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Ph.D. Research Proposal

Doctoral Program in "Department Name"

Constructing an Energy Management and Fault Prediction Model for Solar Energy Sources using Hybrid Bi-LSTM with Differential Evolution and J48 Classifiers

by

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<Date of Submission (DD MM 20YY>

I. INTRODUCTION / BACKGROUND

In recent years with the growing demand for energy increasing concerns for environmental pollution and rising oil prices, efforts are being taken by governments around the world, in developed countries, these programs include the integration of renewable resources such as wind, solar, biomass, geothermal and small hydro-electric power. Due to its competitive cost of energy compared to fossil fuel, wind power is proving to be the fastest growing, cost effective and reliable renewable energy source of electricity in the remote areas around the world. It is estimated that the wind could supply 12 percent of the world's electric demand by 2020. In this race, solar energy conversion systems (SECS) have stood ahead of other renewable energy sources like wind energy, which still lags behind owing to high cost per kilowatt-hour (kWh) of electrical power generated. Overall, the contribution of these renewable energy systems to the power system has been increased rapidly from the last two decades.

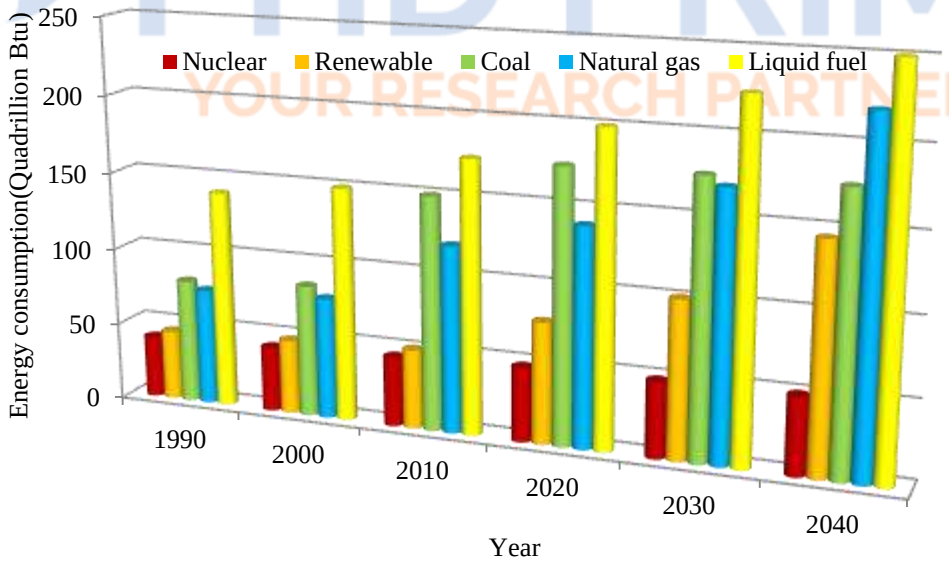


Figure.1. World energy consumption

Figure.1 illustrates the world energy demands projection from history to future. From the figure, we can see that world energy consumption increases rapidly over years. Thus it is necessary to improve the renewable energy sources in order to handle growing energy demands.

1.1 Research Objectives

The main objective of this study is to design the power systems and to improve the performance of power system. For this purpose, we adapted this work in our research work for providing an adaptive control for consumers. Since the renewable energy sources are the major solution for demanding energy requirement, this work improves the solar renewable power system with PV array system.

II. RESEARCH GAPS

2.1 Common Problem Statement

Current research works are majorly relies on either solar energy or wind energy. However, both solar resource is not available at all time (i.e.) availability of the resources varies with change in seasons, environmental changes, and so on. Thus it is necessary to design power generation system. In this research work, we have focused on solar power generation system that integrates solar energy. Combining both resources may be better solution for power generation. However, the combination also brings many challenges. Thus this research work concentrates on adaptive control of solar power generation system.

2.2 Problem Definition

Proposed an integrated energy management framework consisting of an offline optimization model concurrent with a real-time rule based controller. The optimization is performed in receding horizon with load and solar generation forecast profiles using deep learning-based long short term memory method in rolling horizon to reduce the daily electricity purchase costs. The optimization model is formulated as a multistage stochastic program where used the stochastic dual dynamic programming algorithm in the receding horizon to update the optimal set point for BES dispatch at a fixed interval. To prevent loss of energy during optimal

solution update intervals, introduced a rule-based controller underneath the optimization layer in finer time resolution at the power electronics converter control level.

Problems

- Optimum power supply does not maintained in this work and thus LSTM model needs optimization

Proposed Solutions

- Differential evolution is proposed in Bi-LSTM for supporting optimized value prediction from massive volume of data

Authors in [2] utilizes deep two-dimensional (2-D) Convolutional Neural Networks (CNN) to extract features from 2-Dscalograms generated from PV system data in order to effectively detect and classify PV system faults. An in-depth quantitative evaluation of the proposed approach is presented and compared with previous classification methods for PV array faults – both classical machine learning based and deep learning based. Unlike contemporary work, five different faulty cases (including faults in PS – on which no work has been done before in the machine learning domain) have been considered in our study, along with the incorporation of MPPT. We generate a consistent dataset over which to compare ours and previous approaches, to make for the first (to the best of our knowledge) comprehensive and meaningful comparative evaluation of fault diagnosis.

Problems

- Fault accuracy is very low since environmental issues are not concentrated which reduces fault detection accuracy and also leads to misclassification

Proposed Solutions

- Environmental (weather) information is considered which increases fault detection accuracy and also leads to high classification rate.

Active solar trackers are introduced [3] may be a maximization of generating capacity. However, if motors that update the position of the panels use more energy than the efficiency in their use, the system becomes ineffective. In this way, solar forecasting can be used to actively determine the generation capacity and to assess whether position updating is efficient. Among the algorithms that can be used to predict photovoltaic generation, stands out the Long Short-Term Memory (LSTM) which an artificial recurrent neural network architecture used in deep is learning. This technique stands out among the others for having the ability to handle complex problems with high nonlinearity.

Problems

- Optimum power supply does not maintained in this work and thus LSTM model needs optimization

Proposed Solutions

- Differential evolution is proposed in Bi-LSTM for supporting optimized value prediction from massive volume of data

A data-driven anomaly detection and classification solution is proposed [4], which can accurately detect and classify diverse photovoltaic system anomalies. The proposed solution does not require additional equipment or non-SCADA data collection. More specifically, the proposed work consists of two methods: (1) a hierarchical context-aware anomaly detection method using unsupervised learning, and (2) a multimodal anomaly classification method. The proposed solution has been deployed in two large-scale solar farms (39.36 MWp and 21.62 MWp). Multi-month operation demonstrates the effectiveness, robustness, as well as cost- and computation-efficiency of the proposed solution.

Problems

- Data collection is insufficient to predict anomaly
- Computational cost is very high

Proposed Solutions

- Data collection is sufficient and huge in size to predict anomaly
- Computational cost is very low

A comprehensive method for identifying, classifying, locating and correcting faults is introduced. The proposed method is assessed with the expansion of the diagnostic space of graph-based semi-supervised learning (GBSSL) algorithm [5] and an increased number of class labels. After identifying the type and location of a fault, the system temporarily isolates the fault to function without interruption until it is fully corrected. The problem of overlapping cell data in normal and fault-prone modes is resolved by applying different methods of normalization.

Problems

- After identifying the type and location of a fault, the system temporarily isolates the fault to function which decreases load supply for consumers

Proposed Solutions

- Faults are identified as before with the use of future data

III. RESEARCH CONTRIBUTIONS

ENERGY MANAGEMENT AND CONTROL

Features are introduced in the algorithm to avoid over fitting/under fitting and increase the accuracy of the predicted values. For household electricity demand forecasts, the important features such as holiday or working day, month, day of the week, and previous 15 historical data are considered as features. These features help to predict the residents' electricity load patterns. Learning such patterns from the whole-house data with 1min intervals introduces large prediction errors. Therefore, we consider forecasting load at a 15min time interval.

For forecasting, Bi-LSTM method is used, which is one of the RNN structures. In contrast to the standard, RNN is based on a series of repeating modules with relatively simple structure. Although a conventional feed-forward neural network can learn sequences, LSTM is more powerful because it constrains a memory cell in its structure to remember the important

states in the past and has a forget gate to learn to reset the memory cell for the unimportant features during the learning process. To reset the network and optimize the performance, different evolution algorithm is used.

FAULT PREDICTION

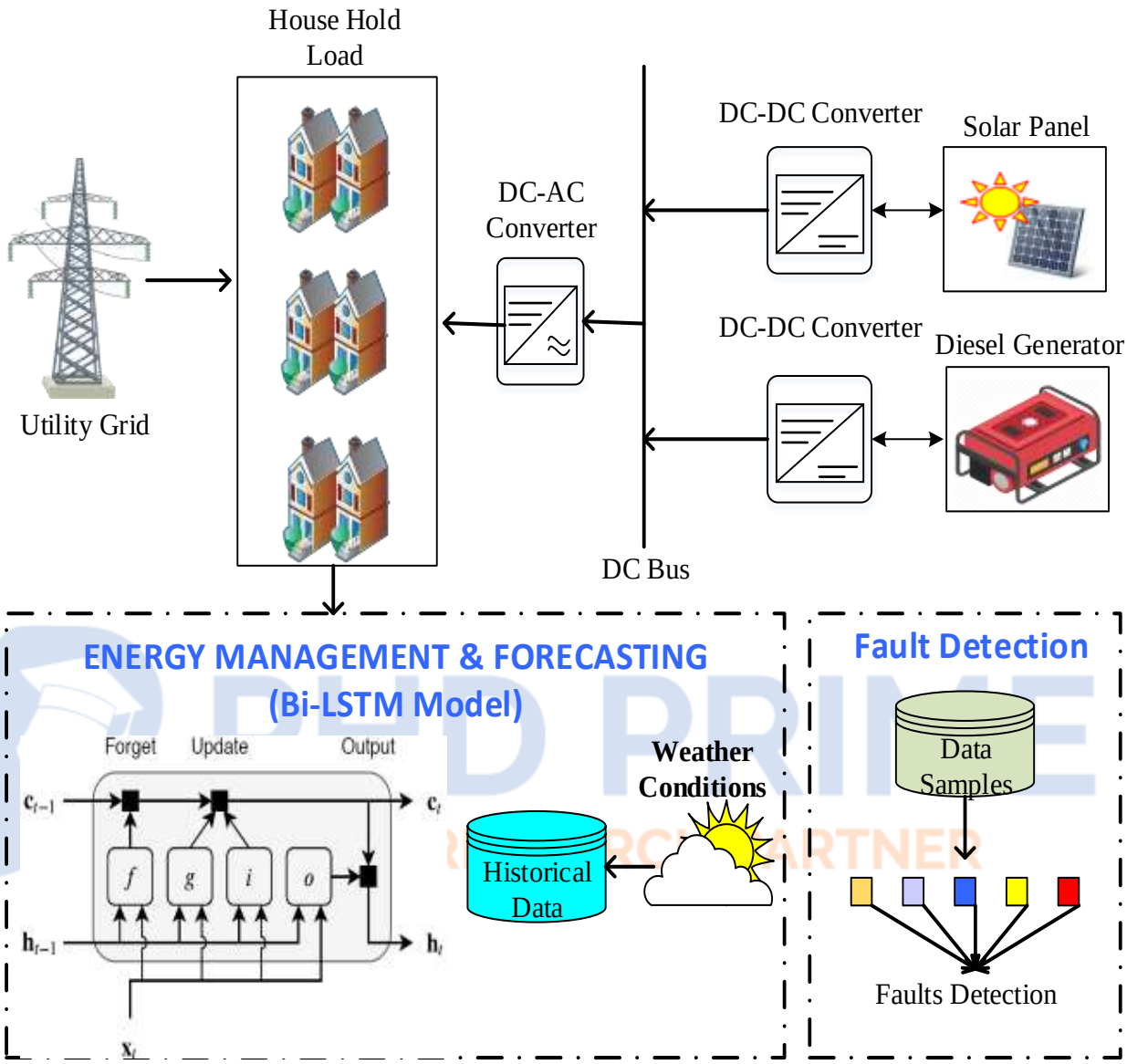
No fault, LL, OC, PS, fault in PS and series arc fault are the six cases considered for the evaluation of proposed method. Data attributes such as irradiance, temperature, short circuit current, open circuit voltage, photovoltaic current, MPP current, MPP voltage and MPP power were the eight values from the PV array output and three values from the boost converter such as maximum current, voltage and power are selected as data samples.

Performance Evaluation

The performance of the model is quantified for diverse parameters such as

- Fault Classification Accuracy
- Execution Time
- Precision and Recall

SYSTEM ARCHITECTURE



IV. PREVIOUS WORKS & LIMITATIONS

Paper 1

Title – Stochastic Modeling and Integration of Plug-In Hybrid Electric Vehicles in Reconfigurable Microgrids with Deep Learning-Based Forecasting

Concept

Network reconfiguration could be employed to change the topology of the network, and help obtain a feasible solution. Also found that the optimal dispatching solutions are varied when considering DRL, compared to conventional assumptions that neglect the DLR constraint to protect power lines. This is mainly due to that when conductors approach their maximum capacity in the islanded MG mode

Paper 2

Title – Residential Demand Forecasting with Solar-Battery Systems: A Survey-Less Approach

Concept

This research applies the Adaptive Boost Regression Tree algorithm as an alternative to traditional methods, such as feed forward neural network (FFANN). The results investigate three case study precincts and show that this algorithm improves over an FFANN in aspects such as peak event estimation and daily variability, achieving an R2 value of 0.86.

Paper 3

Title – MPPT Perturbation Optimization of Photovoltaic Power Systems Based on Solar Irradiance Data Classification

Concept

This study proposes a novel solution to balance the trade-off between performance and cost of the MPPT method. The perturbation step size is determined off-line for a specific location based on the local irradiance data. The support vector machine (SVM) is employed to automatically classify the desert or coastal locations using historical irradiance data. The perturbation step size is optimized for better system performance without increasing the control complexity. Simulations and experiments have been carried out to verify the effectiveness and superiority of the proposed method over existing approaches.

Paper 4

Title – A review on Forecasting of Photovoltaic Power Generation based on Machine Learning and Metaheuristic Techniques

Concept

Among these energy sources, solar energy is a major source of alternative energy that is used to generate electricity through photovoltaic (PV) system. However, the performance of the power generated is highly sensitive on climate and seasonal factors. The unpredictable behaviour of the climate affects the power output and causes an unfavorable impact on the stability, reliability and operation of the grid. Thus an accurate forecasting of PV output is a crucial requirement to ensure the stability and reliability of the grid. This study provides a systematic and critical review on the methods used to forecast PV power output with main focus on the metaheuristic and machine learning methods. Advantages and disadvantages of each method are summarized, based on historical data along with forecasting horizons and input parameters.

Paper 5

Title – Building Energy Management for Demand Response Using Kernel Lifelong Learning

Concept

In this study, DR control policies for lighting and air-conditioner systems for the individual spaces in buildings are proposed. The policies are designed to achieve the energy reduction amount specified in the DR request while minimizing the user discomfort. A significant challenge is to cope with the uncertainty of various environmental factors such as the solar illuminance and ambient temperature, as well as the psycho-economic factors such as the energy usage preferences of the occupants. Our novel idea is to take advantage of the structural similarity of the control policies across the spaces in a lifelong multi-task learning framework

Paper 6

Title – Enhanced Bayesian Based MPPT Controller for PV Systems

Concept

Under dynamic changes, most MPPT techniques fail to rapidly locate the global maximum power point and are stuck at global maxima leading therefore to inconsistent power generation and low system efficiency. In this study we apply Bayesian fusion, a machine learning technique otherwise used for unsupervised classification, curve detection, and image segmentation, in order to achieve global maximum power point tracking in record time.

Paper 7

Title – Multi-Criteria Spatial Decision Making Support system for Renewable Energy Development in Kazakhstan

Concept

The paper covers developed multi-criteria decision-making system (MCDM) and software tools for processing of spatial heterogeneous data which could be applied for evaluation of the RES potential. The developed system serves to evaluate the potential of usable RES as it allows the assessment of a territory of the country in terms of installing photovoltaic and wind generators .A feature of the proposed MCDM is the use of an analytical hierarchical process (AHP) in combination with the Bayesian approach, which allows obtaining two complementary assessments of the territory areas. The method allows a rough estimate in an event of lack of data. The verification performed based on the available data on the installed solar and wind power stations shows that the system gives a relatively small root-mean-square error within 15%.

Paper 8

Title – A Novel Convolutional Neural Network Based Approach for Fault Classification in Photovoltaic Arrays

Concept

This paper presents a novel approach that utilizes deep two-dimensional (2-D) Convolutional Neural Networks (CNN) to extract features from 2-Dscalograms generated from PV system data in order to effectively detect and classify PV system faults. An in-depth

quantitative evaluation of the proposed approach is presented and compared with previous classification methods for PV array faults – both classical machine learning based and deep learning based. Unlike contemporary work, five different faulty cases (including faults in PS – on which no work has been done before in the machine learning domain) have been considered in our study, along with the incorporation of MPPT.

Paper 9

Title – Sample Efficient Home Power Anomaly Detection in Real Time Using Semi-Supervised Learning

Concept

SEPAD consists of two classifiers: an appliance pattern matching classifier (APMC) and an energy consumption habit classifier (ECHC). The APMC uses a single-source separation framework based on a semi-supervised support vector machine (semi-SVM) model. This semi-supervised learning method requires only a small amount of labeled data to achieve high accuracy in near real time and is a sample efficient detection method. The hidden Markov model (HMM)-based ECHC improves the rationality of SEPAD by providing anomaly detection functionality with respect to the daily activities of householders, especially the elderly and residents in developing areas.

Paper 10

Title – Solar power generation forecasting using ensemble approach based on deep learning and statistical methods

Concept

The machine learning models include long short-term memory (LSTM), gate recurrent unit (GRU), Auto Encoder LSTM (Auto-LSTM) and a newly proposed Auto-GRU. To enhance the accuracy of the proposed Machine learning and Statistical Hybrid Model (MLSHM), we employ two diversity techniques, i.e. structural diversity and data diversity. To combine the

prediction of the ensemble members in the proposed MLSHM, we exploit four combining methods: simple averaging approach, weighted averaging using linear approach and using non-linear approach, and combination through variance using inverse approach. The proposed MLSHM scheme was validated on two real-time series datasets, that sre Shagaya in Kuwait and Cocoa in the USA.

Paper 11

Title – A Study of Machine Learning Techniques for Daily Solar Energy Forecasting Using Numerical Weather Models

Concept

The prediction of solar energy can be addressed as a time series prediction problem using historical data. Also, solar energy forecasting can be de-rived from numerical weather prediction models (NWP). Our interest is focused on the latter approach. We focus on the problem of predicting solar energy from NWP computed from GEFS, the Global Ensemble Forecast System, which predicts meteorological variables for points in a grid. In this context, it can be useful to knowhow prediction accuracy improves depending on the number of grid nodes used as input for the machine learning techniques. However, using the variables from a large number of grid nodes can result in many attributes which might degrade the generalization performance of the learning algorithms.

Paper 12

Title – Solar Power Generation Forecasting Using Ensemble Approach Based on Deep Learning and Statistical Methods

Concept

In this research, authors propose a hybrid model (MLSHM) that combines machine-learning methods with statistical method for more accurate prediction of future solar power generation from renewable energy plants. To enhance the accuracy of the proposed MLSHM, we

employ two diversity techniques, i.e. structural diversity and data diversity. To combine the prediction of the ensemble members in the proposed MLSHM, we exploit four combining methods: simple averaging approach, weighted averaging using linear approach and using non-linear approach, and combination through variance using inverse approach. The proposed hybrid model was validated on two real-time series datasets, Shagaya in Kuwait and Cocoa in the USA.

Paper 13

Title – A Machine Learning Approach for Solar Power Technology Review and Patent Evolution Analysis

Concept

First, a solar power knowledge ontology schema (or a key term relationship map) is constructed from the comprehensive literature and patent review. Non-supervised machine learning techniques for clustering patents and literature combined with the Latent Dirichlet Allocation (LDA) topic modeling algorithm identify sub-technology clusters and their main topics. A word-embedding algorithm is applied to identify the patent documents of the specified technologies. Cross-validation of the results is used to model the technology progress with a patent evolution map. Initial analysis show that many patents focus on solar hydropower storage systems, transferring light generated power to water power gravity systems. Batteries are also used but have several limitations.

Paper 14

Title – State of the Art of Machine Learning Models in Energy Systems, a Systematic Review

Concept

This paper presents the state of the art of ML models used in energy systems along with a novel taxonomy of models and applications. Through a novel methodology, ML models are identified and further classified according to the ML modeling technique, energy type, and application area. Furthermore, a comprehensive review of the literature leads to an assessment

and performance evaluation of the ML models and their applications, and a discussion of the major challenges and opportunities for prospective research. This paper further concludes that there is an outstanding rise in the accuracy, robustness, precision and generalization ability of the ML models in energy systems using hybrid ML models. Hybridization is reported to be effective in the advancement of prediction models, particularly for renewable energy systems, e.g., solar energy, wind energy, and biofuels.

Paper 15

Title – Machine Learning Techniques for Supporting Renewable Energy Generation and Integration: A Survey

Concept

Harnessing energy from renewable sources range from small scale (e.g., a single household) to large scale (e.g., power plants producing several MWs to a few GWs providing energy to an entire city). An inherent characteristic common to all renewable power plants is that power generation is dependent on environmental parameters and thus cannot be fully controlled or planned for in advance. In a power grid, it is necessary to predict the amount of power that will be generated in the future, including those from the renewable sources, as fluctuations in capacity and/or quality can have negative impacts on the physical health of the entire grid as well as the quality of life of its users. As renewable power plants continue to expand, it will also be necessary to determine their optimal sizes, locations and configurations.

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