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Fuzzy Based ALO Implementation for Fast Patrol Craft Tests in Marine Industry Using Wind Energy Conversion System for Multi Objective Power Dispatch

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Abstract*: Shipbuilding and Repair actions are characterized as marine conveyance equipment sector, though they also cover supply of fixed and floating structures to the offshore industry. The Marine industrial master plan between the year 2006 – 2020 identify the following challenges i) global competition ii) rising costs of raw materials iii) excess capacity iv) shortage of qualified personnel v) inadequate technology vi) lack of infrastructure and support facilities. This manuscript deals with the new technology that is required for Fast Patrol Craft Tests. The Fast Patrol Craft Tests is designed using fuzzy based ALO implementation in WECS used in Microgrid uses multi objective genetic algorithm which works on different swept speed using a set of wind turbines that are applied to different dimensions. The Power generation using WECS depends on the wind speed and swept area of the wind turbine. The objective of the simulation is to investigate the entire system operation. The objective dictates the extent of idealization of every model in the system. The MFS problem is formulated as a multi-objective search, aiming at searching for a set of control variable settings that are comparatively 'equally good' for multiple objectives. In order to select a suitable representative solution for the multiple objectives, fuzzy decision making mechanism concept is used. In this manuscript the WECS is modeled and FGALO algorithm is implemented on the controller to attain stability under different swept rotor speeds.

Keywords: Fuzzy ALO Algorithm, Wind Energy Conversion System, Microgrid.

I. INTRODUCTION

A wind turbine is a device that converts the wind's kinetic energy into electrical power. The term appears to have been adopted from hydroelectric technology (rotary propeller) [1]. The technical description of a wind turbine is aerofoil-powered generator [2]. As a result of over a millennium of windmill development and modern engineering, today's wind turbines are manufactured in a wide range of vertical and horizontal axis types[3].

The smallest turbines are used for applications such as battery charging for auxiliary power for boats or caravans or to power traffic warning signs. Slightly larger turbines can be used for making contributions to a domestic power supply while selling unused power back to the utility supplier via the electrical grid[4]. Arrays of large turbines, known as wind farms, are becoming an increasingly important source of renewable energy and are used by many countries as part of a strategy to reduce their reliance on fossil fuels [5-7].

A. Wind Turbine Model Description

The wind turbine model consist of 8.5KW wind farm of base power 9.5 KVA connected to the distribution system which exports power to a grid through feeder [8]. The wind turbine existing in this demonstration contains synchronous generator connected to a diode rectifier, a DC-DC MOSFET based PWM boost converter and a DC/AC MOSFET based PWM converter modelled by voltage sources[9-10].

This Scenario allows extracting maximum energy from the wind for low wind speeds by optimizing the turbine speed, while reducing the mechanical stress on the turbine during gust of wind [11].

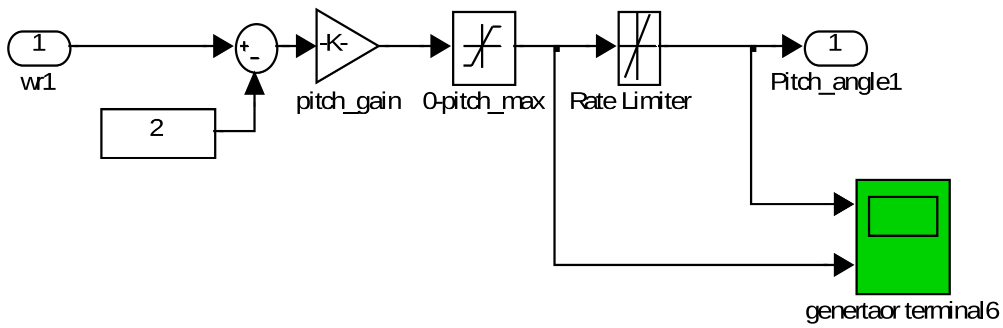

Figure.1 Wind Turbine Pitch Angle Controller

In this demo the wind speed is maintained constant at 12 m/s. The control system of the DC-DC converter is used to maintain the speed at 1 pu. The reactive power produced by the wind turbine is regulated at 0 Mvar. Right-click on the “Wind Turbine Type 4” block and select “Look under Mask” to see how the model is built. The sample time used to discretize the model (Ts= 50 microseconds)is specified in the Initialization function of the Model Properties. Open the “Wind Turbine Type 4” block menu to see the data of the generator, the converter, the turbine, the drive train and the control systems. In the Display menu select “Turbine data for 1 wind turbine”, check "Display wind turbine power characteristics" and then click apply. The turbine Cp curves are displayed in Figure 1. The turbine power, the tip speed ratio lambda and the Cp values are displayed in Figure 2 as function of wind speed. For a wind speed of 15 m/s, the turbine output power is 1 pu of its rated power, the pitch angle is 8.9 deg and the generator speed is 1 pu.

II. ANT LION OPTIMIZER

The ant lions are a class of net-winged insects in nature. The lifecycle of ant lions include larvae and adult. A larva is the lengthiest retro in their lifespan and ant lions mostly pursuit during this passé. An ant lion larva lodgings a cone shaped pit in sand by poignant along a circular path, then the larvae hides underneath the lowest of the cone and waits for the prey to be trapped in the pit. Once the ant lion realizes a prey in the trap, it tries to catch it by perceptively throw sands in the direction of the edge of the pit to slide the prey into the bottom of the pit. After consuming the prey, ant lions throw leftovers outside the pit and amend the pit for next hunt. The ALO mimics the interactions between the ant lions and ants in the trap. The ants are allowed to move over the search space and ant lions hunt those using traps to become fitter. These activities are mathematically modeled and are detailed in the literature (Mirjalili, 2015). The main steps involved in the ALO are random walk of ants, trapping in ant lion’s pits, building traps, entrapment of ants in preys, catching in preys and rebuilding of traps.

A. *Random Walks of ANTS*

To model the interactions between ant lions and ants in the trap, ants are necessitated to move over the search space and ant lions are consented to hunt them and become fitter using traps. A random walk is chosen for modeling ants’ movement, since, during the search for food, the ants move stochastically in nature. Therefore, to facilitate the random walks inside the search space, they are normalized using Eq. (1).

$$X_i^k = \frac{(X_i^k - r_i)(m_i - q_{i,k})}{(m_{i,k} - r_i)} + q_i \qquad (1)$$

B. *Trapping in Ant Lion’s Pits*

The assumption considered in ALO is that “The random walks of ants are affected by ant lion’s traps” (Mirjalili, 2015). The above assumption is mathematically modeled as (2):

$$q_{i,k} = AL_{j,k} + q_k \; ; m_{i,k} = AL_{j,k} + m_k \qquad (2)$$

C. Building Trap

In this phase, a roulette wheel operator is used to select the ant lions based on their fitness during optimization. This mechanism offers high possibilities to the fitter ant lions for grasping ants.

D. Exploration of Search Space Catching Prey and Re-Building the Pit

To prevent the trapped ants from escaping the radius of ants' random walks hyper-sphere is reduced adaptively. To mathematically model the above behavior, the following equations, which shrink the radius of updating ant's positions and mimic the sliding process of ant inside the pits, are used as (3).

$$q_k = {q_k}/{R}; m_k = {m_k}/{R} \qquad (3)$$

Where, $R = 10^S (k/iter_{max})$ and $S = 2$ if $k > 0.1\ iter_{max}$; = 3 if $k > 0.5\ iter_{max}$; = 4 if $k > 0.75\ iter_{max}$; = 5 if $k > 0.9\ iter_{max}$; = 6 if $k > 0.95\ iter_{max}$. The accuracy level of exploitation depends on the constant S.

E. Catching Prey and Re-Building the Pit

The final stage of hunting behavior is when an ant reaches the bottom of the pit and is caught in the ant lions's jaw. After this stage, the ant lion pulls the ant inside the sand and consumes its body. This behavior is modeled using the following equation (4).

$$AL_{j,k} = A_{i,k} \quad iff\ (A_{i,k}) > f(AL_{j,k}) \qquad (4)$$

F. Elitism

It is assumed that every ant randomly walks around a selected ant lion from the roulette wheel and the elite simultaneously as follows as (5)

$$A_{i,k} = {R_{A,k} + R_{B,k}}/{2} \qquad (5)$$

The fuzzy mechanism has been incorporated in the ALO algorithm, to develop a Fuzzy Guided ALO (FGALO) in order to handle multiple operational objectives.

III. FGALO IMPLEMENTATION FOR MULTI-OBJECTIVE POWER DISPATCH IN WECS

The algorithm for multi-objective power dispatch in WECS is as follows

Step 1: Read the system data and initialize the algorithmic parameters such as wind speed, Wind Power (Ps), maximum number of iterations ($iter_{max}$), number of blades in wind turbine (Nd) and its limits.

Step 2: The decision variables such as real power outputs of generating units are randomly generated within the lower and upper bounds to initialize the first population of ant and ant lions using Eqs. (6) and (7).

$$Pk^j = P_j^{min} + rand * (P_j^{max} - P_j^{min})\ k = 1,2,....Pw;\ j = 1,2,..Nt \qquad (6)$$

$$P^{AL}{}_k^j = P_j^{min} + rand * (P_j^{max} - P_j^{min})\ k = 1,2,......Pw;\ j = 1,2,...Nt \qquad (7)$$

The wind speed matrix of ants (Pop^A) and ant lions (Pop^{AL}) are formed as matrices as in respectively.

IV. STATISTICAL FORMULATION OF WIND TURBINE REPRESENTATION

The mechanical Power Output from Wind Turbine Is Given as in (12) and model shown in fig.3.

$$P_m = \omega_r [J.d\omega/dt] + P_g \qquad (8)$$

The Wind Turbine drive train based on 2 mass models is utilized in shaft modeling analysis. Driving by the dynamic torque T_d, the wind turbine rotor rotates at ω_r and the braking torque is represented as T_{lb}. The dynamics of rotor is characterized by the state equation in first order differential equation representation.

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$$J_r\, d\omega_t/dt = T_d - T_{lb} - k_r\omega_t \tag{9}$$

The low speed shaft results T_{lb} from the torsion and friction effects due to the difference between x_t and the low-shaft speed x_{lb}. This torque act as a breaking torque on the rotor.

$$T_{lb} = B_{lb}\,(\theta_t - \theta_{lb}) + K_{lb}\,(\omega_t - \omega_{lb}) \tag{10}$$

The torque on high shaft is generated by torque on low shaft using gear box

$$T_{hs} = {T_{ls}}/{G} \tag{11}$$

Pitch angle and pitch speed of the gear box is given as

$$\begin{aligned} \theta_g &= G.\theta_{ls} \\ \omega_g &= G.\omega_{ls} \end{aligned} \tag{12}$$

The low shaft speed ω_{ls} is enlarged by the changing the gearbox ratio so as to obtain the generator speed ω_g, while the low-speed shaft torque T_{ls} is increased. If we presume an ideal gearbox the gear ratio can be written as

$$G = \frac{T_{ls}}{T_{hs}} = \frac{\omega_g}{\omega_{ls}} = \frac{\theta_g}{\theta_{ls}} \tag{13}$$

The generator is driven by the high-speed shaft Torque T_{hs} and braked by the generator electromagnetic torque T_{em}

$$J_g\,\dot{\omega}_g = T_{hs} - K_g\omega_g - T_{em} \tag{14}$$

The electromagnetic torque is represented as T_{em} and is given by

$$T_{em} = \frac{P}{\omega}\left[E_R i_R + E_y i_y + E_B i_B\right] \tag{15}$$

In a Linear model the voltage and flux equation with respect to stationary reference frame is given as

$$\begin{aligned} V_{ds} &= I_{ds}R_{ds} + {d\varphi_{ds}}/{dt} \\ V_{qs} &= I_{qs}R_{qs} + {d\varphi_{qs}}/{dt} \end{aligned} \tag{16}$$

Considering the Stator, Rotor and magnetizing inductance the flux through the dq reference frame is written as

$$\begin{bmatrix}\varphi_{ds}\\ \varphi_{qs}\\ \varphi_{dr}\\ \varphi_{qr}\end{bmatrix} = \begin{bmatrix} L_s & 0 & L_m & 0\\ 0 & L_s & 0 & L_m\\ L_m & 0 & L_r & 0\\ 0 & L_m & 0 & L_r\end{bmatrix}.\begin{bmatrix}I_{ds}\\ I_{qs}\\ I_{dr}\\ I_{qr}\end{bmatrix} \tag{17}$$

Simulation Output of WECS

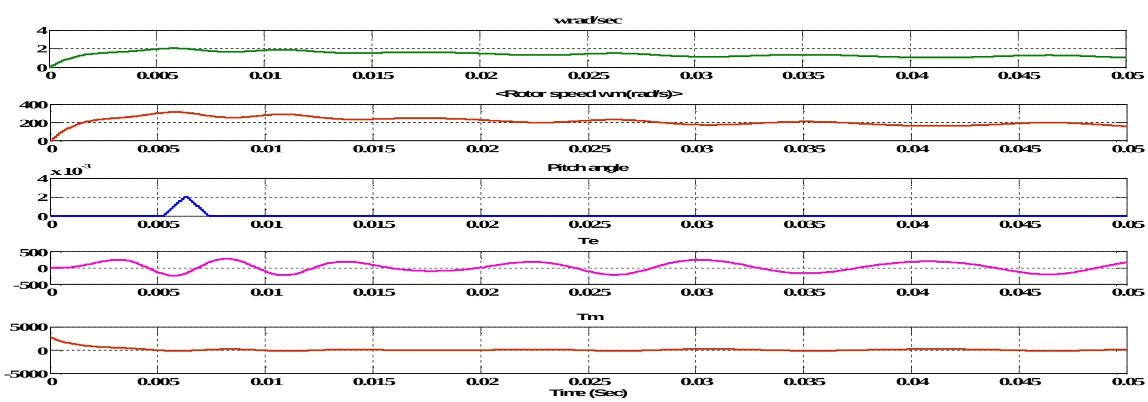

Figure.2 WECS Parameters

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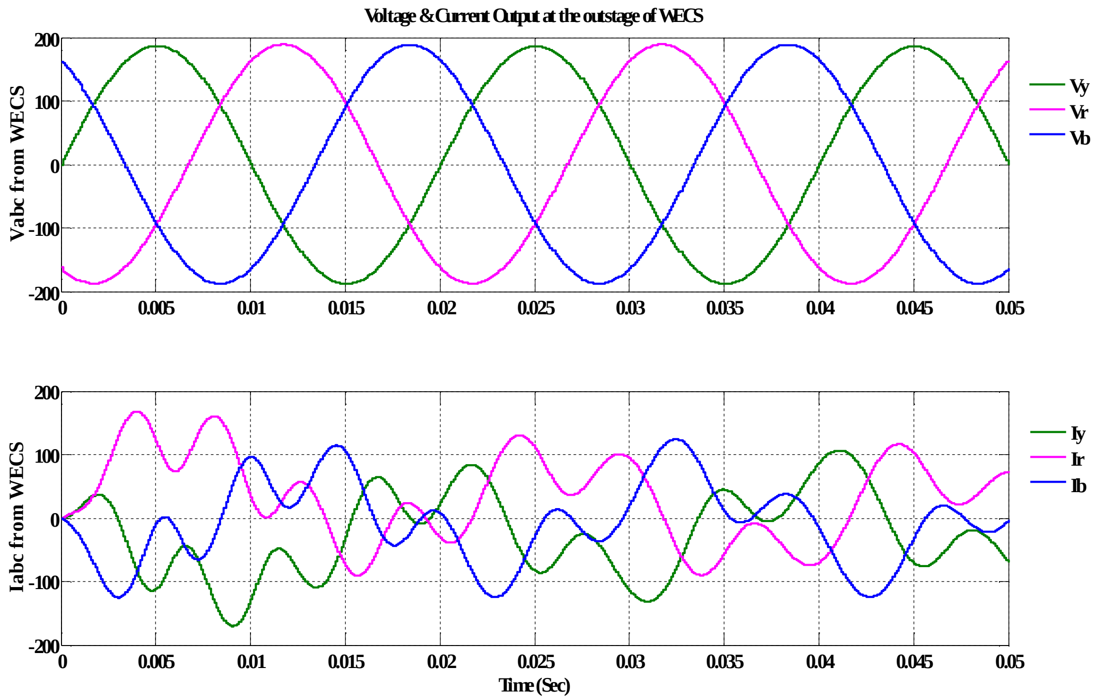

Figure .3 WECS output voltage and current

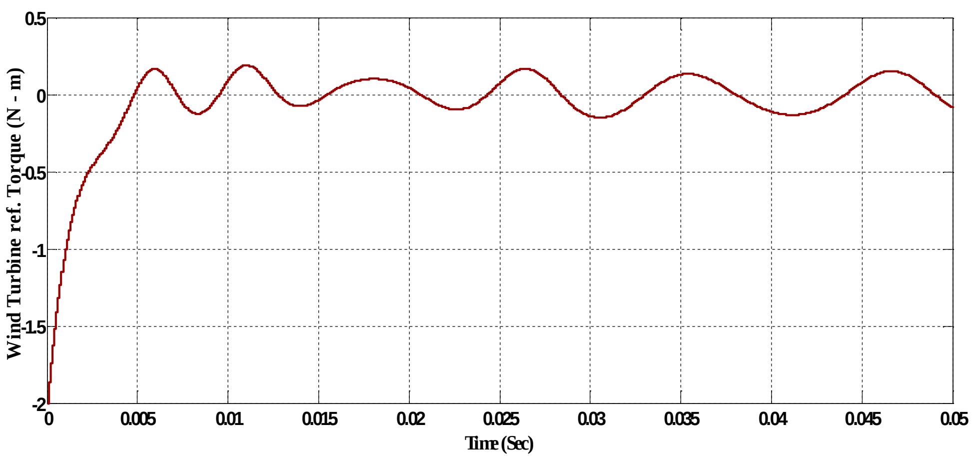

Fig.4.a Wind Turbine Reference Torque

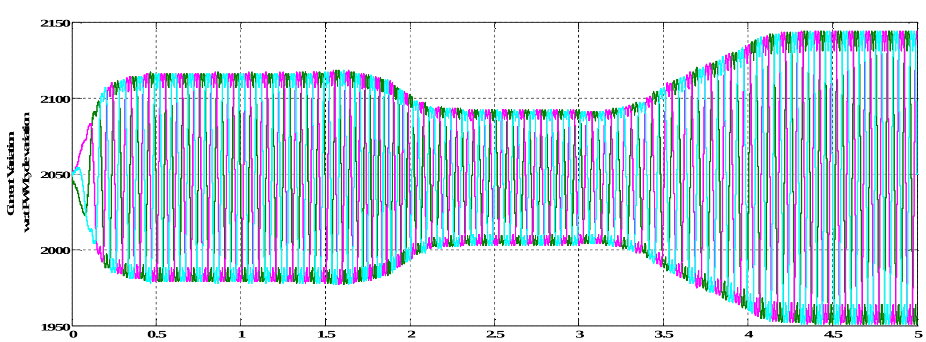

Figure.4.b Stationary ref. frame current variation w.r.t SVPWM switching sequence

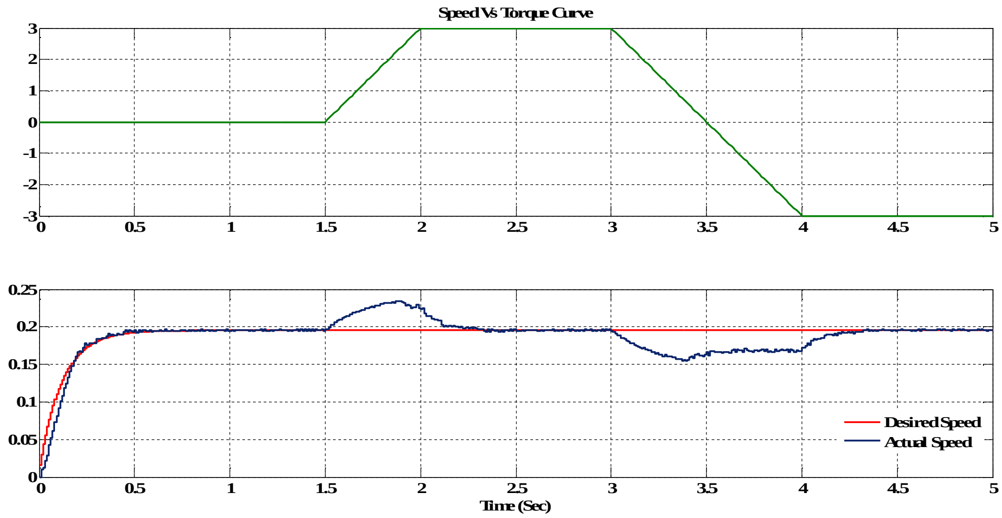

Figure.5 Wind Turbine Speed Vs Torque Characteristics

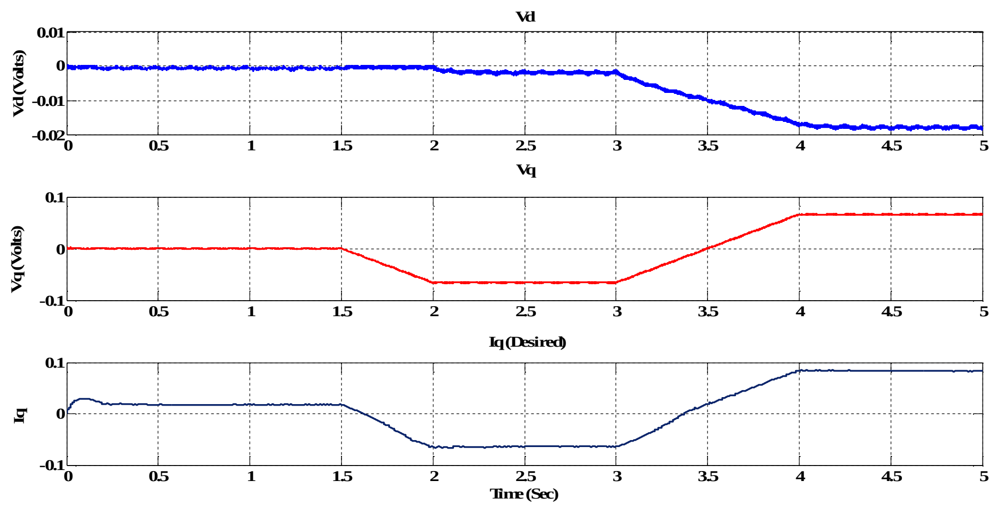

Figure.6 Orthogonal quantity of voltage and Current

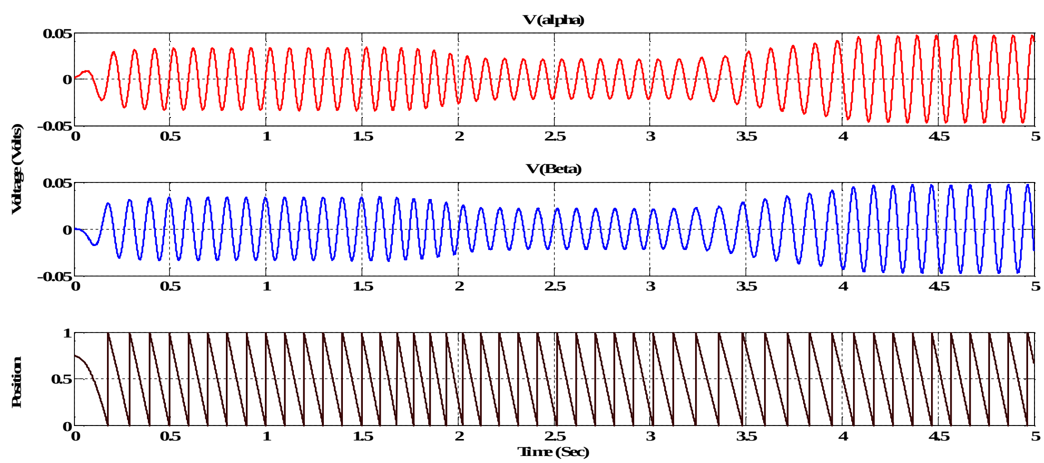

Figure.7 Vα, Vβ and position

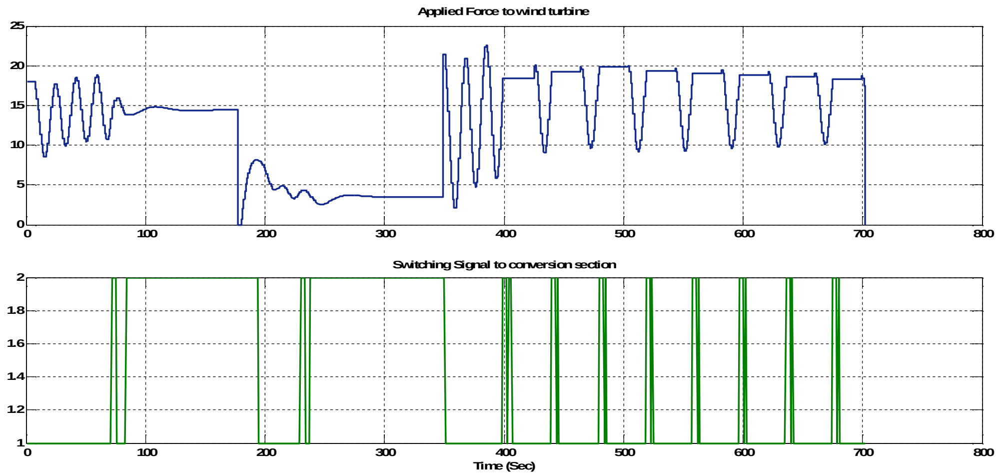

Figure.8 FGALO Controller output

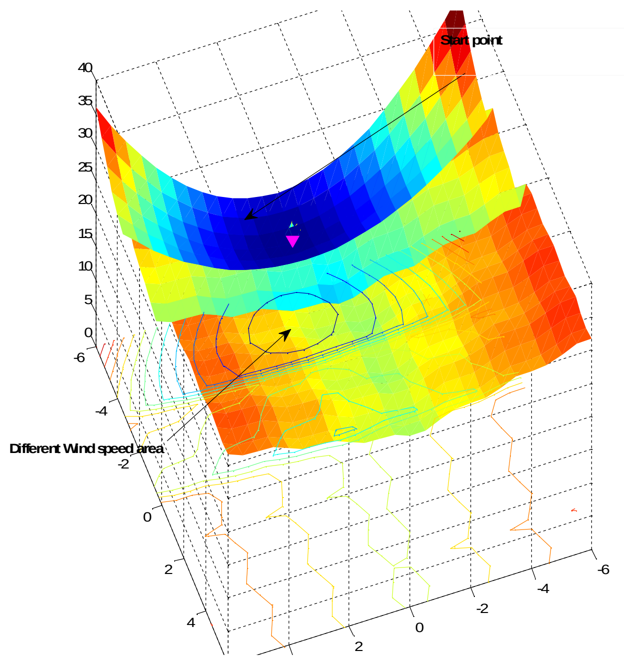

Figure.9 FGALO Controller output

The controller part output described with difference wind spread region, which shows the achievement of the proposed work. And the angular position in Fig 5-9.

V. CONCLUSIONS

Scarce intelligences have been made at fiscal process considering PQCF and MFS to perform Fast Patrol Craft Tests. In this manuscript, the most genuine operative archetypal including MFS is proposed. The realistic load dispatch problem is intricate because of these operative constrictions. The contemporary swarm particle optimization algorithm with fuzzy decision making mechanism in WECS extracts the BCS in the multi-objective framework. One of the main contributions of this research is the inclusion of MFS in WECS. The multi-area dispatch schedules also validates that the intended algorithm is highly suitable for real situations in marine applications.

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