Embedded Data Acquisition Systems for tracking energy consumption from renewable sources

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***Abstract* — Most countries in the world are working hard to make a shift towards the use of renewable energy sources. Renewable energy sources are ideal to narrow the energy gap between demand and availability. Monitoring energy consumption from renewable energy sources will enable effective control of the load. It is important to monitor the energy consumed from the renewable sources in order to balance the demand and the capacity. This paper discusses how embedded Data Acquisition Systems (DAS) can be used to monitor the electrical energy drawn from the renewable source and how to use National Instruments dashboard app to see real-time energy consumption. We will develop a prototype of embedded DAS that monitors energy consumption rate by the domestic appliances and later see it in real-time.**

***Index Terms*: embedded DAS, tracking energy consumption from renewables.**

I. INTRODUCTION

The integration of renewable energy resources such as wind and solar power is usually very challenging because of their intermittency and inter-temporal variations [1]. Most modern digital electronics devices have to do some form of data collection and processing. Data Acquisition Systems have gained more applications in both analog and digital electronics fields [2] [4] [5] [6] [7]. Various authors propose to optimally distribute the workload among geographically dispersed data centers such that people can benefit from the location diversity of different types of available renewable energy resources [1]. Few experts have modelled the inter-temporal variations of the available wind power as a Markov chain based on field data [3]. In this paper we use National Instruments (NI) myRIO to capture progressive energy consumption from the renewable energy source. The simulation results are displayed on LabVIEW. We monitor the electrical energy drawn from the renewable source using embedded DAS and also use National Instruments dashboard app to see real-time energy consumption. The main objective is to develop a prototype of embedded DAS that will record progressive electric energy consumption by domestic appliances which are connected to the renewable energy source.

The sub-objectives are:

- To use onboard LEDs to warn consumers about excessive consumption
- To display real-time power usage on a National Instruments app called data dashboard.

II. EMBEDDED DAS ARCHITECTURE

A. Hardware components

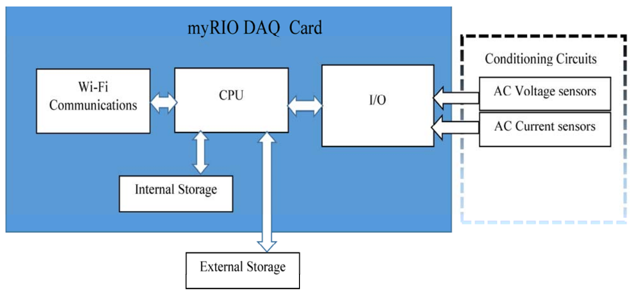

Figure 1. Embedded DAS hardware.

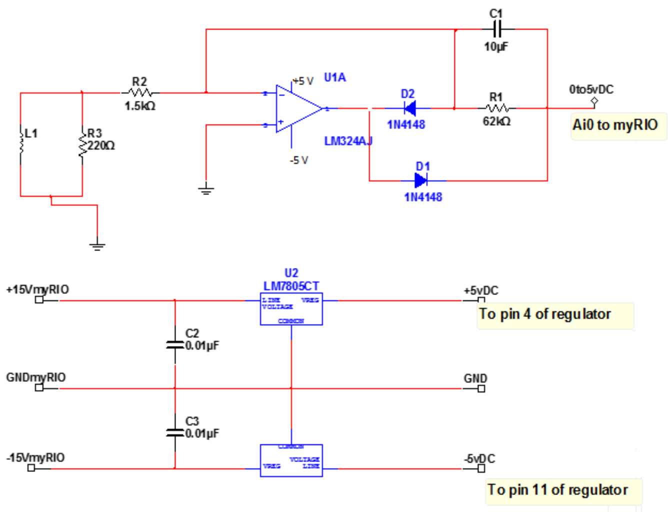

Figure 2: AC current Sensor circuit

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The system in Figure 1 consists of two conditioning circuits. The first conditioning circuit on Figure 2 consists of a current sensor that is used to convert varying current onto maximum voltage of 5 V as required by channel A and B of myRIO DAQ card [11].

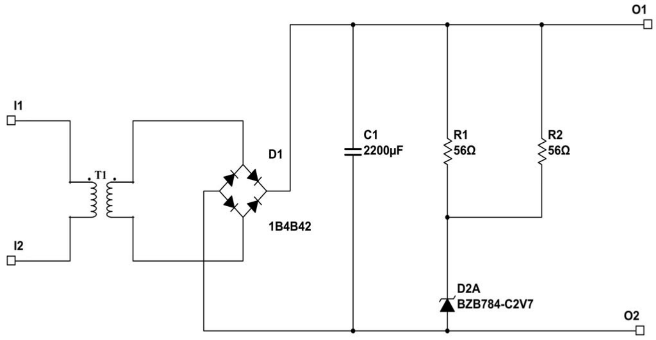

Figure 3: AC Voltage sensing circuit

The second conditioning circuit consists of 6 V and a transformer that step down an AC Voltage of 230 Vrms down to the peak voltage of 8.9 V. In Figure 3, transformer, a bridge rectifier together with the capacitor converts the transformer's secondary AC voltage into a smooth DC voltage.

The Zener diode is used to keep a constant DC voltage of 2.7 V and therefore leaves 5 V across the load resistor where DAS input channel is connected. Any current and voltage variations from the mains will cause the sensors output voltage to vary. The DAS acquires these varying inputs and alters the output power accordingly. Remember that Power = Voltage multiplied by Current.

In figure 1, Input / Output port (I/O) represents input and output channels where the input signal is sampled and digitized by the ADC channels within the DAS. Central processing unit (CPU) controls the operations of DAS and polls channels for any signals in any of the inputs.

In figure 1 the memory stick is used for external storage of Electrical energy that is been recorded by the DAS. Communication is done through myRIO built in WIFI. The user is able connect to the WI-FI network and use his smart phone/ tablet to logon from to myRIO using National instrument dashboard [11] that will enable him / her to view real-time power consumption. Experts have used the NI-myRIO embedded system on LabVIEW platform for implementation of Relay-Based Emergency Communication System [8]. Some authors have used NI-myRIO and interfaced with motors and PC installed with LabVIEW 2014 and with the help of PC tried to control the movements of the DC Motor [9].

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B. DAS Software

Figure 4 illustrates the flowchart for the DAS software. The DAS will start by reading signals from the input channels. It then takes product of these two signals and multiply constant. The significance of the constant is to translate data onto corresponding electrical energy in kWh. By using the software we then writes the total energy every two seconds to an MS Excel sheet. If myRIO button is pressed the device abort the execution or else it uses onboard LEDs to indicate the power level and continues reading values.

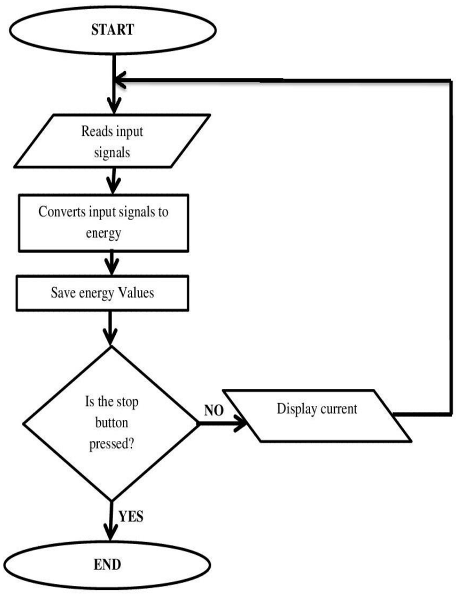

Figure 4: Flowchart for the DAS Software

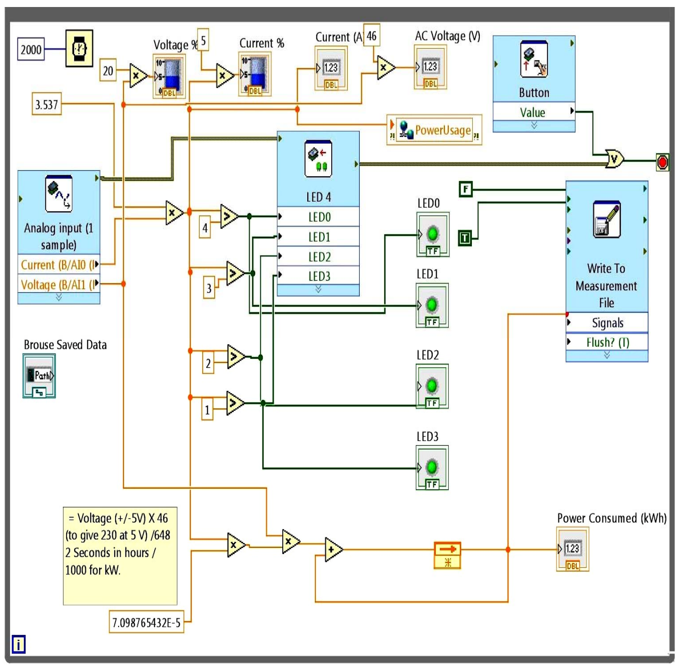

Figure 5: DAS software in LabVIEW

Figure 5 illustrates the DAS software code that is used to save progressive energy values onto MS Excel. The values are derived from input currents and voltages. LED description under figure 5 is as follows, the input current is tested and the LEDs illuminate as follows: If the current ranges between 0 and 2.5 A only LED 0 is on and for a range between 2.5 and 5 A, LEDs 0 and 1 are both on and for a range between 5 and 7.5 A the LEDs 0, 1 and 2 will be on. Finally any current above 7.5 A will illuminate all the LEDs.

Test Methodology

First step of testing procedure was to validate the readings given out by the DAS. To do that, an ammeter was used to validate the current that was read by the DAS. In a Similar fashion the voltmeter was used to validate voltage values. The AC current and voltage sensors shown on figure 1 were there after subjected to the load the made up of various domestic appliances such as Plasma TV, home theatre, refrigerator, microwave oven etc. DAS was left to run for duration longer than 12 hours. The DAS was also connected to a renewable energy source of 350 W. This time the load was made of equipment such as routers, chargers and left to run from a period longer than an hour.

III. RESULTS AND DISCUSSIONS

During validation procedure, lower values were found to be affected by noise when compared to higher values. Since values above 500 mA are less affected by this noise and this device is intended for applications that draws above 500 mA, this noise is of less concern now. In the two sections that follow, the results that were obtained when testing the DAS are highlighted.

A. Test from grid energy power source

Here the power is supplied by grid. Table I gives sample values randomly selected sets of progressive energy consumption in kWh and changes in energy from one level to the other.

TABLE I: RANDOMLY SELECTED PROGRESSIVE ENERGY VALUES

Time (06-07 December 2015)	Energy	Difference in Energy
17:38:26	1.309513	0.002249
17:38:50	1.311762	0.002229
18:25:48	1.379272	0.000625
18:26:13	1.379897	0.000585
18:26:39	1.380482	0.000578
18:27:05	1.38106	0.000617
18:27:30	1.381677	0.000599
0:39:40	1.717996	0.000444
0:40:15	1.71844	0.000447
0:40:50	1.718887	0.000436
0:41:59	1.719764	0.000443

Table I indicates that energy consumption was very high on 06th of December around 17h38, moderate around 18h25 and reaching low from 7th of December at around 00:39:40.

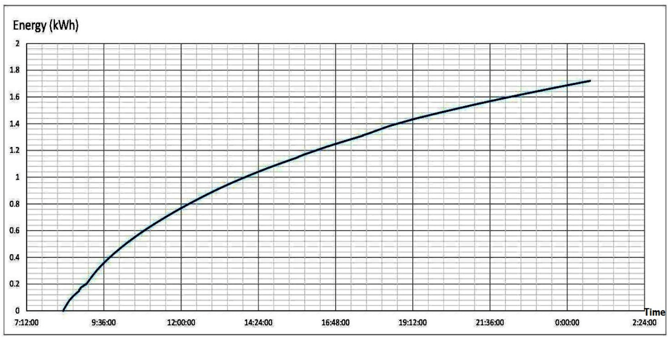

Figure 6: Progressive energy consumption from the grid over the time domain.

The graph on Figure 6 indicates progressive energy consumption for the entire period between the 6th and 7th of December 2015. Note that the fast rise of the curve illustrates high consumption whilst flat surface indicates low consumption. Table I and Figure 6 illustrated that between 18:25:48 and 18:27:30 the consumer used high power domestic appliances, from 18:30 to 00:30 they were using moderate equipment and finally only few equipment were running as from 00:40:15

A. Test from renewable energy power source

Renewable energy system consists of solar panels that are used to charge battery banks via charge controllers. A battery bank supplies an inverting equipment with power. The DAS equipment is connected to monitor both current and voltage values at the output of the invertor. As in [10] the Power is computed using the formula as in equation 1:

$$P=VI \tag{1}$$

Where P is the power, I the current and V is the voltage, ignoring power factor since the load is not inductive.

Here the power is supplied by renewable energy source, namely a 350 W inverter that is connected to a 33 Ah Battery. Table gives sample the first few recorded progressive energy value kWh and changes in energy from one level to the other.

TABLE II: FIRST 10 RECORDED PROGRESSIVE ENERGY VALUES

Time: 12/Dec/2015	Energy	Difference in Energy
8:20:10 AM	0.000221	0.000054000000
8:20:12 AM	0.000275	0.000049000000
8:20:14 AM	0.000324	0.000063000000
8:20:16 AM	0.000387	0.000049000000
8:20:18 AM	0.000436	0.000039000000
8:20:20 AM	0.000475	0.000034000000
8:20:22 AM	0.000509	0.000011000000
8:20:24 AM	0.00052	0.000054000000
8:20:26 AM	0.000574	0.000020000000

Table II illustrate that the changes in energy never been that much, however it should be noted this significant when considering the Energy supply potential of a renewable source. Renewable energy sources are not capable of giving out high energy when compared to their nonrenewable energy counter parts. It is therefore important to keep their output energy within desired limits, by limiting the connected appliances.

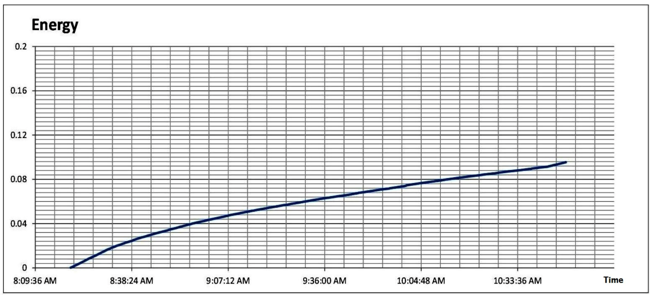

Figure 7: Progressive energy consumption from the renewable energy source over the time domain.

The graph on Figure 7 indicates the progressive energy consumption by the renewable energy source over a period between 08:10 and 10:30 AM. When contrasting Figure 6 and Figure 7 it will be observed that it took renewable energy source 2.5 hours to match the energy that a nonrenewable source has supplied within 0.2 hour. The response as illustrated by Figure 6 was for the national grid power as opposed to the one by the renewable energy source as in Figure 7. You have to improve output capacity of the renewable energy source by at least 2.5 hour / 0.2 hour that is equal to 12.5 times. However the renewable energy only gave out 25% of its rated power. It will therefore have to be redesigned to be 3.125 times of its rated power for full load. In these calculations, load fluctuations, efficiency, linearity, etc. have not been considered. However it is demonstrated that crucial data required for renewable energy design is being collected.

The Progressive energy is updated using equation 2 as follows:

$$E_T = \text{Total Energy} + E_I \qquad (2)$$

Where E_T is the Total Energy and E_I Instantaneous Energy consumption.

The MS Excel chart was used to plot the total consumed energy in kWh over the time domain as illustrated by Figure 7. Instantaneous Energy is viewed using National Instrument data dashboard for LabVIEW available from the app store. See Figure 8 for a screen shot showing instantaneous energy consumption in kWh.

Figure 8: Energy consumption - National Instrument data dashboard

IV. Conclusions

Embedded DAS can be used to create a load analysis tool that collects and record electrical energy values which are crucial needed for the calculation of renewable energy power rating. This tool can be collaborated with an app called data dashboard for monitoring of real time data and/ or utilize onboard LEDs display any parameter of interest. Onboard LEDs provided of embedded device were used to indicate the level of current consumption and ultimately warn against excessive power usage.

It was also observed that grid energy source can only be replaced with renewable energy source after the load has been significantly reduced from the grid source, alternative the power of renewable energy source is significantly increased.

Acknowledgement

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References

[1] Mahdi Ghamkhari and Hamed Mohsenian-Rad, "Optimal Integration of Renewable Energy Resources in Data Centers with Behind-the-Meter Renewable Generator", in *Proc. of the IEEE International Conference on Communications (ICC'2012)*, Ottawa, Canada, June 2012

[2] B. Goncalves, A. E. L. P. Inst. de Plasmas e Fusao Nucl., J. Sousa, A. Batista, and R. Pereira, "ATCA Advanced Control and Data acquisition systems for fusion experiments," 2009 16th IEEE-NPSS Real Time Conference, pp. 28-34, May 2009.

[3] C. Wu, H. Mohsenian-Rad, J. Huang, and A. Y. Wang, “Demand side management for wind power integration in microgrid using dynamic potential game theory,” in Proc. of IEEE GLOBECOM Workshop on Smart Grid Communications and Networking, Houston, TX, Dec. 2011.

[4] Q. Ran, G. Yang, L. Mei, and G. Chengqiu, "Design of data acquisition system for dynamic simulation centrifuge test," Electronic Measurement & Instruments (ICEMI), vol. 2, pp. 147-150, Aug. 2011.

[5] W. Abidin, A. K. Othman, K. H. Ping, M. Abdullah, and B. V. Pai, "Best position method for experimental data acquisition systems using low-cost GPS receiver," Space Science and Communication (IconSpace), pp. 200-205, Jul. 2011.

[6] A. Marchioro, S. Bonacini, A. ur Rehman, and W. Pribyl, "A Lossless Data Compression System for a Real-Time Application in HEP Data Acquisition," Nuclear Science, IEEE Transactions, Vol. 58, no. 4, pp. 1738-1744, May 2011.

[7] M. C. Corporation. (2012) MCCDAQ [Online]. http://www.mccdaq.com/pdfs/anpdf/Data-Acquisition-Handbook.pdf [Accessed 01/12/2015]

[8] C. H. Lee, I. Orikumhi, C. Y. Leow, M. A. B. Malek and T. A. Rahman, "Implementation of Relay-Based Emergency Communication System on Software Defined Radio," *2015 IEEE 21st International Conference on Parallel and Distributed Systems (ICPADS)*, Melbourne, VIC, 2015, pp. 787-791. doi: 10.1109/ICPADS.2015.104

[9] Hussain et. al, Control and Interfacing of Motors with NI-LabView using NI-MyRIO, IJRST International Journal of Technology, Vol(1) Iss 8, January 2015, ISSN: 2349-6010

[10] S. Sharma, "Basics of Electrical Engineering," in Basics of Electrical Engineering. New Delhi, India: I.K. International Pty Ltd, 2007, ch. 1, pp. 33-36.

[11] N. Instrument, “NI myRIO - 1900 User guide and specifications,” August 2013. [Online]. http://www.ni.com/pdf/manuals/376047a.pdf [Accessed 07 December 2013].