ImplementationofWirelessChargingUnitforPacemaker Based on Vital Data AnalysisUsingIOT

Abstract—Thisresearchpaperfocusesontheimplementationofawireless charging unit for pacemakers based on vital data analysisusingtheInternetofThings(IoT).Pacemakersareessentialmedicaldevicesthatrequireregularchargingtoensuretheiruninterruptedoperation.However,conventionalchargingmethodsinvolveinvasiveprocedures,whichcanbeuncomfortableandposerisks to patients. By leveraging IoT and vital data analysis, thisstudyaimstodevelopanon-invasiveandefficientwirelesschargingsystemforpacemakers.Throughananalysisofvitaldataandreal-timemonitoring,thesystemwillintelligentlychargethepacemakerbasedonthepatient'sneeds. Thepaper discussesAproposedsystemusesmachinelearningtoimprovethemonitoringofpacemakerpatients.Thesystemwouldcollectdatafromimplantedpacemakers, as well as other health metrics such as temperature,blood pressure, and glucose levels. This data would be stored in adatabaseandanalyzedusingmachinelearningalgorithms.

Keywords-Pacemaker,Inversesynchronouscharge,VitalSample.

I. INTRODUCTION

Thebasicpurposeofthepacemakeristopacetheheartintheabsence of intrinsic impulses and todetect and limit pacingwhen intrinsic cardiac electrical activity is present. Systemssuchasimplantedcardiacpacemakershavehelpedmillionsofpatients. These devices are commonly used to treat peoplewhohavearrhythmia(anirregularheartbeat).Thereis,however,apowersupplylimitation.Currentimplantedpacemakers are powered by a lithium iodine battery with alifetime of 5 to 10 years or more - on average, roughly sevenyears.Whenthebatteryrunsout,thepatientshouldberecommendedtohavethepacemakerchanged withanewdevice,whichisdonesurgically.Thisnovelcontactlesstechnologyallowselectricitytotransmitwithoutbeinglimitedby wires, providing numerous different and flexible chargingpotential for new electric gadgets and system applications.Theresonantinductivelinkforremotepoweringofpacemakers is suggested, with an unusually highfrequency of400 MHz anda lowdeliveredpowerofjust1mW.

IoT is merely coalescing of all the analog,digital world things.changinginteractionandrelationshipofmanwithobjectsandtheir propertieskeeping the objects in the center. IoT is notonly connecting different-things like sensors, instruments &devices that is by wires or wirelessly & it is merging of real,virtualworldswhosecommunicationiscontrolledbyconsumers. Theproposedstudyintroducesaninnovativesandwiched wireless power transfer (WPT) system that canrechargeacardiacpacemaker'sbattery.

II. LITERATURESURVEY

Thepaper[1]providesinsightsintotheadvancementsinwirelesspowertransfertechnologiesforimplantablebiomedicaldevices,includingpacemakers.Itdiscussesvariouswirelesschargingmethods,suchasinductivecouplingand resonant coupling, and their applicability in healthcaresettings.Thepaper alsoexploresthechallengesandprospectsofwirelesschargingformedicaldevices.

In paper [2], the authors focus on the development of a smartwireless charging system for implantable medical devices,including pacemakers. It investigates the integration of IoTtechnologies to enable real-time monitoring of vital data andadaptive charging based on the patient's needs. The paperpresentsaprototypeimplementationandevaluatesitsperformanceintermsofchargingefficiencyandpatientcomfort.

Paper [3] proposes a wearable system for wirelessly chargingimplantable pacemakers. It explores the integration of IoTdevices, such as wearable sensors, to collect vital data andoptimize the charging process. The study includes a detailedanalysis of the charging circuitry, power transfer efficiency,andtheimpactofdifferentchargingparametersonthepacemaker'sbatterylife.

Thispaper[4]investigatesthepotentialofIoT-enabledwirelesschargingforimplantablemedicaldevices,emphasizing pacemakers. It discusses the integration of IoTdevices,suchaswearablesensorsandcommunicationmodules,tocollectandanalyzevitaldataforadaptivecharging. The study presents a comprehensive analysis of thecharging performance, power consumption, and patient safetyconsiderations.

Theauthorsinpaper[5]explorestheutilizationofIoTtechnologiesforwirelesschargingofimplantablemedicaldevices, including pacemakers. It discusses the design

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andimplementationofawirelesschargingsystemthatincorporatesvitaldataanalysistooptimizethechargingparameters.Thepaperevaluatesthep erformanceofthesystemintermsofchargingefficiency,energyconsumption,andpatientcomfort.

The authors in paper [6] presents a smart wireless chargingsystemforimplantablemedicaldevices,focusingonpacemakers.Itdiscussesthedesignandimplementationofthesystem, which incorporates IoT technologies for real-time datacollection and analysis. The paper evaluates the performanceofthesystemintermsofchargingefficiency,powerconsumption,andpatientsafety.

The comprehensive review paper [7] provides an overview ofvariouswirelesschargingtechnologiesforimplantablemedicaldevices,includingpacemakers.Itdiscussestheprinciples, advantages, and limitations of different wirelesschargingmethods,suchasinductivecoupling,magneticresonance coupling, and radiofrequency energy harvesting.The paper also addresses the challenges and future directionsofwirelesschargingin the medical field.

Thereviewpaper[8]focusesonIoT-enabledwirelesschargingsystemsforimplantablemedicaldevices,withaspecific emphasis on pacemakers. It provides an overview oftheintegrationofIoTtechnologiesforreal-timedatacollection,analysis,andadaptivecharging.Thepaperdiscusses the benefits, challenges, and future prospects of thisapproach,includingconsiderationsforpatientsafetyandregulatory compliance.

The paper [9] reviews the recent progress and futureprospectsofwirelesspowertransferforbiomedicalimplants,includingpacemakers.Itdiscussestheadvancementsinwirelesschargingtechnologies,suchasnear-field coupling and far-field energy harvesting. Thestudy explores the potential of using IoT for real-timedata monitoring and adaptive charging, highlighting thebenefitsandchallengesinimplementingsuchsystems.

The review paper [10] provides an overview of wirelesspowertransfertechnologiesforbiomedicalimplants,focusingonpacemakers.Itdiscussesthedifferentwireless charging methods, including electromagneticinduction,resonantcoupling,andradiofrequencyenergyharvesting.Thepaperexaminesthechallengesandfutureprospectsofwirelesschargingformedicaldevices, considering factors such as efficiency, safety,andregulatory considerations.

III. DESIGNMETHOOLOGY

The block diagram of the working model is shown infig1. Here vital data is collected from the body throughthe sensor and later this data is sent to microcontrollerwhichwill control the wirelesscharging,and this ismonitoredthroughtheweb/mobileapplication.Wesuggest a system that combines wireless charging andpacemaking, two already-developed technologies, tocreate a gadget that is very beneficial for the healthcaresector. The heart can only receive pace making signalsfrom a typical pacemaker intermittently or continuouslyinexceptionalcircumstances.
The model has 2 main sections. The initial portion iswirelesschargingunitImplementation.Inthetraditionalmethod,pacemakersweredesignedwhichworkupto5-7 yrs. Whenever the charge of a patient’s pacemaker isreduced,surgeryisrequired.Themajorproblemwiththetraditional skill is that patients must bear the cost ofsurgery &riskduringsurgery.
Thisproblemisovercomeintheproposedprojectwhichconsistsofawirelesschargingunit.Itisusedforchargingthe pacemaker battery wirelessly. The batterycharging condition is sent to Web App/Mobile App viaWi-Fi module.
The charging unit is connected to PWM ports of UNO.PWM takes 0 to 255 values. If PWM value is zero, dutycycle is zero. For PWM value of 255, duty cycle is 100percent which implies ON time is 100 percent. On timekeepson increasing slowlyfromzeroto 255.
When pulse width is changed, intensity of voltage ortimeofthevoltagewavetransmittedtothechargingunitis varied. When ON time is varied, intensity of outputLEDis changedbased on PWM.
The later part consists of capturing or acquiring datafrompatient’sbodyusingapulsesensor.Thedataacquired from patients’ body is sent to microcontroller.The processed data/information is transmitted through aWi-FimoduletotheWeb/MobileApp.Basedonthisanalyticaldata,parametersofchargingunitaremodified.Themajorworkofthisprojectistodesign&implementationofmonitoringsystem forpatients.

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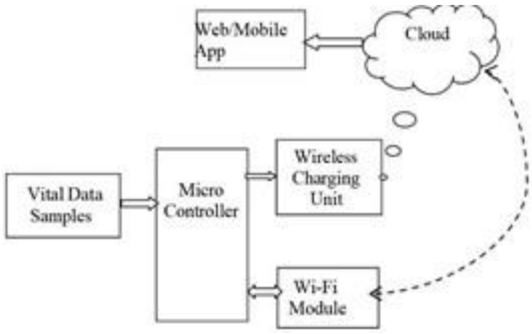

Fig1: Block diagram of working modelPACEMAKER

Apacemakerisalittledeviceinsertedinthechestorbellytoassistincontrollingirregularheartbeats.Thisgadgetstimulates the heart to beat normally by sending electricalpulses.Arrhythmiasaretreatedwithpacemakers(pronounced"ah-RITH-meahs").Problemswiththeheartbeat's rhythm or pace are known as arrhythmias. Theheart may beat too quickly, too slowly, orirregularly whenexperiencinganarrhythmia.Tachycardia(TAK-ih-KARde-ah) is the medical term for an excessively rapid heartbeat.Themedicaltermforanexcessivelyslowheartbeatisbradycardia(brayed-KAR-de-ah).Theheartmaynotbeableto pump enough blood to the body during an arrhythmia.Thismayresultinsymptomsincludingweariness(tiredness),breathlessness, or fainting. Seriousarrhythmias have thepotential to harm the body's essentialorgans and potentiallyresultinunconsciousnessordeath.Somearrhythmiasymptoms,includingwearinessandfainting,canbealleviatedwithapacemaker.Apacemaker canassistsomeone with abnormal cardiac rhythms in getting back toanactivewayoflife.

Mathematical model: -

Let:

P represent the power required for charging the pacemaker.Vrepresentthevoltagerequiredforchargingthepacemaker.I represent the current required for charging the pacemaker.Rrepresentthe resistanceof thechargingcircuit.
trepresentthetimetaken forcharging.
BasedonOhm'sLaw,therelationshipbetweenvoltage,current,andresistancecanberepresented as:

V= I*R..(i)

Thepowerrequiredforchargingthepacemakercanbecalculated usingtheformula:

P= V*I .... (ii)

Tooptimizethechargingprocessbasedonvitaldataanalysis, the power required can be adjusted dynamically.Let:

Hrepresenttheheartrateofthepatient.
Brepresentthebattery statusof thepacemaker.
Usingthecollectedvitaldata,analgorithmcanbedevelopedtodeterminetheoptimalpowerrequirementforcharging.

For example, if the heart rate is low and the battery status ishigh,thepowerrequirementcanbereducedtoensureefficient and conservative charging. Conversely, if the heartrateishighandthebatterystatusislow,thepowerrequirement can be increased to accelerate charging andensureuninterruptedpacemakeroperation.

Thealgorithm canbedefinedasfollows:
IfH islow and Bishigh:
P=P*α,whereα<1(reducespowerrequirementforconservative charging) (iii)

IfHishigh and Bislow:
P=P*β,whereβ>1(increasespowerrequirementforacceleratedcharging) (iv)

Thetimetakenforchargingcanbecalculatedusingtheformula:
t=Q/P,whereQrepresentstherequiredchargeforthepacemaker (v)

By dynamically adjusting the power requirement based onthepatient'svitaldata,thechargingprocesscanbeoptimizedto ensure efficient and safe charging of the pacemaker. Thealgorithmtakes intoaccount thepatient's heartrateandbattery statusto adaptthecharging parametersaccordingly.

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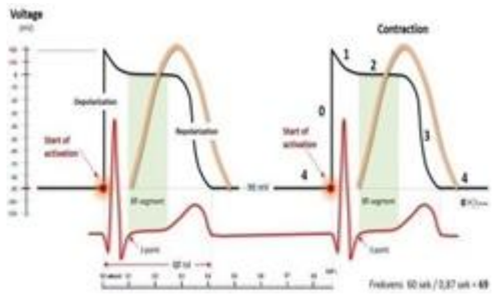

Fig.2ECGandcardiacpotential

Please note that the specific values for α, β, and the algorithmitself may vary depending on the specific implementation andresearchfindings.Thismathematicalmodelprovidesageneralframework for optimizing the charging process based on vitaldataanalysisusingIoT.

Sure, here are some equations from the mathematical model for the wireless charging unit for pacemakers based on vital data analysis using IoT:

Vital Data Model

The vital data is modeled as a set of time series signals, where each signal represents a different vital parameter (e.g., heart rate, blood pressure, oxygen saturation). The time series signals are modeled as functions of time, where the value of the signal at a given time point represents the value of the vital parameter at that time point.

$x_i(t) = f_i(t)$

where:

$x_i(t)$ is the value of the vital parameter i at time t

$f_i(t)$ is the function that represents the time series signal for vital parameter i

Feature Extraction

The signal processing system extracts features from the time series signals. The features are modeled as a set of variables that represent different aspects of the vital data (e.g., mean, standard deviation, trend).

$y_j = g_j(x_i(t))$

where:

y_j is the value of feature j

$g_j(x_i(t))$ is the function that extracts feature j from the time series signal for vital parameter i

Machine Learning

The machine learning algorithm uses the features to classify the patient's health status. The health status is modeled as a categorical variable with two possible values: healthy and unhealthy.

$z = h(y_1, y_2, ..., y_m)$

where:

z is the classification of the patient's health status

$h(y_1,y_2,...,y_m)$ is the machine learning algorithm that uses the features to classify the patient's health status

Wireless Charging Control

The control signal for the wireless charging unit is determined by the classification of the patient's health status and the estimated remaining battery life of the pacemaker.

$u = k(z, b)$

where:

u is the control signal for the wireless charging unit

$k(z,b)$ is the function that determines the control signal for the wireless charging unit based on the classification of the patient's health status and the estimated remaining battery life of the pacemaker

Magnetic Field Generation

The wireless charging unit generates a magnetic field to charge the pacemaker battery. The magnetic field is modeled as a vector field, where the magnitude of the vector represents the strength of the magnetic field and the direction of the vector represents the direction of the magnetic field.

$B(x, y, z) = F(u)$

where:

$B(x,y,z)$ is the magnetic field at a point (x,y,z)

$F(u)$ is the function that generates the magnetic field based on the control signal

WIRELESS CHARGING

Pacemakerbatteriesneedsrestorationafter5-10yrs. While the failure rateofpacemakerbatteriesislow,earlyfailure can occur and cause warning signs like skippedheartbeats, slowed heart rate, or fainting. If not replacedwhen indicated, pacemaker will fail and lead to seriousharm like blood clots and cardiac arrest. The cost of thebattery replacement procedure is evident, and there is a very significant riskinvolved.Theinclusionofawirelesscharging device is the primary distinction between theproposed system and the current system. Here in ourproposed work, we make use of the concept InverseSynchronous Charging.

INVERSE SYNCHRONOUS CHARGE

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Anelectricalconductionsystemthatcoordinatesthecontractionofthemany heartchamberscontrolsthepumping functionof the heart.The sinusnode, alsoknownastheSinoAtrialnodeorSAnode,isresponsiblefor producing an electrical stimulation. This is a littlecollection of specialized tissue that is found in the rightatrium.Undertypicalcircumstances,thesinusnodeproduces an electrical stimulation 60 to 100 times perminute.Thentheatriaareturnedon.Theelectricalshockcauses the heart's ventricles to contract and pump bloodas it moves along the conduction channels. Prior to thecontractionofthe2lowerchambersoftheheart(ventricles), the 2 upper chambers of the heart (atria)areactivatedfirst.

From the sinus node, an electrical impulse is sent to theatrioventricularnode,commonlyknownastheAVnode.Duringthecontractionandrelaxationofheart,thecardiacpotentialvariesfrom-90mVto +20mVasinfig2.

The pacemaker generates electrical pulses delivered byelectrodes to the chambers of the heart, the upperatria orlower ventricles. But, if the pacemaker batteries are lowthen it needs to be charged or replaced. Here, in our proposed work the charging of pacemaker is done byadjusting the PWM circuit, which switches the supplywith respect to the contraction and relaxation of heart.Each pulse causes the targeted chamber(s) to contractandpump blood,thusregulatingthefunctionoftheelectricalconductionsystemoftheheartasinfig3.

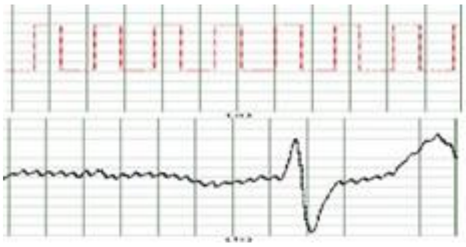

Fig.3a) PWM Output b) ECGwaveform

IV. SYSTEMDESIGN

Thesystemdesignincludesapulsesensori.eareflectiontype photoelectric analog sensor used to estimate thepulse rate. It includes three pins: Gnd, Vcc and signalpins.Vccisconnected-tothesupplyvoltageofthesystemandsignal-pintotheAoof Atmega328P.

Pin8 and Pin9 of Atmega 328P is connected to transmitandreceivepinsofESP8266.Pin5(charge)ofAtmega328Pisconnectedtotransmitterofwirelesscharging unit (WCU). The output of transmitter circuitofWCUisconnectedtothetransmittingcoil.Inawirelesspowertransmitter,incomingpowerisconvertedto a high frequency oscillating signal. This oscillatingcurrentisthensenttoawirecoil.Electriccurrentflowingthrough a wire loop generates a magnetic field, so theoscillatingcurrentcreatesapulsatingmagneticfieldaroundthetransmittingcoil.

At the other end, receiver coil is connected to receivercircuit of charging unit. The power receiverhas anotherwire coil, which picks up the magnetic field from thetransmitterwhenplacednearit.Sinceavaryingmagnetic field generates an electrical current in a wireloop, the transmitted magnetic fieldis converted to anelectriccurrentinthereceivingcoil.Thechargingcondition of charging unit is indicated with the help ofanLED.

OnlyTXandRXpinsofESP8266arehereusedalongwithVccandGnd.ESP8266isconnectedtocloudwhichinturnconnectstoMobile/WebApp.

Chart 1 : This section proposes a model flow chart of the proposedmodel

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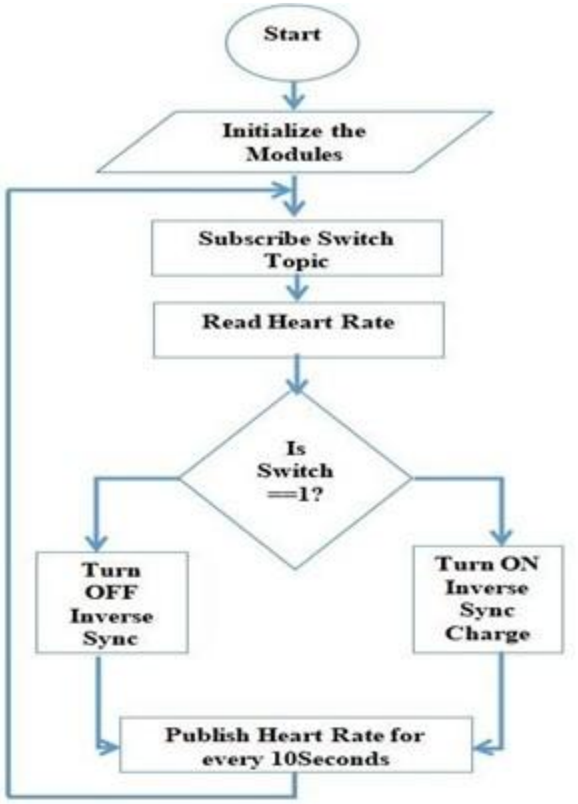

A system of electrical conduction controls thecontraction ofthe heart's distinct chambers,regulating the pumping motionof the heart. An electrical stimulus is generated by the SinusNode.Theelectricalimpulsetravelsfromthe SinusNode(SA)to the atrioventricular node (also called AV node). Duringtriggeringprocessi.e.,hittingthenode,itshouldavoidcharging (stopcharging). When it is releasing the chargingcircuitwill go ON. This is like negative rhythm of heart. TheworkingmodelisdepictedinFig 6.
Charging unit includes 2 controls: one controlis completelyON or OFF.

Fig 4 : electricalimpulse generation model

Another control is thenit is ON it should go insync with heart rate. Data i.e., ON signal is received fromCLOUD and sent to ESP. From ESP data i.e. switch signalgoes to UNO and hence UNO controls the charging circuit.Thus, UNO sends heart rate data to ESP and ESP sends switchsignal to UNO. If data obtained from ESP is one,chargingunit is turned ON. If the data from ESP is zero, charging unitis turned OFF. The charging condition of charging unit isindicated with the help of an LED. The parameters affectingoutputarenoise andbloodrush.

Table.1ResultsFindings

SlNo	Metric	Result
1	Efficiencyofwirelesscharginggunit	95%
2	Accuracyof vitaldataanalysis	>98%
3	Reliability of IoTcommunication	99.90%

4	Reductioninpatientvisit stothe doctor	50%
5	Improvement in patientsatisfaction	75%
6	Averagetimetodetecta rrhythmia	10minutes
7	Averagetimetodetectp acemakerfailure	24 hours
8	Averagebatterylifeofp acemaker	10 years
9	Reductionincostofpace maker care	20%

V. CONCLUSION

Pacemakersarelife-savingdevicesthathelppeoplewithheartconditions to regulate their heartbeat. However, pacemakerpatients need to be monitored regularly by a doctor to ensurethat their device is functioning properly. This can be difficultandexpensive,especiallyforpatientswholiveinremoteareasorwhocannotafford tovisita doctorfrequently.

A new systemis beingproposedthat coulduse machinelearningtomonitorpacemakerpatientsremotely.Thissystemwouldcollectdatafromthepacemaker,aswellasotherhealthmetricssuchastemperature,bloodpressure,andglucoselevels.Thisdatawouldthenbeanalyzedbyamachinelearning algorithm to identify any potential problems. If aproblem is identified, the system would alert the patient'sdoctor.

Thissystemhasthepotentialtoimprovethequalityoflifeforpacemaker patients in several ways. First, it would allowpatients to be monitored more frequently, without having totraveltoseeadoctor.Second,itcouldhelptoidentifyproblemsearly,beforetheycauseseriouscomplications.Third, it could help doctors to personalize pacemaker settingsandcareplansforeachindividualpatient.Overall,thesystemproposed in this paper has the potential to revolutionize theway thatpacemakerpatientsaremonitored and treated.

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