a machine tool is still composed of the basic components such as spindle, moving axes and a cutting tool. Among all these components, spindle is almost the most critical one due to its vital duty in metal cutting process.

Spindles are rotating drive shafts that serve as axes for cutting tool or hold cutting instruments in machine tools. Even though the spindles differ in structure and design for different machine tools such as lathe tool, milling tool etc., they all serve to the same basic purpose which is rotating either the workpiece or the cutter with enough torque and speed against the other which is fixed to enable cutting. The spindle can be powered from a variety of sources. In the ancient times they were run manually through human or animal power, until the development of steam engines in the eighteenth century. Later, hydraulic and pneumatic power were used to run the same spindle until the wide use of electricity in the industry. Today most machine tools are powered by electric motors, however in some cases hydraulic and pneumatic power are also used.

There are different ways of driving a spindle with an electric motor. Nowadays, machine tool spindles are categorized as external or internal driven spindles based on the connection and assembly method of an electric motor to spindle. Externally driven spindles have their motor outside the spindle housing and the power is transmitted through belt, gear or chain systems. On the other hand, internal driven spindles have built in electric motors inside the housing coupled with a spindle shaft.

Current platform is focused on internal driven spindle also called as integrated spindles. Manufacturing or reservicing of any spindle must be followed by testing phenomena. Testing of spindle involves running it at rated conditions and monitoring its behavior using parameters such as temperature, vibration etc. Previous integrated spindle testing concept consist of running test specimen directly by means of variable frequency drive. Required spindle rpm is achieved by changing resistance of potentiometer connected to the drive. After achieving required spindle rpm, its temperature and vibration is measured by means of digital infrared thermometer of Meco make and digital vibration meter of Mextech make respectively. Later, the table containing temperature and vibration readings at calculated rpm send to customer along with the tested spindle.

II. LITERATURE REVIEW

Ioannides, et. al. (2004), developed a PLC based monitoring and control scheme for a three phase induction motor, suggested that PLC can be used in automation industries involving control of induction motor. A control program was developed, through which PLC continuously monitored the inputs and activated the outputs accordingly. A current sensor was employed for load current feedback, a speed sensor for speed feedback, and an additional current sensor was attached to stator circuits. The speed control of motor achieved through PLC gave the system high accuracy in speed regulation at constant speed for variable load operation.

Kaur, et. al. (2017), explained paper automation using PLC, VFD and HMI. In paper industry when raw material, water and chemicals mixed together then the modern paper manufacturing requires and uses high technology tools like PLC, VFD'S and HMI to get a precise quality of paper . The modernization of the conventional system by replacing the command parts like relays, contactors, timers by a modern tool like Programmable logic controller, to run the motor at various speed VFD is used and Monitoring systems get information from a number of motors and VFD's which help to assure the balanced flow of production, this can be achieved by using HMI or SCADA System.

Gupta, et. al. (2018), described about smart electrical control system using PLC and HMI. Automation is the process of handling various parameters of process without presence of responsible person. PLC, VFD and HMI are the tools to handle such parameters. An increasing demand in building for smart electric control system, where appliances can be controlled through switches and the HMI both. It is employed to maximize the energy saving of the lighting system and satisfy the building codes. It serves to provide the right amount of electric where and when it is needed. It complies with the green building and energy conservation programs. It is designed using the complete automation technology which includes PLC and HMI interface and its screen design, input and output power wiring as well as control wiring.

Vastav, et. al (2016), developed a solar tracking system using delta PLC. Solar energy is the primary source of renewable energy in developing the power deficient. But solar panels are less efficient in developing the power due to its fixed panel arrangement. In this paper, automatic solar tracking system is implemented using delta maker PLC which tracks the sun more effectively with its simple and precise control structure in all environmental conditions. The automatic solar tracker maneuvers solar panel towards the sun to extract maximum energy during the day time. The tracking is done by programmed light intensity of the panel with the help of sensors and magnetic reed switches, which controls the speed and direction of the dc gear motor attached to the solar panel through mechanical structure and gear arrangement by programming in PLC.

Putri, et. al. (2014), implemented temperature control of liquid egg pasteurization system using PLC Siemens S7-200 CPU 226, HMI Simatic Panel TP177 Micro, and a Proportional controller, in order to obtain a precise temperature control design for liquid egg pasteurization system. Liquid egg pasteurization on this research was carried out at a temperature of 64°C for 2.5 min. Ladder diagram of the PLC could work well as it could keep the temperature of 64°C according to standard pasteurized eggs. HMI in this study was able to show the trend of temperature and PWM view in real time.

III. SYSTEM DESCRIPTION

The PLC based automated spindle testing platform consist of components such as PLC, VFD, HMI, control panel, push buttons, indicators, tower lamp, choke, relay, SMPS, MCB, connector, rack, PVC channel, wires, temperature sensor, vibration sensor etc. Some of them are briefly explained as given below.

A. PLC and Analog Expansion Module

PLC of delta make was used as they are cost effective. According to application, model DVP14SS211R was selected. It consist of total 14 I/O, out of which 8 are digital inputs while 6 are digital outputs. SS2 stands for standard slim series of delta PLC. 11 denotes given PLC requires AC power input and R denotes relay type output. It has 32 bit CPU for high speed processing. It has 8k steps program capacity and 5k words as data registers. It is an economic and compact model. To log analog data we choosed expansion model DVP06XA. It consist of total 6 I/O, out of which 4 are analog inputs while remaining two are analog outputs. For voltage as an input source it has 12 bit resolution capacity and for current as a input source it has 11 bit resolution capacity. It works on 24V DC power supply similar to PLC.

B. HMI

HMI of delta make was used for easy communication between it and PLC. According to application, model DVP107WV was selected. Here, DOP stands for Delta Operation Panel, 1 stands for 100 series of delta HMI, 07 stands for display size (7" LCD display with 65535 colours) and WV stands for resolution (800pix * 400pix). It has 256 Mbytes flash ROM and 512 Mbytes RAM. It works on 24V DC power supply. It is a full touch screen panel. It is built in RS232/RS422/RS485 serial communication ports. It has 1 USB slave version 2.0 and 1 USB host version 2.0 for storing data in csv format and to download programmed screen respectively.

C. VFD

VFD of Emerson make was used. According to application, model SP2403 was selected. Here, SP stands for Solutions Platform Complete Inverter Drive, 2 is a frame size, 4 stands for voltage rating (380V - 420V), 0 predicts it's a wall mount drive and 3 stands for current rating step. Unidrive SP is designed to operate in any of the four modes which are open loop mode, rotor flux control mode, closed loop vector mode and servo mode. It works on 380V to 420V AC power supply. It has 20HP rating for normal duty application where as 15HP rating for heavy duty application. It has 7 DI, 3 DO, 3 AI and 2 AO. It is built in Devicenet, Ethernet, Modbus and Profibus serial communication protocols. It has a backup option with smart card.

D. Control Panel

Control panel of Eldon make with model number MAS0606030R5 was used. The body material is mild steel with thickness of 1.2 mm. The body is folded and seam welded. It has four 8.5 mm diameter holes for wall fixing which are pressed out to allow air circulation around the rear part of the enclosure. It has a door surface mounted with 130º opening and removable hinges with captive pin. Hinges can be mounted to allow left or right hand opening. Sealing is ensured by injecting one piece of polyurethane gasket in it. It has customized lock facility with double it for easy opening of the door. The mounting plate is marked vertically at 10 mm intervals for easy horizontal positioning of equipment. On the bottom of enclosure, there are holes to facilitate cable fixing with M8 press welded studs. All sides of control panel are strengthened by folded edges. By using auto mounting accessory the mounting plate position can be adjusted to any depth. Gland plate opening is situated at the rear of the enclosure to make cabling onto the mounting plate easier. It complies with IP 66 protection. For outdoor installation the use of a rain hood and 100% polyester paint coating is recommended. It has RAL 7035 structured powder coating. The corrosion resistance must be taken into consideration.

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E. Vibration Sensor

Vibration sensor of Monitron make with model number MTN/2285-2P-10 was selected based on application. It pickups vibrations generated by specimen and converts it into 4mA to 20mA output current. It works on 24V DC voltage supply. It has -25 °C to 90°C operating temperature range. The case material is of stainless steel. It has mounting torque of 8Nm. Weight of this sensor is approximately0.140kg. It complies with IP67 protection. It is built to measure vibration velocity for range 0 mm/sec to 10 mm/sec.

F. Temperature Sensor

Two wire PT100 temperature sensor of Insta control make was selected based on application. It has nominal resistance of100 Ω at 0°C. It complies with 0°C to 100°C temperature measuring range. It consist of 2 wire standard circuit. It has 2.5 kV insulation length. The output of Pt100 sensor is in Ohm but the input for analog expansion module attaches to PLC must be within range either 0V to 10V or 4mA to 20 mA. So we used resistance to current signal converter of Kana Electromech with model number MVC-401-07-1-DIN. It directly converts 0°Cto 100°C into 4 mA to 20mA.

G. SMPS

SMPS of Omron make with model number S8FS-C10024J was selected based on application. It has power rating of 100W. It takes 200V to 240V AC input voltage and gives 24V DC output voltage. It complies with 87% efficiency at 230V AC input voltage. It has 50 Hz to 60 Hz Rated input frequency. It has 1.1A rated input current at 230V and 4.5A rated output current at 24V. It has-20°C to 60°C ambient operating temperature range. It consist of overload protection with automatic reset. It has terminal block facing forward connection. Weight of selected SMPS is approximately 0.4kg.

IV. PROPOSED SYSTEM

Fig.1 given below shows basic circuit diagram for PLC based automated spindle testing platform - Part A. Spindle is driven with the help of variable frequency drive for running it at required revolution per minute. Both the sensors i.e. temperature sensor and vibration sensor are mounted on the spindle to acquire an analog data. They are connected as analog input sources for analog expansion module attached to PLC. Required program is made and downloaded on PLC and HMI, so that it can acquire data as well as drive the given spindle at calculated rpm.

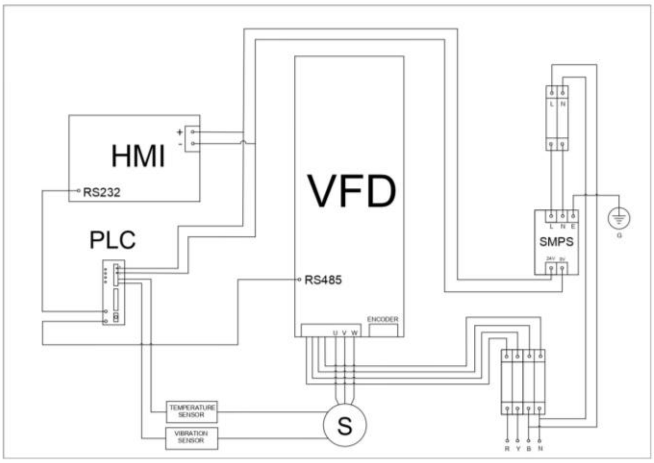

Fig.1 - Basic circuit diagram of PLC automated spindle testing platform Part A

Here, HMI display is used to monitor data as well as to read or write values into PLC. PLC act as interface between VFD and HMI. RS 232 serial communication protocol is used between PLC and HMI where as RS 485 serial communication protocol is used between PLC and VFD. 24V DC power supply is given to PLC and HMI with the help of SMPS on the other hand 3 phase power supply to the VFD is given directly from line. Tower lamp is used to indicate status of the platform whether the spindle is running or not. The buzzer rings when spindle crosses its predefined temperature, vibration limits or the given cycle has completed.

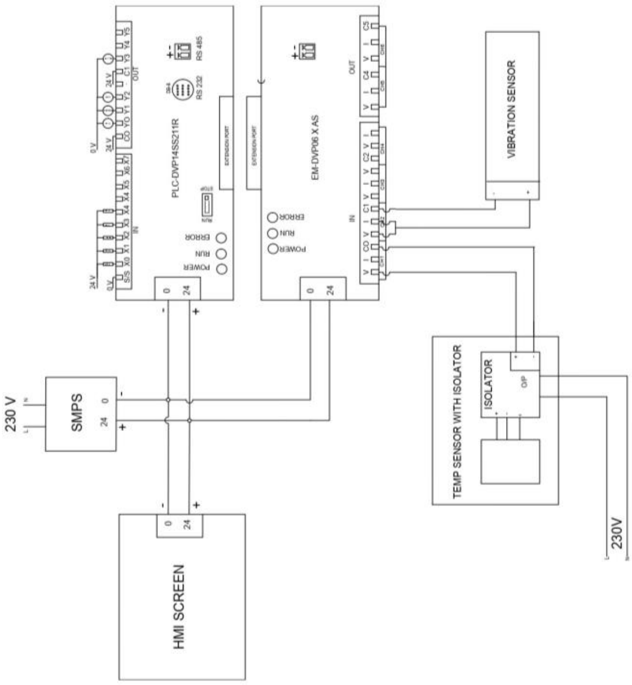

Fig.2 - Basic circuit diagram of PLC automated spindle testing platform Part B

Fig.2 given above shows basic circuit diagram of PLC based automated spindle testing platform - Part B. This figure shows the detail connections between PLC, its analog expansion module, HMI and both the sensors.

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V. SOFTWARE ASPECTS

To make PLC program we used ISPSoft 3.06.ISPSoftis a software development tool for Delta's new generation PLC. It supports five programming languages and adopts a large number of applied instructions. In addition to basic programming functions, ISPSoft also contains many auxiliary tools. It supports five programming languages. They are LD, SFC, FBD, IL and ST. We used ladder diagram language to make the program. Users can also use more than one programming language in one project. It supports traditional Chinese, simplified Chinese, and English. Users can import and export projects by means of the Import and Export functions. It provides various solutions for motion control. It supports COMMGR, a new generation communication manager. It provides several password setting mechanisms and data protection mechanisms. It supports several types of online operation such as monitoring programs online, editing programs online, monitoring devices online, debugging programs online, operating or setting a PLC online, and etc. It provides many convenient functions such as making comments, creating bookmarks, activating or inactivating networks, managing devices and symbols, simulation, and etc

To make HMI program we used DOP Soft 4.0004.DOPSoft is a software development tool for Delta's new generation HMI. The software is supportable for DOP -100 series HMI models such as DOP-103BQ, DOP-103WQ, DOP-107BV, DOP-107CV, DOP-107EG, DOP-107EV, DOP-107WV, DOP-110CS, DOP-110WS etc. After installing this software on PC we made the required program for our PLC automated spindle testing platform and then downloaded on selected HMI screen DOP 107WV. It provides more advanced and user friendly functions. It comes with user friendly editing interface. It consist of versatile 3D image library. It has smooth display for number of elements. It complies with powerful search function. It has faster downloading speed compare to old series of Delta's HMI. It improves the readability of the output results after compilation.

VI. PLATFORM WORKING

Fig.3 given below shows the actual working of PLC based automated spindle testing platform. Spindle to be tested is connected as a output of control panel. Both the temperature and vibration sensors are mounted on given spindle. Defined running cycle is given to the spindle by means of HMI. After completion of the entire cycle, generated platform output is saved. More information is explained in succeeding point.

Fig.3 - Front view of PLC based Automated Spindle Testing Platform

VII. RESULT & DISCUSSION

Table 1 given below shows data recorded on HMI screen number 3 of a tested 4 pole spindle with rated 21000 rpm and 700 Hz frequency. For testing purpose we divided total rpm in 7 cycles such as 3000, 6000, 9000,.......,21000 rpm. Each cycle consist of 15 minutes running time and 5 minutes off time. The temperature and vibration limits for given spindles are 45 °C and 1mm/sec respectively. Table is followed by graphs which are plotted as different parameters v/s rpm . If the temperature, vibrations and running noise of spindle are within predefine limits then the data table as well as graph are send to customer along with the given spindle as a spindle testing report otherwise spindle is send for rework or reservice.

Table 1 - Data table recorded by HMI screen number 3

Freq (Hz)	**Speed (rpm)**	**Temp (°C)**	**Vib (mm/sec)**	**Amp (A)**	**Vol (V)**
100	3000	32	0.24	1.99	51
200	6000	32	0.22	1.84	93
300	9000	33	0.22	1.82	134
400	12000	33	0.22	1.87	174
500	15000	33	0.23	1.94	219
600	18000	33	0.24	2.07	262
700	21000	34	0.25	2.62	305

Graph between respected rpm and vibration-

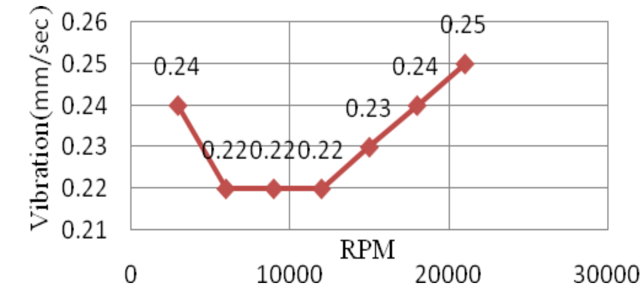

Fig.4 - Graph between respected rpm and vibration (mm/sec)

Graph between respected rpm and temperature-

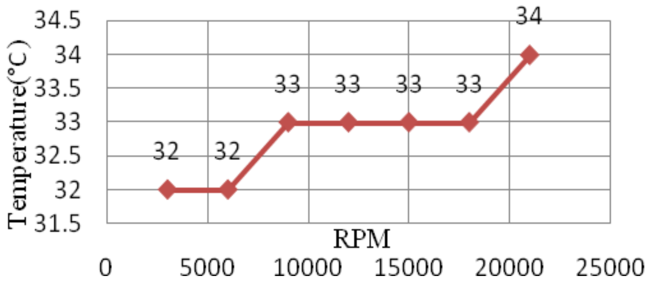

Fig.5 - Graph between respected rpm and temperature(°C)

Graph between respected rpm and voltage-

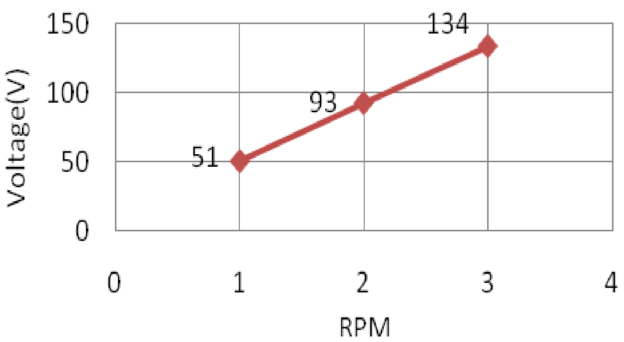

Fig.6 - Graph between respected rpm and voltage (V)

Graph between respected rpm and current-

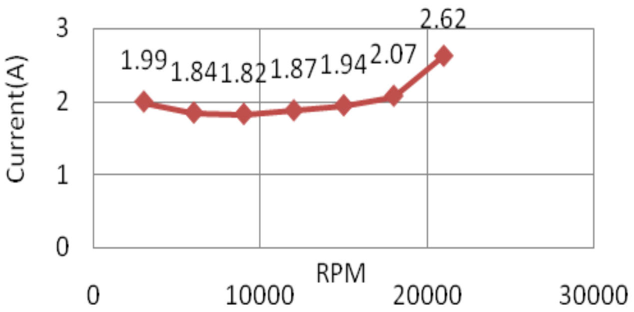

Fig.7 - Graph between respected rpm and current (A)

VII. CONCLUSION

The PLC based automated spindle testing machine was successfully developed. Running of spindle at a required revolution per minute with 99 % accuracy was achieved by means of VFD though a modbus communication. With the help of PLC and HMI program automated foolproof test cycle was well defined. The behavior of running spindle was continuously observed by mounting temperature and vibration sensor on same spindle. All the data obtained from HMI was used to plot various trends such as rpm v/s temperature, rpm v/s vibration, rpm v/s output current and rpm v/s output voltage. These trends help to generate accurate and precise spindle testing report.

VIII. FUTURE SCOPE

Further work can be expanded by implementing concept such as IOT, Industry 4.0 to the present platform. SCADA system may be used to handle two or more platforms simultaneously. Also by increasing number of temperature and vibration sensor, more accurate spindle testing report can be generated.

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REFERENCES

[1] Maria G. Ioannides, "Design and Implementation of PLC-Based Monitoring Control System for Induction Motor", IEEE transactions on energy conversion, pp. 469-476, ISSN 0885-8969, Vol. 19, No. 3, Sept. 2004.

[2] Amanpreet Kaur, Pardeep Singh, " Paper Machine Automation using PLC, VFD's and HMI ", International Journal of Engineering Research & Technology (IJERT), ISSN: 2278-0181, Vol. 6 Issue 05, May - 2017.

[3] Mahesh Kumar Gupta, Prince Kumar Gupta, Rajat Kumar Giri and Abhishek Gupta, " SMART ELECTRIC CONTROL SYSTEM USING PLC & HMI ", International Journal of Mechanical Engineering and Technology (IJMET) Volume 9, Issue 4, April 2018.

[4] Betha Karthik Sri Vastav, Dr. Savita Nema, Dr. Pankaj Swarnkar, Doppllapudi Rajesh, "Automatic solar tracking system using delta PLC", International Conference on Electrical Power and Energy Systems (ICEPES), 12 Dec 2016.

[5] Tri Oktaviana Putri, Rahmadwati, Bambang Siswojo, "Temperature Control of Liquid Egg Pasteurization System Using PLC Siemens Simatic S7-200 and HMI Simatic HMI Panel", EECCIS,2014.