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Scada Based Automated Control System for Turbo Gas Units

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Abstract: Turbo gas units are combined gas and steam turbine. In the turbo gas unit, turbine gets the momentum to run by the appropriate injection of the gas and air in correct proportion. In order to obtain the turbo speed another superheated steam sources are used. Hence in the turbo gas unit turbine control can be controlled precisely by two variables namely gas injected in the fuel stock and the inlet speed of the superheated steam. Since turbo gas units operate at high speeds and often speed varies with respect to changing loads,the acceleration and deceleration rates have to be controlled precisely in order to prevent the turbine vibrations which causes the increased torsional and shear stresses in the shaft of the turbine. Hence the problem objective is to control the acceleration and deceleration rate by controlling the pressure and temperature for gas inlet and steam inlet by a valve. Earlier methods used make use of the PIDcontrol which controls the fuel gas injection control and steam inlet control. This results in increased vibration during the changing loads. Also when there is sudden change between the reference speed and error the higher control action causes bumps in the controlled outputs. In order to achieve the bumpless control DL450 PLC is used. DL450 PLC has the option of ramp control which can be used with a PID control in cascaded form to prevent the vibration of the turbine. The work proposes to implement the Turbogas unit turbine speed control to minimize the turbine vibration using PLC DL450.The ladder logic is implemented for the speed control and results are compared with other control techniques with only PID as a control unit without cascading it with ramp control.

Keywords: Gas turbine, turbine shaft, KingviewSCADA.

. Introduction

It's a combined gas and steam turbine. A gas turbine produces vitality from gas, whereas the created deplete gasses are utilized to deliver extra vitality by means of a steam turbine. Separately the gas turbine proficiency is as it were around 35-40%.The steam turbine raises the overall effectiveness to around 60%.

Gas Turbine Controller has the control to productively and dependably control gas turbine. It provides a versatile and traditional method for regulating a mechanical or aerospace auxiliary gas turbine. The Gas Turbine Controller (GTC) not only regulates speed and control, but also provides protection against excessive temperatures, speeds, or pressures, and manages the fuel flow during startups and shutdowns. It is designed for use with single or multishaft turbines powering variable-speed loads or synchronous generators. The novel and more cautious approach to fault resilience is defined by their repetitive inputs, blame location, fallback procedures, and excessive controller highlights, surpassing any previously available for such machines. The GTC can be combined with standard applications for Surge Avoidance Control and Station Control. Combining these applications give an coordinates control of turbine-driven compressors. GTC calculates fuel control valve request agreeing to prepare working focuses. Pumps, valves, other associated equipment are frequently upgraded as part of the control system upgrade process for many gas turbines. In fuel conversion projects, fuel systems are occasionally introduced to increase the fuel capacity of a turbine that was previously running on a single fuel. Complete fuel system designs that work with the control system are provided by CCS. The design of the gas turbine is determined by its intended use, which maximizes the most ideal energy form. Tanks, trains, airplanes, and electricity generators are all powered by gas turbines.

2. Existing System

Before SCADA implementation, the control system for turbo gas units is primarily manual, relying on human operators to monitor and adjust parameters such as fuel flow, turbine speed, and power output. Existing systems have some form of data logging capability to record operational parameters, and they are not easily accessible or analyzed in real-time.

3. Literature Survey

The paper shows how to quickly and accurately estimate gas flow in the steel industry, that can help us better understand how the gas system operates and provide energy scheduling personnel with useful tool for making decisions. The sample's effective noise variance is estimated using a LS-SVM model that includes real-time optimization of hyper parameters. Furthermore, gradient algorithm is devised to optimize the regularization factor and Gaussian kernel width. In order to evaluate how well the suggested method works, we run tests on flow of gases in an industry (Shanghai Baosteel Company Ltd.,) using a test function that includes additional noise. Additionally, several comparative tests are conducted. The results demonstrate that the suggested strategy achieves minimal computing time while maintaining forecast accuracy. Due to these advantageous attributes, this technique can be employed for real-time gas flow prediction in the steel industry.[1]

The authors proposed a technique for designing a control system for Turbo gas units with the help of ladder program. The control system comprises of a startup control sequence, protective measures, process monitoring, anti-surge control, and speed/load regulation functionalities. The integration of functions into a state-of-the-art high-performance PLC in accordance with the IEC 1131-3 programming standard. Experiments were performed to test a mathematical model of a TPU on an industrial PC with hardware interfaces to handle input and output signals. The effectiveness of the control system approach has been confirmed by the results obtained across all operational activities. The modular design of the software, transferring the control system to other PLCs from various manufacturers can be done effortlessly. The software's modular framework enables the accommodation of changes in control strategies.[2]

The utilization of a governor system in numerous pulp and paper plants that rely on steam power generation poses various challenges. These challenges encompass issues such as slow response times, inadequate speed regulation, drifting analog control, high maintenance and support expenses, costly or hard-to-find components, and prolonged lead times. The operational efficiency of the machinery is compromised, potentially leading to extended periods of generator downtime. The remedy to these issues lies in the replacement of the governor system. Upgrading to a PLC-based turbine governor system offers several advantages, including the use of readily available control and hydraulic components, the incorporation of the governor algorithm within the PLC-based regulating system, the independence of the governor system from the lube oil system, the substitution of the flapper nozzle system with a reliable hydraulic proportional valve, a user-friendly interface for control and monitoring, comprehensive alarming and diagnostics, and the ability to connect with the existing mill distributed control system through open communication.[3]

The specific control and safety needs of steam turbines are outlined, along with the introduction of a unit control system that can independently initiate, operate, and shut down a steam turbine while also providing protection throughout all stages of operation. This unit control system then connects to the plant control system at a level that ensures the speed and security of the overall network is suitable for the turbine. Various unit control examples for different turbine types are provided, along with techniques for integrating them into plant control systems. [4]

The control system of the turbine in the efficiency of steam power generation units. The goal of the study is to develop a multivariate PID controller for the steam turbine management system. Linear matrix inequality (LMI) method is applied to determine the conditions under which a robust H_∞ dynamic compensator must exist. The proposed controller is an improvement over the existing proportional controller used in power plants. In order to achieve this objective, a dynamic model of a turbine-generator is created, which includes governor, turbine, and generator elements. The simulation results demonstrate that the proposed controller performs exceptionally well at tracking and rejecting disturbances, even in the presence of system parameters that vary. [5]

The study introduces a method based on radial basis function (RBF) for addressing the fuel injection control issue. Previous neural controllers have mainly focused on utilizing a CMAC neural network, yielding satisfactory results. However, our research demonstrates that an RBF network, significantly smaller in size compared to the CMAC network, can provide better control performance in a mean value engine model simulation. This innovative approach does not necessitate prior knowledge of the engine subsystems, and online learning is facilitated through LMS updates. [6]

The document outlines the design of the control system and presents the findings of experiments conducted on the fuel-injection control system for a specific group of diesel engines. The control system has two rack position measurement channels and an MCS-80C196KC microprocessor, which enable precise measurements over a broad range. It has a cascade structure with loops for controlling engine speed and rack position. Through a decomposition-based robust/adaptive control approach, the system achieves effective rack position control despite model uncertainties. Furthermore, a proficient mapping-oriented fuzzy PID controller is formulated to regulate the speed of the engine. The control system has effectively been implemented on a diesel engine, demonstrating its exceptional performance in all engine operating modes through experimental findings.[7]

Test results demonstrate that the control system functions exceptionally well in all engine operating modes after it has been successfully incorporated into a diesel engine. Rack position control and engine speed control loops make up the cascaded configuration of the control system. Rack position is regulated using a decomposition-oriented robust/adaptive control strategy, while engine speed is controlled using a fuzzy-PID technique. The control system under consideration has undergone testing on a diesel engine, revealing through experimental results the exceptional performance of the control system in various engine operational modes, despite the existence of model uncertainties such as spring deformation, fuel temperature variations, and unanticipated friction.[8]

A supervisory control system was developed for a 500 MW boiler-turbine system model in the research using a T-S fuzzy model and a dynamic decouple PID controller.

The control system skillfullyaddresses the obstacles presented by nonlinear elements and interconnections in synchronized control systems. Furthermore, the system's globalasymptotic stability has been demonstrated. The results of the simulation haveconfirmed the effectiveness of this control strategy.[9]

This paper provides an overview of the mathematical modeling for combustion turbo generator and its control system, which will be used obtain simulation tests. The turbo generator model incorporates the integration of the gas turbine, synchronous generator, turbine control system, and generator control systems. It allows for the simulation of different scenarios, including the initiation of the turbo generator, starting from turn gear-speed to synchronization-speed. Additionally, it enables the loading of the turbo generator across its capability curve, ranging from minimum-load to peak-load conditions. The intended model has been developed to improve performance of the model integrating speed, voltage, real power, and reactive power controls. The simulation results, which demonstrate the utilization of digital PI control algorithms, have been presented.[10]

4. Proposed System

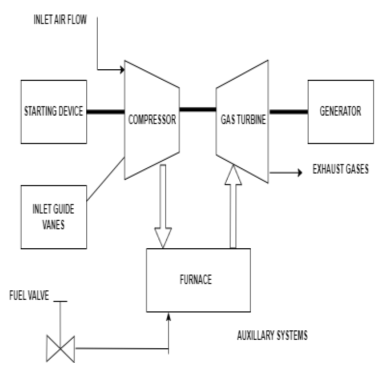

Fig.1: Block diagram of Turbo Gas unit

The Fig.1 shows the block diagram that provides a high-level overview of the major components and their interconnections within a turbo gas unit. [11]

- The starting device is a large gas turbine; a smaller auxiliary gas turbine may be used specifically for starting purposes. This turbine drives the main turbine shaft until it reaches operational speed, at which point the main combustion process takes over.

- The fuel inlet delivers fuel to the combustion chamber in the required quantity and at the proper pressure, manages the temperature of various components within the turbo gas unit and removes exhaust gases safely.
- The compressor compresses incoming air, increasing its pressure before entering the combustion chamber. Where the compressed air mixes with fuel and ignites to produce high-temperature, high-pressure gas, which drives the turbine.
- The Gas turbine receives high-pressure gas from the compressor, combusts it in the combustion chamber, and drives the power output shaft and generating mechanical energy. The turbine is connected to a generator, which converts the mechanical energy into electrical energy.
- The power supply connected to a generator or other power conversion system to convert the mechanical energy from the turbine into electrical power or other usable forms of energy.
- The exhaust gases are expelled from the turbine and pass through a heat recovery system to capture some of the waste heat for other purposes, such as heating water or generating steam.

4.1. Pid Controller

The Fig.2 is the Proportional-Integral-Derivative controller is indeed a widely used control mechanism in various industrial applications. The PID controller continuously compares the desired setpoint with the actual value of the process variable and adjusts the control output accordingly to minimize the error between them. This continuous adjustment ensures that the process variable stays as close to the desired setpoint as possible, providing effective and stable control of various industrial processes. The error is calculated by taking the desired setpoint and subtracting the measured value of the process variable. The controller then uses this error signal as the basis for its control actions, aiming to minimize this error and keep the process variable as close to the setpoint as possible.

The PID controller algorithm utilizes three distinct parameters: proportional (P), integral (I), and derivative (D). These parameters allows engineers to fine-tune the performance of the PID controller to meet specific control requirements and adapt to different types of system.

This paper uses PID controller to regulate various parameters such as fuel flow, air-to-fuel ratio, turbine speed, and exhaust temperature in gas turbine. It regulates the speed of the gas turbine. The controller adjusts the fuel flow rate based on the difference between the desired turbine speed (setpoint) and the actual turbine speed. The proportional term adjusts the fuel flow proportionally to the error, the integral term corrects for steady-state errors over time, and the derivative term anticipates future changes in speed to prevent overshooting or oscillations.

The PID controller monitors and adjusts fuel flow to maintain the exhaust gas temperature and prevent turbine overheating. By adjusting compressor speed or inlet guide vane positions, the controller maintains stable operation of the shaft of the turbine even under varying flow conditions.

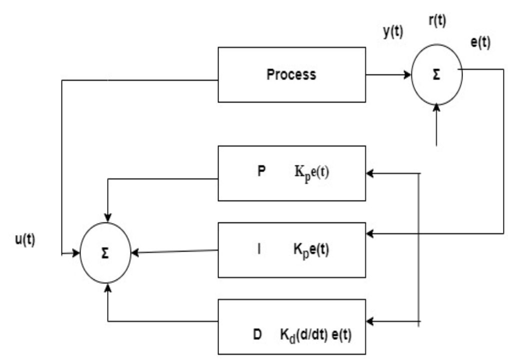

Fig.2: Block diagram of PID Control

$u(t) = MV(t) = Kpe(t) + Ki + Kd\ (d/dt)\ e(t)$

Where

Kp: Proportional gain, a tuning parameter

Ki: Integral gain, a tuning parameter

Kd: Derivative gain, a tuning parameter

e: Error

t: Time or instantaneous time (the present)

τ: Variable of integration; takes on values from time 0 to the present.

4.2. DL450 PLC

The DL450 PLC as shown in Fig.3 is type of CPU can communicate with specialty module in an expansion base. It requires external 125VDC power,30.8K words total memory or EEPROM cartridges available) RLL/RLLPLUS programming, including support for up to 16 PID loops and floating point math. Built-in communication ports include an RS-232C programming

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port and auxiliary RS-232C/RS-422 ports.

Fig. 3: DL450 PLC

4.3. King View Scada

The KingView SCADA that offers graphical visualization tools to aid in operations management, control, and optimization. It enables the creation of Windows-based applications for control, monitoring, and data collection purposes. It triggers outputs and events according to input data, produces graphs and trend charts for analysis, and raises customizable alarms based on specified conditions.It serves as a foundation for constructing a data information service platform within the automation sector. With its graphical visualization capabilities, the software facilitates operations management, control, and optimization. It finds extensive application across various industries including power generation, water conservancy, construction, coal mining, environmental protection, metallurgy, and more. It supports Windows XP, Windows 2000 Professional, Server or Advanced Server, Windows 2003 Server (Standard and Enterprise Editions), Windows 7, and Vista.

It offers robust data storage capabilities, stable communication features, accurate representation of results, and diverse methods for establishing I/O points. It provides a graphical user interface featuring vibrant true-color display graphics and enables smooth transitions between colors. The updated Web Server framework enables seamless full-screen release and real-time display of data, including historical data and database information.It offers unmatched flexibility through full script and graphics animation capabilities. Additionally, it provides robust. This, system facilitates distributed warning dissemination and event management while ensuring the retention of both real-time and historical data across distributed systems. Its robust script language processing allows for the execution of intricate logical operations and decision-making functions.

5. Results and Discussions

The speed control of turbo gas unit is executed with a KINGVIEW SCADA. The temperature and the pressure rates were monitored for the control of speed of the turbine. Upon execution of it was found that the unit slowly increases the output of the PID control action from initial state to final state to avoid a bumpless start. Thus the temperature and pressure values are monitored constantly through SCADA screen which can be controlled using touch view thus protecting the turbine from acceleration.

5.1. Initial Mode

The Fig.4 shows the results of the turbine operation by temperature and pressure control. Thus when the temperature and pressure varies and goes beyond the set point the speed of the turbine does not remain constant. This gives to acceleration of the turbine speed and affects the process. Thus using KINGVIEW SCADA the both the variables are monitored constantly. Thus the results shows that when the temperature and pressure is beyond the operating range it results in shut off the respective valves thus leading to constant speed maintenance of the process.

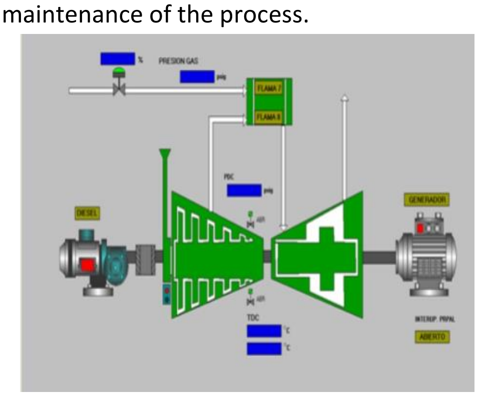

Fig.4: Initial Review in Start Mode

The above screen shows the SCADA screen with tool box arrangement.

RED INDICATION- STOP MOD
GREEN INDICATION-START MODE
SECOND REVIEW IN STOP MODE
SECOND REVIEW IN START MODE

The Fig.5 shows the process is in start mode. The fuel control valve is closed, fuel is given to the combustion chamber. The green indication shows that the diesel engine is in ON condition hence the turbine is in RUN mode. Hence output is generated which shows the generator in GREEN indication.

Thus the screen shots shows that the when temperature exceeds operating range (set point), the temperature inlet valve will be shut off with red indication. When the pressure exceeds operating range (set point), the inlet pressure valve will be shut off and the exhaust valve gets open, thus maintaining the constant temperature and pressure.

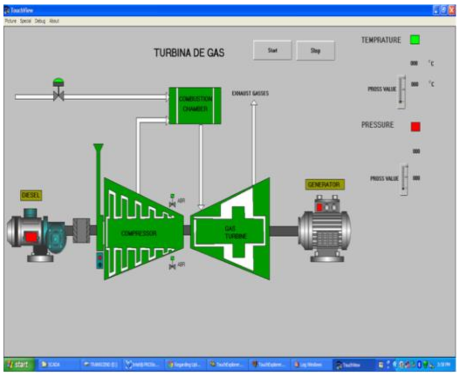

Fig.5: Second Review in Start Mode

SECOND REVIEW IN STOP MODE

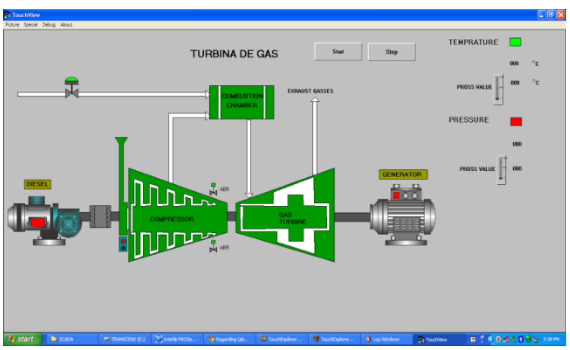

Fig.6: Second Review in Stop Mode

The Fig.6 shows the process is in stop mode. The fuel control valve is open no fuel is given to the combustion chamber. The red indication shows that the diesel engine is in STOP mode hence the turbine is in stop mode. Hence no output is generated which shows the generator in red indication.

6. Conclusion

The speed control of turbo gas unit is executed with a KINGVIEW SCADA. The temperature and the pressure rates were monitored for the control of speed of the turbine. Upon execution of it was found that the unit slowly increases the output of the PID control action from initial state to final state to avoid a bumpless start. Thus the temperature and pressure values are monitored constantly through SCADA screen which can be controlled using touch view thus protecting the turbine from acceleration.

Compliance with Ethical Standards

Disclosure of potential conflicts of interest

Authors declare that they have no conflict of interest.

Ethical approval

This article does not contain any studies with human participants performed by any of the authors.

Data Availability Statement

Data sharing does not apply to this article as no new data has been created or analyzed in this study.

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Authors' contributions:

Mrs. M. Saranya (Corresponding Author): Conceptualization, Methodology, Writing- Original draft preparation.

Dr. S .A. Sivasankari: Supervision

Dr.V.Rukkumani: Supervision

Dr.K.Srinivasan: Supervision

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