IoT Technology Monitoring, Controlling and Data Logging for ATS on Grid Connected Solar-Wind Hybrid System

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Abstract. Global warming and climate change have been world issue in decades, renewable and green energy technology came as the solutions to overcome it. Renewable energy surely gives many benefits, but one of the disadvantages is harvesting these energy are so depending on climate, weather, seasons and time, therefore hybrid system is one of the solutions of combining these energy to a single system. ATS-Automatic Transfer Switch enclosure can be applied for hybrid photovoltaic (PV) and wind turbine, placing grid ac power and generator set as backup or emergency purposes only. The priority is to use renewable energy as the main power source. Automatic sequential can be programmed into microcontroller for supervision, monitoring and data logging of ATS system by using IoT (Internet Of Things) Technology through GPRS GSM internet gateway. These operations can be performed both locally and remotely using IoT technology for historical analysis of data stored in cloud server.

Keywords—ATS; Hybrid PV-wind turbine; IoT Monitoring, GPRS GSM internet gateway;

1. Introduction
In the spirit of “go green” campaign and in the overcoming global warming and decreasing the danger of carbon monoxide footprints, implementing renewable energy as a solution to this problem gives substantial benefits in many aspects [1], solar energy and wind turbine are very important renewable energy nowadays. They are installed worldwide both on rooftop and desert [2,3]. The hybrid system need to be controlled by microcontroller for ensuring efficient power delivery using smart automatic transfer switch (ATS). IoT technology is applied on this system using web base interface for automation of controlling the power transfer switching remotely as well as monitoring, data logging and analysing [4]. This IoT application protocol interface is “open-source” and now commonly used among engineers.

Implementation and installation of an ATS panel with automatic priority selection capability programmed into the microcontroller by using lowest cost and affordable materials available in common market needs to be exercised.

This kind of ATS arrangement could be a new paradigm of implementing clear and clean energy as priority instead of grid or internal combustion generator energy, The metering enclosure is utilized as portable device for controlling any future renewable energy that can deliver ac or dc voltage.
Internet of Things (IoT) has been widely applied over the past few years [5]. The technology itself gives user a freedom to a free or paid term for the use of the internet cloud memory. IoT is physical things talking to each other which are connected to wired and wireless networks [6] through application programming interface (API). IoT is used not only for the field of consumer electronics and appliances but also in other various fields such as a smart city, healthcare, smart home, smart car, smart grid system, and many other industrial applications [7]. As more and more rooftop hybrid photovoltaic-wind turbine systems are getting integrated into the existing grid, there is a growing need for monitoring [8] of real time power generation to optimize the overall performance and to maintain the grid and output power stability [9].

As part of its research plan development, the European Commission (EC) has well-defined IoT as a cohesive part of the Future Internet (FI) where “things having identities and virtual personalities operating in smart spaces using intelligent interfaces to connect and communicate within social, environmental, and user contexts” [10][11]. Therefore once a system is completely tested, running and uploaded to the IoT cloud, it is become a source of analysis data [12].

2. Methodology of IoT Based System for ATS on Grid Hybrid Solar-Wind System

The conceptual of the system is to control a various power sources from any renewable energy and grid connected power sources and making automatic selection of the power sources in accordance with the priority or sequences coding into microcontroller by using IoT technology based network [13].

The information from the sensors both ac and dc power is converted by analog to digital converter (ADC) using serial communication interface (SCI) [14] then transmitted via the mobile radio network gateway. A GPRS GSM module is used to send data and communicate with remote cloud server. Using user friendly and easily set up Graphical User Interfaces (GUI). The system is then monitored, controlled and data logged for future or instant analysis.

2.1 System Architecture

The project basic system wiring is shown on Figure 1 showing the basic power transfer switching for the integrated hybrid system for this project.

![Figure 1. ATS configuration and integrated hybrid power energy system](image)

The basic design of the system can accommodate 5 input power sources to a single system through dc and ac bus, all dc power sources are routed to dc bus. Solar power unit, wind turbine and lead acid battery which has dual functions as power storage or bank and dc power source are connected to dc bus. 2 ac power sources could be supplied from grid and a standby internal combustion engine generator are connected to ac bus [15]. The switching operation as well as power transfer and metering of the power inputs are performed by the microcontroller installed inside the ATS enclosure. The microcontroller uses GPRS GSM SIM800L Module as modem for data and commands to be uploaded to IoT website or cloud server through internet gateway.
2.2 Logic Diagram

The logic diagram programmed into the microcontroller is shown in Figure 3, both SPU and wind turbine output which are expected to be 12 Vdc are pull down using PWM charge controller to dc bus, the “or” gate showing any or both can be parallel to feed the dc bus.

AC voltage source from grid and generator are fed to ac bus as backup power source in the event of the non existence of dc power source to feed the battery as the power storage. This configuration is commonly called automatic power transfer switch or ATS for uninterruptable power supply (UPS).

![Image of logic diagram](image)

**Figure 2.** Logic diagram for uninterruptable power output system

The whole systems then compiled and designed in the wiring of the microcontroller as shown in Figure 4 which can be summarized in project implementation flowchart shown in Figure 3. The activities start with understanding equipments or system to be controlled, then logic diagram and sequential priority of the equipments must be set before wiring can be performed on the panel or enclosure. The next phase is procurement process, purchasing and collecting items to built for the microcontroller, sensors, input/output board and type of LCD for the monitoring and status of the system or network. The next step is fabrication the microcontroller as shown on Figure 4, then microcontroller is programmed per logics and sequences as well as MQTT is written for upload and remote IoT system, if this phase does not work then logics and sequences must be reobserved.

If IoT works, then The data collecting and testing considered finish, otherwise c language program need to be rechecked and modified accordingly.

![Image of flowchart](image)

**Figure 3.** Project implementation flowchart

Figure 4 shows pin to pin and point to point of components used for the complete set of the microcontroller. The printed circuit board (PCB) then designed and fabricated, once this activity is completed, dc power supply can be inserted to its port or terminal, followed by interface cable connection and checking microcontroller card connection to PC. All assigned pins, points, programs, logics, sequences, priority and network assignment can be written and downloaded to microcontroller ATMega328P as the central processing unit of the microcontroller.
Figure 4. Complete microcontroller wiring diagram

2.3 System Components
System components are composed from several things or components or equipments connected together to perform an operation of giving an uninterruptable power source to a system:
2.3.1 Solar Power Unit (SPU). The solar power unit consists of 4 units custom made mono crystalline (mono si) with the capacity output 250 Wp arranged in parallel connection for more current supply to output source. The calculation of maximum power point of PV is given by equation:

\[
F_1 = \frac{V_{MPP}}{(V_{OC-STC} \times N_P)}
\]

\[
F_2 = \frac{I_{MPP}}{(I_{SC-STC} \times N_S)}
\]

\[
F_3 = \frac{G_i}{1000}
\]

\[
F_4 = \frac{T_i}{1000}
\]

where \(V_{MPP}\) is the maximum power point (MPP) voltage, \(I_{MPP}\) is the MPP current, \(V_{OC-STC}\) and \(I_{SC-STC}\) is the open-circuit voltage and short-circuit current of PV array under standard test condition (STC), respectively; \(N_P\) is the number of string in parallel of PV array, \(N_S\) is the number of module in serial of each string. \(G_i\) is the irradiance of PV array, \(T_i\) is the temperature of PV array. Hence, the four attributes are \(F_1, F_2, F_3\) and \(F_4\).

Mono crystalline solar cells are made out of silicon ingots, which are cylindrical in shape. To optimize performance and lower costs of a single mono crystalline solar cell production, four sides are cut out of the cylindrical ingots to make silicon wafers [16].

- The advantages of using this SPU are Mono crystalline solar panels have the highest efficiency rates since they are made out of the highest-grade silicon and the efficiency rates of mono crystalline solar panels are typically 15-20% or 15-20% photon flux incident on the cell or sun light energy that can be converted into via photo voltaics into electricity. Mono crystalline silicon solar panels are space-efficient and produce up to four times the amount of electricity as thin-film solar panels. It has the longest life time among other type of solar panels. It is estimated 25 years factory warranty [17].

- The disadvantages of mono crystalline solar panel are the most expensive from a financial standpoints and mono crystalline solar panels tend to be more efficient in warm weather rather than in cold weather [18].

2.3.2 Inverter. An inverter is used to convert the dc power source mostly 12 Vdc battery (preferably deep-cycle or several batteries wired in parallel to ac power output 220 Vac sine wave with frequency of 50/60Hz. Consequently, the battery then will need to be recharged by running the automobile or a gas generator charger, solar panels, or wind turbine generator. There are two type of common inverters, singe and pure sine waver type. Pure sine wave inverter has very low harmonic distortion and clean power like utility-supplied electricity able to handle inductive loads like microwave ovens and motors. running faster, quieter, cooler, and reduced of audible and electrical noise.

2.3.3 Power storage battery. There are 2 types of affordable and low cost rechargeable battery can be used for inverter dc power inputs. The different of automotive and deep cycle battery is the charging time, the deep cycle battery life is longer than automotive battery therefore it takes longer time to have external power to recharge it. Other alternatives is lithium and titanium dioxide rechargeable battery which is estimated to be 20 years in life time can also be applied but it is still very high in market price.

2.3.4 Charge Controller. There are 2 types of battery charge controller commonly found in the market:

a. Pulse width modulation (PWM) charge controller
b. Maximum power point tracking (MPPT) charge controller

PWM charge controller is a low cost solution for small system while MPPT has more features for charging purposes allowing SPU operate at their optimum power output voltage by improving up to
30% of their performance. This improvement is done by dropping the charging voltage to battery voltage it causes the increase of current flowing into the battery. PWM charge controller is best used in the moderate temperature between 45°C to 75°C and functionally used to pull down the voltage of PV arrays to battery.

2.3.5 ATS enclosure. PVC enclosure with international standard Ingress Protection (IP) 66 which is dust-proof and water resistance is selected to accommodate automatic transfer switch (ATS) components such as miniature circuit breaker (MCB), analog timer relay, contactor and terminal blocks, as well as the microcontroller and the sensors as shown on Figure 5 and 6. The normally open and close contact of LC1D09M07 contactor are connected to LED lamps indication for ac and dc power input source of the inverter.

![Figure 5. Analog Operation ATS wiring diagram](image)

3. Overall System Design and Data
The main reason for the implementation of this system design is the cost effectiveness and the materials are easy to provide, user friendly and easy to assemble. The components are:

- a. 2 units - ZMPT101B single phase ac voltage current sensor module
- b. 2 units - DC voltage and current module max 50V, 20A dc
- c. 1 unit - 4 relay module
- d. 1 unit - 20 x 4 Sainsmart IIC/12C/TWi Serial 2004 LCD Module shield
- e. 1 Unit - Custom made microcontroller unit using ATMega328P microcontroller
- f. 1 Unit - Sim800l GPRS GSM module

The open source C language software coding are embedded into the microcontroller by using 4 pin serial to USB interface cable. The main part of the controller part is the microcontroller ATMega328P which handle all the logical input-output, processing unit as well as establishing wireless network gateway through internet using sim800l GPRS module, so that the whole system can be monitored and controlled remotely using any portable devices such as computer, handphone or any tablet devices.

Figure 6 shows all those affordable components, the system is very cost efficient and easy to find in the market but it gives a good performance as ATS, metering, controlling and networking.

![Figure 6. Microcontroller main components and enclosure](image)

The LCD 20 x 4 Sainsmart IIC/12C/TWi Serial 2004 module shield means the LCD is a 4 rows and 20 characters can be displayed in every row.
Due to unclear screenshot of Figure 7, LCD display shows date, time, power inputs and IoT network status. The c language program coding is kept in ats-v3-03042018.ino file. This program is usually used for arduino or Raspberry Pi microcontroller.

As shown on Figure 8, the program is not only embedded to microcontroller ATMega328P but also to IoT website (adafruit.com), this feature can be applied by using sim800l GPRS GSM module which enable the system to communicate with IoT website through its internet gateway. The username and password stored and embedded in c language into the microcontroller will be used once the program is up and running in the IoT server, all data measured by sensors and output activation are then stored in IoT cloud server for historical data logging for analysis purposes.
Figure 9. IoT dashboard and feeds control and monitoring screen and historical graph data logger

The standalone IoT based web hosting running on the target PC or any portable devices enabling the user to monitor the live real time data from anywhere in the world. Log data file on Figure 9 can be accessed and analyzed and gives many information to user about the condition of local sun light condition, clouding, shading SPU cleanliness, power and energy brought down to battery from time to time. The graph itself represents the true value and condition when the system is in operation and it is very easy to be interpreted.

Message queue telemetry transport application protocol interface (MQTT API) is a protocol for device communication that IoT web page. There are 4 important strings to be typed for this purpose, webpage host, port, username and password. The benefit of using IoT is for ELM as the contribution of the development of artificial intelligent (AI), integrate things in minimizing human efforts using various of microcontrollers. Other benefits is the virtualization using user friendly GUI and API, high Speed and messaging is bi-directional connection between things and cloud server, and this cloud server could be the source of endpoint identity, metadata lifecycle states of all devices.

4. Future Work

Another affordable systems can added to give a better performance for future work to this system are:
   a. Installation of MPPT charge controller
   b. Installation of soft starter for 220Vac Output with cut-off relay and capacitor bank
   c. Convenient Portable cart for the panel, inverter and battery
   d. Portable Pneumatic or hydraulic solar panel frame installation with solar tracking

5. Conclusion

IoT Technology enables us to control, monitor and analyze the commands, measurement data from sensors for historical data research in portable, remote and real time mode using any devices with internet connection. The training process of extreme learning machine (ELM) of a microcontroller is fast and simple, and the parameter selection is easy. Web console base can reduce time and improve energy efficiency.
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