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# EfficientInductionMotorSpeedControlusingZigBeeWirelessTechnology

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## Abstract

**Induction motor speed control plays a significant inindustrialapplications.Theintroductionoftechnologies,likeVFDsandPLCshasgreatlyenhancedtheperformanceofindustrialprocesses.However,astechnologycontinuestoadvance,industries face the challenge of efficiently monitoringand controlling induction motors without incurringsignificantcoststoupgradetheirexistingsystems.**

**This paper focuses on addressing this challenge byproposingacost-effectivesolutionforreal-timemonitoringandcontrolofinductionmotors.Theproposedapproachutilizesawirelessmodule(ZigBee) to establish a connection between a remoteSCADA system and the induction motor. This allowsforconvenientmonitoringofmotorperformanceevenwhileonthemove,usingmobilephones.Furthermore, the solution can be easily implementedinindustriesofanyscaleandwithanytypeof PLC,as PLCs offer advantages over peripheral interfacecontrollers(PICs) duetotheirfewerlimitations.**

***Keywords:PLC,ZIGBEE,SCADA,VFD,MODBUS***

## I. INTRODUCTION

Ensuring the safe-gaurd of induction motors (IMs)incommercialapplicationsisoftheutmostimportance due to their extensive use as actuators.AnewprotectionmethodforIMshasbeenintroduced,leveragingProgrammableLogicControllers(PLCs).Thismethodoffersseveraladvantages,includingtheeliminationoftimers,contactors,relays,andconversioncards.Additionally, it enables the monitoring of voltages,currents,speed,temperature,andanyoccurringissuesinthesystem,withwarningmessagesdisplayed on a computer screen. The utilization ofPLCsnotonlyprovidesasaferandvisualenvironment,butalsooffershigheraccuracy.

Toimplementthistechnique,aVFDisemployedtomeasurethemotor'sparameters,andtheinformation is tanto the SCADA base station usingZigBeetechnology.ByutilizingtheRS485interface with the PLC, it becomes possible to start,stop, and protect the motor against faults such asovercurrent and overheating in windings, as well asunder/overvoltageconditions.TheSCADA system records all received parameter data in a historicaldatabase,enablingreal-timecontrol,monitoring,andprotectionofthe system.

ByincorporatingaVFDasanintermediarybetweentheinductionmotorandthePLC,thesystemachievesefficientandsmoothspeedcontrol,particularlyathigherspeeds.SCADAsystem actively analyses the PLC and manages theoperationoftheinductionmotor.ZigBeetechnology is chosen for wireless communicationdue to its advantages over other options such asGSM, WPANs, and Bluetooth. These advantagesincludelowdatarates,longerbatterylife,andsecurenetworking.

The SCADA system is designed using Intouch 7,while the ladder logic for the PLC is programmedusingWPLSoft2.3.By adoptingthisproposedsolution,industriescaneffectivelymonitorandcontrolinductionmotorsinrealtime,ensuringimproved efficiency and reduced costs without theneed for extensivesystemrefurbishment.

## II. PROGRAMMABLELOGIC CONTROLLER(PLC)

In an industrial setting, a PLC is a system designedtoperformspecificfunctionsbyutilizingprogrammablememory.Thesefunctionsincludelogic operations, sequencing, timing, counting, andarithmetic. The programmable controller interfaceswithmachinesorprocessesthroughdigitalor analog inputsandoutputstofacilitatecontrol.

The programmable controller acts as a computer,wherecontroldevicesprovideincomingcontrolsignals to the unit. These incoming control signalsare referred to as inputs. The inputs interact withinstructionsdefinedintheuserprogram,whichdictates how the programmable controller shouldrespond to the incoming signals. Furthermore, theuserprogramguides the programmable controllerin controlling field devices such as motor starters,pilot lights, and solenoids. An output refers to asignalsentfromtheprogrammablecontrollertocontrolafielddevice.

## III. SUPERVISORYCONTROLAND DATAACQUISITIONSYSTEMS (SCADA)

SCADAisanacronymreferringtoacomputersystem employed to collect and analyse real-timedata. SCADA systems find application in variousindustriesfor monitoring and controlling plants orequipment. These systems gather information, suchas detecting pipeline leaks, and transmit it back to acentralsite,notifyingthehomestationoftheoccurrence.Subsequently,thesystemperformsnecessaryanalysisandcontroltasks,suchasassessingthecriticalityofthleak,whilepresentingtheinformationinalogicalandsystematicmanner.

SCADA systems can range from relatively simpleimplementations,likemonitoringenvironmentalconditionsinasmallofficebuilding,tohighlyintricate setups, such as overseeing the operationsofanuclearpowerplantoramunicipalwater system. The inception of SCADA systems datesbacktothe1960s.

Various computer features fall under the umbrellaof"real-time"technology.Real-timeoperatingsystems, which react quickly to incoming input, areoneexample.Thesesystemsareemployedinsituationswherethecomputermustrespondinstantly to a continuous stream of fresh data, suchasnavigation.Themajorityofgeneral-purposeoperatingsystems,incontrast,maytakeafewseconds or minutes to respond, making them non-real-time.

Additionally, the term "real time" can be used todescribecomputersimulationsthatmimicthespeedat which events happen in the actual world. Forinstance,areal-timeprogrammeingraphicsanimationwouldshowitemsmovingacrossthescreenatthesamespeedastheywouldinreality.

## IV. VARIABLEFREQUECYDRIVE

TheapplicationofVariableFrequencyDrives(VFDs)inHVACsystemshaswitnessedaremarkablesurge,particularlyinrecenttimes.VFDshavebecomewidelyutilizedindiverseHVACcomponents.Gainingacomprehensiveunderstanding of VFDs is crucial for optimizingequipmentselectionandenhancingtheoverallperformanceofHVACsystems.Therefore,theobjective of this paper is to offer a fundamentalcomprehensionofkeyVFDterminology, VFDoperationprinciples,andassociatedbenefits.

## V. VFDOPERATION

Rectifier, DC bus, and inverter are the three maincomponents of a Variable Frequency Drive (VFD),and knowledge of them is crucial to understandingthefundamentalprinciplesunderpinningtheiroperation.Thevoltageofanalternatingcurrent(AC)powersourcehasasinusoidalwaveform,whichmakesitpossibletotransmitsignificantamounts of energy over considerable distances (seeFig.1).Currentflowsinonedirectionwhenthereis a positive voltage, and the opposite is true whenthere isa negative voltage.

Direct current (DC) electricity is created within aVFD by the rectifier, which transforms incomingACpower.Tworectifiersareneededfor eachphase of power, one for positive voltage and theother for negative voltage. Since a minimum of sixrectifiers must be used since the majority of bigpower supply are three-phase, the term "6 pulse" isused to describe a drive with six rectifiers. Multiplerectifier sections, each comprising six rectifiers, areafeatureofVFDsthatenable"12pulse,""18pulse,"or"24pulse"combinations(seeFig.2).Harmonicsectiondiscussedtheadvantagesofmulti-pulseVFDs.

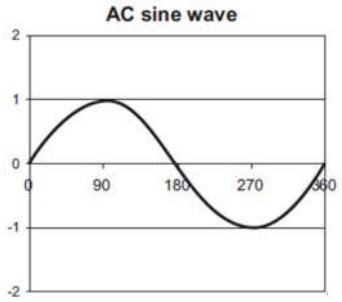



Fig.3.1. ACsine wave

To rectify power, rectifiers might use transistors,SCRs, or diodes. When the voltage has the properpolarity and is applied to a diode, power can flowthrough the device. SCRs are helpful for solid-statestartersbecausetheyhaveagatecircuit thatenablesamicroprocessortocontrolthecommencement of power flow. The most versatileof three devices is provided by transistors thanks totheir gate circuitry. When transistors are used in therectifier part of a VFD, it is said to have a "activefrontend."

After the rectifiers, the energy is stored on a dc busthat has capacitors to take in and hold energy fromthe rectifier section. Inductors, DC links, chokes,and other inductance-introducing devices may beusedonavariablefrequencydrive's (VFD) DCbus. By doing this, the DC bus's incoming powersupplyismademoreuniform.Transistorsthatare

in charge of powering the motor are found in theVFD'sfinalcomponent,the"inverter,"whichisreferredtoassuch.InsulatedGateBipolarTransistors(IGBTs),acommoncomponentincontemporary VFDs, are used. The precise controlof the power supplied to the motor is made possiblebytheseIGBTs'quickswitchingonandoffthousands of times per second. For the purpose ofcreatingasimulatedcurrentsinewaveatthespecified frequency for

Speed(rpm)=Frequency(hertz)x120/Numberofpoles

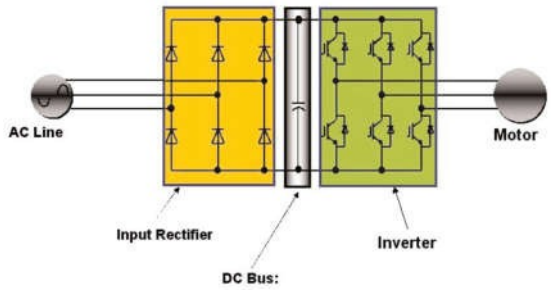



Fig.3.2. VFDbasics:Existingtechnology

## VI. ZIGBEETECHNOLOGY

Althoughtherearemanyhigh-data-rateprotocolsin use today, none of them are compatible with thecommunicationneedsofsensorsandcontroldevices.Evenatmodestbandwidths,thesestandards call for low latency and energy usage.Zigbee technology, a wireless system that is bothaffordable and energy-efficient, stands out for itsremarkablequalitiesandiswell-suitedforanumerousapplicationssuchasindustrialcontrolsystems,embeddedsystems,homeautomationsystem,etc.

ThebasisofZigbeecommunicationistheIEEE 802.15.4standardforwirelesspersonalareanetworks(WPANs),whichisatechnologyspecificallycreatedfor controlandsensornetworks. This communication standard, created bytheZigbeeAlliance,specifiesthephysicalandMAC layers to effectively manage a large numberof low-data-rate devices. The frequencies used byZigbee WPANs are 2.4 GHz, 902-928 MHz, and868Mhz.Itenablesperiodicandtwo-waydatatransmission between sensors and controllers at adata rate of 250 kbps. Widely used in control andmonitoring applications, Zigbee is a low-cost, low-power mesh network that offers coverage over anareaof10to100metres.Zigbeeiseasiertouseand lessexpensivethanothershort-rangewirelesssensornetworkslikeBluetoothandWi-Fi.

Variousnetworkconfigurationsformaster-to-master or master-to-slave communications offeredby Zigbee , enabling battery power conservation. Itcanoperateindifferentmodes,enhancingitsversatility.Byincorporatingrouters,Zigbeenetworks can be extended, allowing multiple nodestointerconnectandcreateawideareanetwork.

Zigbee handles data handling for both periodic andsporadicdatatransmissionatapplication-definedrates, allocating time slots appropriately. Periodicdata is efficiently managed by the beacon system,while intermittent data, such as light switches, canbehandledbyabeaconlesssystemordisconnectedly.Additionally,Zigbeeoffersguaranteedtimeperiods designedexpresslyforapplicationsrequiringlow-latencydata

## VII. PROPERTIESOFZIGBEE TECHNOLOGY

- An easy to follow the approach andit iswidely used.
- Supportsahighdensityofnodespernetwork,allowingforupto18,450,000,000,000,000,000devicesand65,535networks.
- Reducespowerconsumptionandelongatedbattery life.
- Supportsmultiplenetworktopologies
- Forlow latencyapplications, it offers asupplementalguaranteedtimewindow
- Offers a typical range of 50 meters (actualrangecanvaryfrom5to500metersdependingontheenvironment).

## SPEEDOFANINDUCTIONMOTOR

In an induction motor, the rotational frequency(f)andthenumberofpoles(P)onthestatordetermin esthesynchronousspeed(NS)of thestatormagneticfield.Itcanbecalculatedusingthe

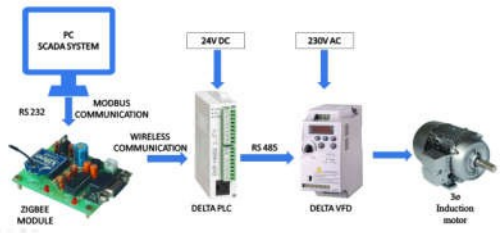
equation**NS=120f/P,**whereNSisexpressedinRPM.

In an induction motor, the rotor's magnetic field,induced by the voltage, is of alternating nature. Inorder to align with the rotating stator flux, the rotorinitiates motion in the same direction as the stator.However,inpracticalscenarios,therotornever manages to completely synchronize with the statorfield.As a result, the rotor rotates at the Base Speed(Nb), which is slower than the stator field.Sliprefers to the variation between NS and Nb. Basedon the load circumstances, slide varies in intensity.An increase in load leads to a decrease in rotorspeedandanincreaseinslip.Incontrast, adecrease in load prompts the rotor to accelerate,which lowersslip.

**RS-485**

RS-485, an EIA standard interface widely utilizedinthedataacquisitiondomain,isaprevalentchoice. It offers a balanced transmission line thatcanbeemployedinMultidropmode,allowingefficientcommunication.RS-485excelsatenablinghigh-speeddatatransmissionoverextendeddistances,evenichallengingreal-worldconditions. It surpasses the capabilities of RS-232bysupportinggreaterbaudratesandlongercommunicationspans.Asperthestandardspecifications, a maximum speed of 100 kbit/s isachievable, with a potential distance coverage of upto 4000feet (1200meters).

**OVERALLDESIGN**

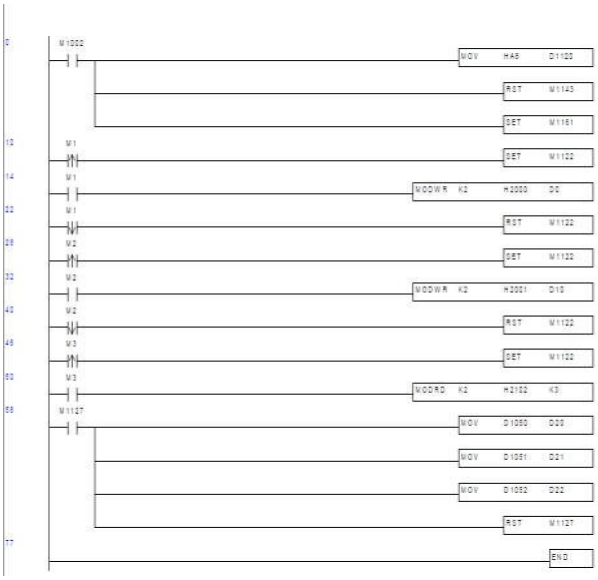



**WORKINGOFTHESYSTEM**

The speed regulation of the IMs is got through theutilizationofVFD.Toestablishcommunicationbetweenthedriveandtheprogrammablelogiccontroller(PLC),anRS-485cableisemployed.This communication method relies on the Modbusdriverforserialdatatransmission.Inaddition, ZigBeetechnologyisemployedtofacilitatecommunication between the SCADA system andPLC,offeringawirelesssolutionthatsurpassesthe limitationsofwiredconnections.Thiswirelesssystem provides real-time capabilities, making it aviableoptionforvariousindustrialapplications.Furthermore,theproposedsystemcanbeseamlessly integrated into existing industrial setupsforenhancedoperationalefficiency.

**HARDWARECONFIGURATION**

**SOFTWARE CONFIGURATIONLADDERLOGICPROGRAMMING**



## VIII. CONCLUSION

This paper presents a comprehensive solution forsmallindustriesseekinganefficientwirelesscontrol andmonitoringsystemforinductionmotors.Theproposedsystemoffersfastandreliable operationwith minimalfaults,providingreal-timedata for efficient decision-making.Theinclusion of a robust database facility ensures easyaccesstohistoricalinformationforfuturereference.Theseamlessintegrationwithprocess

computersforSCADAfurtherenhancesthesystem'sversatilityandusability.Withitslowpowerconsumption andminimalmaintenancerequirements, this wireless control and monitoringsolutionoffersasuccessfulandsustainable approach. By adopting this system, small industriescanoptimizetheiroperations,improveproductivity,andstreamlinetheirprocesseseffectively.

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