JOURNAL OF CRITICAL REVIEWS

ISSN- 2394-5125 VOL 7, ISSUE 15, 2020

HYBRID OPTIMIZATION MODEL FOR SOLAR WIND POWER SYSTEMS USING FUZZY LOGIC CONTROL

[1]S. Vijayaraju, [2]N. Chaitanya, [3]K. Radha Rani

[1]M. Tech Scholar, Department of Electrical & Electronics Engineering, R.V.R & J.C.College of Engineering, Chowdavaram, Guntur (Dt), Andhra Pradesh, India
[2]Associate Professor, Department of Electrical & Electronics Engineering, R.V.R & J.C.College of Engineering, Chowdavaram, Guntur (Dt), Andhra Pradesh, India
[3]Professor, Department of Electrical & Electronics Engineering, R.V.R & J.C.College of Engineering, Chowdavaram, Guntur (Dt), Andhra Pradesh, India

Received: 16 March 2020 Revised and Accepted: 16 June 2020

ABSTRACT: This paper proposes a hybrid optimization model for solar wind systems using fuzzy logic control. A feasible hybrid optimization model for renewable energy sources using HOMER software is analyzed in this paper. A hybrid power generation system with an optimal configuration of different loads such as solar, wind power systems and fuzzy logic control based ac loads is introduced in this paper for an efficient utilization even in the remote areas. The maximum rate of power can be generated by using Perturb & Observe (P&O) algorithm in the solar photovoltaic system as control logic for the Maximum Power Point Tracking (MPPT) controller and uses a Hill Climb Search (HCS) algorithm in the Wind power system as MPPT control logic. The AC supply load voltages and frequencies can be kept at a constant level by implementing the Hybrid Fuzzy logic control based inverter in spite of changes during ordinary circumstances and load. The proposed hybrid system using a hybrid fuzzy controller is developed and simulated on a MATLAB. Furthermore, the mathematical model can also be implemented in MATLAB to carry out the desired loss of power supply probability (LPSP) for a set of system components with the lowest value of the cost function, which is defined in terms of reliability and levelized unit electricity cost (LIGHT) and finally implemented an optimal configuration for a given load.

KEYWORDS: Renewable energy, hybrid optimization model for electric renewable, Hybrid Fuzzy controller, Perturb & Observe (P&O) algorithm

I. INTRODUCTION

Due to the increase in demand for supplying the electricity around the world, governments has been faces many problems and considered it as a challenge. Electricity is generated mainly from spent fossil fuels, global warming from carbon missions, depletion of the ozone layer, population and energy consumption steadily increasing, increased awareness of environmental protection, centralized power system that cannot supply power to remote areas, etc., are some of the reasons to make the world look for alternative sources of production of energy, for example renewable energy sources such as sun, wind, tides, biomass, geothermal, etc [1].

The living, working and playing way of people have been changed by the telecommunication networks. A lot of people all over the world were connected via telecommunication networks. Electricity in the remote area is not accessible or can be accessible in the limited quantities. These types of remote areas were powered by using the battery-operated diesel generators during the last decades. Generally, these types of systems were characterized with their high cost of transportation and high consumption of fuel which are usually placed in areas that are difficult to access and which need a regular maintenance. In addition, the substitute solutions for powering these areas is required immediately because of the growing demand for clean energy technologies to decrease emission of greenhouse gases such as $CO_2, NO_X\ and\ SO_X$ and fast exhaustion of fossil fuel reserves. Stand alone renewable sources can therefore be a valid solution to power these remote areas.

Therefore, solar, wind, fuel cell, biodiesel, etc. are the several renewable energy sources (RES) used in developing countries for the telecommunication applications [5]. Since the increasing rate of petroleum based

ISSN- 2394-5125 VOL 7, ISSUE 15, 2020

product prises and developments of renewable energy based technologies, Hybrid Renewable Energy Systems (HRES) are became most popular to provide electricity for the remote areas as a stand-alone power systems. A hybrid power system, or hybrid power, generally consists of two or more renewable energy sources that are used together to achieve greater system efficiency and a better balance in energy supply. The working process of solar / wind power systems are widely well-known for all and these power generation systems contains some or other disadvantages (considering of stand-alone systems), for example, solar panels are more expensive and the cost of generating power when used them is usually more than the traditional method. They are not available at night or on cloudy days. In the same way wind turbines cannot be operated with high or low wind speeds.

Hybrid solar power system is a hybrid power system which combines the solar energy with another energy source of power generation system from a PV system. Hence, this power system can produce more energy from the solar panel in a summer season and wind turbine can produce their maximum output energy in the winter. The greater economic and ecological benefits can often offered by the Hybrid power systems than stand-alone power generation systems of solar, wind or geothermal systems alone. In this paper a hybrid solar wind power system using fuzzy logic controller based voltage regulated inverter is proposed with the hybrid optimization model for electric renewable to optimize the required parameters for this system. The modelling and simulation can be carried out on MATLAB environment to observe and analyze the optimum sizing configuration of total hybrid photovoltaic / wind / battery system fuzzy hybrid logic controller.

II. MODELS OF ENERGY SYSTEMS

A. PV Array Model

Photovoltaic generator (PV) is a non linear device which is illustrated by equivalent circuit and the I-V characteristics. Various mathematical models are being introduced from the recent years for describing the behaviour of photovoltaic generator [6]. The short circuit current, open circuit voltage, current at maximum power point and the maximum voltage at maximum power point of the photovoltaic panels are known as a "Four Parameter Model" which is the most widely used mathematical model by very good software. The effect of the temperature variation in the photovoltaic cell is taken into account, such as the current variation because of the voltage variation and operating temperature which is due to the operating cell temperature and operating temperature of photovoltaic panel based on the energy balance.

B. Wind Turbine Model

The output power from the wind turbines can be determined by using the various factors such as transmission of mechanical energy and efficiency of the electricity energy conversion, the distribution of the wind speed under the selected area and the height of hub of a wind tower, and curve of the output power as a function of the aerodynamic energy efficiency. Various models are there for estimating the performance and power of wind turbines. The Linear, quadratic, cubic, Weibull parameters, etc. are the some of those models. The Chou & Corotis model is one of the model which is most widely used since it has a simple design and it doesn't need any additional detailed information towards the Weibull shaped parameters and power characteristics curve. The every wind speed distribution that considered the rated power and rated speed of wind turbine as well as the cut-in and cut-out wind speeds can be approximated by the above model to generate an output power from the wind turbine. There is great influence on the available energy of the system by the wind turbine height at installation. Therefore, it is required to adjust the height of wind turbine for efficient generation of wind energy which can be estimated according to the power law. By the consideration of wind speed as a Rayleigh distribution function, the available wind power is estimated at the installation place for every hour. Therefore, wind generator that producing the available total average power is then calculated.

C. Temperature Model

The small role is played by this temperature modelling in the hybrid solar wind power systems as the influence of temperature has a very limited effect on the output power of photovoltaic cells, temperature modelling plays a subordinate role in the design of the solar-wind hybrid system. Several bibliographic reviews are there to predict the data of generating temperature hour by hour from a set of huge number of data from weather stations and various methods are used such as stochastic and diurnal model, artificial neural network, etc. Monte Carlo method was used by the Degelman Larry [25] which generates data of weather hour by hour that contains both deterministic and stochastic models and also considers all the parameters [8].

ISSN- 2394-5125 VOL 7, ISSUE 15, 2020

D. Battery Model

There is always an energy flow and a deficit for every hybrid renewable energy system at any instant of time. The additional energy must be stored, if the renewable resource system generates energy in excess of the energy higher than the requirement of load, while load should be satisfied by the storage system if the renewable resource system generates small amount of energy than the requirement of load. Therefore for any renewable energy stand-alone systems, the storage system is indispensable. For the storage of energy from the renewable sources of batteries, hydrogen in combination with fuel cells etc., several storage technologies are available. The state of charge and discharge of the battery with the relative technical specifications are taken into consideration by the authors Belfkira, Zhang and Barakat in [5].

III. SOLAR WIND POWER SYSTEMS USING HYBRID FUZZY LOGIC CONTROL

The following figure (1) shows the block diagram of proposed hybrid optimization model for solar wind power system using fuzzy logic controller. This proposed hybrid power generation system includes the photovoltaic cell based power generation, wind power generation, AC power generation from Fuzzy logic control based voltage regulated Inverter and telecom loads with the optimal resources sizing model of HOMER.

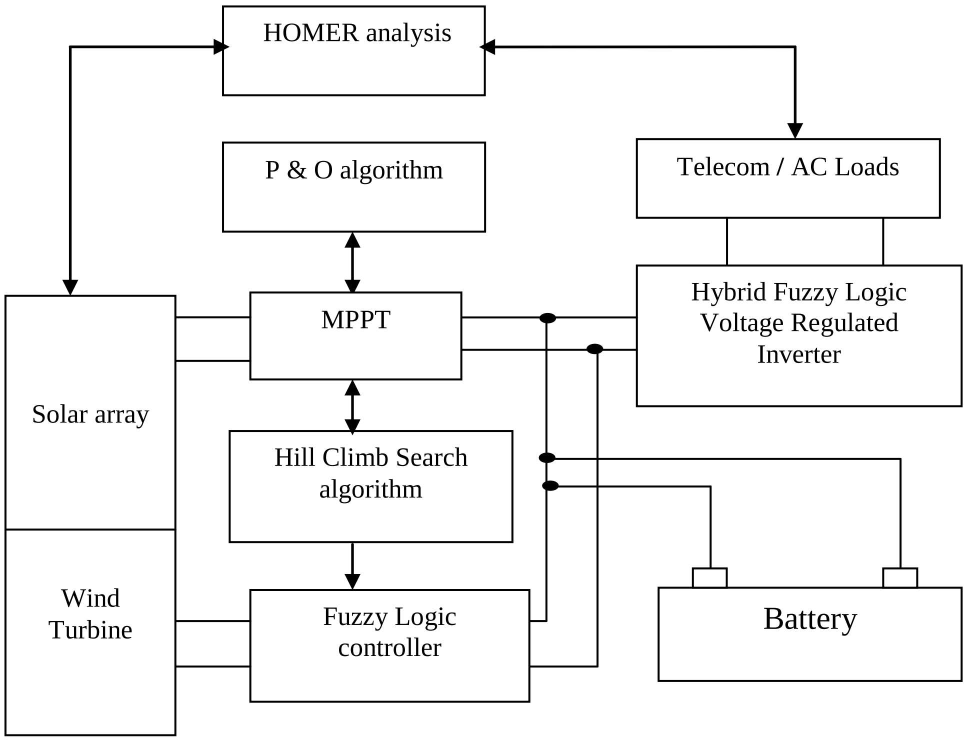

Fig. 1: CIRCUIT OF HOMER BASED SOLAR WIND POWER SYSTEM USING FLC

A. Perturb and Observe MPPT Algorithm for PV array

Solar panels / photovoltaic modules are used to convert the sun's renewable energy into electrical energy. The operating principle of the solar cell similar is to that of semiconductors operation. Since then, the entire ecosystem of planet Earth has been dependent on solar energy and is a great source of infinite energy it is preferred for the project due to its availability, ease of interpretation, number of characters and popularity. Solar panels are photovoltaics that generate electricity through exposure to sunlight. Depending on the position and intensity of the solar radiation, the amount of electrical energy in direct current is generated. The specifications and design of the proposed system is a 12v , 150 watt off- grid solar panel. The standard commercial panel size of 48 "x 22" x 2" works best, but other sizes may also be considered.

The maximum performance of the PV array is monitored by using the Perturb and Observe algorithm (known as P&O) shown in Figure (2). This method involves perturbing the voltage V and observing the change in the

P_{max}

output power P. If disturbance in one direction increases the output power of the photovoltaic system then the same way of disturbance continues. Otherwise the direction of the noise is reversed. Hence, it is a continuous process to find the voltage in the voltage curve (PV) of the power Vs that increases the output power of the photovoltaic field.

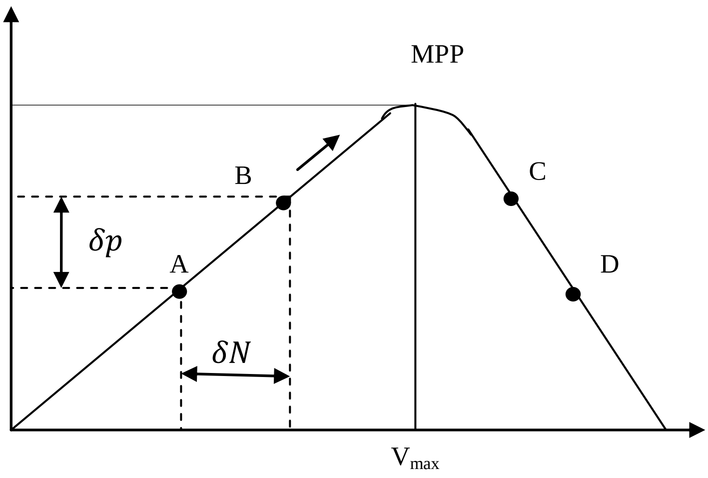

Fig. 2: Description of P&O algorithm for MPPT

B. Hill Climb Search Algorithm for Wind Turbine

In ecosystem of the earth, wind is available at every time. Wind turbine with large blades is attached to the generator rotor and lead to the generation of electricity when it is moved by wind energy. Wind energy is also renewable, never an energy source and readily available in the atmosphere. Wind turbines are much more popular and are much more efficient to generate electricity by the consideration of area in which they are used. The wind turbine is a mechanical system / machine that generate electricity from a renewable source of wind energy. The amount of alternating current is generated depending on the wind speed. The general project generator requires a 500 watt wind turbine with 3 blades and 1 meter of radius. The wind turbine height has to be in the range of 18 meters and a space of 2 x 2 x 4 m is required for the foundation. Within the implementation of the MPPT control logic, a hill climb search algorithm is implemented for the wind power generation system. Voltages, Currents and the permanent magnetic synchronous generator speed are the inputs applied to the controller. The measured current is compared with reference current and is calculated using the voltage and speed samples. Duty cycle of an electronic switch is calculated using error in the step-up converter which controls the operation of the wind power generation at maximum power point.

C. Hybrid Fuzzy Logic Voltage Regulated Inverter

In any hybrid power generation systems, inverter has a significant part. The inverter is used to regulate and maintain the constant voltage and frequency of loads in the stand-alone operation. The Fuzzy logic controller (FLC) is used in the Fuzzy logic implementation. Error and error change are the inputs of that FLC. These inputs are calculated by taking into account of grid voltage of the inverter and are used to calculate as output. The voltage regulated inverter is implemented with the FLC using the implementation of subsystem algorithm for the proposed hybrid solar wind power generation system.

The linearity of the fuzzy controller parts offers a better system response than a classic controller. Since there is a non fixed operating point in fuzzy controller, it offers greater robustness against changes in system parameters than a classic controller. Logically it should be possible to divide the PID controller action into two parts. A good repose of system can be provided by the piecewise linearity of fuzzy logic controller compared to the traditional controller. An improved robustness can also provided than the traditional controller by this for the changes in system parameters as there is a non-fixed operating point in the fuzzy controller. Basically, there is a possibility to divide the proportional integral derivative controller action into two different control actions such as Proportional derivative (PD) controller action to get fast response and Proportional integral (PI) controller

ISSN- 2394-5125 VOL 7, ISSUE 15, 2020

action to eliminate the error of steady-state condition. The PI controller should be able to compensate the power generation system evidently. The PD and PI controllers offers the "course" and "fine" controls respectively as similar to that of two different control rules for "course" and "fine" control. The PI part is activated only when reduced the error and change in error of PD part which are to the range of ZO fuzzy subset where the both PI and PD are present.

Therefore, the rule action calculation at any time includes only four rule rules, whereas a controller with three controlled variables (i.e. a typical PID) needs eight rules. The appropriate valid rules are determined when the every one of three control variables of a hybrid controller contain seven subsets by simply checking the maximum of sixteen subsets. At first, two subsets of ZO are checked by rule search for the PD section and then mostly fourteen subsets are checked for the PI section. The PI and PD sections are individually designed for the hybrid fuzzy PID controller and the logic is controlled if it is switch between two controllers. The logic switches to the PI part if both the error change and the error are within the ZO range. Regardless of the change in the error variable, the PD part should not be reactivated until the error variable leaves the ZO range. Upon reaching steady-state, the PI component evidently produces a change in error which is outside the range of PD 's ZO range and then reactivates the PD part.

G. HOMER Optimization Model

An exponentially increased number of simulations are required if the increased number of variables are there which observe excess of time and effort for the computation. Therefore finding of an accurate and quick process of optimal system configuration is required by the use of feasible optimization techniques. Iterative approach, linear programming, graphical construction methods, genetic algorithm etc. are the several optimization techniques that are most widely used for the hybrid solar wind power system designs. The main aim of every designer towards a certain configuration for the hybrid solar wind power system designs, regardless of the optimization method is to find the best optimal value. Since the iterative approach is an easy model and equivalent to the newly developed optimization techniques such as the genetic algorithm in producing the output as a result, it is used as an optimization technique in this paper.

The number of batteries, wind turbines and photovoltaic modules are considered as the decision variables to determine the optimum sizes. The data regarding to the temperature and speed of wind, and synthetic hourly solar radiation are produced as of monthly average values. Parameter constraints that are used as an assumption in the proposed system for the optimal system configuration are subjected as follows:

$$1 \leq NBat \leq NBat_{max} \text{ ---- (1)}$$

$$1 \leq Nw \leq Nw_{max} \text{ ---- (2)}$$

$$1 \leq NPV \leq NPV_{max} \text{ ---- (3)}$$

$$SOC_{min} \leq (t) \leq SOC_{max} \text{ ---- (4)}$$

Here, $NBat$ and $NBat_{max}$ represent the total and maximum number of batteries respectively. The NPV and NPV_{max} represent the total and maximum number of PV panels, and Nw and Nw_{max} represents the total and maximum number of wind turbines. SOC represents the state of charge of the battery, SOC_{min} and SOC_{max} is the minimum and maximum state of charge of the battery.

Generally, achieving of the optimum cost function (CF) is the main goal of the proposed system. Generated levelized unit cost of electricity (LUEC) and reliability parameters are used to define the cost function for the power generation system. The following equation (5) expresses the CF as,

$$CF = (Probability\ of\ reliability \times Reliability) + (probability\ of\ LUEC \times LUEC) \text{ ------- (5)}$$

A loss of power supply probability (LPSP) model is implemented in the proposed system by the consideration of factor CF. Then the long-term average fraction of the total load which was not powered by the stand-alone system is defined as the loss of power supply probability (LPSP). It represents a load which would be not at all satisfied if the LPSP is 1 and represents a load which would always be satisfied for all time if the LPSP is 0. This LPSP is used for the calculation of reliability given in the following equation (6).

$$Reliability = 1 - LPSP \text{ ------ (6)}$$

ISSN- 2394-5125 VOL 7, ISSUE 15, 2020

Then the optimal sizing settings would be determined by analyzing configuration which satisfies the requirement of LPSP against the target function.

IV. RESULTS

The TSM-175DA01 of Trina Solar photovoltaic system with 8.05 kW, the Hummer H3.1 wind turbine with 1kW x 2 and the T-105 of Trojan with 1125 Ah are utilized in the simulation analysis of proposed hybrid power system under the requirement of remote Dadakhara telecom loads charging system that provides a 99.99% of reliability by optimizing the cost reduction and reliable power generation in proposed system. The optimization simulation results with respect to the change of wind speed and telecom loads of existing system are shown in the figure (3) for the different configuration of systems along with proposed system configuration. It can be illustrated from the below figure (3) is that the PV systems can only be used under the wind speed of 5 m /sec upto 750watts of telecommunication loads. Therefore, it can be said that a PV system with a 6.12 kW KC85T alone cannot meet the requirement of telecom loads. In the same way, the total requirement of telecom loads can be meet by the implementation of wind system alone when the range of wind speed higher than 7.2 m / s.

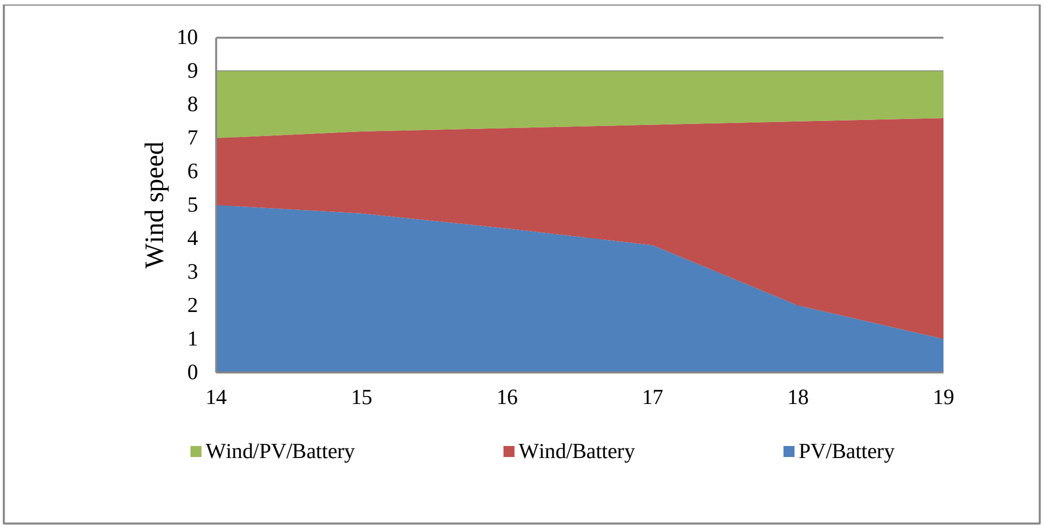

Fig. 3: OPTIMIZATION RESULTS OF DIFFERENT CONFIGURED SYSTEMS

The Dadakharka site used in the simulation section as an existing system is a Nepal Telecom (NT) load that has a Very Small Aperture Terminal (VSAT) with a Code Division Multiple Access Base Transceiver Station (CDMA BTS) and a repeater Station. This can be operated on a indirect mode that means battery can store the generation of power by the renewable energy and this stored energy is delivered from the battery to the load system. Thus, the performance analysis of the proposed hybrid system in terms of reliability and excess of power compared with the existing Nepal Telecom system is shown in the figure (4). It can be described from the figure that in a one year a 27% of excess power is observed and the 99.99% of reliability also observed with the proposed hybrid system while the existing system is observed with poor reliability.

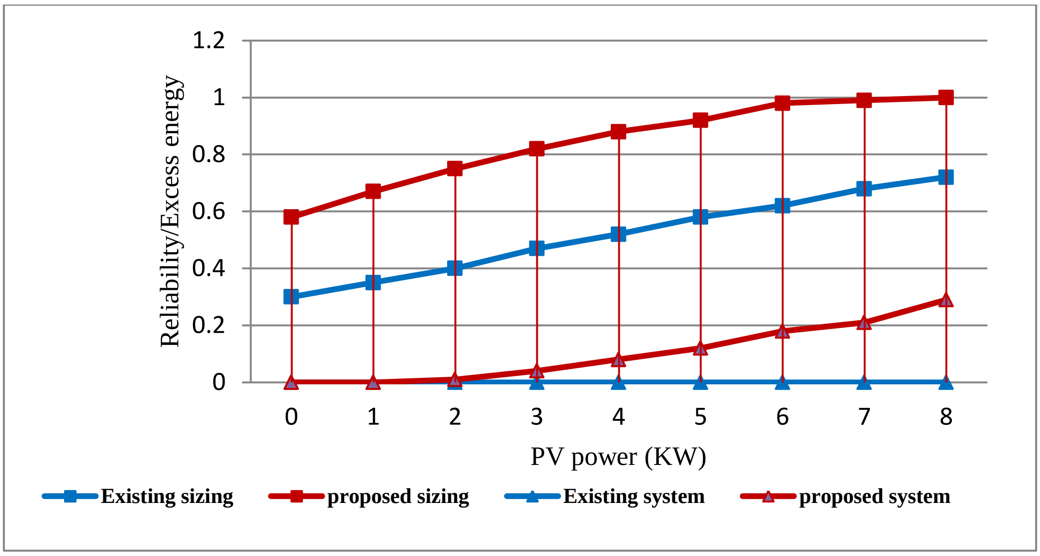

Fig. 4: COMPARATIVE ANALYSIS

V. CONCLUSION

Generally, a plentiful of solar and wind energy is there in environment so the power is generated and distributed over the remote areas by the implementation of hybrid energy system. This system powers the loads in hybrid mode based on the available solar and wind energy. The proposed hybrid photovoltaic wind system, with this perspective offers integration of wind and solar photovoltaic systems at a high rate using a fuzzy hybrid controller in order to obtain optimal energy from the two sources. Hybrid fuzzy logic control is more efficient and reliable than voltage regulated PI inverters. The effect of the MPPT algorithm is enhanced by the FLC on proposed hybrid power generation system in which power is derived from the solar and wind power systems. From this it can be illustrated that the proposed system has real-time applications in dimensioning and analysis of HSWPS.

Acknowledgement:
The authors are greatly acknowledged DST - FIST (Govt.of India) for funding to setting up the research computing facilities at R.V.R & J.C College of Engineering.

VI. REFERENCES

[1] F. Kurokawa, Y. Mizuno, Y. Tominaga, N. Matsui, M. Tanaka, and H. Eto, "Design Optimization of Renewable Energy System Using EMO", *IEEE 6th International Conference on Smart Grid IC Smart Grids 2018*, pp. 258-263, 2019.

[2] Y.Y. Hong, C. Yao and M. Chen, "Novel Adaptive Multi-Clustering Algorithm-based Optimal ESS Sizing in Ship Power System Considering Uncertainty", *IEEE Transactions on Power Systems*, volume: 33, number:1, pp:1-1, 2017.

[3] Shelly Vadhera and Bahadur Singh Pali, "Renewable Energy Systems for Generating Electric Power: A Review," 1st IEEE Inte., Confe., on. Power Elect., Intell., Cont., and. Ener., Sys., (ICPEICES-2016), 2016.

[4] S. Rahman, R. Arghandeh, and M. Pipattanasomporn, "Flywheel energy storage systems for ride-through applications in a facility microgrid", *IEEE Transactions on Smart Grids*, volume: 3, number:4, pp. 1955-1962, December, 2012.

[5] Georges Barakat, Lu Zhang and Rachid Belfkira, "Optimal sizing study of hybrid wind/PV/diesel power generation unit", Solar Energy, volume: 85, pp.100-110, 2011

[6] Villalva MG, Gazoli JR. Comprehensive approach to modeling and simulation of photovoltaic arrays. IEEE Trans Power Electron 2009;24:1198–208.

[7] S. Samineni, B. Johnson, H. Hess and J. Law, "Modeling and analysis of a flywheel energy storage system for voltage sag correction", *IEEE Transactions on Industrial Applications.*, volume: 42, number: 1, pp. 42-52, December/January ,2006.

[8] Degelman Larry, "Simulation and uncertainty: weather predictions", Advanced Bldg, Simulation, (Malkawi and Augenbroe, Ed.), Spon Press, New York and London, chapter: 3, pp. 60-86, 2004.

[9] J. P. Hespanha, "Uniform stability of switched linear systems: extensions of LaSalle's Invariance Principle", *IEEE Trans. Autom. Control*, vol. 49, no. 4, pp. 470-482, Apr. 2004.

[10] P. Wang and R. Billinton, "Reliability benefit analysis of adding WTG to a distribution system", *IEEE Trans. Energy Convers.*, vol. 16, no. 2, pp. 134-139, Jun. 2001

[11] K. Imaie, O. Tsukamoto and Y. Nagai, "Control strategies for multiple parallel current-source converters of SMES system", *IEEE Trans. Power Electron.*, vol. 15, no. 2, pp. 377-385, Mar. 2000

[12] V. Karasik, K. Dixon, C. Weber, B. Batchelder, G. Campbell and P. Ribeiro, "SMES for power utility applications: A review of technical and cost considerations", *IEEE Trans. Appl. Supercond.*, vol. 9, no. 2, pp. 541-546, Jun. 1999.

[13] P. S. Dokopoulos, A. C. Saramourtsis and A. G. Bakirtzis, "Prediction and evaluation of the performance of wind-diesel energy systems", *IEEE Trans. Energy Convers.*, volumr: 11, number: 2, pp. 385-393, Jun. 1996.

[14] A. F. Sultan, G. W. Swift and D. J. Fedirchu, "Detection of High Impedance Arcing Faults Using A Multi-Layer Perceptron", *IEEE Transactions on Power Delivery*, volume: 7, no. 4, pp. 1871-1877, Oct. 1992.

[15] Enslin, J. H. R., "Maximum Power Point Tracking: A ost Saving Necessity In Solar Energy Systems", 16th IEEE Annual Industrial Electronics Society Conference, Pacific Grove, USA, 1990, pp.1073-1077.