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Design of Real-Time Gas Emission Tester for Diesel Power Plant Applications

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***Abstract* — The paper proposes design of real-time gas emission tester for diesel power plant applications. Several sensors are utilized in our design system, such as sensor of KE for O_2 gas, MQ136 for SO_2 gas, TGS 2201 for NO_x gas, MQ7 for CO gas, MQ2 for smoke opacity including Modul DT-Sense SHT 11 sensor for temperature and humidity. All sensors basically produce analog output voltage; therefore the analog data is converted to 8 bit digital data for the further processing and controlling in the ADC pin of ATmega16 microcontroller. The real-time measurement results can be monitored through visualization in Liquid Crystal Display (LCD) and computer monitor after data processing using microcontroller ATmega16 under programming environment of CodeVision AVR V2.03.4. The visualization itself is designed based on the combination between programming language of Microsoft Visual Basic ver. 6.0 and Borland C++. The experimental results show that the proposed design is working properly. The information related to the emitted gas from plant chimney can be collected, stored in real-time and accessed online through web based interface systems.**

***Keywords* — Gas Emission, Gas Sensor, Real-Time, Diesel Power Plant, Microcontroller Atmega16.**

I. Introduction

The issue of smart grid in power engineering has spread out to the environmental impacts of using conventional-fuel power plant, called s*mart environment*. The smart environment may involve the monitoring and control of the gas emission exhausted from the chimney of the plants. There has been significant development in the environmental concern related to the data gas emission using sensor utilizations [1]. The sensor technology is now rapidly developing supported by sophisticated electronic devices, communication and information protocols. As results, the sensor network technology has entered new generation era with cheaper, more accurate and wide-distance detection capability. In addition, the network sensor is more flexible than other methods due to supporting by wireless communication network as media for data transformation. In this respect, the wireless sensor netwrok is a new paradigm for enviromental monitoring systems [2]. Moreover, the wireless sensor network is effectively implemented for environmental monitoring systems with real-time applications [3].

The renewable energy sources are the main consideration globally for power plants in future to reduce the polluted gas emission. However, this kind of systems are not yet so popular in Indonesia for some reasons, for example high cost generation system and less flexible for the emergency power applications where the instant supply of power generation systems is urgently needed. Therefore, the diesel power plant tends to be the best options for electrical supply. The plant systems use liquid oil as fuel source then converted to gas after burning process resulting in high compressed air to rotate the shaft of the turbine and producing electricity. The main advantage of diesel power plant is able to be installed in any locations for main and back-up electrical sources closed to the supply target. Consequently, the diesel power plant may be potential to emit gas pollution, such as Carbon Monoxide (CO), Sulfur Dioxide (SO_2), Nitrogen Oxide (NO_x) and dust contains heavy metal particles [4]. It is well-known that such gas pollution may cause acid rain, global warming, diseases related to human respiratory and chemical poison to the living things.

Due to the importance of diesel power plant in our region, therefore the tasks of environmental observation, data logging, measurement both verbally and visually according to the specific procedure standard should be fulfiled. The main target is the environmental components with one or more indicator parameters performed with good planning, schedulling and controlling in certain periods. Several method and design to have more sophisticated tools to control the gas emission from fossil-fuel based power plant. For instance, continuous emission monitoring systems (CEMS) for the gas power plant by installing laser-type gas analyzer is developed for the purpose of automatic exhausted gas emission monitoring level [5]. However, CEMS technology is only to be applicable for the plant size of more than 50 MW due to the cost of CEMS installation is more expensive than the cost of diesel engine itself. There is another conventional technology, called AVL emission Tester Series 4000 for gas emission tester of vehicles. However, the procedure of measurement is inconvenience because the sensor and other deviced must be deep embedded inside the chimney or gas exhaust system. Also to have high accuracy measurement, additional devices must be accompanied to this techonology make it the operational cost getting more expensive.

For these reasons, our research group attempts to develop and design real-time gas emission tester for diesel power plant applications with low cost provision, easy operational procedure and maintenance. Real-time data can be obtained using sensor network technology, while the the low cost device can be achieved by utilizing local and easy-found on market components. The designed device is very useful for the gas emission management from the power plant by controlling the polluted gas emission below the standar regulation level. In addition, the device is portable and has small dimension to allow the users to carry, operate and maintain in any locations for environmental gas measurement. In this research, the performance integration between several types of gas sensor, microcontroller and computer network is

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proceeded; therefore preparation, design and test implementation is fully conducted. More detailed of our proposed design configuration is explained as follows.

II. Configuration of Proposed Design

Technology development in electronic devices supported by communication and information protocol has led the world to the cheaper, more accurate and wider-range performance sensor devices. Nowadays, the sensor is very small in size, light-weight and of course low cost. Thanks to the rigorous development in design, material and concept of sensor technology which has high potential prospect in future and opened to the unlimited applications concept [6].

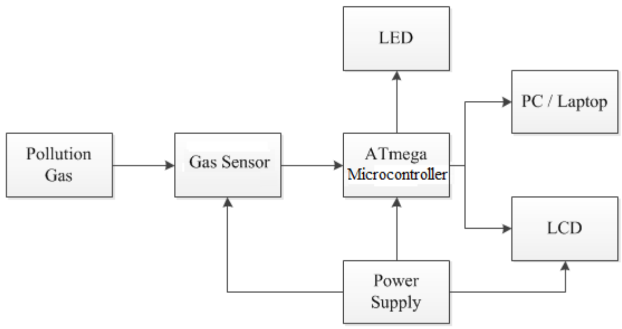

Fig.1. Configuration of proposed design of gas emission monitoring systems

Nevertheless, the sensor utilization for the monitoring and control of the gas emission from diesel power plant is rarely found. In our design of gas monitoring system, several gas sensors, such as sensor of KE for O_2 gas, MQ136 for SO_2 gas, TGS 2201 for NO_x gas, MQ7 for CO gas, MQ2 for smoke opacity including Modul DT-Sense SHT 11 sensor for temperature and humidity are utilized. The configuration of proposed design system is shown in Fig. 1. In this figure, all sensors produce analog output voltage; therefore the analog data is converted to 8 bit digital data for the further processing and controlling in the ADC pin of ATmega16 microcontroller. The real-time measurement results can be monitored through visualization in Liquid Crystal Display (LCD) and computer monitor after data processing using microcontroller ATmega16 under programming environment of CodeVision AVR V2.03.4. The visualization itself is designed based on the combination between programming language of Microsoft Visual Basic ver. 6.0 and Borland C++ [7], [8]. In fact, there are three possible output visualization available, either using LCD, PC/laptop or just LED indicator depending to the type and how the gas emission data are observed.

A. Sensor Utilization

In this section, the profile of the sensor utilization is explained as follows. The GS sensor is the sensor to detect the level of oxigen gas surrounded the diesel power plant area. The newest type of this sensors are KE25 and KE50 with the feature of stable output signal, normal temperature operation, not affected by other gaseous and no external power supply needed. The structure configuration of the oxigen sensor is shown in Fig. 2. The basic working principle is the combination of Pb-O cell and cathode using specific electrolyte to measure the oxigen gas concentration. The measured voltage signal at resistor and thermistor for temperature compensation indicates the oxigen concentration.

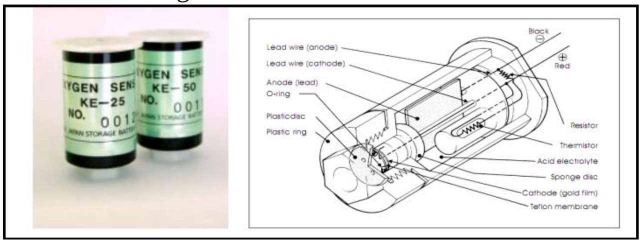

Fig.2. The structure of sensor KE25 / KE50

Meanwhile to measures the SO_2 concentration, typical sensitive semiconductor which has low conductivity in the clean air environment is used. If the SO_2 gas is detected, the conductivity of sensor increases as the gas concentration is high. The sensor name is MQ136 which has also capability to detect smoke contains sulfur. Figure 3 explains the characteristics of the sensor based on the resistance ratio changes (R_s/R_o) as the changes in SO_2 gas concentration. In this figure, R_s is the gas resistance value, while R_o is the resistance of the sensor at 50 ppm SO_2.

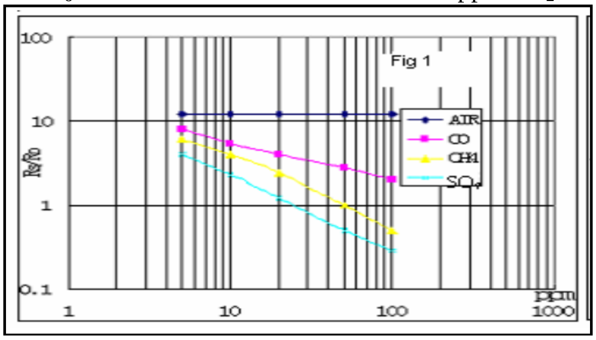

Fig.3. Sensitiviy sensor characteristic of MQ136

On the other hand, TGS 2201 sensor is functioned to detect gas released form diesel oil burning process which dominantly contains gasseous of NO_x, CO and H_2. The sensitivity sensor characteristic to the NO_x gas can be seen in Fig. 4. The working principal of this sensor is the necessity of two input voltages, i.e heater voltage (V_h) and circuit voltage (V_c). The heater voltage (V_h) is used to integrate the heater in order to maintain the sensor element temperature at specific temperature for optimal sensor performance. Meanwhile, V_c is used to refer the output voltage which the value is equivalent to the detected NO_x gas concentration.

The other sensor is MQ7 sensor which has high sensitivity to the CO gas. The MQ7 sensor is the semiconductor gas sensor with layer sensitivity combined with heater. The remained one is the MQ2 sensor which has capability to detect the smoke opacity in the air. The characteristic of this sensor is basically similar to the MQ7 sensor, except the chemoresistor principal that affects to the conductivity process of the sensor. The sensitivity of sensor characteristic of MQ2 is shown in Fig. 5.

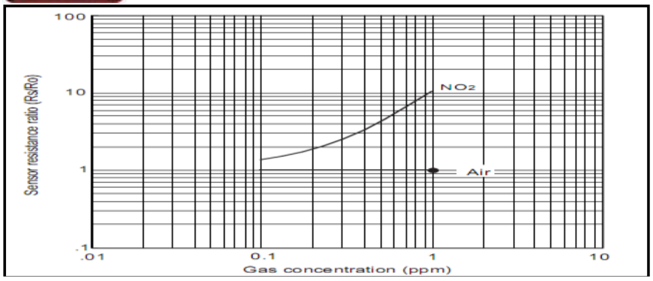

Fig.4. The sensitivity sensor characteristics of TGS 2201

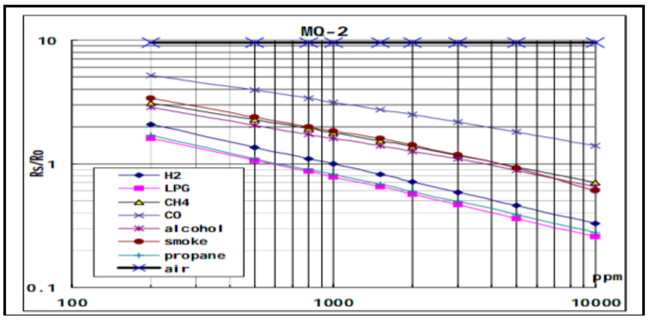

Fig.5. The sensitivity of sensor characteristics of MQ2

The remained type of sensor utilised in this research is the Modul DT-Sense SHT 11. This sensor functions to detect the temperature and humidity surrounded the plant based on the performance of sensirion SHT 11 and two wire serial interface. The technical specification of this sensor provided as follows: temperature range operation is from 40°C to 123.8°C with temperature accuracy measurement of +/- 0.5°C at 25°C; humidity range operation is from 0 to 100% with accuracy absolutet +/- 3.5%; built-up with 8 pin DIP-0.6" with low power consumption (about 30μW) and supply voltage of +5V DC.

B. Hardware Design

The hardware design is divided into physical and electronic circuit designs. The material for physical design based on Aluminum plate to cover the designed electronic circuit. The physical design of gas emission tester for diesel power plant in three dimensional views is shown in Fig. 6.

In the electronic design as shown in Fig. 7, several electronic components are utilized as follows:

- The gaseous sensor for air quality control with the main target of gas emission are Nitrogen Oxide (NO_x), Sulfur Dioxide (SO_2), Carbon Monoxide (CO), Oxigen (O_2), temperature and humidity. The sensor types have been explained in the previous section.
- Microcontroller ATmega16 functions as processing and control units.
- LCD with 16x2 characters for output display of measurement.
- Light Emittig Diode (LED) for level indicator of measured air quality.
- IC MAX 232 and RS232 connector for the computer communication interface.

Fig.6. Physical design of gas emisson tester

Microcontroller Atmega16 has complete facility, fast instruction process and it is supported by Code Vision AVR Evaluation software for simulation and compiler. In addition, it has special feature, especially the facility of Analog to Digital converter. This feature is very important to convert the analog to digital voltage signals since the sensor output is the analog signal, while this signal needs to be processed as digital signal in the microcontroller. The microcontroller circuit is designed to control the overall system design. To activate the microcontroller of ATmega16, the power source with dc voltage of ±5 Volt is required. The clock source of microcontroller is obtained from the connection of crystal oscillator between XTAL1 (pin 13) and XTAL2 (pin 12), then grounded through a capacitor. The frequency of crystal oscillator in this work is 12 MHz with capasitor value of 20 pF. The group of pin A, (PA0-PA7) functions as the input signal to the analog digital converter (ADC) from the sensor circuits. The other pins, such as pin C0 (PC0) to C7 (PC7), except PC3 are used to the output of Liquid Crystal Display (LCD). Meanwhile, pin PB5 (MOSI) to PB7 (SCK) and Reset pin are formed to the downloader connection. In addition DB 9 conector is utilized as the serial communication interface.

The liquid crystal display (LCD) is used as the display device in our proposed air pollution monitoring system. One of common LCD type used is the type of Topway LCD LMB162A. This module is designed with matrix of liquid crystal with the internal controller. The controller has special ROM/RAM as generator character and RAM for display data. All display functions are controlled by set of instructions. The LMB162A is the module of LCD Matrix with configuration of 16 characters and 2 rows. Each character is formed by pixels of 8 rows and 5 columns, while the last pixel with 1 row is the cursor indicator. One of the advantages of using LCD is the simplicity of interfacing circuit where unnecessary to have complicated supported components. Only one resistor is needed to provide contrast voltage to the LCD matrix. In this work, the LCD will give us the indicator value about the air quality in μg/m^3. The type of LCD is Topway LMB162A.

It is well-known that serial communication interface circuit is the communication gate between the microcontroller and the personal computer. The IC serial RS 232 is used as the interface from PC to the external device, or viceversa. There are two type of serial data

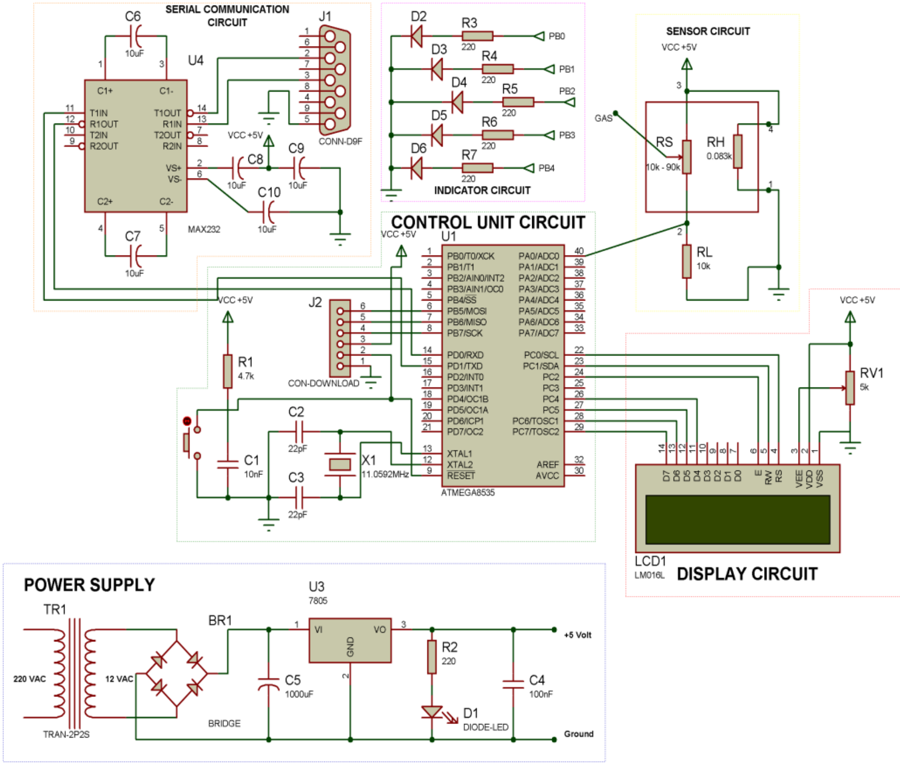

Fig.7. Electronic circuit for electronic design

communications; synchronous and asynchronous types. In the synchronous type, the clock and data communication are sent together. Meanwhile in the asynchronous type, the data and the clock are generated independently both at sending and receiving ends. The IC Serial RS 232 needs connector to the external devices. In this part, there are two type standard of connectors; RS 232 with 25 pin (DB25 connector) dan 9 pin (DB9 connector). In this work, the standard serial communication UART with 1 start-bit, 8 data-bit and 1 stop-bit is used. The required baudrate is 9600 bps as the sufficient baudrate of computer. In this serial interface, the IC MAX232 is needed to convert the digital voltage of serial interface voltage output from the standard voltage 0.5 V to ±15 V in order to maintain the compatibility with serial Port standard of computer. Meanwhile, the RXD points are the points where the circuit receives serial data, while TXD functions to transmit the serial data came from microcontroller.

C. Software Design

The software design is focused on the microcontroller program based on the flowchart shown in Fig. 8. The first step is the initialization stage by setting the USART, LCD, ADC and PORT D from the electronic circuits. Then, the process continues to PORT D processing where the data processing of ADC value considered as sensor unit output. In this step, the ADC value is converted to the part per million (ppm) unit. The output value is displayed in LCD and computer in order to determine the air quality. The indicator of air quality can be accesed through LED after further processing data from the computer unit. The process continues to the initial point by reading the value from PORT D.

III. Real-Time Simulation Results

Several testing have been performed before the real-time simulation for the designed gas emission tester is validated. The testing is for power supply circuit, sensor network measurement, control unit circuit measurement and calibration of device. In the power supply measurement, the output voltage of adaptor should be in the range of 3-12 V_{DC} in order to supply the main circuit that needs 5 V_{DC}. The output voltage of 7805 regulator type is under normal condition. If the tester device is used in the location where the electricity is not available, then the adaptor may be replaced with the battery with 12 V_{DC} output.

Continuing the test at sensor network; the two types of measurements at input voltage and the heater voltage have shown normal condition identified at measuremnet points. According to the measurement results, the sensor voltages are still in the range specified on the datasheet. Meanwhile, the voltage measurement at each pinout of control unit (microcontroller) indicates all the pinout voltages are in the normal level.

It is very important to have the calibration of device for all targeted gas emission to convince the validity of measurement results in real-time. In Table 1, the calibration results yield the normal response of device to the gaseous of NO_x, SO_2, O_2, temperature dan humidity, indicated by small deviation from the conventional measurement devices**.**

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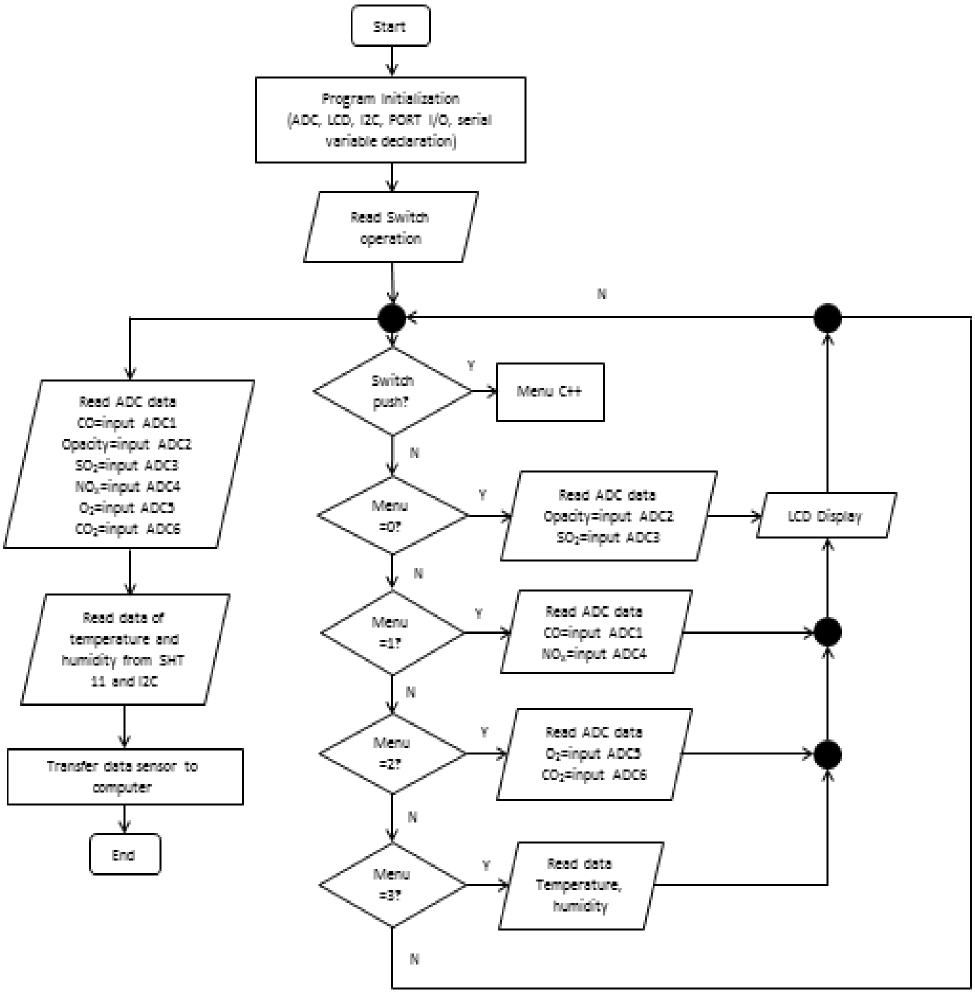

Fig.8. The software design is focused on the microcontroller program based on the flowchart

Table 1. Calibration results of the proposed design

Targets measurements	Conventional tester (ppm)	Proposed design (ppm)	deviation (ppm)
NO_x	35.3	35.4	0.1
SO_2	36.2	36.3	0.1
O_2	37.4	37.4	0.0
temperature	38.1	38.0	0.1
humidity	39.5	39.5	0.0

The display in the computer PC based on real-time measurement is shown Fig. 9. The one-day full measurement of gas emission tester was performed on January 1, 2013 in the diesel power plant belongs to our university. The measurement results shown the level of air quality surrounded the plant indicated by level of gas emission of CO, SO_2, CO_2 and NO_x can be presented online through the PC connected the measurement device.
Our proposed design is basically very useful not only for monitoring the air quality closed to the plant, but it can be used for wide-range environmental monitoring applications. More detailed on-line system can be accessed later at http://222.124.222.154/login.

IV. Conclusions

Design of real-time gas emission tester for diesel power plant applications has been presented. In this paper, several utilized gas sensors which produce analog output voltage. For further data processing and control in the ADC pin of ATmega16 microcontroller, then the analog data is converted to 8 bit digital data. The real-time measurement results can be monitor through visualization in Liquid Crystal Display (LCD) and computer monitor after data processing using microcontroller ATmega16 under programming environment of CodeVision AVR V2.03.4. The visualization itself is designed based on the combination between programming language of Microsoft Visual Basic ver. 6.0 and Borland C++. The experimental results show that the proposed design is working properly. The information related to the emitted gas from plant chimney can be collected, stored in real-time and accessed online through web based interface systems.

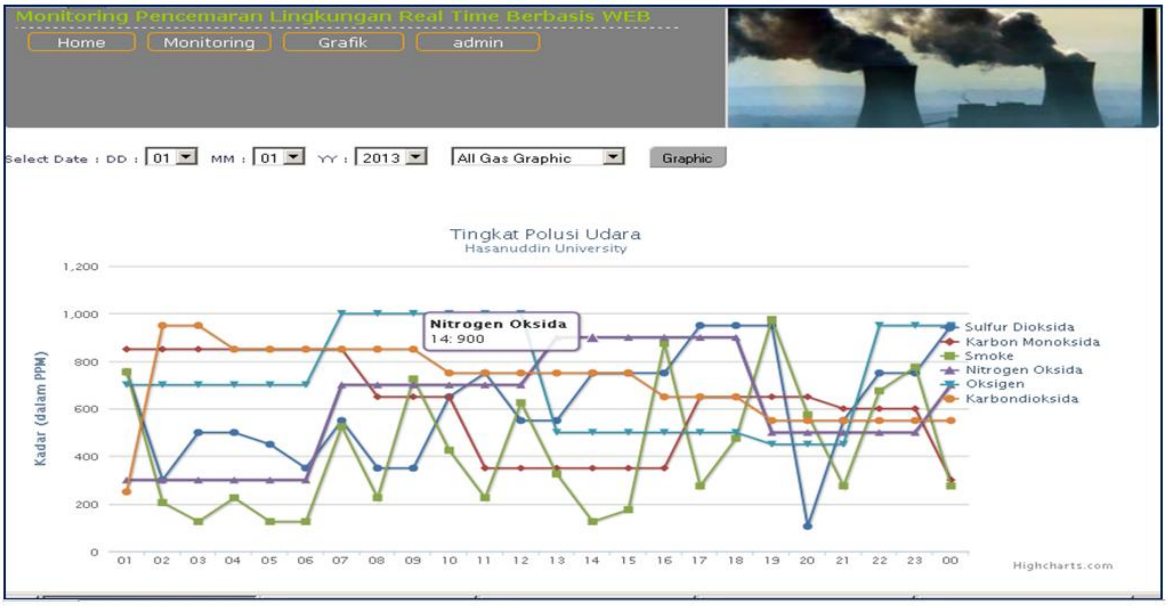

Fig.9. Real-time measurement results

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