

LabVIEW Based Automated Test Set Up of an Electrical System: Compressors

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Abstract

This article offers the overview of an automated test set up for a newly designed and assembled Compressor test bed system. Completely automated test sequence and procedures are taken into consideration while designing the system which is intricately provided in the international standards for Compressor Acceptance Test and also the reference for the project. This standard provides sequential steps that are to be wisely followed so as to calculate the specific energy requirement of an electrical driven compressor. The detailed system is built using National Instrument's LabVIEW, well integrated with HK SCADA (Novatrice Tech. Pvt. Ltd. owned SCADA) to give the complete overview. The output derivatives are displayed on the specifically build GUI with the LabVIEW showcasing the required detailed calculations. The validation of the data is done as per the company standards.

Removing the uncertainties plays a major role while acquiring the data from the compressor and is also mandatory so as to provide the corrected measured values and hence giving a précised result. On basis of the test report generated through the SCADA, compressor performance can be accessed, useful to derive the energy audits where compressor will be installed.

Index Terms: Compressor Test Set-Up, LabVIEW, Validation, Instrumentation, MODBUS.

1. Introduction

In the recent era, optimized and efficient automation for compressor test have proved to be a vital key to derive and analyze the energy consumption and also the performance monitoring to assess the workability of the newly designed and assembled compressor system. New technologies in the automation have emerged, which requires significantly less expertise and also reduction in manpower to avoid the humdrum tasks and controlling the operation of compressor, to maintain the system uprightness and reliability, and the cost associated with it. [1,2]

Brief performance testing of a compressor is very much needed so as to evaluate their present working conditions, its reliability, also to determine whether the equipment is properly designed, manufactured, and assembled and thus meets the specifications. The manifested analysis helps in indicating any physical condition such as fouling, internal wearing and also presence of any uncontrolled environment. Hence it is of utmost importance to obtain the accurate performance data in the field with the necessary instrumentation with a fairly acceptable uncertainty within the measurement limits.[3,9]

This article describes the automated test system of an industrial air compressors(electrical powered), in general, such as screw compressor, centrifugal compressor, axial type compressor and so on with the capacity ranging from few hundreds of CFM (Cubic Feet per Minute) to over 30,000 of CFM.

2. Background

Recently, a many Industries and Organizations are working with the peer technology to build out an out complete solution package for testing an industrial or commercial use compressors. With the ever booming industrial automation solution, many compressor test packaged-solution have emerged. Generally, there are different ways to calculate and assess the compressor performance and plant energy monitoring: volumetric efficiency, isothermal power requirement, actual free air delivery (FAD) of the compressor and most practical is specific power requirement.[4]

Parameters such as power, flow, temperature and pressure should be measured for a period of 10-days to obtain an accurate system snapshot. Usually two main parameters are considered to test the manufactured and assembled system, Power requirement in kW and volume rate of flow in CFM. The Performance Index for all compressed air systems is specific power consumed (kW) per 100 cubic feet per minute (CFM) of compressed air used in the plant. This allows judging how efficient the compressor system is with regard to the energy consumed. The tests are performed either by the manufacturers at the factories or at the site of installation. Test codes have been developed by the international and national organization wherein the guidelines are illustrated which are to be intricately followed to achieve the proper energy assessment. These guidelines are refereed as test codes. Most widely used test codes are listed below.[5]

- British Standard BSi ISO 1217:2009 : This standard specifies the operating and testing conditions which apply when a full performance test is specified, generally for all types of displacement compressors.
- ASME PTC-10 : This standard specifies the performance test codes for compressors (centrifugal and axial) and exhausters.
- ANSI/AHRI Standard 540-2004 : This standard code is specifically for performance rating of positive displacement refrigerant compressors and compressor units.
- JIS B8320 - Japanese Industrial Standard : This standard code is specifically for testing axial, centrifugal and reciprocating machines with air.

3. Development Work

British standard had been referred while following the methods for acceptance test. Fig. 1 shows the general test set-up for a compressor test.

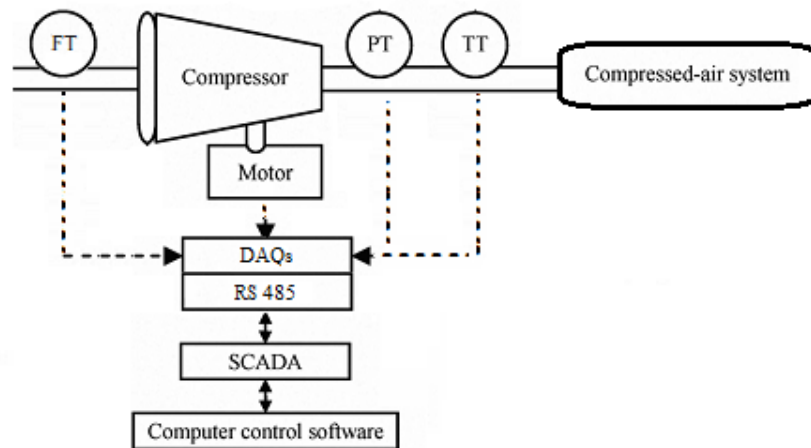


Fig. 1: The general automated test set-up for compressor under test.
The test system consists mainly of following sub-system blocks:

- *Compressor Under Test:* For a new machine the testing may be conducted in the manufacturer's facility under strict controlled conditions or in the field at actual operating conditions. Older compressors that have been placed in service after maintenance or have been operating for an extended period of time may require testing to verify the efficiency and normal operation.
- *Instrumentation:* For the purpose of the data acquisition, various sensors are to be employed on basis of their characteristics mainly how accurate and precise an instrument is how much resolution it provides to the Data Acquisition Systems (DAQs). The Performance Test Code Supplements in the PTC 19 series on Instruments and Apparatus provide authoritative information concerning instruments and their use and should be consulted for such

information. The selection of instrumentation shall be determined by the uncertainty limit requirements of the test as well as suitability for the test site conditions. Table 1, shows are the parameters that are monitored for the purpose of the field test with their sensor type and specification.

- *Communication Devices:* For the purpose of simulation, the used software is MODBUS Slaves to simulate the hardware (live) values of the sensors to the SCADA network. For real validation, Modbus protocol was preferred.

MODBUS devices communicate using a master-slave technique in which only one device (the master) can initiate transactions (called queries). Its physical interface is used as RS485 mode. At present, Modbus protocol has been a standard universal protocol. There are two types of transmission modes: ASCII and RTU. The mode of transmission is usually selected along with other serial port communication parameters (baud rate, parity, etc.) as part of the device configuration. All the data are transferred to the SCADA. [10]

SCADA stands for Supervisory Control and Data Acquisition. As the name indicates, it is not a full control system, but rather focuses on the supervisory level. As such, it is a purely software package that is positioned on top of hardware to which it is interfaced, in general via Programmable Logic Controllers (PLCs), or other commercial hardware modules. LabVIEW (Laboratory Virtual Instrument Engineering Workbench) is a system-design platform and development environment for a visual programming language by National Instruments. As per the guidelines the test set up is built so as to simulate and verify the designed code with real time systems. HKSCADA, the HK Automation make SCADA system has been used for the data logging and code simulation. HKSCADA is compatible to the LabVIEW based platform and so it is the better choice to implement the project as LabVIEW is the choice to perform the code simulation. [11]

Table 1: The Parameters monitored and collected with their make and specifications.

Parameter	Sensor Type/Make	Specifications
Compressor Discharge Pressure, psia	Danfoss make Pressure transmitter type AKS 33	Suitable for all refrigerants, including ammonia. Accuracy: $\pm 0.3\%$ FS (typ.)/ $\pm 0.8\%$ FS (max.) Nom. output signal (short-circuit protected) 4 to 20 mA.[6]
Barometric Pressure, psia		
Nozzle Inlet and Outlet Pressure, psia		
Inlet Temperature, Deg. F	Techno make Temperature transducer (RTD)	Excellent accuracy ($\pm 0.5\%$ to $\pm 0.8\%$) as compared to Thermocouple. Good sensitivity, repeatability and tolerance .Good Linearity. Range 4→20 mA signal(-250 to +650 Deg .C).[7]
Nozzle Inlet Temperature, Deg. F		
Inlet Relative Humidity, %	Nippon make	Linear 0V 100% RH, Range : 0 to

Nozzle Inlet Relative Humidity, %	Humidity transmitter	96.0 % RH, Long Term Stability, Close Tolerances, Resolution : 0.1 RH, Accuracy +/- 3 %[8]
Input Power, kW	Secure – Elite 440 – energy Meter	High Accuracy is up to +/- 0.2 % for KW reading. Modbus Communication via 485- port. Resolution – 6 digit display.

The above listed sensors/instrument data are to be collected by a suitable transmitter or controllers, and transmit over MODBUS communication network to the SCADA server for calculation purpose.

MACHINE DATA

Compressor	Compressor
Compressor Model	L99-TEST
Sales Order No.	Sales Order Nol
Tested by	VBK
Factory Order Date	12-10-2012
Nozzle Size	Nozzle 0.25
Fan Motor Efficiency	0.9
Fan Motor Service Factor	1.1

Fig. 2(a): The general data for Compressor under test.

CALCULATED RESULTS

Speed K1 Correction Factor	1.015
Condensate K1 Correction Factor	1.007
Speed K4 Correction Factor	1.015
Inlet Pressure K5 Correction Factor	1.000
Input Power, Corrected for Speed and Inlet Pressure	26.40
Measured Specific Energy	25.1
Pressure Ratio K6 Correction Factor	1.000
Specific Energy Corrected Above + Pressure Ratio	24.9
Rated Specific Energy	23.8
% Difference Btwn. Rated & Measured Spec. Power	4.6

Fig. 2 (b): Calculated Results - Specific Energy.

4. Results

Considering the British Standard, the guidelines are followed to go through series of calculations giving ultimate requirement for specific power consumption. Fig. 2(a) shows the front mimic or rather the display of the values of compressor from LabView.

Fig. 2(a) shows the machine data of compressor under test. This data is needed to be shown into the final test report specifying compressor's nozzle size, date and duration of the test, factory sales order, motor parameters etc. Fig. 2(b) shows the calculated results as per the guidelines in the BS standard and the parameters collected: The specific energy consumption value is displayed on the mimic of the SCADA, correction factors for speed, condensate, inlet pressure and discharge pressure is also calculated. Correction factors are essential to make sure that the data collected from the field is within the limits for calculation, in case any ambient or relative conditions alter the measurement.

5. Conclusions

The paper describes the resourceful tool for compressor efficiency calculation under the varying healthy test developed using LabVIEW and HKSCADA. The BSi 1217:2009 rating for a compressor serves as a volume rating, indicating how much ambient air the compressor will deliver to the terminal point of the package at the rated pressure. From there, calculations can easily be made to adjust the volume rating to the actual site conditions for the effective efficiency calculations. From performing the simulation it is evident that the correction factors are to be considered and applied to the compressor test data so as to get the more accurate results with the efficiency playing a major role. If there is any minor change with the specific energy calculation, it may result in blunders.

The test data calculation could be useful for the manufacturers, users for energy audit purpose, aiding for better productivity and costing and energy consumption evaluation.

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References

- [1] Low-cost compressor automation provides reliable alarm callout. World Oil, 00438790, Aug95, Vol. 216, Issue 8.
- [2] Automation of Compressor Test Procedure using Advantech Data Acquisition Module ,Abdul Md Mazid , Ryan Martin, 2008 10th Intl. Conf. on Control, Automation, Robotics and Vision Hanoi, Vietnam, 1720 December 2008.
- [3] Practical Methods for Field Performance Testing Centrifugal Compressors by Ed Wilcox, Westlake, Louisiana. Proceedings of the 28th Turbo Machinery Symposium.
- [4] Bureau of Energy Efficiency, chapter 8, ENERGY PERFORMANCE ASSESSMENT OF COMPRESSORS
- [5] BRITISH STANDARD, BSi 1217:2009, Displacement compressors Acceptance tests.
- [6] Technical leaflet Pressure transmitters, type AKS 33.
- [7] <http://ww.techno-instruments.com/thermocouple-rtd-comparison.html>
- [8] <http://ww.nipponindia.com/smartec>.
- [9] Guidelines for Performance Testing Centrifugal Compressor by Fred.L. Van. Laningham, Principal Engineer, Union Carbide Corporation, Houston, Texas.
- [10] Introduction to MODBUS, Technical Tutorial,2002 12 - 06.
- [11] WHAT IS SCADA?,A. Daneels, CERN, Geneva, Switzerland and W.Salter, CERN, Geneva, Switzerland, International Conference on Accelerator and Large Experimental Physics Control Systems, 1999, Trieste, Italy.