GWO Based Cooperative Control of PV Grid System

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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 technique based PV inverter control scheme and GWO -based supervisory EMS are developed and simulated in MATLAB/ Simulink Environment

I INTRODUCTION

A grid-connected photovoltaic power system, or grid-connected PV power system is an electricity generating solar PV power system that is connected to the utility grid. A grid-connected PV system consists of solar panels, one or several inverters, a power conditioning unit 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 grid.

Operation

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 yield revenue 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.

II 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 andcircle 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 ofa five-layered ANFIS are described below:First layer: The first layer or fuzzification layer consists ofsquare nodes (A1, A2, B1 and B2 in figure 4) those containmembershipfunctions assigned to corresponding inputs

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

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

Third layer: Third layer of ANFIS calculates the normalized firing strength of each rule (wn')and forwards to next layer

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

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

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

Fifth layer: The fifth and last layer computes the output bysumming all incoming signals.

$$\gamma = (W_1\gamma_1 + W_2\gamma_2)/\,(W_1 + W_2) \text{ or } \bar{W}_1\gamma_1 + \bar{W}_2\gamma_2.$$

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 beenfollowed 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.

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 properEMS is applied

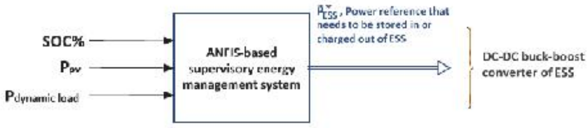

Fig. 2. ANFIS based ESS

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 mayleave 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(Pdynamic 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

. III PROPOSED SYSTEM

Grey wolf (Canislupus) belongs to Canidate 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 inapack. The group size is 5-12 on average. Of particular interest is that they have a very strict social dominanthierarchyasshowninFig.

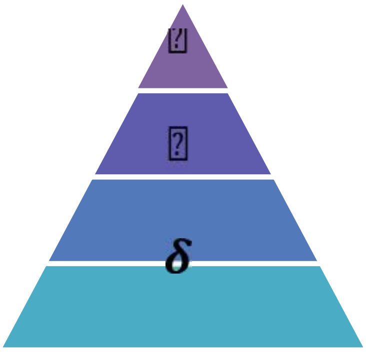

Fig. 3. *Hierarchy of ‿ ey wolf (dominance decreases from top down)*

The 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 wolfsince 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 an discipline of a pack is much more important than its strength.

Thesecondlevel 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 incase one of the alpha wolves passes away or becomes very old. The beta wolf should respect the alpha, but commands the other lower-level wolvesaswell. 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 domin an twolves. They are the last wolves that are allowed to eat. It may seem the omegaisnot an important individual in the pack, butit has been observed that the whole pack face internal fighting and problems incase of losing the omega.Thisisduetotheventingofviolenceandfrustrationofallwolvesbytheomega(s).Thisassistssatisfyingtheentirepackandmaintainingthedominancestructure.Insomecasestheomegaisalsothebabysittersinthepack.

Ifawolfisnotanalpha,beta,oromega,he/sheiscalledsubordinate(ordeltainsomereferences).Deltawolveshavetosubmittoalphas and betas,buttheydominatetheomega.Scouts,sentinels, elders,hunters,andcaretakersbelongtothiscategory.Scoutsareresponsibleforwatchingtheboundariesoftheterritoryandwarningthepackincaseofanydanger.Sentinelsprotectandguaranteethesafetyofthepack.Eldersaretheexperiencedwolveswhousedtobealphaorbeta.Huntershelpthealphasandbetaswhenhuntingpreyandprovidingfoodforthepack.Finally,thecaretakersareresponsibleforcaringfortheweak,ill,andwoundedwolvesinthepack.

IV SIMULATION DESIGN AND RESULTS

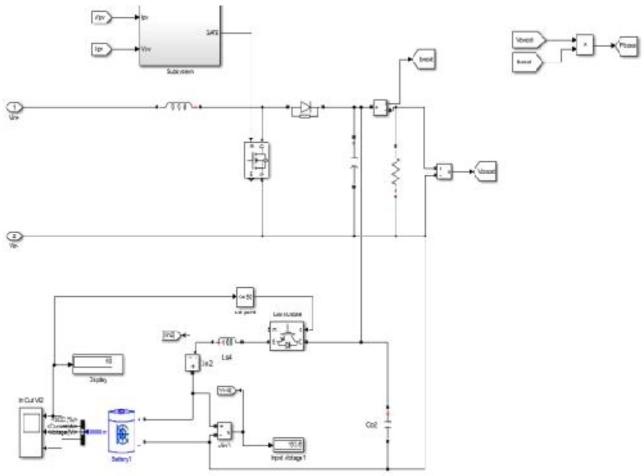

Fig. 4. Simulink Model

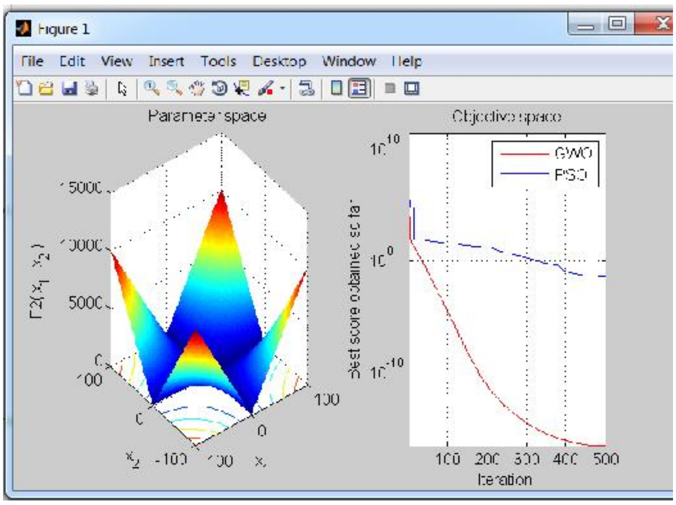

Fig. 5. Gwo Optimization output

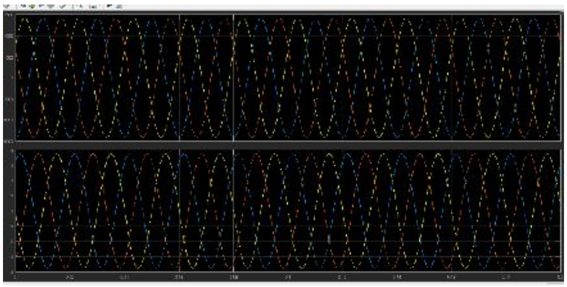

Fig. 6. Input and output voltage

Above figures shows matlab Simulink results GWO optimization and corresponding results

V 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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