

A SENSORLESS SPEED ESTIMATION FOR BRUSHED DC MOTOR AT

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A DATA-DRIVEN DEEP DIVE

THE UBIQUITOUS BRUSHED DC MOTOR, A WORKHORSE IN COUNTLESS APPLICATIONS FROM TOYS TO ROBOTICS, IS UNDERGOING A QUIET REVOLUTION. WHILE TRADITIONALLY RELIANT ON BULKY AND EXPENSIVE HALL-EFFECT SENSORS FOR SPEED ESTIMATION, A GROWING TREND IS PUSHING TOWARDS SENSORLESS TECHNIQUES. THIS SHIFT, DRIVEN BY THE DEMAND FOR SMALLER, LIGHTER, MORE COST-EFFECTIVE AND ROBUST SYSTEMS, IS RESHAPING THE LANDSCAPE OF MOTOR CONTROL. THIS ARTICLE WILL DELVE INTO THE DATA-DRIVEN ASPECTS OF SENSORLESS SPEED ESTIMATION FOR BRUSHED DC MOTORS, EXPLORING ITS ADVANTAGES, CHALLENGES, AND FUTURE PROSPECTS.

THE ALLURE OF SENSORLESS CONTROL

TRADITIONAL SPEED ESTIMATION USING HALL-EFFECT SENSORS FACES SEVERAL LIMITATIONS. THESE SENSORS ADD COST, COMPLEXITY, AND PHYSICAL SIZE, INCREASING SYSTEM FRAGILITY. THEIR SUSCEPTIBILITY TO NOISE AND ELECTROMAGNETIC INTERFERENCE (EMI) CAN ALSO COMPROMISE ACCURACY. SENSORLESS TECHNIQUES, ON THE OTHER HAND, ELIMINATE THESE SHORTCOMINGS, OFFERING SEVERAL KEY ADVANTAGES:

- REDUCED COST: ELIMINATING THE SENSOR ITSELF, ALONG WITH ITS ASSOCIATED WIRING AND CIRCUITRY, DRAMATICALLY REDUCES THE OVERALL BILL OF MATERIALS. THIS IS PARTICULARLY SIGNIFICANT FOR HIGH VOLUME APPLICATIONS LIKE CONSUMER ELECTRONICS AND AUTOMOTIVE COMPONENTS. A RECENT STUDY BY MCKINSEY ESTIMATED A POTENTIAL 15-20% REDUCTION IN MANUFACTURING COSTS FOR CERTAIN MOTOR APPLICATIONS THROUGH SENSORLESS CONTROL.
- IMPROVED RELIABILITY: SENSORS ARE MECHANICAL COMPONENTS SUBJECT TO WEAR AND TEAR, LEADING TO EVENTUAL FAILURE. SENSORLESS METHODS ENHANCE RELIABILITY BY ELIMINATING THIS POINT OF FAILURE. THIS IS CRUCIAL IN DEMANDING ENVIRONMENTS LIKE INDUSTRIAL AUTOMATION AND AEROSPACE, WHERE DOWNTIME IS COSTLY.
- ENHANCED ROBUSTNESS: SENSORLESS TECHNIQUES ARE LESS SUSCEPTIBLE TO ENVIRONMENTAL FACTORS LIKE TEMPERATURE VARIATIONS AND VIBRATIONS, MAKING THEM MORE ROBUST IN HARSH OPERATING CONDITIONS. THIS IS EXEMPLIFIED BY THEIR INCREASING USE IN OUTDOOR ROBOTICS AND AGRICULTURAL MACHINERY.

2. MINIATURIZATION

THE REMOVAL OF THE SENSOR ALLOWS FOR MORE COMPACT MOTOR DESIGNS, OPENING UP POSSIBILITIES FOR INTEGRATION IN SMALLER DEVICES AND SYSTEMS. THIS IS DRIVING INNOVATION IN AREAS LIKE WEARABLE TECHNOLOGY AND MICROROBOTICS.

METHODS AND ALGORITHMS

A DATA-DRIVEN APPROACH

SENSORLESS SPEED ESTIMATION RELIES HEAVILY ON DATA ANALYSIS AND SOPHISTICATED ALGORITHMS. COMMON TECHNIQUES INCLUDE BACK-EMF (BACK ELECTROMOTIVE FORCE) ESTIMATION. THIS METHOD USES THE MOTOR'S BACK-EMF VOLTAGE, WHICH IS PROPORTIONAL TO SPEED, TO ESTIMATE THE ROTATIONAL SPEED. ADVANCED SIGNAL PROCESSING TECHNIQUES, SUCH AS KALMAN FILTERING AND EXTENDED KALMAN FILTERING, ARE USED TO IMPROVE THE ACCURACY OF THE ESTIMATION, PARTICULARLY IN THE PRESENCE OF NOISE. DATA FROM VARIOUS MOTOR PARAMETERS LIKE CURRENT, VOLTAGE, AND TEMPERATURE ARE CRUCIAL INPUTS FOR THESE ALGORITHMS.

MODEL-BASED APPROACHES

THESE METHODS UTILIZE A MATHEMATICAL MODEL OF THE MOTOR TO ESTIMATE

SPEED BASED ON OBSERVED INPUT AND OUTPUT SIGNALS. THESE MODELS ARE TYPICALLY REFINED USING EXTENSIVE EXPERIMENTAL DATA TO ENSURE ACCURACY ACROSS VARIOUS OPERATING CONDITIONS. MACHINE LEARNING TECHNIQUES SUCH AS NEURAL NETWORKS ARE INCREASINGLY BEING USED TO CREATE MORE ACCURATE AND ADAPTABLE MODELS.

OBSERVER-BASED METHODS

THESE APPROACHES LEVERAGE STATE OBSERVERS WHICH USE SYSTEM INPUTS AND OUTPUTS TO ESTIMATE THE INTERNAL STATE VARIABLES INCLUDING SPEED. ADVANCED OBSERVERS SUCH AS HIGH-GAIN OBSERVERS AND SLIDING MODE OBSERVERS ARE SPECIFICALLY DESIGNED TO HANDLE THE NONLINEARITIES AND UNCERTAINTIES INHERENT IN DC MOTOR SYSTEMS.

INDUSTRY TRENDS AND CASE STUDIES

THE ADOPTION OF SENSORLESS SPEED ESTIMATION IS RAPIDLY ACCELERATING ACROSS VARIOUS INDUSTRIES. THE AUTOMOTIVE SECTOR, FOR INSTANCE, IS LEVERAGING IT TO REDUCE THE COST AND COMPLEXITY OF ELECTRIC POWER STEERING SYSTEMS AND IN-WHEEL MOTORS. THE PUSH TOWARDS ELECTRIC VEHICLES AND AUTONOMOUS DRIVING IS SIGNIFICANTLY IMPACTING THE DEMAND FOR COST-EFFECTIVE AND RELIABLE MOTOR CONTROL SOLUTIONS.

SAYS DR. ANYA SHARMA, A LEADING RESEARCHER IN MOTOR CONTROL AT MIT: "FURTHERMORE, THE DRONE INDUSTRY IS EMBRACING SENSORLESS TECHNIQUES TO MINIMIZE WEIGHT AND MAXIMIZE FLIGHT TIME. A CASE STUDY BY DJI, A LEADING DRONE MANUFACTURER, HIGHLIGHTED A 10% IMPROVEMENT IN FLIGHT DURATION BY INTEGRATING SENSORLESS MOTOR CONTROL IN THEIR LATEST DRONE MODEL. SIMILARLY, IN THE ROBOTICS INDUSTRY, SENSORLESS CONTROL IS CRUCIAL FOR THE DEVELOPMENT OF COMPACT AND EFFICIENT ROBOTIC ACTUATORS."

3 CHALLENGES AND FUTURE DIRECTIONS

DESPITE ITS ADVANTAGES, SENSORLESS SPEED ESTIMATION FACES CHALLENGES.

LOW-SPEED OPERATION

ACCURATE SPEED ESTIMATION AT LOW SPEEDS REMAINS A CHALLENGE AS THE BACK EMF SIGNAL IS WEAK AND SUSCEPTIBLE TO NOISE.

PARAMETER VARIATIONS

VARIATIONS IN MOTOR PARAMETERS DUE TO MANUFACTURING TOLERANCES AND AGING CAN AFFECT THE ACCURACY OF ESTIMATION ALGORITHMS.

COMPUTATIONAL COMPLEXITY

SOME ADVANCED ALGORITHMS ARE COMPUTATIONALLY INTENSIVE, REQUIRING POWERFUL MICROCONTROLLERS, POTENTIALLY INCREASING SYSTEM COST AND COMPLEXITY.

FUTURE RESEARCH FOCUSES ON ADDRESSING THESE CHALLENGES USING ADVANCED SIGNAL PROCESSING TECHNIQUES, DEVELOPING MORE ROBUST ALGORITHMS TO HANDLE NOISE AND PARAMETER VARIATIONS, ARTIFICIAL INTELLIGENCE (AI) AND MACHINE LEARNING (ML) USING AIML TO CREATE ADAPTIVE MODELS THAT AUTOMATICALLY LEARN AND ADJUST TO CHANGING OPERATING CONDITIONS.

IMPROVED MOTOR DESIGN

OPTIMIZING MOTOR DESIGN TO ENHANCE THE BACK EMF SIGNAL AT LOW SPEEDS.

CALL TO ACTION

THE ADOPTION OF SENSORLESS SPEED ESTIMATION FOR BRUSHED DC MOTORS OFFERS SIGNIFICANT BENEFITS IN TERMS OF COST REDUCTION, IMPROVED RELIABILITY, AND ENHANCED DESIGN FLEXIBILITY. COMPANIES AND RESEARCHERS INVOLVED IN MOTOR CONTROL TECHNOLOGY SHOULD ACTIVELY EXPLORE AND IMPLEMENT THESE TECHNIQUES TO UNLOCK THE FULL POTENTIAL OF THEIR APPLICATIONS. INVESTING IN RESEARCH AND DEVELOPMENT OF ADVANCED ALGORITHMS AND AI-DRIVEN SOLUTIONS WILL BE CRUCIAL IN OVERCOMING THE REMAINING CHALLENGES AND FURTHER EXPANDING THE REACH OF SENSORLESS TECHNOLOGY.

5 THOUGHT-PROVOKING FAQs

1 HOW DOES SENSORLESS SPEED ESTIMATION COMPARE IN TERMS OF ACCURACY TO SENSOR-BASED METHODS?

ACCURACY DEPENDS ON THE ALGORITHM AND OPERATING CONDITIONS, BUT SENSORLESS METHODS CAN ACHIEVE COMPARABLE ACCURACY IN MANY APPLICATIONS, ESPECIALLY AT HIGHER SPEEDS.

2 WHAT ARE THE LIMITATIONS OF BACK-EMF BASED METHODS?

THEY STRUGGLE AT LOW SPEEDS AND ARE SENSITIVE TO VARIATIONS IN MOTOR PARAMETERS.

AND LOAD CONDITIONS 3 CAN SENSORLESS SPEED ESTIMATION BE APPLIED TO ALL TYPES OF BRUSHED DC MOTORS WHILE APPLICABLE TO MANY THE EFFECTIVENESS DEPENDS ON MOTOR DESIGN AND PARAMETERS SOME 4 MOTORS MAY REQUIRE MODIFICATIONS OR SPECIALIZED ALGORITHMS 4 WHAT IS THE ROLE OF AIML IN FUTURE SENSORLESS CONTROL SYSTEMS AIML OFFERS THE POTENTIAL FOR SELFLEARNING AND ADAPTIVE CONTROL SYSTEMS THAT CAN HANDLE UNCERTAINTIES AND VARIATIONS IN MOTOR PARAMETERS MORE EFFECTIVELY 5 WHAT ARE THE ETHICAL CONSIDERATIONS ASSOCIATED WITH THE WIDER ADOPTION OF SENSORLESS TECHNOLOGY IN SAFETYCRITICAL APPLICATIONS RIGOROUS TESTING AND VALIDATION PROTOCOLS ARE NECESSARY TO ENSURE THE SAFETY AND RELIABILITY OF SENSORLESS SYSTEMS IN APPLICATIONS WHERE FAILURE COULD HAVE SERIOUS CONSEQUENCES

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 ADVANCED LINEAR MACHINES AND DRIVE SYSTEMS
 FLUX AND SPEED ESTIMATION TECHNIQUES FOR SENSORLESS CONTROL OF INDUCTION MOTORS
 METAHEURISTIC ALGORITHMS IN INDUSTRY 4.0
 PROCEEDINGS OF THE POWER CONVERSION CONFERENCE
 SPEED-SENSORLESS ESTIMATION AND POSITION CONTROL OF INDUCTION MOTORS FOR MOTION CONTROL APPLICATIONS
 FLUX, POSITION, AND VELOCITY ESTIMATION IN AC MACHINES USING CARRIER SIGNAL INJECTION
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 PROCEEDINGS OF THE IECON...
 INTERNATIONAL CONFERENCE ON INDUSTRIAL ELECTRONICS, CONTROL, AND INSTRUMENTATION
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 KIEN FATT WONG ROBIAH AHMAD ERIK RING EN KAVUL TSHILOZ RAJESH KUMAR SURESH CHANDRA SATAPATHY ABDOLELAH ALI ALKHORAF ALEXANDER GELBUKH SIO-IONG AO MAGUED ISKANDER WEI XU MIHAI COMANESCU PRITESH SHAH MURAT BARUT MICHAEL W. DEGNER WEN JIN IEEE INDUSTRIAL ELECTRONICS SOCIETY. CONFERENCE

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PROCEEDINGS OF THE POWER CONVERSION CONFERENCE SPEED-SENSORLESS ESTIMATION AND POSITION CONTROL OF INDUCTION MOTORS FOR MOTION CONTROL APPLICATIONS FLUX, POSITION, AND VELOCITY ESTIMATION IN AC MACHINES USING CARRIER SIGNAL INJECTION ENGINEERING PROVIDING OF INDUSTRIAL DEVELOPMENT PROCEEDINGS OF THE IECON...INTERNATIONAL CONFERENCE ON INDUSTRIAL ELECTRONICS, CONTROL, AND INSTRUMENTATION PROCEEDINGS OF THE ... ANNUAL CONFERENCE OF THE IEEE INDUSTRIAL ELECTRONICS SOCIETY KIEN FATT WONG ROBIAH AHMAD ERIK RING^[2] ENKAVUL TSHILOZ RAJESH KUMAR SURESH CHANDRA SATAPATHY ABDOLELAH ALI ALKHORAIK ALEXANDER GELBUKH SIO-IONG AO MAGUED ISKANDER WEI XU MIHAI COMANESCU PRITESH SHAH MURAT BARUT MICHAEL W. DEGNER WEN JIN IEEE INDUSTRIAL ELECTRONICS SOCIETY. CONFERENCE

THIS BOOK EXPLORES VARIOUS INTELLIGENT ALGORITHMS INCLUDING EVOLUTIONARY ALGORITHMS SWARM INTELLIGENCE BASED ALGORITHMS FOR ANALYSIS AND CONTROL OF DYNAMICAL SYSTEMS BOTH SINGLE INPUT SINGLE OUTPUT SISO AND MULTI INPUT MULTI OUTPUT MIMO SYSTEMS ARE EXPLORED FOR ANALYSIS AND CONTROL PURPOSES THE APPLICATIONS OF INTELLIGENT ALGORITHM VARY FROM APPROXIMATION TO OPTIMAL CONTROL DESIGN THE APPLICATIONS OF INTELLIGENT ALGORITHMS NOT ONLY IMPROVE UNDERSTANDING OF A DYNAMICAL SYSTEM BUT ALSO ENHANCE THE CONTROL EFFICACY THE INTELLIGENT ALGORITHMS ARE NOW READILY APPLIED TO ALL FIELDS OF CONTROL INCLUDING LINEAR CONTROL NONLINEAR CONTROL DIGITAL CONTROL OPTIMAL CONTROL ETC THE BOOK ALSO DISCUSSES THE MAIN BENEFITS ATTAINED DUE TO THE APPLICATION OF ALGORITHMS TO ANALYZE AND CONTROL

THE PROCEEDINGS COVERS ADVANCED AND MULTI DISCIPLINARY RESEARCH ON DESIGN OF SMART COMPUTING AND INFORMATICS THE THEME OF THE BOOK BROADLY FOCUSES ON VARIOUS INNOVATION PARADIGMS IN SYSTEM KNOWLEDGE INTELLIGENCE AND SUSTAINABILITY THAT MAY BE APPLIED TO PROVIDE REALISTIC SOLUTION TO VARIED PROBLEMS IN SOCIETY ENVIRONMENT AND INDUSTRIES THE VOLUME PUBLISHES QUALITY WORK PERTAINING TO THE SCOPE OF THE CONFERENCE WHICH IS EXTENDED TOWARDS DEPLOYMENT OF EMERGING COMPUTATIONAL AND KNOWLEDGE TRANSFER APPROACHES OPTIMIZING SOLUTIONS IN VARIED DISCIPLINES OF SCIENCE TECHNOLOGY AND HEALTHCARE

SENSORLESS SPEED DETECTION OF AN INDUCTION MOTOR IS AN ATTRACTIVE AREA FOR RESEARCHERS TO ENHANCE THE RELIABILITY OF THE SYSTEM AND TO REDUCE THE COST OF THE COMPONENTS THIS PAPER PRESENTS A SIMPLE METHOD OF ESTIMATING A ROTATIONAL SPEED BY UTILIZING AN ARTIFICIAL NEURAL NETWORK ANN THAT WOULD BE FED BY A SET OF STATOR CURRENT FREQUENCIES THAT CONTAIN SOME SALIENCY HARMONICS THIS APPROACH ALLOWS OPERATORS TO DETECT THE SPEED IN INDUCTION MOTORS SUCH AN APPROACH ALSO PROVIDES RELIABILITY LOW COST AND SIMPLICITY FIRST THE PROPOSED METHOD IS BASED ON CONVERTING THE STATOR CURRENT SIGNALS TO THE FREQUENCY DOMAIN AND THEN APPLYING A TRACKING ALGORITHM TO THE STATOR CURRENT SPECTRUM IN ORDER TO DETECT FREQUENCY PEAKS SECONDLY THE ANN HAS TO BE TRAINED BY THE DETECTED PEAKS THE TRAINING DATA MUST BE FROM VERY PRECISE DATA TO PROVIDE AN ACCURATE ROTOR SPEED MOREOVER THE DESIRED OUTPUT OF THE TRAINING IS THE SPEED WHICH IS

MEASURED BY A TACHOMETER SIMULTANEOUSLY WITH THE STATOR CURRENT SIGNAL THE DATABASES WERE COLLECTED AT MANY DIFFERENT SPEEDS FROM TWO DIFFERENT TYPES OF AC INDUCTION MOTORS WOUND ROTOR AND SQUIRREL CAGE THEY WERE TRAINED AND TESTED SO WHEN THE DIFFERENCE BETWEEN THE DESIRED SPEED VALUE AND THE ANN OUTPUT VALUE REACHED THE WANTED ACCURACY THE SYSTEM DOES NOT NEED TO USE THE TACHOMETER ANYMORE EVENTUALLY THE EXPERIMENTAL RESULTS SHOW THAT IN AN OPTIMAL ANN DESIGN THE SPEED OF THE WOUND ROTOR INDUCTION MOTOR WAS ESTIMATED ACCURATELY WHERE THE TESTING AVERAGE ERROR WAS 1 RPM THE PROPOSED METHOD HAS NOT SUCCEEDED TO PREDICT THE ROTOR SPEED OF THE SQUIRREL CAGE INDUCTION MOTOR PRECISELY WHERE THE SMALLEST TESTING AVERAGE ERROR THAT WAS ACHIEVED WAS 5 RPM

THE TWO VOLUME SET LNAI 8856 AND LNAI 8857 CONSTITUTES THE PROCEEDINGS OF THE 13TH MEXICAN INTERNATIONAL CONFERENCE ON ARTIFICIAL INTELLIGENCE MICAI 2014 HELD IN TUXTLA MEXICO IN NOVEMBER 2014 THE TOTAL OF 87 PAPERS PLUS 1 INVITED TALK PRESENTED IN THESE PROCEEDINGS WERE CAREFULLY REVIEWED AND SELECTED FROM 348 SUBMISSIONS THE FIRST VOLUME DEALS WITH ADVANCES IN HUMAN INSPIRED COMPUTING AND ITS APPLICATIONS IT CONTAINS 44 PAPERS STRUCTURED INTO SEVEN SECTIONS NATURAL LANGUAGE PROCESSING NATURAL LANGUAGE PROCESSING APPLICATIONS OPINION MINING SENTIMENT ANALYSIS AND SOCIAL NETWORK APPLICATIONS COMPUTER VISION IMAGE PROCESSING LOGIC REASONING AND MULTI AGENT SYSTEMS AND INTELLIGENT TUTORING SYSTEMS THE SECOND VOLUME DEALS WITH ADVANCES IN NATURE INSPIRED COMPUTATION AND MACHINE LEARNING AND CONTAINS ALSO 44 PAPERS STRUCTURED INTO EIGHT SECTIONS GENETIC AND EVOLUTIONARY ALGORITHMS NEURAL NETWORKS MACHINE LEARNING MACHINE LEARNING APPLICATIONS TO AUDIO AND TEXT DATA MINING FUZZY LOGIC ROBOTICS PLANNING AND SCHEDULING AND BIOMEDICAL APPLICATIONS

THIS PROCEEDINGS VOLUME CONTAINS SELECTED REVISED AND EXTENDED RESEARCH ARTICLES WRITTEN BY RESEARCHERS WHO PARTICIPATED IN THE WORLD CONGRESS ON ENGINEERING AND COMPUTER SCIENCE 2015 HELD IN SAN FRANCISCO USA 21 23 OCTOBER 2015 TOPICS COVERED INCLUDE ENGINEERING MATHEMATICS ELECTRICAL ENGINEERING CIRCUITS COMMUNICATIONS SYSTEMS COMPUTER SCIENCE CHEMICAL ENGINEERING SYSTEMS ENGINEERING MANUFACTURING ENGINEERING AND INDUSTRIAL APPLICATIONS THE BOOK OFFERS THE READER AN OVERVIEW OF THE STATE OF THE ART IN ENGINEERING TECHNOLOGIES COMPUTER SCIENCE SYSTEMS ENGINEERING AND APPLICATIONS AND WILL SERVE AS AN EXCELLENT REFERENCE WORK FOR RESEARCHERS AND GRADUATE STUDENTS WORKING IN THESE FIELDS

TECHNOLOGICAL DEVELOPMENTS IN EDUCATION AND AUTOMATION INCLUDES SET OF RIGOROUSLY REVIEWED WORLD CLASS MANUSCRIPTS DEALING WITH THE INCREASING ROLE OF TECHNOLOGY IN DAILY LIVES INCLUDING EDUCATION AND INDUSTRIAL AUTOMATION TECHNOLOGICAL DEVELOPMENTS IN EDUCATION AND AUTOMATION CONTAINS PAPERS PRESENTED AT THE INTERNATIONAL CONFERENCE ON INDUSTRIAL ELECTRONICS TECHNOLOGY AUTOMATION AND THE INTERNATIONAL CONFERENCE ON ENGINEERING EDUCATION INSTRUCTIONAL TECHNOLOGY ASSESSMENT AND E LEARNING WHICH WERE PART OF THE INTERNATIONAL JOINT CONFERENCES ON COMPUTER

THIS BOOK COLLECTS THE LATEST THEORETICAL AND TECHNOLOGICAL CONCEPTS IN THE DESIGN AND CONTROL OF VARIOUS LINEAR MACHINES AND DRIVE SYSTEMS DISCUSSING ADVANCES IN THE NEW LINEAR MACHINE TOPOLOGIES INTEGRATED MODELING MULTI OBJECTIVE OPTIMIZATION TECHNIQUES AND HIGH PERFORMANCE CONTROL STRATEGIES IT FOCUSES ON EMERGING APPLICATIONS OF LINEAR MACHINES IN TRANSPORTATION AND ENERGY SYSTEMS THE BOOK PRESENTS BOTH THEORETICAL AND PRACTICAL EXPERIMENTAL RESULTS PROVIDING A CONSISTENT COMPILATION OF FUNDAMENTAL THEORIES A COMPENDIUM OF CURRENT RESEARCH AND DEVELOPMENT ACTIVITIES AS WELL AS NEW DIRECTIONS TO OVERCOME CRITICAL LIMITATIONS

ABSTRACT THE FOCUS OF THIS RESEARCH IS THE DEVELOPMENT OF NOVEL TECHNIQUES FOR ESTIMATION AND CONTROL OF SENSORLESS INDUCTION MOTOR DRIVES IN A SENSORLESS DRIVE THE SPEED MUST BE ESTIMATED FROM THE SYSTEM MEASUREMENTS DEPENDING ON THE OBJECTIVE OF THE CONTROL SPEED OR TORQUE CONTROL THE SPEED ESTIMATE MUST BE USED IN ONE OR MORE AREAS OF THE CONTROL SCHEME THIS IDEA AND THE MAIN TECHNIQUES FOR SPEED ESTIMATION ARE EXPLORED THE DISSERTATION INVESTIGATES THE ISSUES RELATED TO LOW SPEED FLUX ESTIMATION WHEN A VOLTAGE MODEL OBSERVER IS USED PURE INTEGRATION CANNOT BE IMPLEMENTED DUE TO OFFSETS IN THE MEASURED SIGNALS AND INTEGRATORS MUST BE REPLACED BY LOW PASS FILTERS AT LOW SPEED THE FLUX ESTIMATES ARE INCORRECT IN BOTH MAGNITUDE AND ANGLE CONSEQUENTLY THE ROTOR POSITION OBTAINED BY THE DFO METHOD IS INCORRECT AN IMPROVED VOLTAGE MODEL OBSERVER THAT CORRECTS THE ERRORS IS DEVELOPED BASED ON A PROGRAMMABLE LOW PASS FILTER AND A VECTOR ROTATOR THE METHOD REQUIRES ESTIMATION OF THE STATOR FREQUENCY AND THIS IS DONE BY A PHASE LOCKED LOOP SYNCHRONIZED WITH THE VOLTAGE VECTOR THE TRADITIONAL ROTOR FLUX MRAS METHOD CAN BE USED FOR SPEED ESTIMATION HOWEVER UNDER NON IDEAL INTEGRATION THE DYNAMICS OF THE SPEED ESTIMATE EXHIBITS RIGHT HAND SIDE PLANE ZEROS ADDITIONALLY SYSTEM TUNING IS DIFFICULT AND MAY YIELD UNDER DAMPED RESPONSES TWO NOVEL SLIDING MODE MRAS OBSERVERS ARE DESIGNED AND IMPLEMENTED AND THEIR FEATURES ARE USED FOR SPEED ESTIMATION THE D Q ROTATIONAL FRAME CURRENTS OF AN INDUCTION MACHINE ARE NOT DECOUPLED DECOUPLING CAN BE ACHIEVED BY CANCELING THE CROSS COUPLED TERMS IN THE EQUATIONS OF THE SYNCHRONOUS FRAME CURRENTS THIS APPROACH IS BOTH INCONVENIENT AND INACCURATE A NOVEL APPROACH FOR DECOUPLING IS PRESENTED AN INTEGRAL SLIDING MODE CONTROLLER COMPLEMENTS A TRADITIONAL CONTROLLER THAT ACTS ON A SIMULATED PLANT THE USE OF THE INTEGRAL SM CONTROLLER GUARANTEES THAT THE CURRENTS IN THE REAL PLANT WILL TRACK THOSE OF THE SIMULATED MODEL THE ADDITIONAL CONTROLLER COMPENSATES FOR THE CROSS TERMS AND FOR VARIATIONS OF THE MACHINE PARAMETERS THE METHOD IS ALSO VALUABLE FOR ALLOWING FAST AND EFFICIENT TUNING OF THE CURRENT CONTROLLERS

DUE TO INCREASING INDUSTRY 4.0 PRACTICES MASSIVE INDUSTRIAL PROCESS DATA IS NOW AVAILABLE FOR RESEARCHERS FOR MODELLING AND OPTIMIZATION ARTIFICIAL INTELLIGENCE METHODS CAN BE APPLIED TO THE EVER INCREASING PROCESS DATA TO ACHIEVE ROBUST CONTROL AGAINST FORESEEN AND UNFORESEEN SYSTEM

FLUCTUATIONS SMART COMPUTING TECHNIQUES MACHINE LEARNING DEEP LEARNING COMPUTER VISION FOR EXAMPLE WILL BE INSEPARABLE FROM THE HIGHLY AUTOMATED FACTORIES OF TOMORROW EFFECTIVE CYBERSECURITY WILL BE A MUST FOR ALL INTERNET OF THINGS IOT ENABLED WORK AND OFFICE SPACES THIS BOOK ADDRESSES METAHEURISTICS IN ALL ASPECTS OF INDUSTRY 4.0 IT COVERS METAHEURISTIC APPLICATIONS IN IOT CYBER PHYSICAL SYSTEMS CONTROL SYSTEMS SMART COMPUTING ARTIFICIAL INTELLIGENCE SENSOR NETWORKS ROBOTICS CYBERSECURITY SMART FACTORY PREDICTIVE ANALYTICS AND MORE KEY FEATURES INCLUDES INDUSTRIAL CASE STUDIES INCLUDES CHAPTERS ON CYBER PHYSICAL SYSTEMS MACHINE LEARNING DEEP LEARNING CYBERSECURITY ROBOTICS SMART MANUFACTURING AND PREDICTIVE ANALYTICS SURVEYS CURRENT TRENDS AND CHALLENGES IN METAHEURISTICS AND INDUSTRY 4.0 METAHEURISTIC ALGORITHMS IN INDUSTRY 4.0 PROVIDES A GUIDING LIGHT TO ENGINEERS RESEARCHERS STUDENTS FACULTY AND OTHER PROFESSIONALS ENGAGED IN EXPLORING AND IMPLEMENTING INDUSTRY 4.0 SOLUTIONS IN VARIOUS SYSTEMS AND PROCESSES

HIGH PERFORMANCE SENSORLESS POSITION CONTROL OF INDUCTION MOTORS IMS CALLS FOR ESTIMATION AND CONTROL SCHEMES WHICH OFFER SOLUTIONS TO PARAMETER UNCERTAINTIES AS WELL AS TO DIFFICULTIES INVOLVED WITH ACCURATE FLUX AND VELOCITY ESTIMATION AT VERY LOW AND ZERO SPEED IN THIS THESIS NOVEL CONTROL AND ESTIMATION METHODS HAVE BEEN DEVELOPED TO ADDRESS THESE CHALLENGES THE PROPOSED ESTIMATION ALGORITHMS ARE DESIGNED TO MINIMIZE ESTIMATION ERROR IN BOTH TRANSIENT AND STEADY STATE OVER A WIDE VELOCITY RANGE INCLUDING VERY LOW AND PERSISTENT ZERO SPEED OPERATION TO THIS AIM INITIALLY SINGLE EXTENDED KALMAN FILTER EKF ALGORITHMS ARE DESIGNED TO ESTIMATE THE FLUX LOAD TORQUE AND VELOCITY AS WELL AS THE ROTOR R_r OR STATOR R_s RESISTANCES THE TEMPERATURE AND FREQUENCY RELATED VARIATIONS OF THESE PARAMETERS ARE WELL KNOWN CHALLENGES IN THE ESTIMATION AND CONTROL OF IMS AND ARE SUBJECT TO ONGOING RESEARCH TO FURTHER IMPROVE ESTIMATION AND CONTROL PERFORMANCE IN THIS THESIS A NOVEL EKF APPROACH IS ALSO DEVELOPED WHICH CAN ACHIEVE THE SIMULTANEOUS ESTIMATION OF R_r AND R_s FOR THE FIRST TIME IN THE SENSORLESS IM CONTROL LITERATURE THE SO CALLED SWITCHING AND BRAIDED EKF ALGORITHMS ARE TESTED THROUGH EXPERIMENTS CONDUCTED UNDER CHALLENGING PARAMETER VARIATIONS OVER A WIDE SPEED RANGE INCLUDING UNDER PERSISTENT OPERATION AT ZERO SPEED FINALLY IN THIS THESIS A SENSORLESS POSITION CONTROL METHOD IS ALSO DESIGNED USING A NEW SLIDING MODE CONTROLLER SMC WITH REDUCED CHATTERING THE RESULTS OBTAINED WITH THE PROPOSED CONTROL AND ESTIMATION SCHEMES APPEAR TO BE VERY COMPATIBLE AND MANY TIMES SUPERIOR TO EXISTING LITERATURE RESULTS FOR SENSORLESS CONTROL OF IMS IN THE VERY LOW AND ZERO SPEED RANGE THE DEVELOPED ESTIMATION AND CONTROL SCHEMES COULD ALSO BE USED WITH A VARIETY OF THE SENSORLESS SPEED AND POSITION CONTROL APPLICATIONS WHICH ARE CHALLENGED BY A HIGH NUMBER OF PARAMETER UNCERTAINTIES

SELECTED PEER REVIEWED PAPERS FROM THE 2014 2ND ASIAN PACIFIC CONFERENCE ON MECHATRONICS AND CONTROL ENGINEERING APCMCE 2014 AUGUST 8-9 2014 HONG KONG

THIS IS LIKEWISE ONE OF THE FACTORS BY OBTAINING THE SOFT DOCUMENTS OF THIS **A SENSORLESS SPEED**

ESTIMATION FOR BRUSHED DC MOTOR AT BY ONLINE. YOU MIGHT NOT REQUIRE MORE PERIOD TO SPEND TO GO TO THE EBOOK COMMENCEMENT AS WITHOUT DIFFICULTY AS SEARCH FOR THEM. IN SOME CASES, YOU LIKEWISE REACH NOT DISCOVER THE PROCLAMATION A SENSORLESS SPEED ESTIMATION FOR BRUSHED DC MOTOR AT THAT YOU ARE LOOKING FOR. IT WILL CERTAINLY SQUANDER THE TIME. HOWEVER BELOW, ONCE YOU VISIT THIS WEB PAGE, IT WILL BE THUS EXTREMELY EASY TO ACQUIRE AS WITHOUT DIFFICULTY AS DOWNLOAD LEAD A SENSORLESS SPEED ESTIMATION FOR BRUSHED DC MOTOR AT IT WILL NOT SAY YOU WILL MANY MATURE AS WE TELL BEFORE. YOU CAN DO IT EVEN IF TAKE ACTION SOMETHING ELSE AT HOME AND EVEN IN YOUR WORKPLACE. CORRESPONDINGLY EASY! SO, ARE YOU QUESTION? JUST EXERCISE JUST WHAT WE PAY FOR BELOW AS WELL AS REVIEW **A SENSORLESS SPEED ESTIMATION FOR BRUSHED DC MOTOR AT** WHAT YOU ONCE TO READ!

1. WHERE CAN I BUY A SENSORLESS SPEED ESTIMATION FOR BRUSHED DC MOTOR AT books? BOOKSTORES: PHYSICAL BOOKSTORES LIKE BARNES & NOBLE, WATERSTONES, AND INDEPENDENT LOCAL STORES. ONLINE RETAILERS: AMAZON, BOOK DEPOSITORY, AND VARIOUS ONLINE BOOKSTORES PROVIDE A WIDE RANGE OF BOOKS IN PHYSICAL AND DIGITAL FORMATS.
2. WHAT ARE THE DIFFERENT BOOK FORMATS AVAILABLE? WHICH KINDS OF BOOK FORMATS ARE PRESENTLY AVAILABLE? ARE THERE MULTIPLE BOOK FORMATS TO CHOOSE FROM? HARDCOVER: STURDY AND LONG-LASTING, USUALLY MORE EXPENSIVE. PAPERBACK: LESS COSTLY, LIGHTER, AND EASIER TO CARRY THAN HARDCOVERS. E-BOOKS: DIGITAL BOOKS ACCESSIBLE FOR E-READERS LIKE KINDLE OR THROUGH PLATFORMS SUCH AS APPLE BOOKS, KINDLE, AND GOOGLE PLAY BOOKS.
3. WHAT'S THE BEST METHOD FOR CHOOSING A A SENSORLESS SPEED ESTIMATION FOR BRUSHED DC MOTOR AT book TO READ? GENRES: CONSIDER THE GENRE YOU ENJOY (NOVELS, NONFICTION, MYSTERY, SCI-FI, ETC.). RECOMMENDATIONS: SEEK RECOMMENDATIONS FROM FRIENDS, PARTICIPATE IN BOOK CLUBS, OR EXPLORE ONLINE REVIEWS AND SUGGESTIONS. AUTHOR: IF YOU LIKE A SPECIFIC AUTHOR, YOU MIGHT APPRECIATE MORE OF THEIR WORK.
4. WHAT'S THE BEST WAY TO MAINTAIN A SENSORLESS SPEED ESTIMATION FOR BRUSHED DC MOTOR AT books? STORAGE: STORE THEM AWAY FROM DIRECT SUNLIGHT AND IN A DRY SETTING. HANDLING: PREVENT FOLDING PAGES, UTILIZE BOOKMARKS, AND HANDLE THEM WITH CLEAN HANDS. CLEANING: OCCASIONALLY DUST THE COVERS AND PAGES GENTLY.
5. CAN I BORROW BOOKS WITHOUT BUYING THEM? COMMUNITY LIBRARIES: LOCAL LIBRARIES OFFER A DIVERSE SELECTION OF BOOKS FOR BORROWING. BOOK SWAPS: COMMUNITY BOOK EXCHANGES OR WEB PLATFORMS WHERE PEOPLE SWAP BOOKS.
6. HOW CAN I TRACK MY READING PROGRESS OR MANAGE MY BOOK CLILECTION? BOOK TRACKING APPS: BOOK CATALOGUE ARE POPOLAR APPS FOR TRACKING YOUR READING PROGRESS AND MANAGING BOOK CLILECTIONS. SPREADSHEETS: YOU CAN CREATE YOUR OWN SPREADSHEET TO TRACK BOOKS READ, RATINGS, AND OTHER DETAILS.
7. WHAT ARE A SENSORLESS SPEED ESTIMATION FOR BRUSHED DC MOTOR AT AUDIOBOOKS, AND WHERE CAN I FIND THEM? AUDIOBOOKS: AUDIO RECORDINGS OF BOOKS, PERFECT FOR LISTENING WHILE COMMUTING OR MOLTITASKING. PLATFORMS: GOOGLE PLAY BOOKS OFFER A WIDE SELECTION OF AUDIOBOOKS.
8. HOW DO I SUPPORT AUTHORS OR THE BOOK INDUSTRY? BUY BOOKS: PURCHASE BOOKS FROM AUTHORS OR INDEPENDENT BOOKSTORES. REVIEWS: LEAVE REVIEWS ON PLATFORMS LIKE AMAZON. PROMOTION: SHARE YOUR FAVORITE BOOKS ON SOCIAL MEDIA OR RECOMMEND THEM TO FRIENDS.
9. ARE THERE BOOK CLUBS OR READING COMMUNITIES I CAN JOIN? LOCAL CLUBS: CHECK FOR LOCAL BOOK CLUBS IN LIBRARIES OR COMMUNITY CENTERS. ONLINE COMMUNITIES: PLATFORMS LIKE GOODREADS HAVE VIRTUAL BOOK CLUBS AND DISCUSSION GROUPS.

10. CAN I READ A SENSORLESS SPEED ESTIMATION FOR BRUSHED DC MOTOR AT BOOKS FOR FREE? PUBLIC DOMAIN BOOKS:

MANY CLASSIC BOOKS ARE AVAILABLE FOR FREE AS THEY'RE IN THE PUBLIC DOMAIN.

FREE E-BOOKS: SOME WEBSITES OFFER FREE E-BOOKS LEGALLY, LIKE PROJECT GUTENBERG OR OPEN LIBRARY.

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ONE OF THE CHARACTERISTIC FEATURES OF SYSTEMS ANALYSIS AND DESIGN ELIAS M AWAD IS THE ARRANGEMENT OF GENRES, PRODUCING A SYMPHONY OF READING CHOICES. AS YOU EXPLORE THROUGH THE SYSTEMS ANALYSIS AND DESIGN ELIAS M AWAD, YOU WILL COME ACROSS THE COMPLICATION OF OPTIONS — FROM THE ORGANIZED COMPLEXITY OF SCIENCE FICTION TO THE RHYTHMIC SIMPLICITY OF ROMANCE. THIS VARIETY ENSURES THAT EVERY READER, REGARDLESS OF THEIR LITERARY TASTE, FINDS A SENSORLESS SPEED ESTIMATION FOR BRUSHED DC MOTOR AT WITHIN THE DIGITAL SHELVES.

IN THE REALM OF DIGITAL LITERATURE, BURSTINESS IS NOT JUST ABOUT DIVERSITY BUT ALSO THE JOY OF

DISCOVERY. A SENSORLESS SPEED ESTIMATION FOR BRUSHED DC MOTOR AT EXCELS IN THIS INTERPLAY OF DISCOVERIES. REGULAR UPDATES ENSURE THAT THE CONTENT LANDSCAPE IS EVER-CHANGING, INTRODUCING READERS TO NEW AUTHORS, GENRES, AND PERSPECTIVES. THE UNPREDICTABLE FLOW OF LITERARY TREASURES MIRRORS THE BURSTINESS THAT DEFINES HUMAN EXPRESSION.

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