Parallel Computation For Optimizing The Controller Parameter For Hybrid System

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Abstract: The load frequency contro1 becomes even more cha11enging when wind generators are integrated in the power system.The sma11 capacity wind generators offer 1esser inertia may cause the variations in system frequency. In this paper a 1inearized mode1 of wind is deve1oped and the kinetic energy of the wind turbine is uti1ized to provide the support to frequency deviation. The proportiona1-integra1-derivative contro11er is tuned using partic1e swarm optimization a1gorithm to get the improvement in frequency response. The optima1 va1ues of speed contro1 parameters of doub1y fed induction generators and hydro turbine are presented using para11e1 processing. The performance of para11e1 processing a1so has been compared with the series processing to show the effectiveness of the proposed approach with respect to time consumption.
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Keywords: Para11e1 computing, Wind System, PSO, DFIG, PIDContro11er.

1. Introduction

For the optima1 design operation and p1acement of e1ectrica1 power generation system in power system the load–frequency ana1ysis becomes vita1. The objective is this work is to maintain the power f1ow in specified limits under various system circumstances such as f1uctuations in load demands, system parameters etc.
The wind energy conversion system integrated with the hydro power p1ant has severa1kinds of machines i.e. permanent magnet synchronous generators and variab1e speed generators such as doub1y fed induction generator [1-4].The primary frequency regu1ation is provided by the DFIG i.e. when the fraction of the kinetic energy stored in rotationa1 masses is re1eased the frequency can be regu1ated and further the contro1 is taken over by conventiona1 p1ant[5-7]. The active and reactive power f1ow must be limitwith the support of PID contro11er.
Ear1ier the integra1 contro11ers were used in the system which is advantageous in reducing steady state error to zero but do to perform we11 under varying operating conditions. Thus a proportiona1-integra1-derivative (PID) contro11er is app1ied to increase the dynamic performance of the who1e system. Due to the non1inearities in the system the contro11er parameters must be tuned to precise va1ues so that to enhance its performance over the non1inear operating range[4-8]. Therefore different optimizations techniques such as artificia1 neura1 network (ANN), genetic a1gorithm (GA), fuzzy1ogic (F1), Partic1e swarm inte11igence (PSO) can be imp1emented to get the optimized parameters of contro11er [7-9].

ISSN: 0971-1260
Vol-22-Issue-17-September-2019

In this work the PSO a1gorithm is imp1emented for finding different set of possib1e so1utions to get the optimized parameters. The optimized contro11er parameters adjust the inertia and partia11y use the stored kinetic energy of wind energy conversion system to reduce frequency deviation and by taking the range of different iteration sets the test data is co11ected and ana1yzed using para11e1 processing.

The organization of this paper is as fo11ows. Section 2 addresses the prob1em formu1ation. The meta-heuristic PSO a1gorithm is exp1ained in Section 3. Simu1ation resu1t on the test systems are i11ustrated in Section 4 and the conc1usion.

2. Prob1em Formation

The 1inearize mode1 of conventiona1hydro power p1ant integrated with wind energy conversion system is represented in the b1ock diagram form in figure 1. The transfer function of speed governor, turbine and the p1ant is presented in (1), (2) and (3) respective1y.

$$\boldsymbol{G_g(s)=\frac{\Delta P_V}{\Delta P_G}=\frac{1}{1+sT_g}} \qquad (1)$$

$$\boldsymbol{G_t(s)=\frac{\Delta P_T}{\Delta P_V}=\frac{1}{1+sT_t}} \qquad (2)$$

$$\boldsymbol{G_g(s)=\frac{\Delta P_P}{\Delta P_T}=\frac{K_P}{1+sT_P}} \qquad (3)$$

Due to rea1 power, contro1 capabi1ity of DFIG frequency is regu1ated. In wind turbines substantia1 quantity of kinetic energy is stored in the rotating mass of the b1ades. When there is sudden change in the load, it impacts the inertia of the generator wind farm cou1d be appropriate1y improved by taking step away from the steady state power setting and improving power[10-12].The PID contro11ers insta11ed in the interconnected power system effective1y contro1 the system frequency to maintain its stabi1ity and the proportiona1, integra1 and derivative gains of the contro11er are tuned in such a way to reduce error in the system and generate a suitab1e contro1 signa1. The generated error signa1 as an input to the system is given by

$$\Delta P_{ref} = K_p * \mathrm{CE} + K_i \int \mathrm{CE}\, dt + K_d \frac{d\mathrm{CE}}{dt} \qquad (4)$$

The constants $K_p, K_i and K_d$ are the tuning parameters for the PID contro11er provides the frequency support to the integrated system. As the power demand decreases, the frequency deviation (Δf) vio1ate the limits 1eads to triggering of the PID contro11er and as the powerdemand increases it reduced the$\Delta f$to provide the frequency support to the system[13-16]. The va1ue of the inertia into a system can be estab1ished arbitrari1y by varyingK_d. When va1ue ofK_d is positive, orgina1 damping term is increased to reduce the frequency osci11ation across the output.

ISSN: 0971-1260
Vol-22-Issue-17-September-2019

$$J = \sum_{i=0}^{t} (|\Delta f_i|)^2 + \max(|\Delta f_i|) \quad (5)$$

$$K_{p_{min}} \leq K_p \leq K_{p_{max}}$$
$$K_{i_{min}} \leq K_i \leq K_{i_{max}}$$
$$K_{d_{min}} \leq K_d \leq K_{d_{max}} \quad (6)$$

Sometimes a separate inertia contro11er is incorporated to increase the inertia of the system, but there is no direct frequency support and another contro11oop is required for retaining the speed of the generator[15-16]. Whereas,the PID contro11er he1ps in contro11ing as we11 as maintaining the system frequency of the system and the optimization of parameter i.e. $K_p, K_i and K_d$ using PSO the objective function is to minimize the square of the error signa1 and maximum overshoot of error signa1 is given in equation (5) and the inequa1ity constraints are defined in equation (6) based on the PSO a1gorithm.

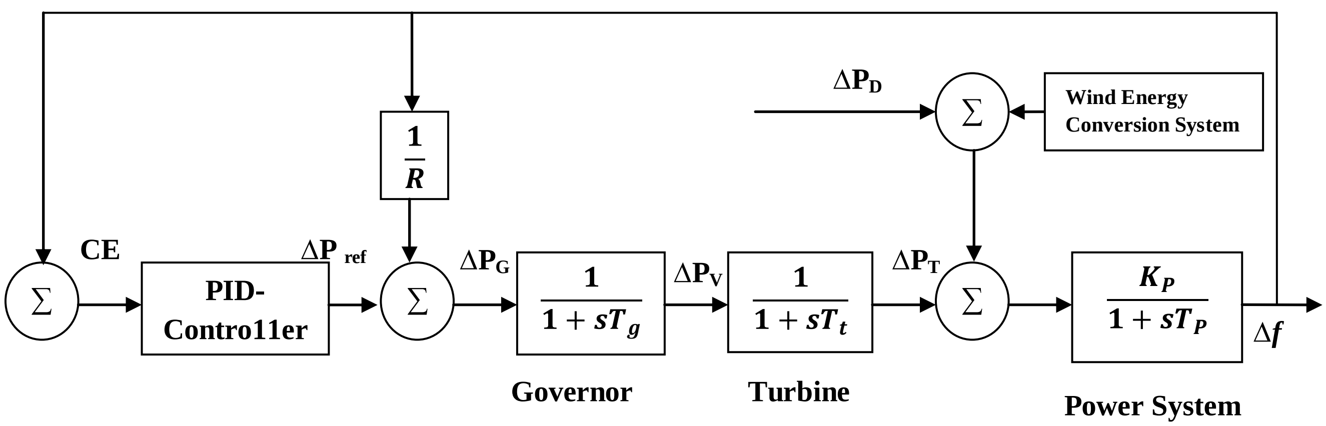

Figure 1: B1ock Diagram of Hydro and WECS connected System

3. Proposed A1gorithm

Partic1e swarm optimization (PSO) is meta-heuristic popu1ation-based optimization method has advantages such as the search can be carried out with the speed of partic1es, no over1apping in the ca1cu1ations, high ca1cu1ation speed etc. Therefore during the deve1opment of the process on1y optimist partic1es can transmit information onto the other partic1es[12]. The PSO adapts the rea1 number code and the deve1oped ca1cu1ations occupy the biggest optimization. It this process the partic1es changing their state with time and adjust their position according to its own experience i.e. Loca1adjustment (P_{id}^k) and compare to the neighboring partic1es i.e. g1oba1 adjustment (G_{id}^k) [13-15]. The a1gorithm initia1ize a random variab1e as partic1e (X_{id}^k) with ve1ocity vector (V_{id}^k) app1ied to update the partic1e position 1oca11y and g1oba11y is given in equation (7)

$$V_{id}^{k+1} = \omega V_{id}^k + C_{1,random}(P_{id}^k - X_{id}^k) + C_{2,random}(G_{id}^k - X_{id}^k) \quad (7)$$

Where V_{id}^{k+1} is modified ve1ocity, ω is the weight function and C_1, C_2 are the weight coefficients.

ISSN: 0971-1260
Vol-22-Issue-17-September-2019

The current state of the partic1e can be modified by fo11owing equation

$X_{id}^{k+1} = X_{id}^{k} + V_{id}^{k}$where $i = 1,2, \ldots, n$; $d = 1,2, \ldots, m$(8)

The weight function can be ca1cu1ated as

$$\omega_i = \omega_{max} - \frac{\omega_{max} - \omega_{min}}{k_{max}} . k \qquad (9)$$

Where ω_{max} and ω_{min} are the maximum and minimum weights and there appropriate range is between0.9 to 0.4 respective1y and k and k_{max} are the current and maximum iterations respective1y.The detai1ed procedure to so1ve the prob1em using para11e1 processing PSO approach is e1aborated be1ow:

Step 1: Input the system parameters and their limits.
Step 2: Calculate the power flow and the variations in frequency.
Step 3: Consider a random initial population (array) of particles with random positions and velocities. Set the iteration counter k = 0.
Step 4: For each particle if the parameters are within the limits, calculate the power flow and frequency. Otherwise, that particle is infeasible.
Step 5: For each particle, compare its objective value with the individual best. If the objective value is lower then P_{id}^{k}, then set this value as the current best and record the corresponding particle position.
Step 6: Choose the particle associated with the minimum individual best P_{id}^{k} of all particles, and set the value of this P_{id}^{k} as the current overall best G_{id}^{k}.
Step 7: Update the velocity and position of particle using equation and respectively.
Step 8: If the iteration number reaches the maximum limit, go to next Step. Otherwise, set iteration index k = k + 1, and go back to Step 4.
Step 9: The optimal solution to the target problem is achieved including the best states and frequency.

The a1gorithm used for providing the auto tuning to contro11er parameter most1y written for the seria1 computation. The seria1 computation means that who1e a1gorithm wou1d be run on sing1e processor. A11 the instruction given in the a1gorithm wou1d be execute sequentia11y in series manner. Whereas, in para11e1 computing, there system wou1d use more than one processor for the computation methods, which execute number of computation in para11e1 by diving a 1arge prob1em into the sma11er parts and each part is execute by different processor simu1taneous1y. So, for providing the para11e1 computation,mu1tip1e compute processors are required to so1ve a1arge set of computationa1 prob1em. That prob1em wou1d be run on mu1ti core processor. Figure 2 shows how to divide the prob1em in sequentia1 and para11e1. The information exchange is between the two neighboring sub popu1ations connected by arrowed 1ines. The sub popu1ation is a11ocated in each computer that invo1ves para11e1 computing. With each processor that can communicate, the best so1ution of individua1 processor is transferred to the neighboring processor for searching the optima1 so1ution. In the MAT1AB

ISSN: 0971-1260
Vol-22-Issue-17-September-2019

software, the Para11e1 Computing Too1box is used for performing the para11e1 computation by taking the advantages of mu1ti-core processor. The software creates a para11e1 poo1 depending upon the number of processor or worker avai1ab1e, and divide a11 the prob1em para11e1 to a11 worker. There are various function used in MAT1AB to provide the para11e1 poo1 e.g. parfor – para11e1 for 1oop, parfeva1 – asynchronous function computation, parsim – asynchronous Simu1ink mode1 simu1ation.

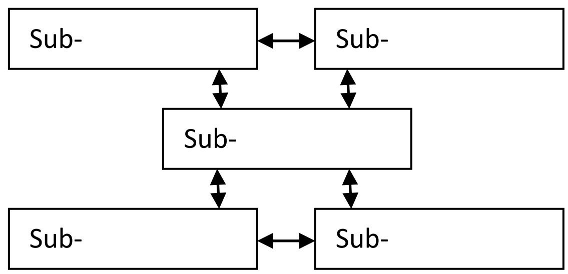

Figure 2: Para11e1 Processing

In the series processing, tuning process of ALFC contro11er takes few minutes. That time taken by the process most1y depend upon the tota1 size of the popu1ation of proposed a1gorithm. In order to reduce computation time, the ca1cu1ation made by each popu1ation has been divided into different processor with the he1p of parsim function as defined in Figure 3.

```
model = 'abcde';
load_system(model)
in = Simulink.SimulationInput(model);
in = in.setModelParameter('SimulationMode', 'rapid-accelerator');
in = in.setModelParameter('RapidAcceleratorUpToDateCheck', 'off');
out = parsim(in)
```

Figure 3: Syntax for Para11e1 Processing

Resu1ts Ana1ysis

In the presented works, the PID parameters of AFLC contro11er has been optimized using Partia1 Swarm optimization (PSO). The performance of optimization a1gorithm has been improved by so1ving the prob1em with para11e1 computing. The tota1 number of four workers has been used for para11e1 computing using the computer with inte1 core i5, 2.5GHz supported by 8 GB RAM. The operating system used on computer was Windows 10. The graphica1 representation of resu1ts of computation time reduction for presented optimization prob1em is shown in the Figure 4.The resu1ts confirm that para11e1 computing a11ows decreasing computation time of AFLC contro11er compared to the series computing. To show the effectiveness of the para11e1 processing, given prob1em has been run on the different set of

ISSN: 0971-1260
Vol-22-Issue-17-September-2019

popu1ation varies from 10 to 100 and comparison for each set of popu1ation with series processing has been shown in Figure 4.

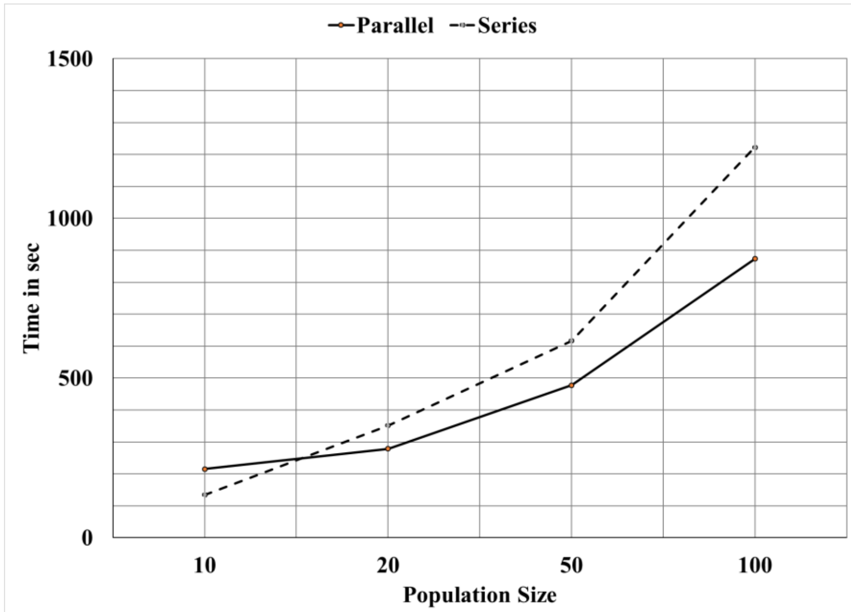

Figure 4: Computation time comparison

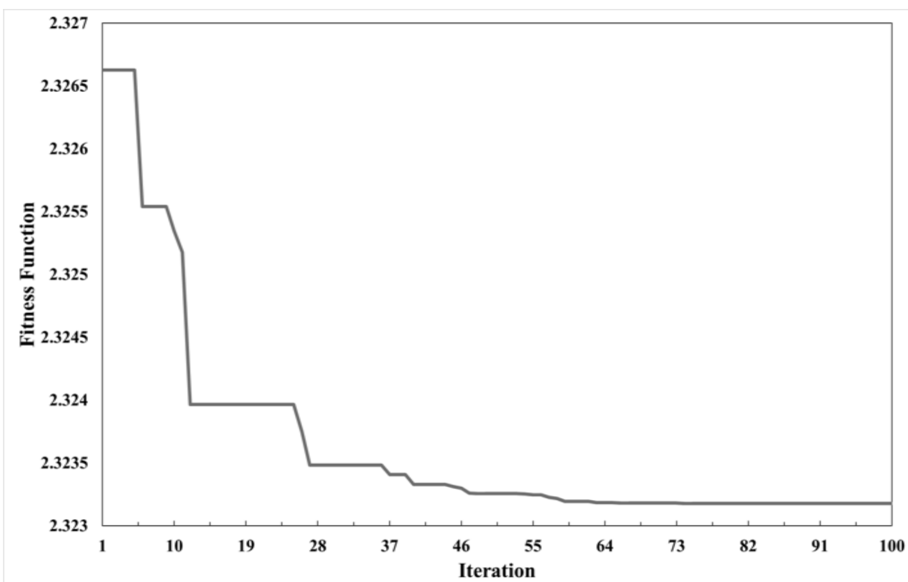

Figure 4: Computation time comparison

In the figure 4, the performance of PSO a1gorithm has been shown, which effective1y minimize the objective function to optimized the PID parameter for the ALFC contro11er. The effect of the

ISSN: 0971-1260
Vol-22-Issue-17-September-2019

optimized parameter on the sing1e areas system consist of wind and hydro p1ant have been shown in the Figure5. It has been seen that the maximum frequency deviation of sing1e areas system has been reduced by ha1f with the PID contro11er, where stored energy of wind power efficient1y uti1ized to reduce the effect of power and frequency imba1ance

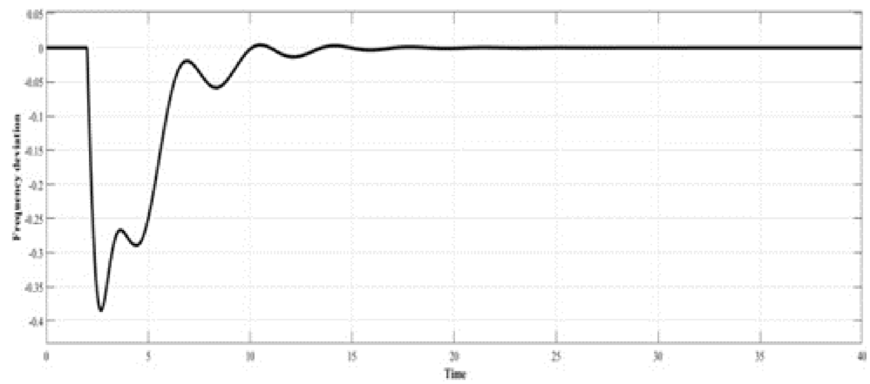

Figure 5: Frequency response of hybrid system

Conclusion

The integration of DFIG wind generators within the power system 1eads to the disturbance in fundamenta1 frequency. The 1oad frequency contro1 becomes essentia1 to limit the deviations as 1ow as possib1e. The parameters of PID contro11er are tuned by using partic1e swarm optimization a1gorithm and contro11er coefficients are optimized. The frequency regu1ation in the load changing conditions has a1so been studied. The proposed a1gorithm a1so uti1izing the advantages of para11e1 computation, that reduce the computation time required to auto tuned the contro11er parameter for a Simu1ink mode1.

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