International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347 - 6435 (Online) Volume 2, Issue 2, February 2014)

Hybrid Low Power Touch ECG Using Dry Metal Sensor And HRV Analysis Using MATLAB

S. Sowmiya[1], T. Jayanthi[2]
[1]*M.Tech*, [2]*Assistant Professor*, *SRM University*, *Chennai*, *TN*, *India.*

***Abstract*— ECG or Electrocardiogram is the first and the foremost basic diagnostic tool for cardiovascular problems. Our main aim is to make the ECG circuit, which is noise free and wire free acquisition without causing discomfort to the patient. This can is achieved by dry metal electrodes that can be fixed on the patients bed handles or at wheelchairs. One of the main problems in ECG acquisition is the power line inference. This adds more noise to the signal and also a hazard to the patient. This can be overcome by battery source but it is economically not feasible for peripheral health care centres for providing UPS to setup the back-up power supply. Hence we have come out with a novel idea of constructing an ECG amplifier that is potentially driven by hybrid power i.e. solar and wind energy and also with easy signal acquisition by touch metal sensor that can perform effectively whenever there is power failure and also in cases of emergency. The electrodes used in this device are dry metal made of German silver, where patient keeps their thumbs on the sensor plate and the signal is acquired. A hybrid power driven ECG monitoring system is mainly developed for its applications in rural areas. The performance and functioning of the ECG remains uninterrupted irrespective of power failures. Moreover, it is a simple portable device that could be operated even in remote places. This ECG uses a battery to power the amplifier circuit which is charged by hybrid source. It can also be powered by the commercial AC power supply. By using PC interface, ECG is processed into the MATLAB for further processing like Heart Rate Variations (HRV) analysis in time domain and frequency domain.**

***Keywords*— Dry metal electrodes for ECG acquisition, German silver, hybrid (solar and wind) power driven ECG, HRV analysis, touch ECG.**

I. INTRODUCTION

The cyclic muscular contraction and relaxation of the heart is called the systole and diastole respectively. This is caused by the electrical impulses that pass from the Sino-atrial (SA) node to the purkinje fibers. Measurement of this electrical conductivity of heart is called the Electrocardiogram or ECG. The ECG signal, which is an electric bio-potential originating from excitable cells of heart muscle, is commonly extracted from the patient's skin by attaching electrodes. Most of current approaches use wet or gel type surface electrodes because it will increase signal quality by improving conductivity between skin electrode interfaces. However, there is a toxic concern to use wet electrode for long-term application.

Skin preparation with alcohol before electrode attachment is a mandatory process to prevent from the bacterial growth which will cause skin irritation. Using wet electrode for repeated ECG monitoring is therefore both expensive and inconvenient. In addition, the electrode cable which interconnects between electrodes and sensor monitor, are the most cumbersome part in use. Eliminating the cables by directly integrating the electrode with monitoring device or by laying the lead wires inside the chair/bed handles and even reducing the numbers of sensing electrodes not only increase patient's mobility but also reduce motion artifacts and interferences.

Cardiovascular disease is the leading cause of deaths worldwide, cardiovascular mortality rates have declined in many high-income countries. At the same time, cardiovascular deaths and disease have increased at a fast rate in low- and middle-income countries. Therefore, increased emphasis on preventing atherosclerosis by modifying risk factors, such as healthy eating, exercise, and avoidance of smoking tobacco.

The available method is acquiring ECG by three lead systems or by 12 leads which use disposable gel type electrodes. Another new way for acquiring ECG through thumb was proposed earlier which use copper dry metal electrodes. It was a capacitive coupling ground free ECG extraction[1]. As the resistance of copper material changes in due course of time and also it is a capacitive coupling method, the resistance and the capacitance play a major role in signal acquisition. Therefore frequent calibration of the system is often required. This adds noise to the ECG signal.

The power line interference is the main noise from the transformer used. To overcome this, a hybrid power supply by using solar and wind is used, because only solar power driven system will have some drawbacks like quick discharge of battery[4]. In rainy season, there will not be any availability of the solar energy. Therefore the battery discharges and we finally tend to use commercial power. The dry metal electrodes we use are made up of German silver which is an alloy of copper, nickel and zinc. It has high corrosion resistance therefore the resistance of the metal does not change. This metal plate can be attached in the handles of wheelchair or bed, so that there will not be any wires lying on the patient and they themselves feel comfortable in this kind of acquisition.

International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347 - 6435 (Online) Volume 2, Issue 2, February 2014)

II. METHODOLOGY

ECG is the first and foremost basic test taken for cardiac disturbances. The electrical activity of the heart is measured using 12 lead or 3 lead systems. Our system consists of dry metal electrodes that follow three lead systems. The major advantage of using dry metal electrode is the patient comfort by reducing allergies and burns.

A. Electrodes

The dry metal electrode is made up of German silver or Nickel silver. It is a copper-based alloy that contains from 10% to 45% zinc and from 5% to 30% nickel. It is yellowish brown in color. Sometimes tin and lead are also added to improve the casting properties of the metal. The major advantage of copper makes the metal more ductile and more corrosion resistance and has good electrical conductance. Higher amount of zinc slightly improves corrosion resistance, lowers the melting point, and raises its strength and hardness. German silver has a melting point of 1,110 degrees Celsius. It expands more than gold but less than silver when heated from room temperature to 100 degrees Celsius. The alloy is 5 percent to 15 percent as electrically conductive as pure copper, depending on the exact ratio of metals in the alloy. It will not rust and the alloy is usable in very hot or very cold conditions. This metal sheet is made as small plates for easy placement of electrodes through which the ECG signal is acquired.

Fig.1 Dry metal electrode.

B. Signal conditioning

The output from the electrodes is fed into its corresponding amplifier module with high input impedance. This unit consists of two amplifiers coupled with two integrator filter and a low pass filter. OP 07 is used in pre-amplification to increase the voltage of signal from each lead. LM 324 is used to combine the entire signal for full amplification.

This is a very sensitive stage, where the block diagram is specified below. There are some very critical requirements that must be met for this stage. The requirements and the reasoning behind those requirements are given below.

The amplitude of the ECG signal is approximately 20 – 100 µV.

Frequency of the normal ECG signal is approximately 5 Hz and thus the amplifier should have a frequency response from 0.1 -125 Hz.

When the thumb is placed at the two dry metal electrodes which is widely separated by a distance, will generate a continuously shifting potential difference. As the electrodes are dry metals, there will be high skin impedance at the skin electrode interface, which will add noise to the feeble ECG signal. This can be removed by adding a high input resistor to the OP 07 which has supply of 12V. Setting the gain for these OP-AMPS is very essential and important for taking only the ECG signal from all other noises. The gain of the OP-AMP is splited up so that the noise is reduced by quick discharge of the capacitor. Therefore when the noisy ECG is passed to the first OP-AMP OP 07, due to less gain the signal and the noises are amplified only to a smaller extent.

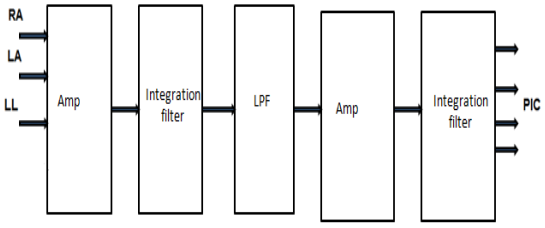

Fig.2 Block diagram for signal conditioner.

The integrator filter and the low pass filter are combined such that it will make the output linear. The main use of LPF is, it allows only the ECG signals to the quad OP-AMP LM 324 so that only the signal gets amplified to large extent because of the high gain. A resistor is connected to the positive terminal of the OP-AMPs and is grounded at the other end so that ground noise is removed. For having a variable gain at a wide range, span is used. It is a variable resistor connected at the input side. This helps for acquire various age group of patients.

Zero is a switch kind of resistors where it protects the OP-AMP as well as current does not back flow into the electrode. To remove the offset and null two resistors are connected parallel to the negative supply and pin 1 and 5. LM324 is a quad amplifier where 4 OP-AMPs are embedded in a single IC with a single power supply.

International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347 - 6435 (Online) Volume 2, Issue 2, February 2014)

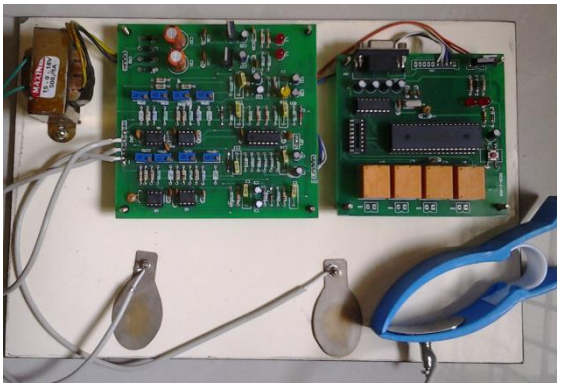

Fig.3 ECG acquisition unit.

In this chain a microcontroller is needed because the analog data from the amplifier unit should be made compatible for using in the PC. For changing it into a digital data, analog to digital conversion is required with some built in logic is needed so we are using a microcontroller here to solve the problem.

The microcontroller which is implemented here is the PIC16F877A which is called as an embedded controller because it is having all the built in components in it. Peripheral Interface Controller (PIC) is enhanced version of microcontrollers. A zener diode with a cut off of 5V is placed between the amplifier and the controller, because the controller will work only on 0 to 5V. Therefore when there is a voltage fluctuation zener cuts the voltage which is more than 5V, and prevents the failure of PIC.

C. Hybrid power supply

This system consists of two energy source i.e., wind and solar for voltage source. For wind energy, we are using low turbines made up of D.C generators with mechanical model. To acquire solar energy, we use photo-voltaic cell made up of amorphous silicon module, very rigid, high thermal stability. The voltage acquired from both the sources is given to a high end high frequency charge controller to charge the battery by trickle pulse method. Multilevel charging system enhances to high end usage. This helps to avoid AC interference in the ECG signal.

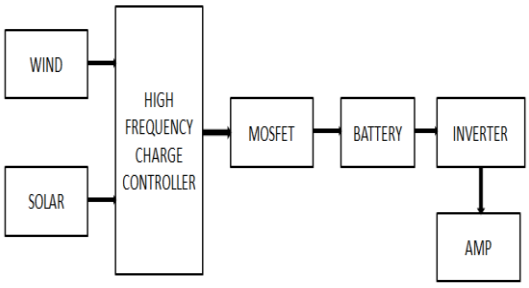

Fig.4 Block diagram of hybrid supply.

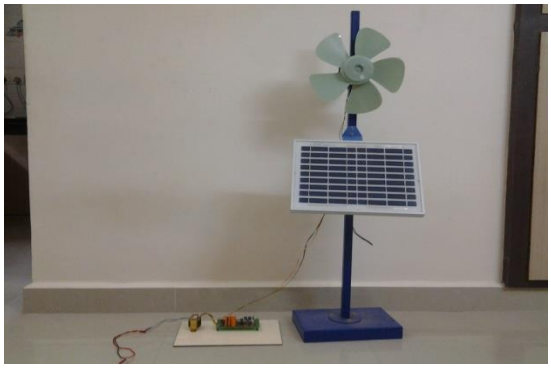

Fig.5 Hybrid supply unit

III. HRV ANALYSIS

The digital value from PIC is given into the MATLAB using serial to USB. Using MATLAB plot, the signal is displayed in analog format with time and amplitude information. Heart Rate Variability (HRV) analysis is also called RR variability which defines that variation in time interval between heartbeats. The HRV analysis has many main functions. Here we consider the time domain analysis and the frequency domain analysis.

A. Time domain analysis

The time-domain methods are the simplest to perform since they are applied straight to the series of successive RR interval values. The most evident such measure is the mean value of RR intervals (RR) or, correspondingly, the mean HR (HR). In addition, several variables that measure the variability within the RR series exist. The standard deviation of RR intervals (SDNN) is defined as

$$SDNN = \sqrt{(1/(N-1)) \sum_{j=1}^{N} (RRj - \overline{RR})^2}$$

Where RRj denotes the value of j'th RR interval and N is the total number of successive intervals. The SDNN reflects the overall (both short-term and long-term) variation within the RR interval series, whereas the standard deviation of successive RR interval differences (SDSD) given by

$$SDSD = \sqrt{(E\{\Delta RRj^2\} - E\{\Delta RRj\}^2)}$$

can be used as a measure of the short-term variability. For stationary RR series $E\{\Delta RRj\} = E\{RRj+1\} - E\{RRj\} = 0$ and SDSD equals the root mean square of successive differences (RMSSD) given by

$$RMSSD = \sqrt{(1/(N-1)) \sum_{j=1}^{N-1} (RRj+1 - RRj)^2}$$

International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347 - 6435 (Online) Volume 2, Issue 2, February 2014)

Another measure calculated from successive RR interval differences is the NN50 which is the number of successive intervals differing more than 50 ms or the corresponding relative amount

pNN50= NN50/ (N-1) X 100%

and these are the few statistical measure in HRV analysis in time domain.

B. Frequency domain analysis

In the frequency-domain methods, a power spectrum density (PSD) estimate and wavelet decomposition is calculated for the RR interval series. The regular PSD estimators implicitly assume equidistant sampling and, thus, the RR interval series is converted to equidistantly sampled series by interpolation methods prior to PSD estimation. The PSD estimation is generally carried out using FFT. Using the complex conjugate from a frequency axis for the first 127 points is used to plot the result.

IV. RESULT

Hybrid low power touch ECG has a very easy acquisition and also suited for the energy constrained portable healthcare applications. It is designed such that the electrodes can be made as handles at the bed or at wheel chairs, so the patients does not know about taking ECG through their thumbs, in which the wires does not lay on the patient. The dry metal electrode is made up of German silver which is an alloy of copper, nickel and zinc. Through the hybrid supply the power line interference noise is removed. With good signal conditioning circuit IC noises are removed. It can also be continuously monitored for critical patients and simultaneously it can be interfaced with PC and stored in Excel.

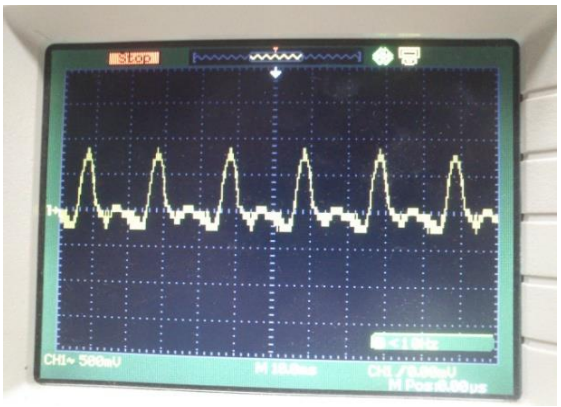

Fig.6 ECG display in DSO

In PC, ECG is displayed in MATLAB and processed for HRV analysis. The stored digital values of ECG in Excel can be given as input to any ECG analysis software. This helps in fine analysis of ECG.

In Heart Rate Variability, time domain and frequency domain analysis are mainly done for studying about the spatial and frequency characteristics of ECG signal. In Fig. 7, R peaks are detected using Discrete Wavelet Transform (DWT). Hence from the peaks and sampling rate Heart rate can be calculated.

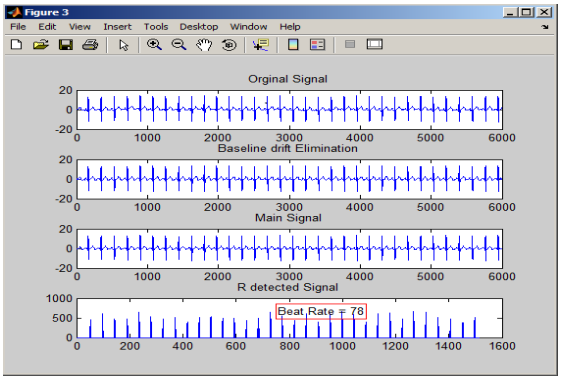

Fig.7 R peak detection and Heart Rate evaluation.

Now a dialog box is created for time analysis or frequency analysis. As in Fig. 8, 0 for time analysis and 1 for frequency analysis.

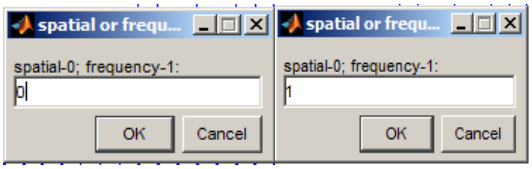

Fig.8 Spatial or frequency selection.

In time domain analysis, difference in successive RR intervals for 5 sec, 10 sec, 15 sec, 30 sec are calculated.

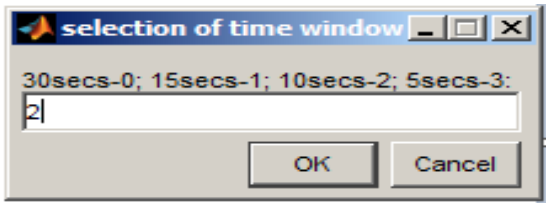

Fig.9 Time selection for successive difference in RR interval.

The result is displayed in new window for corresponding seconds.

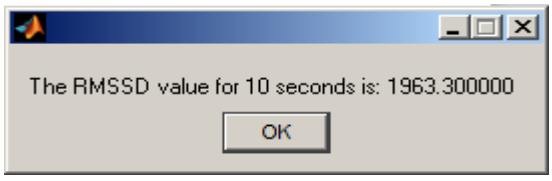

Fig.10 RMSSD value of corresponding time interval.

International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347 - 6435 (Online) Volume 2, Issue 2, February 2014)

Other parameters in time domain like average, standard deviation are displayed in command window of MATLAB.

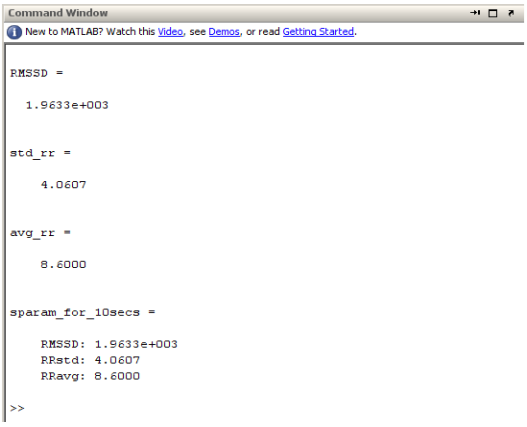

Fig.11 Other time domain parameters of ECG signal.

In frequency domain analysis, PSD of the ECG signal is displayed in Fig. 12.

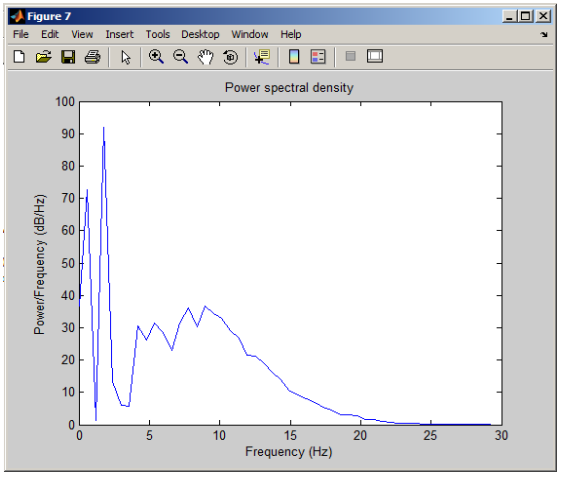

Fig.12 PSD of ECG signal.

V. CONCLUSION

Power cuts play a major hurdle now a day. In villages it is more common for 8-10 hours. All the peripheral health centers are affected due to this. By using renewable energy sources we overcame this problem by producing power through solar and wind energy. This helps ECG machine work. Dry metal electrode acquisition make patient feel comfortable. The digital values of ECG can be given into any ECG analyzing software for processing.

REFERENCES

[1] Long Yan and Hoi-Jun Yoo, 'A Low-Power Portable ECG Touch Sensor with Two Dry Metal Contact Electrodes'. Journal of semiconductor technology and science, vol.10, no.4, December, 2010.

[2] Zeli Gao, Jie Wu, Jianli Zhou, Wei Jiang and Lihui Feng. 'Design of ECG signal acquisition and processing system' 2012 International Conference on Biomedical Engineering and Biotechnology.

[3] S.A. Raza Naqvi, S.R. Khan, W. Hassan, and C. Yi. 'Portable Low Cost Electrocardiogram Ambulatory Support System For Cardiologists'. 2012 IEEE Global High Tech Congress on Electronics.

[4] Parin Dedhia, Harsh Doshi, Mrunal Rane, Govinda Ahuja. 'Low Cost Solar ECG with Bluetooth transmitter'. 2012 International Conference on Biomedical Engineering (ICoBE), Penang, Malaysia, 27-28 February 2012.

[5] Prof. Lionel Tarassenko, Hilary Term 2012, Biomedical Instrumentation.

[6]] John.R. Hampton. Edinburgh London New York Oxford Philadelphia, St Louis Sydney Toronto 2003, The ECG in practice.

[7] Mohammadreza Balouchestani, Kaamran Raahemifar and Sridhar Krishnan. Proceedings of 2013 ICME-International Conference on Complex Medical Engineering, Low Sampling-rate Approach for ECG Signals with Compressed Sensing Theory, May 25 - 28, Beijing, China.

[8]] Liang-Hung Wang, Tsung-Yen Chen, Shuenn-Yuh Lee, Tai-Hsuan Yang, Shi-Yan Huang, Jen-Hao Wu, and Kuang-Hao Lin. 978-1-4673-5936-8/13 ©2013 IEEE, A Wireless Electrocardiogram Detection for Personal Health Monitoring.

[9] Anucha Punapung , Suradej Tretriluxana, Kitiphol Chitsakul. The 2011 Biomedical Engineering International Conference (BMEiCON-2011), A Design of Configurable ECG Recorder Module.

[10] Ju-Won Lee and Gun-Ki Lee. International Journal of Control, Automation, and Systems, vol. 3, no. 1, pp. 137-142, March 2005, Design of an Adaptive Filter with a Dynamic Structure for ECG Signal Processing.

[11] J. Parak, J. Havlik. Department of Circuit Theory, Faculty of Electrical Engineering, Czech Technical University in Prague,] ECG signal processing and heart rate frequency detection methods.

[12] Valtino X. Afonso, ECG QRS Detection.

[13] Pandelis Perakakisa, Mateus Joffilyb, Michael Taylor, Pedro Guerra, Jaime Vila. computer methods and programs in biomedicine 2 0 1 0.

[14] KARDIA: A Matlab software for the analysis of cardiac interbeat intervals.

[15] Juha-Pekka Niskanen, Mika P. Tarvainen, Perttu O. Ranta-aho, and Pasi A. Karjalainen. University of Kuopio Department of Applied Physics Report Series ISSN 0788-4672, Software for advanced HRV analysis.

[16] CleveLabs Laboratory Course System – Teacher Edition.

[17] Juha-Pekka Niskanen, Mika P. Tarvainen, Perttu O. Ranta-aho, and Pasi A. Karjalainen, University of Kuopio Department of Applied Physics Report Series ISSN 0788-4672, Software for advanced HRV analysis.

[18] J. Parak, J. Havlik, Department of Circuit Theory, Faculty of Electrical Engineering, Czech Technical University in Prague. ECG signal processing and heart rate frequency detection methods.