IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 1 Issue 5, July 2014.
www.ijiset.com
ISSN 2348 – 7968

Power Quality Improvement of Impedance Cardiovasograph (ICVG) For Measurement of Electrical Impedance

[1]Mithilesh Singh (Ph.D. research scholar), [2] Shubhrata Gupta

CVRU, SSIPMT Raipur (C.G.)
[2]N.I.T. Raipur (C.G.), senior IEEE member

Abstract: Impedance Plethysmography is a technique which measures electrical impedance of any part of body offered to flow of electric current; the impedance is inversely proportional to blood changes in body segment. The blood volume changes cause minute variation in impedance, which can be monitored using an instrument Impedance Cardiovasograph (ICVG). It serves for the purpose of providing state of art technology in the field of bio-electric Impedance measurement. Provide computer controlled system with no front panel controls on the instrument to facilitate easy employment on the patients and for easy future reference.

Key words; ICVG, Impedance Plethesmography, peripheral heamodynamics.

1.0 Introduction:

The study of peripheral vascular diseases involves study of peripheral heamodynamics. The study of peripheral heamodynamics is carried out using various techniques Invasive and Non- Invasive. Invasive techniques give a quantitative measure of peripheral blood flow but they are not preferred, as it requires surgical exposure of arteries. Out of several non invasive techniques used impedance plethysmography is one of them.

The arteriography and electromagnetic flow meter are most accurate procedures but are invasive in nature. The non-invasive methods are classifieds mainly in to three categories i.e. Ultrasonic methods, Plethysmographic methods, Phonoangiography methods.

Plethesmography is a technique, which measures volume changes in any part of body by either displacement method or by impedance measurement. Impedance Plethysmography is a technique which measures electrical impedance of any part of body offered to flow of electric current, the impedance is inversely proportional to blood changes in body segment. The blood volume changes cause minute variation in impedance, which can be monitored using an instrument Impedance Cardiovasograph (ICVG) [2].

In recent past technique has attracted the attention of many clinicians for usage in peripheral blood flow. It is more accurate because of direct relation to blood flow, but is less popular due to its cumbersome diagnosis procedure, which is unknown to lot of physicians.

This Impedance Plethesmography technique was put forward by Jindal et.al *.and* a microprocessor based system was employed for assessment of Peripheral Arterial Occlusive Diseases (PAOD) by Impedance Plethesmography[1]. It was reported to yield approximate anatomical location of the block, Status of collateral circulation, Distal arterial runoff.

The Impedance Plethesmography diagnosis correlated very well with angiographic finding for patients with arterial occlusive diseases. The main objective in this paper is to provide a computer controlled ICVG system with user friendly software for diagnosis of peripheral arterial and aortic diseases; this up gradation in technology will be more acceptable to clinicians as it includes the facility of saving the data acquired for future retrieval. It provide user friendly graphical user interface to easy use by the clinicians.

2.0 Literature Review: Impedance Plethesmography is the measurement of electrical impedance (Zo) changes in the impedance as a function of time (ΔZ)

and the rate change of impedance w.r.t.(dz/dt) in a given segment of body. Since blood is a good conductor of electricity the changes in blood volumes in any part of body cause minute variations in the electrical impedance. These minute variations can therefore be utilized to access the blood circulation in the body segment under investigation. The technique was first introduced by Jan Nyboer in 1940 that correlated the change in impedance with the flow of blood both in vitro and vivo studies [3]. It was concluded that alternation in the physiological conditions of blood vessels, alternation in the volume of blood passing through the vessels and the degree of such abnormalities could be correlated to changes in waveform. This technique received an impetus in 1966 from kubicek et al. who introduced the first time derivative of the impedance (dZ/dt) for computing stroke volume, cardiac output obtained using kubicek's formula and other invasive techniques are found to be consistent. The block diagram of impedance cardiovasograph is shown in fig.1.0 [2].

2.1 Electrical Conductance in Biological Matter: Biological tissues, bones and fluids are neither conductor of electricity nor bad conductor of electricity. Intermediate property of the biological matter makes it measurement feasible by simple instruments. The conductivity of the biological fluids is more than that of tissues due to availability of charge carrier in the fluids.

If L is the length and A is the area of cross section of a homogeneous cylindrical conductor, the resistance is given as $R = \rho L/A$, where ρ is given as resistivity which in terms is reciprocal of the conductance. Biological matter have slightly different behavior than ohmic conductors. Measurement of ρ in biological materials is complicated by electrolytic nature of fluids, distribution of the materials in suspensions and orientation of which are relatively poor conductors.

2.2 Impedance measurement of Biological Materials: Impedance measurement becomes difficult in biological materials or any other electrolytic substance as the application of steady electric fields results in polarization at the electrodes. The factor responsible for such polarization is (a) the capacitance formed by the electrodes with the biological specimen as the dielectric. (b) the capacitance effect of the double layer at the surface of electrodes and (c) the faradaic admittance in parallel with the double layer.

This difficulty is reduced to a large extent by employing time varying electric field. The frequency of time varying field is chosen between 20 KHz to 200 KHz for the measurement of biological materials to reduce the effects described above.

Generally constant current method or bridge method is employed for the measurement of impedance. In this method constant amplitude current is passed through the object and voltage signal developed across the conductor is measured. Division of voltage measure by the current passed is the measure of the impedance. Bridge method is extension of the ohm's law method which is highly precise and based on the principle balancing of Wheatstone bridge.

A typical impedance measuring system is comprised of sine wave oscillator followed by voltage to current converter. This converts output sinusoidal current of constant amplitude (1 – 10 mA) which can be passed through body segment with the help of two band electrodes called current electrode I_1 and I_2. Voltage signal developed along the current path is sensed with the help of another pair of electrodes called sensing electrodes or the voltage electrodes V1 and V2 as shown in fig.1.0. Amplification and detection of this signal yields an output signal which is proportional to the instantaneous impedance (Z) of the body segment. Initial value of the impedance also known as basal impedance (Z0) are obtained from a sample and hold circuit.

Small changes in the impedance of the body segment cause by physiological process like blood circulation, respiration etc. are obtained by subtracting the initial value of impedance from the instantaneous impedance and is called ΔZ waveform. The Z is also differentiated w.r.t. time to get the rate of change of impedance or dZ/dt waveform. By convention - ΔZ and - dZ/dt are recorded to relate these waveforms with the blood volume changes directly and are colloquially called $\Delta Z(t)$ and dZ/dt wave forms. Since $\Delta Z(t)$ and dZ/dt are produced by physiological processes it is possible to extract the changes produced by one particular process by either suppressing the other process or by signal processing technique. For example to extract the signal produced by blood circulation, the subject under investigation

can be instructed to hold this breath. On the other hand a low pass filter can suppress changes caused by blood circulation and can give changes produced by respiration. Measurement of this physiological process from these impedance signals is a vast field known as Impedance Plethesmography or Impedance Cardiovasography.

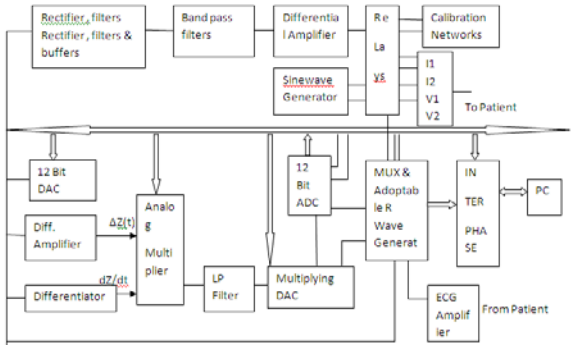

Fig1.0 Block diagram component used in ICVG

3.0 Parallel conductor Theory:

According to this theory action of the systole is to place additional impedance Zb of the body segment (Z0) at the end of diastole. The instantaneous impedance of the body segment (Z) is therefore given by the parallel combination of Z0 and Zb as follows: $Z = Z0.\ Zb / Z0 + Zb$

It is possible to calculate Zb from this equation as :

$Zb = Z0.Z / Z0 – Z$

Since Z0 and Z differ by a very small amount, Z in the numerator can be replaced by Z0 to give

$Zb = (Z0)^2 / dZ$ where dZ is the change in the impedance.

Assuming the volume of blood which corresponds to Zb can be represented as a uniform conductor having a length L and area of cross section A , Zb can be replaced by $\rho bL / A$ or $\rho bL^2 / dv$ where ρb is the resistivity of the blood and dV is the volume of blood entering in to body segment. Above equation therefore becomes

$(\rho bL^2 / dV) = (Z0)^2 / dZ$ or $dV = (\rho bL^2.dZ)/(Z^0)^2$

Same equation can be obtained by two compartment model, which is more closer to practical situation.

3.1 Two Compartment Model :

In this model body segment is considered as a uniform cylinder with a column of blood along its axis and body tissue surrounding the blood column. If L be the distance between the sensing electrodes, the impedance Z of the body segment is given as :

$1/Z = 1/Zt + 1/ Zb,$

Where Zt is the impedance of the surrounding tissue and Zb is the impedance of the blood column. If At and Ab are the cross sectional area and ρt and ρb are the resistivity of the surrounding tissue and blood column respectively, by ohms law Zt and Zb are given as :

$Zt = \rho t.\ L / At$ and $Zb = c.L / Ab$. Therefore

$Z = (\rho t.\ \rho b.\ L) / (\rho b.At + \rho t.\ Ab) = (\rho t.\ \rho v.\ L^2) / (\rho b.Vt + \rho t.Vb)$

Where Vt and Vb are total volume of surrounding tissue and blood conductor respectively. Assuming that a volume of blood dVb enters the region between the sensing electrodes, it results in a small increase in area of blood conductor and doesn't alter the volume of surrounding tissue. Accepting this fairly reasonable physiological assumption, the expression for the change in resistance (dZ) of the body segment can be given as:

$dZ = (\rho b.\ \rho t^2.L^2) / (\rho t\ Vb + \rho bVt)^2$

Therefore the change in blood volume dVb can be written as

$dVb = (\rho b.\ \rho t.^2.\ L^2) / (\rho t\ Vb + \rho bVt)^2$

substituting $(\rho t\ Vb + \rho bVt) = \rho b.\ \rho t.L^2 / Z,$

$dVb = -(\rho b.\ L^2 dZ / Z^2$ keeping in mind that basic assumption cross sectional area of the tissue mass remains constant, the area of blood conductor increases with entry of blood and length L remain unchanged.

Above equation is used for estimation of blood volume dVb entering in to the body segment. The negative sign signifies that entry of blood produces decreased in electrical impedance. By convention however a decrease in impedance is recorded as positive deflection in an IPG system. For calculating the total volume of the blood (ΔV) entering in to the body segment during entire systole the dZ in the equation is replaced by a total change in the impedance (ΔZ) occurring during the period as $\Delta V = \rho b.\ L\ \Delta Z / (Zo)^2$.

4. Results: The dZ/ dt waveform varies significantly from location to location. This variation in principle can be due to non uniformity in the area of cross section in an extremity, variation in tissue composition from location to location in an extremity. Hence this variation is of importance to the clinician for the study of peripheral

ISSN 2348 – 7968

haemodynamics. Clinicians can therefore have just a look at the waveform and interpret in a manner similar to that of ECG records fig. (2.1&2.2)

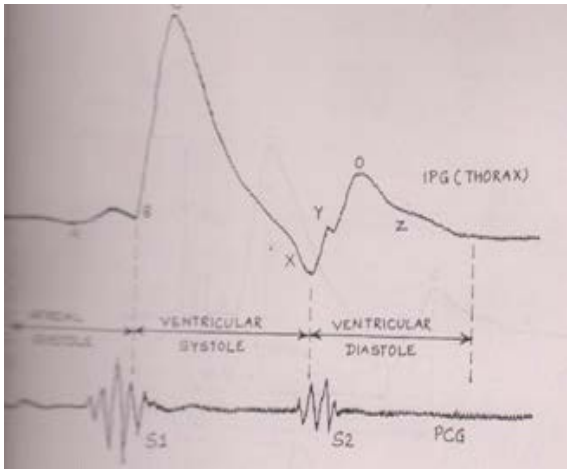

Fig. 2.1

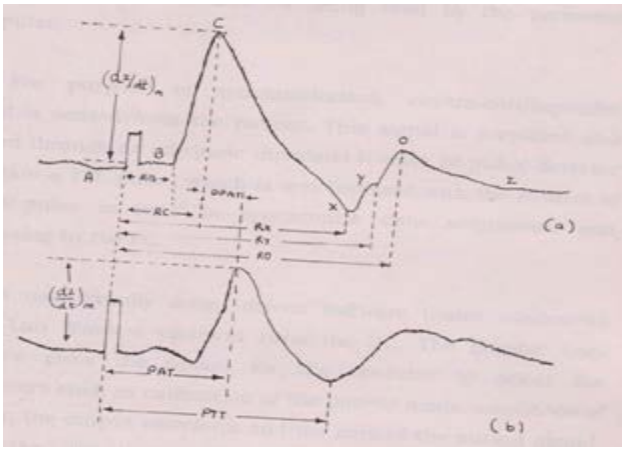

Fig 2.2 Measurements on IPG waveforms

5. Conclusion:

The amplitude of dZ/dt waveform depends on blood flow index in the body segment and also on the basal impedance value of the segment being diagnosed. The value of basal impedance had taken in to consideration while performing the diagnosis. In contrast to this the amplitude NdZ/dt waveform is independent of the basal impedance value and is directly related to blood flow index in the limb segment. The clinicians can thus give the diagnosis just by visual inspectio0n of the waveforms. The ICVG system linked with PC in Lab view software environment which can measure central and peripheral blood flow very accurately and hence power quality of the ICVG is improved.

6. References:

1. Jindal GD, Babu JP, Calibration of dZ/dt in impedance plethesmography. Md. BioEngg. & Comput.23,279.
2. Partulkar G.B., Padamshree R.B., bapat r.D., Rege R.V., Bhagtani K.C., Jindal G.D. and S.K. Kataria : An introduction to Impedance Cardiovasograph, A new electrical Impedance plethesmograph, Observation in arterial occlusive. J. Postgraduate . med. 27, pp.66-72
3. Nyboer J., Bagno S., Barnett A. and Halsey R.H.: Radio cardiograms- the electrical impedance changes of the heart in relation to electrocardiograms and hearts sounds, J. clin, Invest.
4. Ms. Geeta Kadam & Prof.P.C.Bhaskar ," Reduction of power line interference in ECG signal using FIR filter", IJCER ,Vol. 2 , pp. 314-319, 2012.
5. Rahul Dev,"Different Techniques to Remove Baseline Wander from ECG Signal : A Review", proc. VSRDIJEECE, Vol. 2 (7), pp.532-537,2012.
6. Mithilesh Singh, Dr. A.S. Zadgaonkar, Power Quality Measurement by Artificial Neural Network *International Journal Of Computational Engineering Research (ijceronline.com) Vol. 2 Issue. 6.*
7. Naik G.R., Kumar, D.K., Palaniswami M., 2008. "Multi run ICA and surface EMG based signal processing system for recognising hand gestures," *Computer and Information Technology, 2008. CIT 2008. 8th IEEE International Conference* on, pp. 700 – 705.