Ph.D. Research Proposal

Doctoral Program in "Department Name"

Hybrid Renewable Energy System (Wind and Solar Energy) Using Optimized CNN with Circular Reward Based Markov Chain Model

by

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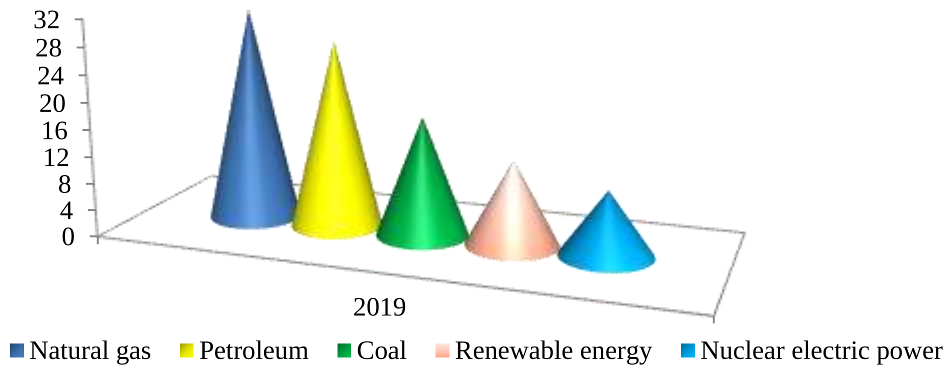
<Date of Submission (DD MM 20YY>

I. INTRODUCTION / BACKGROUND

In today world, the raid growth of human population increases the need of pollution free renewable energy sources. Since the conventional energy sources are depleting day by day and increases pollution, these problems lead to the use of renewable energy sources for power generation. Renewable energy is dependable and copious and will potentially be very cheap, once this technology and its present infrastructure are enhanced. The major sources of renewable energy include solar, wind, biomass, geothermal, hydropower and tidal energy. Non-renewable energy, such as coal, natural gas and oil, require costly explorations and potentially dangerous mining and drilling, and they will become more expensive as supplies diminish and energy demand increases. Renewable energy produces only small levels of carbon emissions and therefore, helps battle climate change caused by fossil fuel burning.

Among all the renewable sources, wind has been utilized as a source of power generation since it is being most economical, clean and emission free technology. Wind energy is characterized by large commercial wind farms comprising hundreds of turbine. In recent time, hybrid power generation systems become promising solution to resolve the increasing energy requirements.

As per World Energy Outlook (WEO-2010) the prospects for renewable energy based electricity generation hinge critically on government policies to encourage their development. Worldwide, the share of renewable in electricity supply is expected to increase from 19% in 2008 to 32% in 2035; but it reaches only 23% at present. The three major fossil fuels are petroleum, natural gas, and coal. The primary production of these major fuels in U.S is reported in figure.1.1



	2019
Natural gas	31.8
Petroleum	28
Coal	17.8
Renewable energy	12.7
Nuclear electric power	9.6

Figure.1. Energy production in U.S reported for 2017

Enormous multi-objective optimization algorithm is proposed for the design of HRES that are PSO (Particle Swarm Optimization) [2], [7], [9], [10], GA (Genetic Algorithm) [2], [7], Fuzzy Set Theory [6], NSGA-II [11], TOPSIS [5], [8], IHOGA [4] and so on. These algorithms produce very poor optimizing result in terms of LSPP, renewable factor and COE.

1.1 Research Outline & Scope

This research work concentrates on adaptive control of power transmission from the renewable energy resources like photovoltaic (PV) cells, and wind turbine (WT) to the grid with the help of artificial neural network (ANN). Solar power and wind power are major solutions to handle the increasing electricity demands over the world. Perhaps, both resources are better than other non-renewable resources in terms of cost and environmental effects; it also involves with some challenges along with design of solar arrays and wind turbines. Current research works are majorly relies on either solar energy or wind energy. However, both solar resource and wind resource are 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 a hybrid power generation system. In this research work, we have focused on hybrid power generation system that integrates solar energy and wind 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 hybrid power generation system.

1.2 Research Objectives

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

II. RESEARCH GAPS

2.1 Common Problem Statement

Today the entire world is facing the problem of power supply. Fulfilling consumers demand and providing uninterrupted power supply are very challenging tasks. There is no single renewable system does not addresses the energy need of the world. Due to the importance of power, the important of HRES has increased gradually and well researched among researchers.

When combine solar PV and wind turbine, other factors such as climate conditions must be considered such as sun, clouds, wind, rain, etc. If sun rises is strong and rate of temperature is high, the density of air is reduced in the wind and it tends to be weak. Similarly, when the rate of density air is strong, the rate of temperature is less and it tends to be weak. Hence a combination of solar and wind will maximize the generation of energy and also meets consumers demand.

Furthermore, battery lifetime maximization, the absence of demand side detail (Critical and Non-Critical Load) leads to performance degradation of the system. There is huge gap between battery lifetime extension and system performance (in terms of Cost and Loss of Power Supply Probability (LSLP)) since most of the works only focus on the theoretical aspect and the real-time battery management like battery equalization has not been concentrated.

2.2 Specific Problem Definition

In this paper [1], authors presented the design of hybrid system for optimization of renewable sources. To optimize the various configuration parameters of hybrid power system in this work several optimization algorithms are proposed such as GA, PSO, BFPSO, and TLBO. There are three categories of configuration parameters are evaluated in this hybrid power system, namely technical (renewable factor), social (job creation, PM, and HDI), and economical (penalty, fuel consumption and COE). Considered renewable energy sources are PV, Wind, Diesel generator, Battery Bank, and Biomass, which are tested for six cases: Case-I (Battery, Diesel, Biomass and PV), Case-II (Diesel, Battery and PV), Case-III (Battery, Diesel, Biomass, and Wind), Case-IV (Wind, Battery and Diesel), Case-V (Battery, Diesel, Wind, PV), and Case-VI (Wind, Diesel, Battery, PV, and Biomass). The simulation of this system is tested using MATLAB software. Finally, TLBO has proved that it obtained high performance in hybrid power system in terms of technical, social and economic parameters.

Problems

- TLBO is more accurate, but it requires lot of iterations to give result as accurate and thus TLBO is a time consuming optimization method. Some of other drawbacks of this TLBO is follows:
  - TLBO optimization problem leads to slower convergence rate since it is based on the learner who improves his/her performance and give outcomes either through the teacher classroom or other learners. This requires lot of efforts from the teacher to improve the learners performance
  - It is not compatible for real cases and neglected the information of learner's new knowledge (if learners gain knowledge during tutorial hours from teacher or other learners).
- Today's HRES, cost of electricity must be reduced. Hence, the optimization parameters must be improve further to attain effective performance

- In all cases, CO_2 emission rate and net present cost is very large and there are three parameters are only considered such as technical, social, and economic, but environmental parameters are also required in hybrid power system.

In this paper [2], a hybrid wind or solar or battery system is designed using hierarchical and distributed prediction control model. This model is based on the cooperative control of power supply between wind, solar and battery resources and realizes the method plug and play for energy distribution. The main objective of this model is to check and coordinate the allocation of power to reduce the overall costs of the operation. This model consists of two layers which focus on energy management (Wind/Solar/Battery Power units) and control tracking of the upper layer in the lower layer, respectively.

Problems Defined

- Energy management in wind-solar-power generation is effective and in certain cases load change demand and weather condition demand due to the cutting off of certain wind turbine
- Uncertainty in the forecast due to the weather condition changes.

Authors of this paper [3] presented a HRES for two resources such as PV and Wind with also consists of improved hybrid optimization genetic algorithms (IHOGA). The sensitivity analysis is implemented for this hybrid system which aid to access the effect of uncertainty/change in the attribute and determines the most suitable solution for this HRES. The process of HRES is follows: (1). Data collection, (2). Load data from specific study area, (3). Resource input data and (4). Optimize size and cost of HRES. The objective function of IHOGA is to decrease the total net present cost (NPC), which is computed using replacement cost, capital cost and other cost of each component.

Problems

- The proposed hybrid optimization genetic algorithm. However GA suffers from a low convergence speed

- Careful planning and competent forecasting and solar radiation and wind speed analysis would require while designing optimum and long live HRES.

This paper [4] presents optimal sizing with load management in standalone hybrid renewable energy systems. The considered constraints are net present cost (NPC), cost of energy (COE) and emission rate. Optimal sizing is carried out by using HOMER tool. Then the optimal size is tested in Matlab model. The optimal sizing considers total net present cost (TNPC), levelized cost of energy (LCOE) and reliability as the objective functions. Further, this work determines the voltage constant, safe operating range of SOC and voltage quality.

Problems

- The load management is achieved through optimal sizing. However, optimal sizing only optimizes the sate variables upon the historical load demand. For better load management, the current status of load must be estimated.
- As the work only depends upon the historical data, there is high possibility for power shortage in critical loads. It couldn't handle the load uncertainties which are the prime factor in load management.

In [5], optimal sizing is performed along with load forecasting. This paper highlights that load forecasting is the important aspect in optimal sizing of standalone hybrid renewable energy systems. For load forecasting, neural network, regression trees model, multiple linear regression model and curve fitting model algorithms are utilized. Then the mean absolute percentage error (MAPE) is computed to forecast the load. In addition, the load charging schedule is also presented.

Problems

- Using four machine learning algorithms for forecasting is time consuming process. In that, regression trees, linear regression and curve fitting models have lower accuracy which degrades the performance of load forecasting.

- Lack of optimal sizing degrades the overall system performance in terms of cost and reliability.

Proposed Solutions

- We aimed to ensure power supply without shortages. Besides, we consider the load criticality factor in the optimal operation mode selection and also battery equalization.

III. RESEARCH CONTRIBUTIONS

In order to design the Wind Turbine Solar Energy we perform the following stages:

Energy Management and Optimization

To optimize the size and cost of HRES, propose CNN with Most Valuable Player Algorithm. Here CNN is used to compute large size of time series measurement as an input. For each input we compute the weight (fitness value) in MVP algorithm. In first stage, the proposed approach forecasts the Load and Weather by using historical data. Here, determine the forecasting data from historical weather and load data. Then, the forecasted data is fed into the optimizer stage (i.e.) second stage.

Current & Future State Prediction

It is supported using Circular Rewards based Markov Chain Model. The result of solar PV panel and wind turbine is based on the environmental parameters. When solar and wind power is not supplied, in such case diesel generator is used. If wind power and solar power reach its average level, then we turn off the diesel generator. This case is suitable for real time HRES.

Tracking Errors and Prediction Update

Most of the previous works only optimize the size and cost of input parameters of HRES, but none of them has studied about error correction and further optimization. To track errors during optimization, proposed a Continuous Extended Kalman Filter, which has two properties such as prediction and update. In update, it is further classified into timely update and measure update.

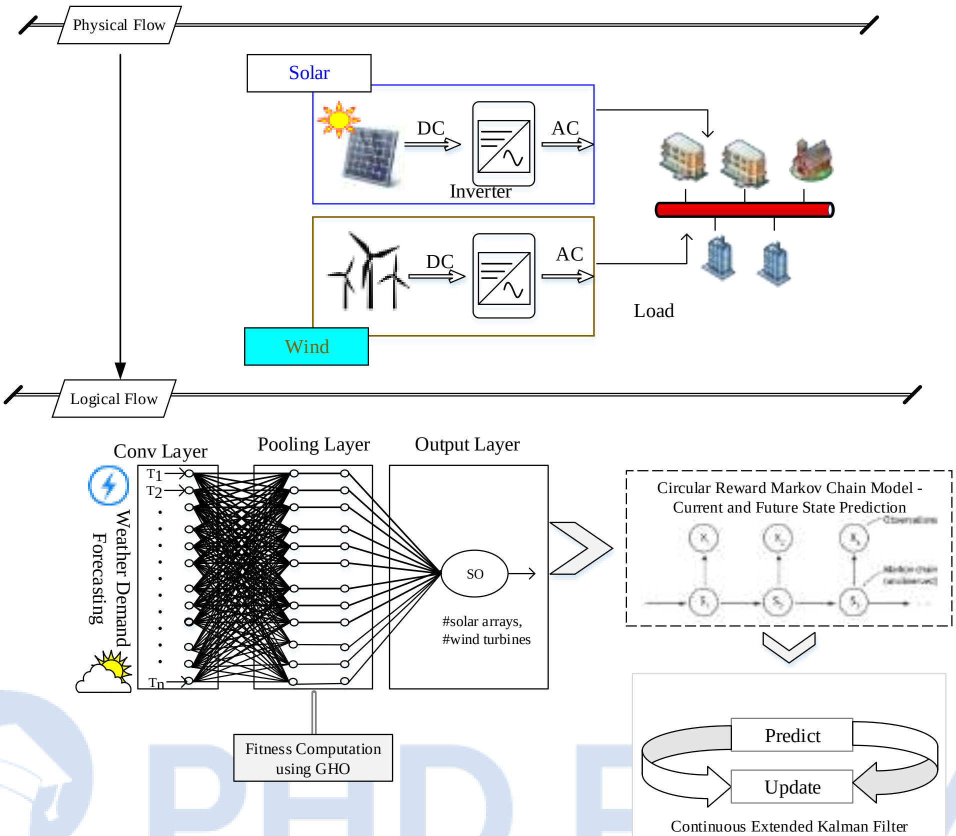
Performance Evaluation

Case studies of the combination of HRES are implemented in the following manner.

- Solar and Wind (Case Study 1)
- Solar (Case Study 2)
- Wind (Case Study 3)

Finally, it is proved that the output parameters case 1 is more optimized and better than other two case studies.

SYSTEM ARCHITECTURE



IV. RESEARCH NOVELTIES

- An intelligent HRES system is designed to achieve uninterrupted power supply to the loads.
- Current operational mode is selected in a dynamic manner by considering current load demand and battery status
- Battery lifetime is extended by employing battery equalization that is processed by an intelligent decision making approach

V. PREVIOUS WORKS & LIMITATIONS

Paper 1

Title - Multi-Objective Optimization of Hybrid Renewable Energy System using an Enhanced Multi-Objective Evolutionary Algorithm

Concept

This paper effectively address the multi-objective problem (MOP) by proposing multi objective evolutionary algorithm with decomposition [Localized Penalty based Boundary Intersection (LPBI)]. The power generation is tested for two modes (Island and Grid Connected) for different renewable energy resources such as PV, battery, diesel generator, and battery.

Paper 2

Title – Multi-Objective Optimization of a Hybrid Distributed Energy System using NSGA-II algorithm

Concept – Authors of this paper is presented a multi objective optimization algorithm called NSGA-II (Non-Dominated Sorting Generic Algorithm), which derives group of non-dominated pareto solutions. Then fuzzy set theory is employed to determine the best compromised pareto solution.

Limitations

- NSGA-II is superior to the traditional weighting algorithms, but it does not given results in more accurate and objective manner.

Paper 3

Title – Optimal Sizing of a Hybrid Solar Energy System using Particle Swarm Optimization Algorithm based on Cost and Pollution Criteria

Concept – This paper proposed a new method for optimum size of hybrid batteries bank, PV, diesel generator. The optimization of this system is investigated using minimum system cost and minimum pollution criteria. In order to minimize this size, PSO algorithm is used, which guarantees global optimum solution. It meets the minimum carbon emission criteria.

Limitations

- However, PSO does not provide the optimum sizing in HRES.

Paper 4

Title – Optimization of Renewable Hybrid Energy Systems- A Multi-Objective Approach

Concept – In this paper, a normalized weighted constrained multi objective (NWCMO) approach is presented, which is a meta-heuristic optimization algorithm. This algorithm will works on the aspect of technical, social, economic and environmental parameters and thus provide optimum set of results in the design of renewable hybrid energy systems. For four objectives, PSO is applied for weighting criteria, which considers normalized weight values for objectives and user constraints and finally optimum system configuration is defined.

Limitations

- PSO does not works well for real cases and the Capability and feasibility must be high for the design for HRES.

Paper 5

Title – Technico-economic analysis of off grid solar PV/ Fuel cell energy system for residential community in desert region

Concept –

This paper presents an off-grid hybrid renewable power system. Off-grid power systems also known as standalone power system that utilizes power generated from renewable sources only. In this paper, hybrid Solar PV/Fuel Cell power system is designed and optimized. The main objective is to optimize the hybrid system design and to dispatch the power in an optima manner. For that, renewable energy system simulation, modelling, optimization and control strategies have been presented. The presented strategies consider capital cost, operation and maintenance cost as the objective functions.

Paper 6

Title – Fuzzy multi-objective placement of renewable energy sources in distribution system with objective of loss reduction and reliability improvement using a novel hybrid method

Concept –

Fuzzy-based multi objective optimization algorithm is presented, which main objective is to design HRES that decreases loss and improves reliability of the system**. A** hybrid multi-objective optimization algorithm is proposed called teaching learning based optimization with grey wolf optimizer. The main purpose of this hybrid optimization algorithm is it has high convergence speed and it does not lead to local optimum.

Limitations

- Low renewable factor due to the design of PV and wind turbine

Paper 7

Title – Optimal sizing of hybrid fuel cell-supercapacitor storage system for off-grid renewable applications

Concept

This paper designs a hybrid renewable energy system that combines hydrogen fuel cell and a super capacitor. The prime aim of this work is to find the optimal size of the composite energy storage system. Further, it uses PV arrays to supply power for the commercial loads. Here, the PV array is the primary source of energy and the hydrogen and super capacitor system acts as the backup to manage the power fluctuations introduced by the primary source. For this purpose, the cost of energy, net present cost and the reliability are considered as the objective functions. For optimal sizing Homer optimizer is considered.

Paper 8

Title – Feasibility design and techno-economic analysis of hybrid renewable energy system for rural electrification

Concept

In this work, the hybrid renewable energy system is designed for rural electrification. In order to design an optimal system, this work uses load prediction methodology. Initially, the load level of the rural area is predicted from the Artificial Neural Network-Back Propagation (ANN-BP) algorithm. The ANN-BP works upon the feedback propagation and Levenberg-Marguardt (LM) data training optimization technique. Here, the forecasted data is further used to find the optimal sizing of the hybrid system.

Paper 9

Title – Overview of Energy Storage in Renewable Energy Power Fluctuation Mitigation

Concept

In this paper, the power fluctuations in hybrid renewable system is mitigated in four aspects as frequency, unit ramp, low frequency oscillation and cascading failure. Mainly, this work focuses on the energy storage systems including Physical energy storage (pumped storage, compressed air energy storage and flywheel), Chemical energy storage (lead battery, lithium-ion battery and other batteries) and Electromagnetic energy storage (supercapacitor, superconducting storage). Power fluctuation is the main issue in all kinds of batteries. One of the chief solution is to maintain proper SOC level in the storage system.

Paper 10

Title – Multi-criteria Assessment of Hybrid Renewable Energy Systems for Nigeria's Coastline Communities

Concept

Authors of this paper is proposed multi criteria based decision making algorithm called TOPSIS is proposed for optimum size and cost of energy, which main intention is to design the best HRES which satisfy various criteria socio, economic and environmental. However the best design of HRES must provide reliable, cost effective and efficient performance and also the system should be environment friendly. There are four HRES is optimized using TOPSIS algorithm, which is implemented using HOMER Software. Finally, it concludes that the design of the best HRES is the combination of Diesel-PV-Wind and it is proved that it has great potential to be compatible and feasible for any weather conditions.

Limitations

- The proposed TOPSIS consumes lot of time for computation of optimum size and cost of HRES and Diesel-PV-Wind requires best and fast optimization algorithm to meet load demand for emergency situations.

Paper 11

Title – Energy management system for hybrid PV-wind-battery microgrid using convex programming, model predictive and rolling horizon predictive control with experimental validation

Concept

Energy management is one of the prime issues in hybrid renewable systems. This paper focuses on energy management in hybrid PV-wind-battery system in microgrids. The objective of this paper is to minimize the operating cost and to maximize the self-consumption of RESs. The overall system is designed in a two-layer structure. In first layer, Convex Optimization technique is incorporated to find the reference values for the power. In second layer (i.e.) lower layer, the reference values are used with Rolling Horizon Predictive Controller. In this manner, both layers cooperatively work to achieve better energy management.

Paper 12

Title – Intelligent Energy Management for Off-Grid Renewable Hybrid System Using Multi-Agent

Concept

This paper also focuses on energy management in off-grid renewable energy systems. Here, an intelligent energy management system is introduced along with multiple agents. In detail, the multi-agent tasks are identified by the system to reach the goal of intelligent energy management. This paper highlights that incorporation of multiple intelligent agents (i.e.) intelligent energy equipment improves the control over the energy systems. The overall system comprises multiple agents namely agent SEC, agent ESC, agent ERC, agent USC and agent home.

Paper 13

Title – Energy Management in Zero-Energy Building using Neural Network Predictive Control

Concept

To enable efficient energy management, this paper proposes Neural Network Predictive Control (NNPC) method. The NNPC combines neural network and model predictive control methods in order to handle energy in a zero-energy building. In NNPC, the ANN model first forecasts the energy from the renewable energy sources. The overall work supports online process in order to enable remote access. The forecasted data is further fed into NNPC to achieve better energy management. This paper highlights that the optimal energy management system allows the overall system to run without need of external grid.

Limitations

- ANN is unable to handle the large size data which needs better and deep learning approach

Paper 14

Title – A flower pollination optimization algorithm for an off-grid PV-Fuel cell hybrid renewable system

Concept

Optimal sizing is the major issue in designing hybrid renewable energy systems. In this paper the optimal sizing problem is formulated as the optimization problem and resolved by the flower pollination algorithm (FPO). Here, the objective function is formulated upon the LPSP and cost value. Then, the optimal state variables are determined. This paper shows that FPO works better than PSO, artificial bee colony (ABC) algorithms. The considered state variables are number of PV panels, wind turbines, and storage tanks.

Limitations

- The optimization algorithm can't handle the huge amount of historical data to find the optimal state variables.

Paper 15

Title – Multi-Objective Particle Swarm optimal sizing of a renewable hybrid power plant with storage

Concept

This paper focuses on optimal sizing in standalone hybrid renewable energy systems to be used in the microgrids. For that, this paper proposes a multi-objective PSO algorithm. The proposed model contains 12 parameters to represent the size of each component. The 12 parameters cover various energy sources, storages and grid connection options. However, the aim of this work is to minimize the possibility to connect with grid (i.e.) the proposed system must work in off-grid mode. The multi objective PSO algorithm considers the LPSP as the objective function.

Limitations

- PSO algorithms most of the time stuck into the local optima which is unable to optimize the size

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