CHAPTER 51

TECHNOLOGY
INSTRUMENTATION AND CONTROL
ENGINEERING

Doctoral Theses

01. ANJU PRABHA
Biomedical Signal Processing Using Soft Computing Tools.
Supervisors: Prof. Jyoti Yadav Prof. Vijander Singh
Th 25800

Abstract

The main objective of this work is to develop automated disease detection systems using efficient biomedical signal analysis tools that are more convenient and accessible to the general population. Using different features of a signal can eliminate the need for multiple signals to make diagnostic decision. Sleep apnea (SA), diabetes mellitus (DM) and depression are some of the diseases that often go undiagnosed due to the inconvenience, unavailability or unaffordability of the diagnostic system. This work focuses on automating the diagnosis of these diseases. An automated SA detection system is developed using the single-channel abdomen respiratory effort signal (Abd RES). Different feature sets of Abd RES are used with multiclass support vector machine and random forest classifiers to compare their performance. An improved random forest classifier is proposed to deal with the imbalance in the input dataset and get better classification results with the reduced feature set obtained by principal component analysis. A non-invasive DM detection system based on wristband photoplethysmography (PPG) signal and basic physiological parameters (PhyP) is proposed. The novel Mel frequency cepstral coefficients extracted from the 5 s PPG signal segments and PhyP are used as input to the machine learning (ML) classifiers. A hybrid feature selection method is proposed to reduce the input data size. Since regular monitoring of blood glucose levels (BGL) is essential for DM patients, an automated BGL monitoring system with ML regression model is developed using the same feature set. A study on depression during coronavirus disease-2019 (COVID-19) in the education sector is conducted to develop a novel stroop test (ST) based depression detection system. The difference in response time before and after showing a video stimulus in ST and emotional ST along with PhyP are used. The proposed system can serve as an instant screening tool for depression.

Contents

02. JITENDRA KUMAR

Performance Analysis of Intelligent Adaptive Controllers for Nonlinear and Time-Varying Systems.

Supervisors: Prof. Vineet Kumar and Prof. K.P.S. Rana

Th 25797

Abstract

Adaptive control theory is concerned with changing the behavior of nonlinear, uncertain, and time-varying complex systems to achieve goals like maintaining desired outputs of a system around the desired set point and assuring that the states follow specified trajectories. A conventional controller such as proportional-integral-derivative (PID) provides adequate performance for linear and time-invariant systems but fails to perform well for nonlinear and time-varying systems. Many attempts have been made in control engineering to address this complex problem. As a result, intelligent adaptive control techniques have emerged a potential solution. An attempt has been made in this thesis to survey different established classical and intelligent adaptive control techniques. Further, a systematic plan is proposed to carry out the research work and an efficient, intelligent adaptive controller. This thesis examines a fractional order self-tuned fuzzy PID (FOSTFPID) controller to control a highly nonlinear, coupled multi-input, multi-output, three-link rigid robotic manipulator system. The FOSTFPID controller's performance for trajectory tracking, disturbance rejection, noise suppression, and model uncertainty is explored. A comparison of the performances of FOSTFPID, fractional-order fuzzy PID (FOFPID), integer-order self- tuning fuzzy PID (IOSTFPID), and fractional-order fuzzy PD plus fractional-order integrator (FOFPD+FOI) controllers. Gains of all the investigated controllers are tuned for the minimum weighted sum of integral of absolute error using the cuckoo search algorithm (CSA). The study revealed that the FOSTFPID controller offers superior action for trajectory tracking, disturbance rejection, noise suppression, and model uncertainty. Further, the FOSTFPID controller is applied to control a three-link electrically driven rigid robotic manipulator (EDRRM) system The result is compared with PID, fractional-order PID, and FOFPD+FOI controllers for trajectory tracking, disturbance rejection, noise suppression, and model uncertainty. CSA was used to tuned gains of the controllers. The FOSTFPID controller offers the best results among all the explored controllers in the entire study.

Contents

03. MANISH KUMAR

Efficiency Enhancement Techniques for Electric Vehicles.

Supervisors: Prof. Bhavnesh Kumar Prof. Asha Rani

Th 25798

Abstract

Energy efficient battery enabled electric vehicles not only reduce the power demand but also increase the runtime in a single charge. Various methods are proposed in this work for efficiency enhancement of indirect field-oriented control of induction motor driven electric vehicle. The primary objective is to optimize the induction motor rotor flux, so that maximum efficiency is attained in the facets of parameter and load variations. A robust Fuzzy Logic based flux estimator is proposed for the

appropriate flux estimation. Further an adaptive neuro-fuzzy inference system-based rotor flux estimator is introduced for the electric vehicle. The efficacy of the developed system is studied by analyzing it under varying load conditions. It is revealed from the results that suggested methodology provides an improved efficiency in comparison to constant flux operation. Model reference adaptive system-based estimation of speed and torque is used in loss model to evaluate the loss components corresponding to d-axis and q-axis stator current. The improved efficiency is achieved by making these losses equal. The error between the losses is reduced by optimized PI regulator which provides the most suitable rotor flux of the drive. The salp swarm algorithm-based scheme provides an efficient and robust methodology for induction motor. A loss equalizing rotor flux (LERF) based loss minimization strategy is also proposed for electric vehicle driven by poly-phase induction motor. Furthermore, Grasshopper Optimization Algorithm tuned PI controller is used to obtain the optimal flux level. The strategy is robust, efficient, fast and has smooth flux adaptation with high accuracy. Further constrained minimization is also used for flux estimation, to improve the performance. The suggested fmincon rotor flux estimator-based loss model control strategy outperforms the differential calculus rotor flux and LERF based schemes. The complete analysis reveals that efficient control of flux provides savings in energy for various realistic conditions.

Contents

04. MANISHA
Some Investigation on Solar Hybrid Systems and Applications.
Supervisor: Prof. Prerna Gaur
Th 25803

Abstract

The primary aim of this work is to study the performance of the solar photovoltaic system under different conditions and the key requirement associated with the maximum utilization of solar energy. For the maximum utilization, two problems are considered: estimation of solar potential for selecting the type of solar photovoltaic system and to develop a novel Maximum Power Point Tracking (MPPT) controller for optimal power generation. Also, the integration of Renewable energy Sources (RES) with conventional energy generation units via the electrical grid can lead to new challenges such as safety of supply, base load capacity frequency synchronization, environmental effect and so on. By virtue of the fitful essence of RES the power quality degrades. The estimation of daily Global Solar Radiation (GSR) has been evaluated in this thesis. Diverse empirical models comprising of numerous climatological constraints sunshine hour, temperature, relative humidity was chosen and their applicability was tested for the Baramati region (Maharashtra). The models with multiple parameters regression constants of the developed and proposed model were computed and the performance analysis was evaluated. The comparison among various models was done by using metrics Root Mean Square Error (RMSE), Mean Bias Error (MBE), Mean Percentage Error (MPE), and Correlation Coefficient. Further, in the thesis, generated power from solar PV is regulated closer to its optimal point with variations in irradiance and/or temperature. A novel fuzzy-assisted nonlinear proportional-integral (f-NPI) MPPT controller is proposed for a 100kW grid-connected solar photovoltaic (SPV) system with boost converter topology.

f-PI and novel f-NPI based PV array reference current predictor is implemented to adjust the duty cycle for the converter. The gain parameters of controllers are being fairly tuned using the Teaching-Learning-based Optimization (TLBO) technique. A comprehensive simulation analysis is carried out using MATLAB R2017a, to verify the utilization of primitive parameters i.e. irradiance and temperature in the proposed controller that results in enhanced performance in comparison to extant Perturb and observe (P&O) and Fuzzy Logic Controller (FLC) (using secondary/conventional parameters like voltage and current) in terms of settling time, efficiency and Total Harmonic Distortion (THD). Moreover, the operation of the novel f-NPI based method is studied to comply with IEEE 929 standard. To reform the power quality power converters and system authenticity different configurations of a microgrid are used in conjunction with RES and customized power devices. The basic operation of a microgrid lies in generation and demand. A proper design is required for the reliable operation of the microgrid. In the microgrid, attempt if made to identify new RES as clean sources of energy, converter for power quality enhancement and load to consume the energy. The presence of RES creates new challenges like DC output, variable frequency, or AC output to maintain the stability of the grid. Therefore, suitable architecture and complex control are required to manage the power flow with different micro-sources, load, and grid. Six configurations were defined in the thesis as the architecture of microgrids named as: AC grid, DC grid, Hybrid Grid (AC/DC grid), AC microgrid with DC storage, DC-Zonal microgrid, and Solid-State Transformer (SST) based microgrid. The topologies, advantages and disadvantages of these configurations are discussed in the thesis.

Contents

05. PANJWANI (Bharti)
Design, Analysis and Control of Physiological Systems.
Supervisors: Prof. Vijander Singh and Prof. Asha Rani
Th 25799

Abstract

The present work aspires to design optimal drug schedules for chemotherapeutic treatment of cancer. Advanced numerical tools, artificial intelligence and expert control techniques are utilized to improve the drug delivery in cancer chemotherapy. Chemotherapy employs cyto-toxic drugs for treatment of cancer, that aims to kill abnormally proliferating cells, however, it adversely effects and kills the healthy cells as well. Higher drug concentration in blood causes increased cancer cell killing but at the cost of healthy cells, while lower drug concentration is ineffective and also results in the development of drug resistance. Therefore, optimal drug schedule needs to be designed for balancing the effectiveness and toxic effects of chemotherapeutic drugs. The design of treatment strategy depends upon the dynamics of tumour growth and type of chemotherapy drugs. In this work, mathematical models are used to predict the tumour growth and advanced controllers are employed for successful treatment of cancer. Incorporating fractional calculus and increasing degree of freedom in classical PID controller is utilised for superior PID control action. A cascade control technique is employed wherein individual 2DOF FOPID controllers regulate the drug concentration and toxicity simultaneously, leading to an effective chemotherapy in the presence of uncertainty

and disturbances. Another challenging aspect of the effective chemotherapeutic treatment is to formulate accurate tumour growth under the effect of cell-cycle specific drugs in the presence of resistance. Resistance to chemotherapeutic agents may lead to complete failure of treatment, and therefore, constrained optimal control problem is formulated and solved by non-dominated sorting genetic algorithm-II (NSGA-II). Impact of resistance, cell-cycle specificity of drugs is thoroughly studied and capability of NSGA-II to provide multiple solutions, proves to be highly effective in drug scheduling. Therefore, introduction of advance control techniques in medical sciences may lead to successful chemotherapy by optimisation and automatic regulation of the chemotherapeutic drugs delivered to the patient.

Contents

06. RAWAT (Anuj)
Investigation on Renewable Energy Systems.
Supervisors: Prof. S.K. Jha and Bhavnesh Kumar
Th 25796

Abstract

In the face of rising environmental problems, it is imperative to conduct a thorough inquiry of the primary causes of ecological disruption around the world. According to the Climate Action Tracker (CAT) study, there are 32 major sources of pollution that account for 80% of total Green House Gas emissions. As a result, the world must reduce carbon dioxide emissions by almost 144 million tonnes by 2025 in order to keep global temperatures from rising above 1.5°C. Solar energy, which is one of the most promising source of energy, has grown in popularity as a result of these enormous current global climatic changes. Solar power's benefits of a pollution-free environment, less fuel costs, noiseless power generation, and minimal maintenance costs have raised demand for the sort of eternal energy. Solar energy is now a days widely used in a variety of applications, including solar heating, solar distillation, solar electric power generation, and solar water pumping. Agriculture is one of the most important sources to India's gross domestic product (GDP). In India, agriculture is primarily reliant on irrigation, which consumes more than 75% of total water. This water is pumped using water pumps powered by either gasoline engines or electric motors. Farmers are forced to employ oil-based pumping equipment instead of electric motor pumps due to dwindling and unreliable electric supply. In contrast to oil-based engines which release carbon dioxide, has a negative impact on the environment. Currently, photovoltaic (PV) based pumping systems are the most cost-effective and environment friendly alternatively available irrigation system. It is a highly simple system to operate and maintain, with low operating and maintenance costs. Even though the initial commissioning cost of these systems is significant, but the power generated is mostly affected by variations in insolation level, wind speed, and temperature. The cost of photovoltaic (PV) modules and the efficiency of energy conversion are two limiting variables that have hampered the free use of PV systems. A control arrangement for MPPT system is implemented in this thesis work for the operation of a PV system under fluctuating solar irradiation and load condition, in order to attain the maximum efficiency. Even after implementing the MPPT, the available power from solar cells may be reduced further depending on the climatic and loading conditions. Aside from the energy conversion in the solar cells, the extraction of the converted energy is also holds paramount importance. As

a result, in order to extract the maximum possible power, a control system known as maximum power point tracking (MPPT) is commonly used to keep a PV system running at its best under fluctuating operating conditions. Various MPPT techniques, such as perturb and observe (P&O), constant voltage, fractional open-circuit voltage/short-circuit current, intelligent technique, and incremental conductance technique have been documented in the literature. In this thesis, implementation of feedback based MPPT along with Fractional order Nonlinear PID controller (FONPID) is implemented. This controller is perfectly tuned by Meta heuristic algorithm namely Elitist Teaching learning based optimization ETLBO. PV cell generates more electric power when light beams from the sun get directly incident over it. The incident light over the solar panel keeps on changing throughout the day and all around the year due to rotation of the earth about its own axis and its revolution around the sun in elliptical orbit. Therefore, Sun Tracking System (STS) is used to align the solar panels in the direction of the sun so as to get the direct sun beams incident over it. These types of mechanisms are essential for applications in the field like space vehicles and transportation. In this work, Genetic Algorithm (GA), swarm based algorithms such as Particle Swarm Optimization (PSO), and human based algorithm namely Teaching Learning Based Optimization (TLBO) have been used with PID controller to control the position of STS. Next, application of PV system in the form of Solar Water Pumping System (SWPS) has also been incorporated in this research work. Output of PV water pumping system varies due to changing weather conditions and hence it has to be designed in such a manner that both performance and efficiency would not be affected by varying climate conditions. In order to achieve this performance, control techniques such as MPPT control and Commutation control in motor side has been incorporated in this thesis.

Contents

07. SHARMA (Sachin)
Some Studies on Oscillation Detection Techniques in Process Control Loops.
Supervisors: Prof. Vineet Kumar and K.P.S. Rana
Th 25795

Abstract

Control loop performance monitoring is an essential task for the glitch-free operation of a process plant. It is directly related to the profitability and overall safety of the plant. Oscillations in control loops indicate a bad performing loop and are very common. Process control loops can oscillate due to improperly tuned controllers, inherent nonlinearities in the plant, non-linear final control element (FCE), or harsh environmental conditions. Manual monitoring of control loops is impossible due to the sheer size of a typical process plant with thousands of control loops. It leads to the need for an automatic and efficient oscillation detection and quantification algorithm. This thesis investigates different oscillation detection algorithms based on data modelling techniques and machine learning (ML) approaches. Apart from that, artificial neural network (ANN) based modeling of FCE suffering from non-linearity has also been presented in this thesis work. In data modeling techniques, linear predictive coding (LPC) analysis and PRONY method for designing infinite impulse response filter have been employed to develop the automatic oscillation detection

and quantification algorithm. Simulated oscillatory data was used to assess the performance of both algorithms. In continuation with this, industrial and actual plant data were also used to gauge further the effectiveness of the algorithms for oscillation detection in real case scenarios. Furthermore, a comparative study was also done between both algorithms to identify the superior algorithm for the underlying oscillation detection and quantification task. It was observed and reported that the oscillation detection method utilizing PRONY analysis was more robust and noise-tolerant than the LPC analysis method. Different classifiers such as ANN, deep neural network (DNN), and support vector machines were used in the ML approach for oscillation detection. Denominator polynomial coefficients from the industrial data set acted as the feature vector to train the classifiers. Statistical analysis was used to finalize the number of neurons in hidden layers of ANN and DNN. The effectiveness of classifiers was tested and evaluated with the help of a variety of simulated and actual plant data. Comparative analysis among the classifiers made the DNN the best choice for ML-based oscillation detection. Finally, the ANN-based modeling technique was proposed to model the pneumatic control valves suffering from a stiction kind of non-linearity. The presented modelling technique was evaluated with the help of Choudhury's data-driven stiction model [Choudhury, Thornhill and Shah, 2004; Choudhury, Thornhill and Shah, 2005] and real pneumatic control valve suffering from the stiction kind of non-linearity. Flow rate data from the laboratory-sized flow process plant was used to model the actual pneumatic control valve.

Contents