International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878 (Online), Volume-8 Issue-2, July 2019

Integrated Simulation of Pacemaker and Heart Model with VISSIM

Nitika Khurana, Ritula Thakur

Abstract: The heart is a muscular pump whose pumping action is controlled by an electrical conduction system. The disturbance in conduction may results in inefficient pumping of blood. To maintain the conduction in rhythm the device known as pacemaker can be used to deliver electrical impulses to heart. The number of heart patients has pacemaker implantation every year. While patient have implanted with pacemaker it is necessary that pacemaker should provide therapy according to the need of patient. But, there may be problems in coordination while patient's use pacemaker leading to delivery of inefficient pulses needed for heart contractions. In this paper, a simulation tool is proposed aiming to achieve synchronization of heart and pacemaker on basis of heart's timing properties which help patient adaption to pacemaker. Electrocardiogram is used as input diagnostic signal for evaluation of heart. An integrated simulation of pacemaker and heart model using VISSIM software is proposed for synchronization and optimization of the pacing pulses of pacemaker to check the adaptation of pacemaker by patient.

Index Terms**: *Electrocardiogram, Heart, Integration, Optimization, Pacemaker, Pacing threshold, Simulation, VISSIM.***

I. INTRODUCTION

The pacemaker is a device that assists the heart and maintains its rhythm regularity and periodicity by generating electrical impulses. Patient specific pacemaker functioning leads to accurate rhythm therapy delivery to heart. To synchronize the pacemaker system with heart condition of patient is analyzed by monitoring the Electrocardiogram and based on its extracted featured intervals the pacemaker adjust its timers and delivers pulses. This coordination of pacemaker with heart is necessary to achieve optimal rhythm therapy.

Revised Manuscript Received on 30 July 2019.
* Correspondence Author
NitikaKhurana*, M-Tech Department of Electrical Engineering NITTTR, Panjab University.
Dr. Ritula Thakur, Assistant Professor Department of Electrical engineering National Institute of Technical TeachersTraining and Research, Chandigarh, India.

A. Cardiac Conduction system

The cardiac action potential arises from a group of specialized cells, the sinoatrial node. This action potential passes further to nodal cells and Purkinje cells that keep the synchronization of the atria and the ventricle leading to contraction of myocardium.

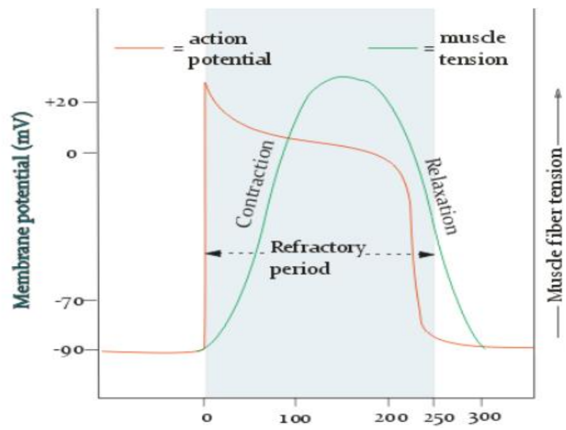

Fig.1.the Action potential leading to muscle contraction

B. Electrocardiogram

It is a vital rhythmically repeating bio-signal synchronized by the function of heart represented by P, QRS &T waves. The shape, polarity and timing of the signal can be used to evaluate heart functions. ECG features are used in development of pacemaker controller algorithm.

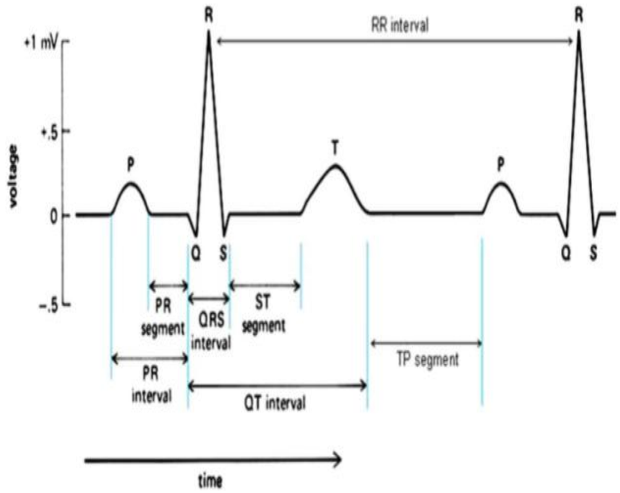

Fig.2. Electrocardiogram with Intervals shown

Retrieval Number: B2044078219/19©BEIESP
DOI: 10.35940/ijrte.B2044.078219
Journal Website: www.ijrte.org

Published By:
Blue Eyes Intelligence Engineering & Sciences Publication

C. Heart Rate Determination

Heart rate is defined as the number of contractions of the heart muscle per minute. Heart rate is calculated with R-R interval where:

Heart rate =60 / R-R interval value.

R-R interval represents one cardiac cycle. The normal R-R interval range is from 0.6 to 1.2 sec. The heart rate need to be in proper range for efficient pumping.

D. Pacemaker and its Issues

A pacemaker is an electronic device used to regulate heart rate when it is not maintained naturally by SA node in bradycardia patients. It monitors intrinsic EMG of heart with electrodes placed on heart muscle to check if heart is beating too slowly or pause too long between beats and generate pulses for contraction of heart.

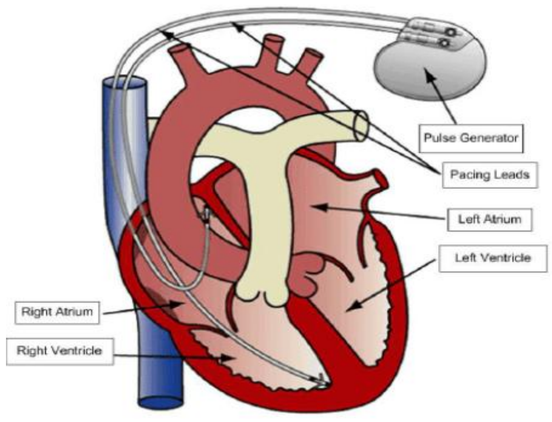

Fig.3. showing Pacemaker leads connected to Heart

E. Pacing Therapy

The pacing therapy is said to be correct if it can maintain the regularity and periodicity of heart rhythm and ensure heart contractions. So, the pacemaker must be able to monitor heart rate and pacing threshold and delivering optimal output pulse sufficient to contract heart muscle. The timing control unit of pacemaker manages the correct pacing functioning.

II. LITERATURE REVIEW

ECG features extraction algorithm and pacemaker modeling and interaction between two is demonstrated by various approaches. In paper [1] the QRS complex detection from ECG signal is described for determination of R-R interval and other features describing the heart behavior. In paper [2], pacemaker and heart model verification is demonstrated emphasizing on closed loop interaction of heart with pacemaker based on timing properties of heart. In paper [3], an algorithm to analyze the ECG signals is developed for use in delivering pulses during electro-poration based treatment. Further, paper [4] presented a model of pacemaker with rate adaptive feature using ECG's QT interval eliminating the need of rate sensors. The paper [5] presented an approach of automatically detecting and adapting features like rate response, mode switching and AV interval by pacemaker with presented algorithm. The paper [6]-[11] presented an algorithm for evaluation of pacemaker therapy and functional testing of pacemaker software. This study is helpful in development of the proposed integrated simulation.

III. PROPOSED SYSTEM

Aim of this paper is to develop an integrated simulation of heart and pacemaker model using VISSIM software to synchronize and optimize the pacemaker pacing function. A pacemaker system must be able to regulate heart rate and adjust its output pacing pulse according to patient's need. The project aims to develop a simulated system by integrating heart and pacemaker model to improve adaption of pacemaker with patient. The proposed system consists of heart model and pacemaker model developed with VISSIM software which is a visual block diagram language for simulation of dynamic system and model based design of embedded systems in less time with easy visual blocks instead of hard mathematical equations. The integrated model synchronizes pacemaker timers with ECG intervals to optimize pacing function of pacemaker.

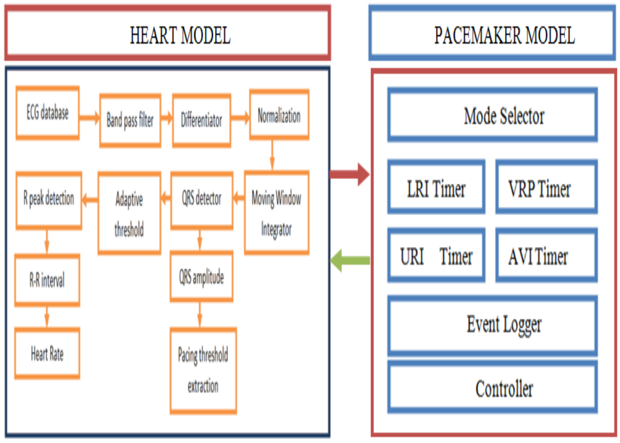

Fig.4.the Block Diagram of Integrated Heart and Pacemker model

IV. METHODOLOGY

A. Algorithm of development of Proposed System

In order to develop the proposed system the methodology is as follows:

1) ECG of arrhythmia patients from MIT/BIH database is utilized and real time monitoring is done in simulation environment of VISSIM for a user-defined duration.
2) Implementing Pan and Tompkins algorithm QRS complex of ECG is detected and features like R-R interval, QRS amplitude and Heart Rate are extracted.
3) The pacemaker model is developed with timed automaton in simple VVI mode with its appropriate timers.
4) The controller of pacemaker model compares the detected ECG intervals with programmed intervals and modifies timers of pacemaker.
5) The strength-duration curve is used to optimize the duration of output pulse corresponding to pacing threshold changes.

Retrieval Number: B2044078219/19©BEIESP
DOI: 10.35940/ijrte.B2044.078219
Journal Website: www.ijrte.org

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

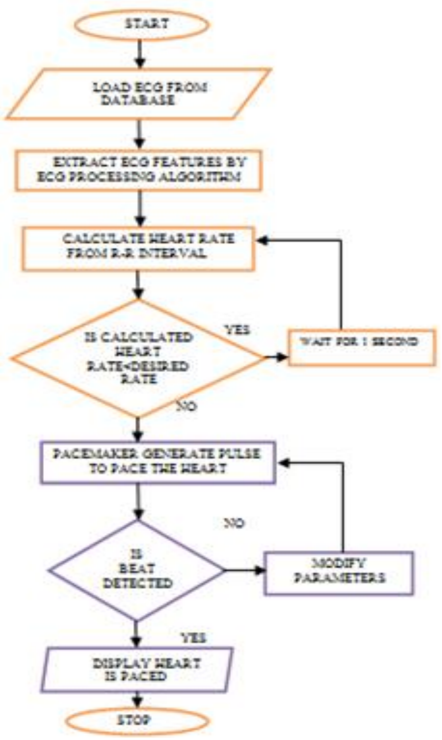

Fig.5.the Flow Chart of systematic development of proposed System

B. Software Implementation in VISSIM

The Integrated model is developed in VISSIM software an intuitive graphical environment for model-based embedded development in which diagrams are automatically converted to highly-optimized and compact code. The heart and pacemaker model is developed. Figure below is showing front screen of developed model:

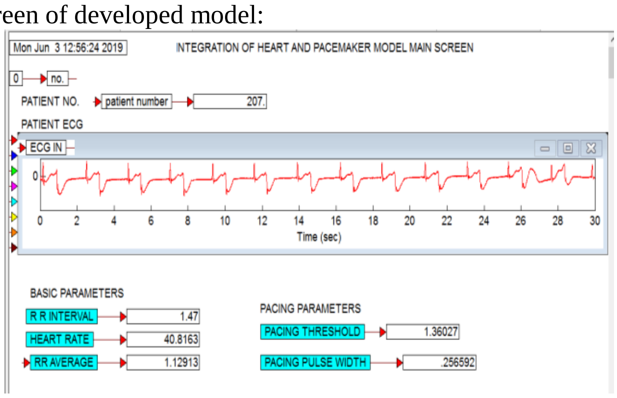

Fig.6.the Front Screen of Integrated System in VISSIM

C. ECG Processing Module

The ECG processing module of heart model is developed with Pan and Tompkins algorithm which detects QRS complex of given ECG and further determines the R-R interval, heart rate and other features. The figure below shows implementation of ECG processing module in VISSIM:

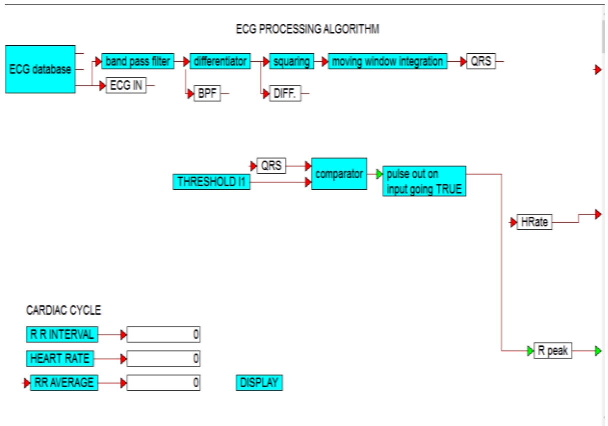

Fig.7. the ECG Processing Module implemented in VISSIM

D. Heart Beat Profile

The heart contraction and expansion is there with every heart beat. The figure below shows implementation of heart beat profile algorithm in VISSIM:

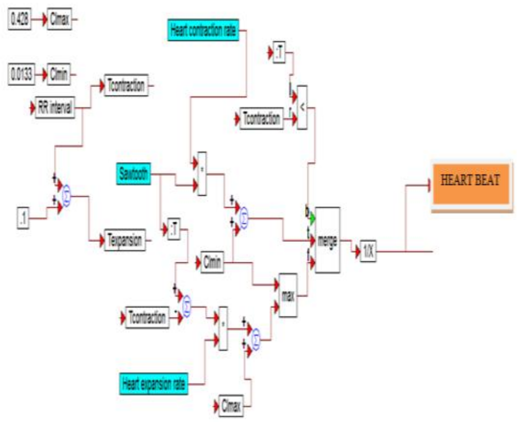

Fig.8.the Heart Beat Profie Implemented in VISSIM

E. Integrated Pacemaker and Heart Model

The heart model and pacemaker model developed in VISSIM and Integrated by sensing and pacing signals with controller algorithm.The contractions of heart muscle is shown by color transitions of LED.

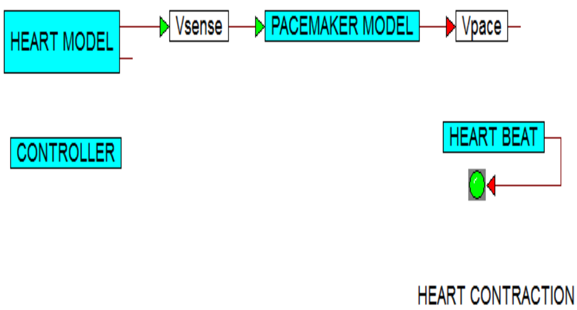

Fig.9. the Integrated Heart and Pacemaker Model Implemented in VISSIM

F. Pacing Threshold determination

Pacing width is determined using strength duration Curve based on the formula:

$A = a + (b/PW)$

A represents pacing amplitude (V),
PW represents pacing pulse width (ms) and
a,b are empirically determined constants

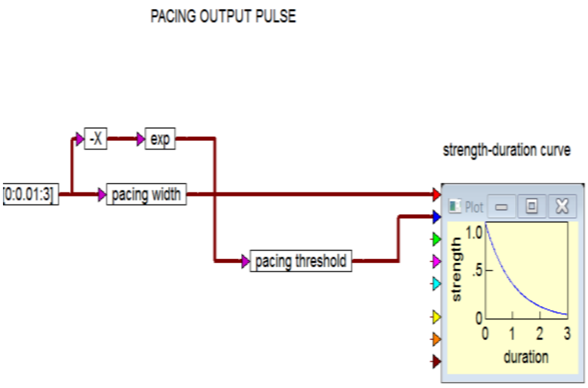

Fig.10. the Pacing Width Detection according to Pacing Threshold

V. RESULTS

To optimize operation of pacemaker a model of the heart model uses ECG of patients from MIT/BIH database having recordings of annotated ECG with a sampling rate of 360-Hz and 11-bit resolution over a 10-mV range. The pacemaker according to the algorithm based on Timed Automaton interacts with heart timing properties extracted from ECG utilizing well known Pan and Tompkins algorithm. Extracted feature of ECG helps in determining heart timing behavior. Timed automata formalism is used in pacemaker modeling because timing behaviors of heart can be captured by timed automata. The verification of pacemaker model is done with detected pacing pulse on ECG. The patient database no. 207 is analyzed below.

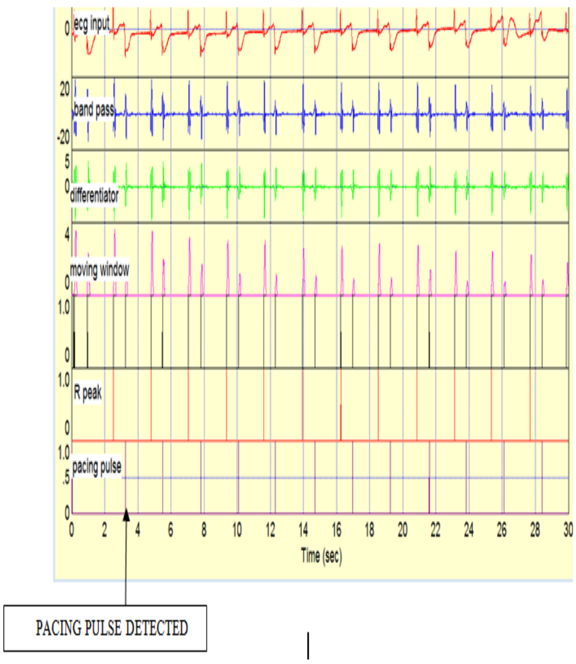

Fig.11. the Display Screen Showing a Patient ECG Analysis

VI. CONCLUSION

An integrated simulation of pacemaker and heart model using VISSIM software is developed providing a common environment for realistic simulation of human heart with pacemaker. It provides low cost solution and improves critical decision making ability allowing the user to analyze the function of pacemaker and adaptation to patient needs. The ECG evaluation and the pacing capture are analyzed visually. The patient's ECG signal synchronizes the timers of pacemaker and pacing width is determined effectively to optimize rhythm therapy making pacemaker more adaptable to patient's heart.

ACKNOWLEDGEMENT

The authors are deeply appreciative for the support provided by National Institute of Technical Teachers' Training and Research, Chandīgarh.

REFERENCES

1. Jiapu Pan Willis and J. Tompkins, "A Real-Time QRS Detection Algorithm", IEEE Transactions on Biomedical Engineering, Vol. BME-32, No. 3, March 1985.
2. Z. Jiang, M. Pajic, S. Moarref, R. Alur, and R. Mangharam, "Modeling and verification of a dual chamber implantable pacemaker," in Tools and Algorithms for the Construction and Analysis of Systems,Springer,2012, pp.188–203.
3. Zhihao Jiang and Rahul Mangharam, "Modeling Cardiac Pacemaker Malfunctions with the Virtual Heart Model",33rd Annual International Conference of the IEEE, 2011.
4. MartaKwiatkowska,HarrietLea-Banks,Alexandru Mereacre and Nicola Paoletti, "Formal modelling and validation of rate-adaptive pacemakers", IEEE International Conference on Healthcare Informatics, 2014,pp. 23-28.
5. Tuan, L.A., Zheng, M.C., Tho, "Modeling and Verification of Safety Critical Systems: A Case Study on Pacemaker". Fourth IEEE International Conference on Secure Software Integration and Reliability Improvement, Los Alamitos, 2010, pp. 23–32.
6. Wei Vivien Shi, Timothy N. Chang, and Meng Chu Zhou "Method to Detect Cardiac Abnormalities Based on Electrocardiography and Sinoatrial Pacemaker Model" Proceedings of the 2010 IEEE, International conference on mechatronics and Automation, Xi'an, China August 4-7, 2010.
7. Taolue Chen, Marco Diciolla, Marta Kwiatkowska and Alexandru Mereacre,"Quantitative verification of implantable cardiac pacemakers over hybrid heart models", Information and computation, 2014, pp. 87-101.
8. Biffi, M., Sperzel, J., Martignani, C., Branzi, A., & Boriani, G., "Evolution of pacing for bradycardia:Autocapture", European Heart Journal Supplements, 2007, pp. I23–I32.
9. Zhenqi Huang, Chuchu Fan, Alexandru Mereacre, Sayan Mitra, Marta Kwiatkowska, "Simulation-based Verification of Cardiac Pacemakers with Guaranteed Coverage", IEEE design and Test, Vol.32(5), USA,2010,pp. 27-34
10. T. Chen, M. Diciolla, M.Z. Kwiatkowska and A. Mereacre, "A Simulink hybrid heart model for quantitative verification of cardiac pacemakers," in HS CC,2013,pp. 131–136.
11. Stanislaw Osowski and Tran Hoai Linh, "ECG Beat Recognition Using Fuzzy Hybrid Neural Network",IEEE Transactions on BiomedicalEngineering,2001.

AUTHORS PROFILE

NitikaKhurana, B-Tech in Instrumentation & Control Engineering from Haryana Engineering College, K.U.K university and pursuing M-Tech in Electrical Engineering from NITTTR, Panjab University. Published paper in UGC approved journal.Areas of interest are simulation, LABVIEW,microcontroller programming and fuzzy system.

Dr. Ritula Thakur, received B.E degree in Electrical engineering with Honours, M.E. degree in Power systems with distinction and Ph.D from Panjab University, Chandigarh.Currently, she is working as Assistant Professor at National Institute of Technical TeachersTraining and Research, Chandigarh, India. Dr. Thakur has also worked as Visiting Scholar in Richard Russel Research Laboratory, Athens, USA. Her research interests are in the areas of Embedded systems and Microcontrollers, Electrical Engineering and Information Technology in Agriculture, Quality Analysis and Detection Technology in Food Materials Sensors and Instrumentation, Power Systems, Power Quality,PLC and SCADA, Micro Grid and Smart Grid. She has around 100 papers in variousConferences and Journals.