A CO-OPERATIVE OPERATION OF NOVEL PV INVERTER CONTROL SCHEME AND STORAGE ENERGY MANAGEMENT SYSTEM BASED ON GREY WOLF OPTIMIZATION

(Grey Wolf Optimizier)

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Abstract— *Power electronics plays an important role in controlling the grid-connected renewable energy sources. Increasing penetration of photovoltaic (PV) as well as increasing peak load demand has resulted in poor voltage profile for some residential distribution networks. The voltage regulation problem in low voltage power distribution networks integrated with increased amount of solar photovoltaics (PV) has been addressed. This project proposes and evaluates the cooperative performance of a novel proportional-integral-derivative (PID) control scheme for PV interfacing inverter based on GWO optimization for regulating the voltage of three-phase grid connected solar PV system under any nonlinear and fluctuating operating conditions. The proposed scheme dynamically controls the PV inverter to inject/ absorb appropriate reactive power to regulate the voltage at point of common coupling (PCC)and provides robust response at any system worst case scenarios Regulation. The proposed techniques based PV inverter control scheme and GWO -based supervisory EMS are developed and simulated in MATLAB/ Simulink Environment.*

Keywords— PID, Smart Grid, Energy Storage System, Distributed Generation

1. Introduction

A grid-connected photovoltaic power system, or grid-connected PV power system is an electricity consists of solar and grid connection equipment. They range from small residential and commercial rooftop systems to large utility-scale solar power stations. Unlike stand-alone power systems, a grid-connected system rarely includes an integrated battery solution, as they are still very expensive. When conditions are right, the grid-connected PV system supplies the excess power, beyond consumption by the Connected load to the utility, Panels one or several inverters, a power conditioning unit

Fig .1.Photovoltaic power station at Nellis Air Force Base, United States

Residential, grid-connected rooftop systems which have a capacity more than 10 kilowatts can meet the load of most consumers. They can feed excess power to the grid where it is consumed by other users. The feedback is done through a meter to monitor power transferred. Photovoltaic wattage may be less than average consumption, in which case the consumer will continue to purchase grid energy, but a lesser amount than previously. If photovoltaic wattage substantially exceeds average consumption, the energy produced by the panels will be much in excess of the demand. In this case, the excess power can yielder venue by selling it to the grid. Depending on their agreement with their local grid energy company, the consumer only needs to pay the cost of electricity consumed less the value of electricity generated. This will be a negative number if more electricity is generated than consumed. Additionally, in some cases, cash incentives are paid from the grid operator to the consumer. Connection of the photovoltaic power system can be done only through an interconnection agreement between the consumer and the utility company. The agreement details the various safety standards to be followed during the connection.

The rest of this brief introduces in section I. Next the related works and existing schemes are considered in Section II. Then, in Section III, the proposed is presented. Section IV presents an experimental Results and performance analysis to illustrate the effectiveness of the hardware security approach. Finally, the conclusions are summarized in Section V.

2. RELATED WORKS AND EXISTING SCHEMES

Adaptive neuro-fuzzy inference system is an intelligent system based on learning and parallel data processing ability of artificial neural network and inference ability of Takagi–Sugeno fuzzy inference system. Figure shows a general architecture of a 5-layer ANFIS where both square nodes and circle nodes are used to reflect different adaptive capabilities. For figure, the 5 layered ANFIS has 2 inputs and one output . Node functions in the different layers inside of a five-layered ANFIS are described below:

A. *First layer*: The first layer or fuzzification layer consists of square nodes (A_1, A_2, B_1 and B_2 in figure 4) those contain membership functions assigned to corresponding inputs

B. *Second layer:* In this layer, fixed nodes identify the corresponding rules. The incoming signals are multiplied and forwarded to the next layer W_n

$$W_n = \mu_{A_m}(\alpha)\,\mu_{B_m}(\beta) \quad \text{where, } m, n = 1, 2, 3..$$

C. *Third layer*: Third layer of ANFIS calculates the normalized firing strength of each rule (W_n) and forwards to the Next Layer.

$$\bar{W}_n = \frac{W_n}{W_1+W_2+W_3+W_4+\cdots} \quad \text{where, } n = 1, 2, 3\ldots$$

D. *Forth layer:* The forth layer consists of square nodes where the node function can be written as,

$$O_n^4 = \bar{W}_n \gamma_n \quad \text{where, } \gamma_n = p_n\alpha + q_n\beta + r_n$$

E. *Fifth layer:* The fifth and last layer computes the output by summing all incoming signals.

i. ANFISPID-based PV inverter control scheme design

Four ANFISPID-based control schemes (ANFISPID-I, ANFISPID-II,ANFISPID-III and ANFISPID- IV) have been applied on the grid-interfacing PV inverter to regulate active and reactive power appropriately to regulate the voltage during normal conditions and to provide LVRT during three phase symmetric grid fault condition. Each of the ANFISPID based control scheme has one intelligent ANFIS control scheme (ANFIS- I, ANFIS- II, ANFIS- III or ANFIS- IV)

Grid partitioning technique on the training data has been followed to generate the initial fuzzy inference system structure. For reducing the computational burden, triangular membership functions have been used for both the inputs .A hybrid method that combines the least squares estimation method and back propagation method has been used to tune the membership function parameters to emulate the training data.

ii. ANFIS-based supervisory energy management system design for ESS:

Connecting ESS with grid-tied solar PV system enhances the controllability, power quality and reliability and it provides ancillary services such as voltage regulation support if proper EMS is applied

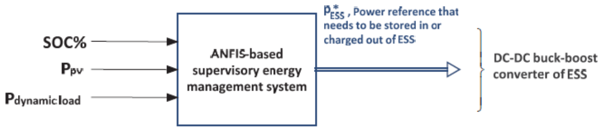


Fig 2.ANFIS based ESS

Generally, the generated power from PV gradually increases and reaches to peak at midday and starts to decrease after that. The amount of surplus energy after satisfying the consumers depends upon the nonlinear behavior of the dynamic loads varying through the parts of the day and seasons of the year In our study, an ANFIS-based supervisory EMS intelligently controls the charge/ discharge of ESS to balance the PV power generation and dynamic load demand that enhances the voltage support for the system(during short-term fluctuations too) by cooperating with PV inverter control scheme. This control scheme is advantageous over constant charging/ discharging rate strategy that may leave the storage capacity unused .

The structure of proposed ANFIS-based supervisory EMS has been illustrated in figure . It has three inputs. They are, the total power generated by solar PVs (PPV), the total demand of the dynamic load connected with the grid-tied PV system(P dynamic load) and the state of charge (SOC%) of the battery bank (ESS). SOC is the available capacity of ESS expressed as the percentage of the rated capacity. As output, the ANFIS based supervisory EMS provides power references to the DC-DC buck-boost converter through which the battery bank is connected with the central DC bus. Several researchers have implemented classic state-based EMS to control the charge/ discharge states of ESS

3. PROPOSED SYSTEM

A.GREY WOLF OPTIMIZATION

Grey wolf (Canislupus) belongs to Candidate family. Grey wolves are considered as apex predators, meaning that they are at the top of the food chain. Grey wolves mostly prefer to live in a pack. The group size is 5-12 on average. Of particular interest is that they have a very strict social dominant their arches shown in Fig.

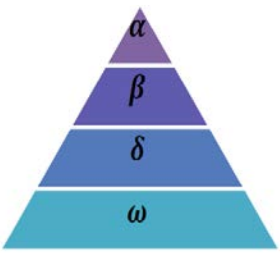


Fig 3 .Hiearchy of grey wolves

Leaders are a male and a female, called alphas. The alpha is mostly responsible for making decisions about hunting, sleeping place, time to wake, and so on. The alpha's decisions are dictated to the pack. However, some kind of democratic behavior has also been observed, in which an alpha follows the other wolves in the pack. In gatherings, the entire pack acknowledges the alpha by holding their tails down. The alpha wolf is also called the dominant wolf since his/her orders should be followed by the pack. The alpha wolves are only allowed to mate in the pack. Interestingly, the alpha is not necessarily the strongest member of the pack but the best interms of managing the pack. This shows that the organization a discipline of a pack is much more important than its strength. The second level in the hierarchy of grey wolves is beta. The betas are subordinate wolves that help the alpha indecision-making or other pack activities. The beta wolf can be either male or female, and he/she is probably the best candidate to be the alpha in case one of the alpha wolves passes away or becomes very old. The beta wolf should respect the alpha, but commands the other lower-level wolves as well. It plays the role of an advisor to the alpha and discipliner for the pack. The bet are in forces the alpha's commands throughout the pack and gives feedback to the alpha.

The Lowest Ranking Grey Wolf is omega. The omega plays the role of scape goat. Omega wolves always have to submit to all the other dominant wolves. They are the last wolves that are allowed to eat. It may seem the omega is not an important individual in the pack, but it has been observed that the whole pack face internal fighting and problems in case of losing the omega. This is due to the venting of violence and frustration of all wolves by the omega(s).This assists satisfying the entire pack and maintaining the dominance structure. In some cases the omega is also the baby sitters in the pack. If a Wolf is Not an Alpha, beta, or omega, he/she is called subordinate (or delta in some references).

Delta Wolves Have to submit alphas and betas, but they dominate the omega. Scouts, sentinels, elders, hunters, and care takers belong to this category. Scouts are responsible for watching the boundaries of the territory and warning the pack in case of any danger. Sentinels protect and guarantee the safety of the pack. Elders are the experienced wolves who used to be alpha or beta. Hunters help the alphas and betas when hunting prey and providing food for the pack. Finally, the care takers are responsible for caring for the weak, ill, and wounded wolves in the pack. According to Muro*e tal.* the main phases of grey wolf hunting are as follows:

- Tracking, chasing, and approaching the prey.
- Pursuing, encircling, and harassing the prey until it stops moving.
- Attack towards the prey.

Fig 4Hunting behavior of grey wolves: (A) chasing, approaching, an tracking prey(B-D) pursuiting, harassing, anti-encircling(E)stationary situation and attack

B.PSEUDO CODE ALGORITHM

Initialize the grey wolf population X_i (i = 1, 2, ..., n)
Initialize a, A, and C
Calculate the fitness of each search agent
X_α=the best search agent
X_β=the second best search agent
X_δ=the third best search agent
***while** (t < Max number of iterations)*
  ***for** each search agent*
    Update the position of the current search agent by equation (3.7)
  end for
  Update a, A, and C
  Calculate the fitness of all search agents
  Update X_α, X_β, and X_δ
  t=t+1
end while
return X_α

Fig 5 pseudo code of the GWO algorithm

C. PENGUINS SEARCH OPTIMIZATION ALGORITHM

We propose a new meta-heuristic algorithm called penguins Search Optimization Algorithm (PeSOA), based on collaborative hunting strategy of penguins. In recent years, various elective methods, inspired by nature and based on cooperative strategies, have been proposed to solve NP -hard problems in which, no solutions in polynomial time could be found. The global optimization process starts with individual search process of each penguin, who must communicate to his group its position and the number of fish found. This collaboration aims to synchronize dives in order to achieve a global solution (place with high amounts of food). The global solution is chosen by election of the best group of penguins who ate the maximum of fish. After describing the behaviour of penguins, we present the formulation of the algorithm before presenting the various tests with popular benchmarks. Comparative studies with other meta-heuristics have proved that PeSOA performs better as far as new optimization strategy of collaborative and progressive research of the space solutions.

D. HUNTING STRATEGY OF PENGUINS

The optimality theory of foraging behaviour was modelled in the works of [15,16]. These two studies hypothesized that dietary behaviour may be explained by economic reasoning: when the gain of energy is greater than the expenditure required to obtain this gain, so it comes to a portable food search activity. Penguins, as biological beings, use this assumption to extract information about the time and cost of food searches and energy content of prey, on one hand, and the choice to hunt or not in the selected area, depending on its high resource and the distance between feeding areas, on the other. The behaviour of air-breathing aquatic predators including penguins was noticed by [11]. The surface is a place for penguins as they are forced to return after each for aging trip. The duration of a trip is limited by the oxygen reserves of penguins, and the speed at which they use it, that is to say their metabolism [7, 26]. The works in the animal of penguins has given us clear and motivating ideas for the development of a new optimization method based on the behaviour of penguins.

Penguins are sea birds, unable to y because of their adaptation to aquatic life[7, 28, 21, 9]. The wings are ideal for swimming and can be considered as penguins y through water and can dive more than 520m to search for food. Although this is more efficient and less tiring to swim underwater than at the surface, they must regularly return to the surface to breath. They are able to keep breathing while swimming rapidly (7 to 10 km / h) [8]. During the dives, the penguin's heart rate slows down. Under water, the hunting eyes of the penguin are wide open, his cornea is protected by a nictitating membrane. The retina allows him to distinguish shapes and colors. Penguins feed on fish and squid. For this, they must hunt in group and synchronize their dives to optimize the foraging [21]. Penguins communicate with each other with vocalizations. These vocalizations are unique to each penguin (like fingerprints in humans). Therefore, they allow the unique identification of each penguin and the recognition of penguins to each other [7]. This factor of identification and recognition is important since there is a large size of the colonies and a great similarity of the penguins. The amount of the necessary food for a penguin is variable depending on species, age, variety and quantity of food available in each region. Studies had shown that a colony of 5 million of penguins may eat daily 8 million pounds of krill and small fish [7].

E. PESUDOCODE ALGORITHM

The optimization algorithm based on the hunting behavior of penguins can be described in numerous ways. While all methods agree to optimize their objective functions such as maximizing the amount of energy extracted from the energy invested, we propose to simplify the optimization function by using rules, described below, to guide the search strategy by the penguins:

Rule 1: A penguin population is made up of several groups.

Rule 2: Each group is composed of a variable number of penguins that can vary depending on food availability in a specific location.

Rule 3: They hunt in group and move randomly until they food when oxygen reserves are not depleted.

Rule 4: They can perform simultaneous dives to a depth identical.

Rule 5: Each group of penguins starts searching in a specific position (hole "i")and random levels (levels "j_1, j_2, ..., j_n").

Rule 6: Each penguin looks for foods in random way and individually in its group, and after rough number of dives, penguins back on the ice to share with its the location (represented by the level or depth of the dive) where the found food and plenty of it (represented by the amount of eaten fish). This rule ensures intra-group communication.

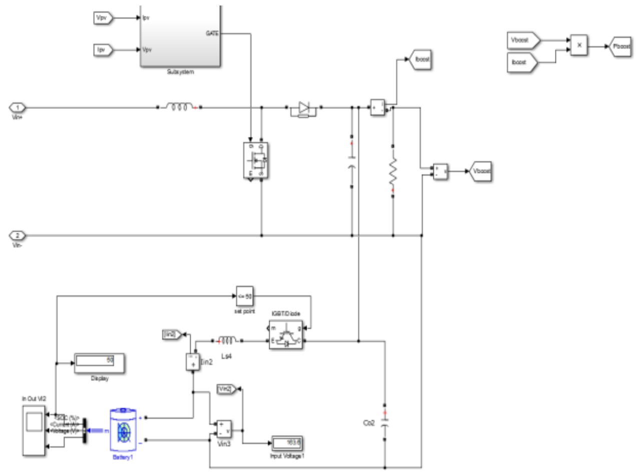
Rule 7: At one level, one can have from 0 to N penguins (penguin or any group) according to the abundance of food.

Rule 8: If the number of fish in a hole is not enough (or none) for the group, part of the group (or the whole group) migrates to another hole. (This rule ensures inter-group communication)

Rule 9: The group who ate the most fish delivers us the location of rich food represented by the hole and the level.

In the algorithm each penguin is represented by the hole "i" and level "j" and the number of fish eaten. The distribution of penguins is based on probabilities of existence of fish in both holes and levels. The penguins are divided into groups(not necessarily the same cardinality) and begin searching in random positions. After a fixed number of dives, the penguins back on the ice to share with its affiliate's depth (level) and quantity (number) of the food found (Inter group Communication).

4. SIMULATION DESIGN AND RESULTS



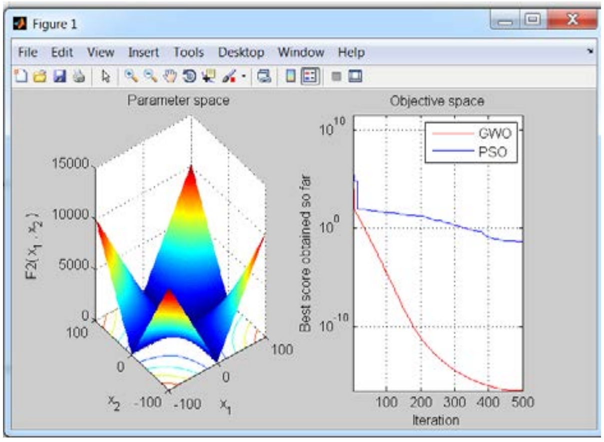


Fig 6. Gwo Optimization output

5. CONCLUSION

Voltage regulation issue is one of the most significant issues that needs to be taken care of for ensuring system stability. This paper has presented a novel GWO optimized control algorithm for the renewable interfacing inverter. The controller works satisfactorily under the dynamic operating conditions. The GWO based PV inverter control scheme damps oscillations and provides robust response while regulating PCC voltage under any worst-case scenarios and three-phase faults. This prevents many critical power system contingencies which are expensive to recover. Moreover, it eliminates the necessity of expensive manual trial-and-error method for tuning conventional PID parameters at a regular basis and provides' plug-and-play' feature for automatic tuning once implemented. The simulation results were obtained from a realistic model replicating an actual weak distribution network integrated with large-scale of solar PVs.

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