Iot Sourced Real Time PV, Wind And Fuel Cell Models For Micro And Nano Grids

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Abstract: Integration of Renewable energy in Grid is increasing enormously. The main Grid comprises of multiple Micro Grids and numerous Nano Grids. Micro Grid is a localized Grid that can disconnect from the Main Grid to operate autonomously when the Main Grid fails. Nano Grids consists of small Micro Grids which supplies power to single building or a small area. In order to pre-determine the electrical system parameters in the Nano and Micro Grids, the mathematical model of proposed RE sources (Photovoltaic PV, Wind, Fuel cell) are developed and analyzed through real time data. The IOT based cloud is to be used to acquire real time data from various locations. The designed mathematical model is to be simulated by suitable software package and experimentally evaluated through the recent embedded TEXAS INSTRMENTS LAUNCH PAD's (MSP432E401Y, CC3220SF), Arduino Due and (Raspberry pi) hardware. The both simulated and emulated outputs are compared and equated in real time.

Index Term: Solar PV, Wind Energy, Fuel Cell, Micro grid, Nano Grid, IoT.

1 INTRODUCTION

Integration of Renewable energy in Grid is increasing enormously [1-2]. The main Grid comprises of multiple Micro Grids and numerous Nano Grids. Micro Grid is a localized Grid that can disconnect from the Main Grid to operate autonomously when the Main Grid fails. Nano Grids consists of small Micro Grids which supplies power to single building or a small area. In order to pre-determine the electrical system parameters in the Nano and Micro Grids, the mathematical model of proposed RE sources (Photovoltaic PV, Wind, Fuel cell) are developed and analyzed through real time data [3-6]. The IOT based cloud is to be used to acquire real time data from various locations. The designed mathematical model is to be simulated by suitable software package and experimentally evaluated through the recent embedded TEXAS INSTRMENTS LAUNCH PAD's (MSP432E401Y, CC3220SF), Arduino Due and (Raspberry pi) hardware. The both simulated and emulated outputs are compared and equated in real time [14-25]. In this paper, internet of things has been integrated with renewable energy resources such as solar PV, wind energy and fuel cell. IoT used to monitor the parameters of the renewable energy sources for monitoring and controlling in micro and nano grid system. The rest of paper as follows, abbreviation used in this paper is described in the next section. Section 3 provides the details of the literature survey. Methodology and materials used is explained in the section 4. Simulation model of IoT and renewable system is described in the section 5. Experimental of the real time system is PROVIDED IN THE SECTION 6. CONCLUDING REMARKS IS GIVEN IN THE SECTION 7.

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2 ABBREVIATION

IOT	Internet Of Things
PV	Photovoltaic
TI	Texas Instruments
GPIO	General Purpose Input Output
SEIG	Self-Excited Induction Generator
DAC	Digital To Analog Converter
ADC	Analog To Digital Converter
I2C	Inter Integrated Circuit
SPI	Serial Peripheral Interface
DNL	Differential Nonlinearity
INL	Integral Nonlinearity
HMI	Human Machine Interface
SOC	System on Chip
DSO	Digital Storage Oscilloscope
MPPT	Maximum Power Point Tracking
EPROM	Erasable Programmable Read Only Memory
HTTP	HyperText Transfer Protocol

3 PREVIOUS WORKS

As the world population increases the need of energy also gets increased the demand changes with respect to the usage of technology, population and other geo-political factors. Most of the energy demand is met by the energy produce by conventional energy sources but it is associated with the problem of pollution as well as in some cases there is a demand for cooling the machineries used. Comparing the disadvantage of conventional energy sources with the renewable sources, the latter becomes the clear winner. In solar and in wind there comes a need for energy conversion by means of converters. Hybrid Energy System combines many energy sources. To combine those, we need to have a common platform to get the data and to act upon that data so IoT becomes the obvious choice the get data and to act upon it. In IoT all the device is provided with an IP for data

exchange. The exchanged data should be managed in a common platform that is secure enough to protect the data. To pre-determine the electrical parameters in the Nano and Micro Grids, the mathematical model of the Photovoltaic (PV) Array, Wind Turbine, Doubly-Fed Induction generator, Permanent magnet synchronous generator, Self-excited induction generator and Fuel Cell are to be implement in the physical Texas Instruments Launch pad (embedded controlled hardware) and raspberry pi 3 B are hardware used. The entire programming of the above system will be handled by embedded Simulink coder. The proposed real time system will be evaluated through the suitable real hardware and emulated systems. The PV system continues to provide energy to a part of the network even after the process of islanding. This at times becomes hazardous for the people who are maintaining the network [1, 13]. The network is simulated using MATLAB/Simulink environment, algorithm and real-time implementation is done in the same environment. For getting the accurate result as that of the real world model dSPACE 1104 can be used [2]. The effects of interactions between electrical and mechanical components are not accurately taken into account [3] as it will further complicate the simulation processThe micro grid provides opportunities for new entrants in hybrid energy generation space as in hybrid energy generation the need for solar goes high compared to wind also the scope of IoT is also expected to be in uptrend [4]. While integrating solar with the micro grid appropriate interfacing algorithm has to be employed to achieve effective interfacing. Here IoT plays the major role for data collection and in co-ordination. MPPT has also to be used where solar find its position. Appropriate converters to be used based on the demand [5, 6]. The operation of Self Excited IG is not the same of both linear and Non-linear loads, its non-linearity can be successfully compensated with the addition of capacitor bank [7]. The usage of microcontrollers and PLC should be chosen based on the type of application [8].
The data transmitted from different locations through transmission systems of various types met with the problem of different time stamping [9]. While interconnecting various energy sources in the micro grid [11, 12, 26, 27] appropriate synchronizing techniques has to be followed. An advanced PEM fuel cell mathematical model is described and realized in four ancillaries in the MATLAB–Simulink environment [14-25]. To design and develop the hybrid energy system model based on IOT for Micro and Nano grid real time model for analyzing the performance and characteristic based on this analysis, protective and future protection of the system is decided. To develop a program using MATLAB and Raspberry pi 3 B, CC2000, CC3220SF, Arduino Due hardware for fetching data from various place. The figure 1 shows the block diagram of IoT sourced PV, wind and fuel cell models for Micro and Nano grids. The Environmental characteristic data such as temperature, irradiation and wind speed are measured using suitable sensors which is an analog signal. The measured signals are fed into ADC which converts analog signal into digital signal. ADC used in our model is Ic mcp3008 which is a 10-bit data transfer medium. Digital signals are uploaded to Thing speak cloud Platform through TI Launchpad CC3220SF. Data stored in the cloud is downloaded using Raspberry pi 3B and fed TI launch Pad MSP432E401Y. Digital data is now converted back again to analog data using DAC, which is Ic mcp4725 12-bit data transfer medium. Analog data is now fed as input to various proposed models and the corresponding outputs from the models are obtained.

4 MATERIALS AND METHOD

The main components used are:
ADC (MCP3008)
TI Launch pad CC3320SF
Raspberry pi 3b
TI Launch pad MSP432E401Y
DAC (MCP4725)

ADC (Analog to Digital Converter) MCP3008 device is a 10 bit SAR type ADC coupled with a sample and hold circuit. The MCP3008 can be programmed to have 4 different pseudo-differential input pairs i.e., it can be considered as 8 different inputs. SPI protocol provides the provision to communicate with the device by means of serial communication. Up to 200ksps conversion rate is possible with this IC. This particular IC can be operated at voltages levels in between 2.7V & 5.5V.
IoT operation is made possible with the board Launchpad CC320 as it offers on board devices like accelerometer, Wi-Fi and protocols for security. The Raspberry Pi 3 has 40-pin general-purpose input-output (GPIO). The High of GPIO corresponds to 3.3V and LOW of GPIO corresponds 0V. Thus, by analyzing different climatic conditions at different places and accessing the data through common cloud platform. This enhances the proper selection of location for installation of various Renewable Energy (RE) sources and to yield maximum output from the proposed models. The real time data are sourced via IOT based cloud system. The complete process involved in IoT is given in figure 1.

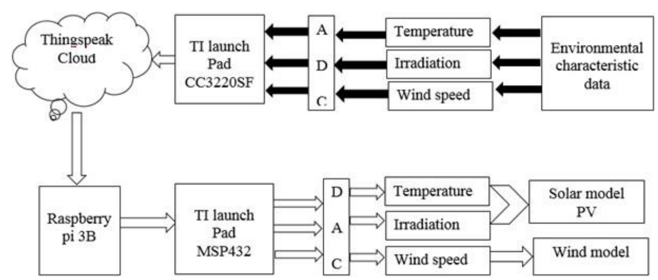


Fig. 1. *IoT based real-time system*

5 SIMULATION MODEL OF PHOTO VOLTAIC (PV), WIND AND FUEL CELL

This chapter deals about the simulation software used to develop the circuit. In this real time weather characteristic data has been uploading for instead result. This chapter describes the Internet of Things (IOT) detailing of each block used in the process. In this summarizes the basic knowledge about the possibilities and limitations in developing the hardware part of the project. There are many simulation software comprising the components of power system, electrical machines, power electronics and embedded systems such as, MATLAB, CODE COMPOSER STUDIO, and ENERGIA etc. Each simulation software has its own advantages and limitations. Considering the requirements of this project, auto code generation option available with MATLAB/SIMULINK is utilized.

5.1 PV with IoT using Thingspeak platform

The figures 2 and 3 are the data send to cloud. ThingSpeak is an open-source Internet of Things (IoT) application and API to store and retrieve data from things using the HTTP protocol over the Internet or via a Local Area Network. ThingSpeak is an IoT analytics platform service that allows you to aggregate, visualize, and analyze live data streams in the cloud. You can send data to ThingSpeak from your devices, create instant visualizations of live data, and send alerts using web service like MATLAB analytics inside ThingSpeak, you can write and execute MATLAB code to perform preprocessing, visualizations, and analyses. IoT platform ThingSpeak have been used for data transmission and to get data, the same data is retrieved and was given as input to the Matlab/Simulink PV model for simulation as depicted in figures 4 and 5. Figure 6 shows the simulated output of the PV model.

TABLE 1

MODEL PARAMETER FOR PV

Parameters	*value*
Maximum Power (W)	*213.15*
Open circuit voltage Voc (V)	*36.3*
Voltage at maximum power point Vmp (V)	*29*
Temperature coefficient of Voc (%/deg.C)	*-0.36099*
Cells per module (Ncell)	*60*
Temperature coefficient of Isc (%/deg.C)	*0.102*
Short-circuit current Isc (A)	*7.84*
Current at maximum power point Imp (A)	*7.35*
Light-generated current IL (A)	*7.8649*
Diode saturation current I0 (A)	*2.925e-10*
Diode ideality factor	*0.98117*
Shunt resistance Rsh (ohms)	*313.3991*
Series resistance Rs (ohms)	*0.39383*

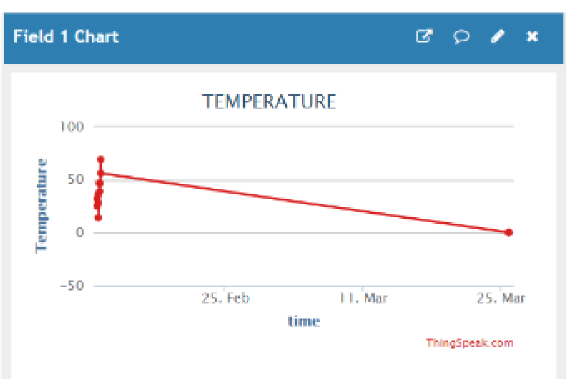


***Fig. 2**. Imported data to the cloud*

***Fig. 3**. Data written on the cloud*

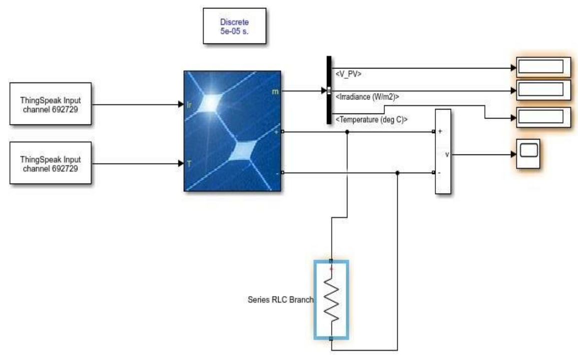


***Fig. 4.** Circuit diagram of PV model with R Load*

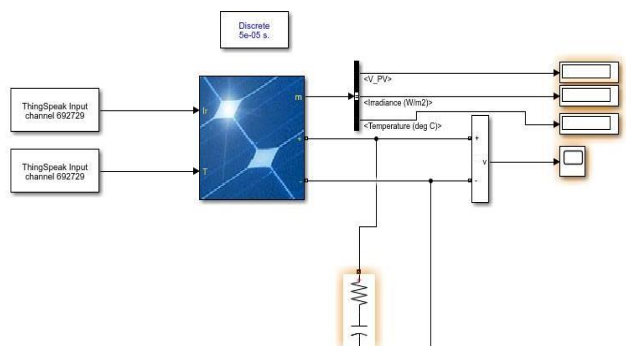
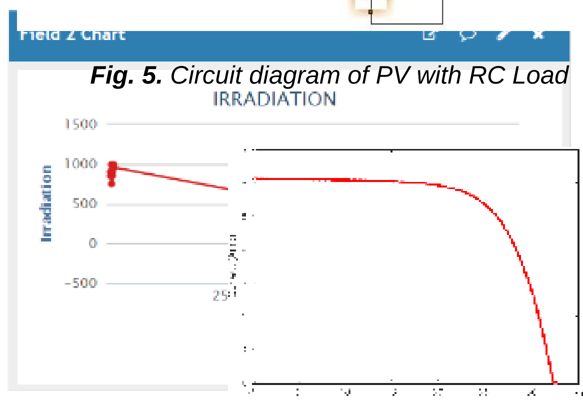


***Fig. 5.** Circuit diagram of PV with RC Load*



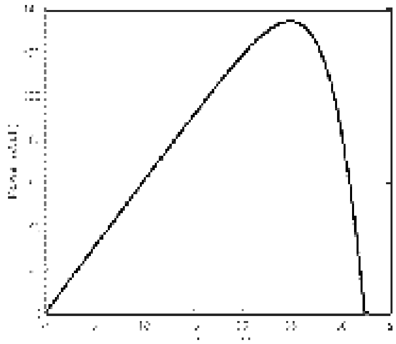


***Fig. 6**. PV output simulation for I-V and power*

TABLE 2

MODEL PARAMETER FOR SEIG

Parameters	value
Nominal mechanical output power (W)	*1.5e6*
Base power of the electrical generator (VA)	*1.5e6/0.9*
Base wind speed (m/s)	*12*
Maximum power at base wind speed (pu)	*0.73*
Base rotational speed (p.u. of base generator speed)	*1.2*
Pitch angle beta to display wind-turbine power characteristics (beta >=0) (deg)	*0*

SEIG (Self-Excited Induction Generator) code

```
clear; T = 30;
Ts = 1e-4;
sim_t = 0:Ts:T;
ln = length(sim_t); f = 60;
w = 2*pi*f; Lm = 0;
Ls = 3.49/w; Lr = Ls;
Rs = 0.696;
Rr = 0.743;
Lsm = Ls; Lrm = Lr; Wg = 385;
P = 4;
Td = 15;
J = 0.2;
Rl = 150; Ll = 50e-3; Vds = 0.5;
Vqs = 0.5; C = 57e-6; Ki = 0.21;
Kv = 0.29;
Kw = J/w;

Ids = zeros(ln,1); Iqs = zeros(ln,1); Idr = zeros(ln,1); Iqr
= zeros(ln,1); Vcd = zeros(ln,1); Vcq = zeros(ln,1); Ild =
zeros(ln,1); Ilq = zeros(ln,1); for k = 2:ln;
m = k-1;

Te = (3/2)*(P/2)*Lm*(Ids(m)*Iqr(m) - Iqs(m)*Idr(m));

Wg = Wg + Kw*Ts*(P/(2*J))*(Td - Te);
G = 1/(Lm^2-Ls*Lr);

Ids(k) = Ids(m) + Ki*Ts*G*(Lr*Rs*Ids(m) -
Wg*Lm^2*Iqs(m) - Lm*Rr*Idr(m) - Wg*Lm*Lr*Iqr(m) +
Lr*Vcd(m) - Lm*Vds);

Iqs(k) = Iqs(m) + Ki*Ts*G*(Wg*Lm^2*Ids(m) +
Lr*Rs*Iqs(m) + Wg*Lm*Lr*Idr(m) - Lm*Rr*Iqr(m) +
Lr*Vcq(m) - Lm*Vqs);

Idr(k) = Idr(m) + Ki*Ts*G*(-Lm*Rs*Ids(m) +
Wg*Lm*Ls*Iqs(m) + Ls*Rs*Idr(m) + Wg*Lr*Ls*Iqr(m) -
Lm*Vcd(m) + Ls*Vds);

Iqr(k) = Iqr(m) + Ki*Ts*G*(-Wg*Lm*Ls*Ids(m) -
Lm*Rs*Iqs(m) - Wg*Lr*Ls*Idr(m) + Ls*Rr*Iqr(m) -
Lm*Vcq(m) + Ls*Vqs);
Vcd(k) = Vcd(m)  + Kv*Ts*(Ids(k)-Ild(m))/(C);

Vcq(k) = Vcq(m) + Kv*Ts*(Iqs(k)-Ilq(m))/(C); Ild(k) =
Ild(m) + Ki*Ts*(Vcd(k)/Ll - Rl/Ll*Ild(m));

Ilq(k) = Ilq(m) + Ki*Ts*(Vcq(k)/Ll - Rl/Ll*Ilq(m)); Im =
sqrt((Ids(k)+Idr(k))^2+(Iqs(k)+Iqr(k))^2);
Lm = 0.205 + 0.0053*Im - 0.0023*Im^2 + 0.0001*Im^3;

% Lm = 1.1*(0.025+0.2974*exp(-0.00271*Im));

Ls = Lm + Lsm; Lr = Lm + Lrm;
end
```

5.2 Simulation of SIEG with code

The simulation is done with the help of MATLAB software. The components required for simulation are taken from Simulink support package. After taking the components they are connected as shown in figure 6. For each component the value is set by double clicking it, as per our requirement

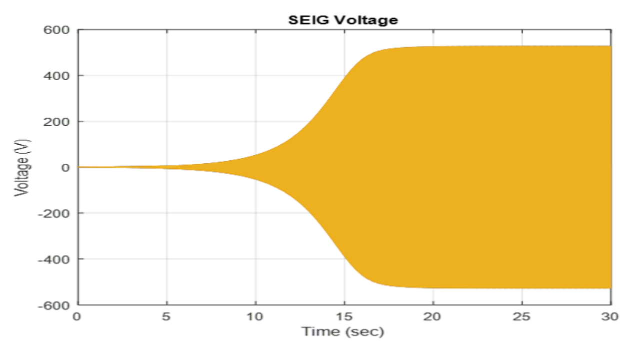


***Fig. 7**. Output voltage of SEIG*

The given input is temperature, irradiation and output are taken across IOT as depicted in figure 7. The simulation for real time weather characteristic data using Internet of Things is performed and analyzed by MATLAB/Simulation software. The simulation output is successfully viewed.

6. HARDWARE DESCRIPTION & OUTPUT

This chapter mainly deals with the modelling of the components that are present in the block diagram into a working miniature model that can be used for real time applications. It gives us the way in which the components are used, interlinked and the rating of the major components. The PV panel and SEIG available with the MATLAB/SIMULINK environment has been utilized fully to produce the real-time data as if the real working model been there at our disposal. The generated data are uploaded to the cloud (in this case the chosen cloud is “Thingspeak”). The real-time data like the temperature, irradiation and wind velocity has been uploaded to the cloud. Then the same is retrieved by using TI’s IoT enabled board for further processing. The PV model is deployed on the Raspberry pi 3B hardware which acts as a master from which data transferred to ARDUINO DUE (slave). Communication between master and slave takes place through I2C bus. According to the variations given on input (i.e.) irradiation the corresponding output is visualized in DSO (Digital Storage Oscilloscope). The slave consists of inbuilt DAC which helps to convert the digital signal to analog signal and which is displayed in the DSO (Digital Storage Oscilloscope).

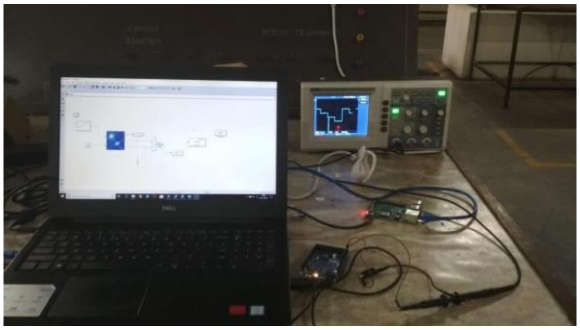


Fig.8. *Real time simulation of PV model*

Fig. 9. *Output waveform of Real-time hardware*

Thus, real time simulation for proposed models are achieved using embedded hardware and are shown in the figure 8 and 9.

7. Conclusion

The combined usage of various energy sources available at the locality will provide an effective solution for future energy demand by way of integrating the sources using micro grid. As the sources and the loads are highly interconnected in a micro grid there is a demand of data communication to the data centre. This can be achieved by the effective usage of IoT concepts, so that the real-time data can be transferred to the general co-ordinating centre time to time. Real-time data will make the co-ordinating centre to decide upon the various possible options available to meet the energy demand of the particular locality. TI boards, Arduino and Raspberry pi have been used to feed and to retrieve data form the cloud.

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