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Automatic Generation Control of Multi-Area Power Systems with Renewable Energy Sources using Soft D Computing Technique

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Abstract: ***With the emerging technologies the requirement of clean and sustainable energy has become a challenge for the Electrical Engineers in their day to day life. Recent studies suggest that in the next five decades, large portion of the Non-Renewable sources accessible will be diminishing. This is the prime concern for attracting the attention for the enhancement in the performance of the renewable energy sources which abundantly exist in the nature. Wind, solar photovoltaic, and solar thermal power systems are emerging renewable technologies that can be developed as a viable option for the future generation of electrical energy. In this paper, we have considered an autonomous hybrid generation system consisting of Wind turbine generator (WG), solar photovoltaic (S-PV), diesel generator(DG),fuel cell(FC), battery energy storage system (BES), solar thermal power system(STPS) and aqua electrolyzer (AE) for simulation studies. In the power system, the frequency deviations are generally due to deviations in load or generation or both. The comparative performance of the controllers installed to alleviate this frequency deviation for different hybrid systems, is carried out using time domain simulations. In practical, tuning of PI and PID controllers is challenging and time consuming. With the introduction of computational intelligence has opened a new pathway for advanced new generation control process. Here, PSO is used as the optimization method to determine the controller gains for the proposed hybrid system. From the results, we can demonstrate the effectiveness of the PSO based controllers in terms of reduced settling time, over shoot, and oscillations. The results are compared with conventional controllers and with the controllers whose gains are tuned by GA.***

Keywords: ***Particle swarm optimization (PSO), Genetic algorithm (GE), PI controller, PID controller, Aqua electrolyzer (Ae), Fuel cell (Fc), Diesel generator (DG), Battery energy storage system (BES), Wind turbine generator (WG), solar photovoltaic (S-PV).***

NOMENCLATURE

Δf	–	Deviation in system frequency
P_s	-	system total power generation
P_L	-	absorbed power in average by load
K_{Sy}	–	frequency characteristic constant of hybrid power system
$G_{Sy}(s)$	–	first order transfer function of hybrid system
ΔP_e	-	error in supply to power demand
M	-	inertia constant of Hybrid model power system
D	-	damping constant of Hybrid model power system
P_{WG}	-	power output of wind turbine generator
$G_{WG}(s)$	-	first order transfer function of wind turbine generator system
K_{WG}	-	Gain of wind turbine generator
T_{WG}	-	time constant of wind turbine generator
P_{DG}	-	power output of diesel generator
$G_{DG}(s)$	-	first order transfer function of diesel generator system
K_{DG}	-	Gain of diesel generator
T_{DG}	-	time constant of diesel generator
$P_{S\text{-}PV}$	-	power output of solar photovoltaic system
$G_{S\text{-}PV}(s)$	-	first order transfer function of solar photovoltaic system
$K_{S\text{-}PV}$	-	Gain of solar photovoltaic system

$T_{S\text{-}PV}$	-	time constant of solar photovoltaic system
P_{Fc}	-	power output of Fuel cell generator
$G_{Fc}(s)$	-	first order transfer function of Fuel cell generator
K_{Fc}	-	Gain of Fuel cell generator
T_{Fc}	-	time constant of Fuel cell generator
P_{BES}	-	power output of battery energy storage model
$G_{BES}(s)$	-	first order transfer function of battery energy storage model
K_{BES}	-	Gain of battery energy storage model
T_{BES}	-	time constant of battery energy storage model
P_{STS}	-	power output of solar thermal integrated model
$G_{STS}(s)$	-	first order transfer function of solar thermal integrated model
$K_{STS\text{-}S}$	-	Gain of solar collector model
$K_{STS\text{-}T}$	-	Gain of turbine model of thermal system
$T_{STS\text{-}S}$	-	time constant of solar collector(s) model
$T_{STS\text{-}T}$	-	time constant of turbine model of thermal system
$G_{Uc}(s)$	-	first order transfer function of Ultra capacitor system
T_{Uc}	-	time constant of Ultra capacitor system
P_{Ae}	-	power output of Aqua Electrolyzer unit
$G_{Ae}(s)$	-	first order transfer function of Aqua Electrolyzer unit
K_{Ae}	-	Gain of Aqua Electrolyzer unit
T_{Ae}	-	time constant of Aqua Electrolyzer unit

I. INTRODUCTION

In the present trends, Electricity plays a vital role in all the aspects of human life. With increasing trends in technology demands more power to be generated through fossil fuel. Thus this increase in power demand leads to ecological imbalance such as increase in carbon emission and global warming. These shifting trends of technology required the necessity for clear, ecofriendly and sustainable energy. Research shifted to the alternative generation sources which are available abundantly in nature such as wind, solar, geo-thermal, tidal, bio-mass, are some of the sustainable green energy sources. Among all the available renewable sources wind and solar are more trending as they have high potential and good efficiency with considerable cost when compared to others. Fuel cell and ultra-capacitors also exhibit similar characteristics and can be considered as green sustainable sources for the future.

It is known, that not all the systems can be connected to the grid, some located far form generation stations are to be maintained off-grid. Single source systems such as solar photovoltaic, wind generators, micro-hydro systems, diesel generators, or a combination of above systems called as hybrid generation system are use for delivering the load demand. The hybrid system not only delivers load demand but also includes energy storage systems in the form of batteries. Through this system we can deliver both AC and DC power. Thus, by using proper equipment we regulate the overall performance of the system.

The design of the controllers includes both conventional and computational intelligence techniques. Numerous optimization methodologies, such as differential evaluation, genetic algorithm, particle swarm optimization, artificial neural network, bat algorithm, are applied to optimize and calculate the gains of the controllers for automatic generation control. The above stated methods were limited to conventional systems but never applied for hybrid systems for optimization of gains for the controllers. In hybrid systems, the controllers generally used are proportional plus integral (PI) which regulates the output power to achieve power equilibrium condition due to abrupt increase in loads and generation. We employ trial and error method described by Ziegler and Nichols to determine the gain values for the conventional PI controller to achieve better balance. This conventional method was not suitable since the gains obtained by this method are suitable for limited operating points. With increase in the number of optimization parameters the conventional controllers does not meet the required robust performance which is certainly not desired. In this paper, the PSO PI, PID controllers used whose gain values are calculated using PSO technique. The PSO is a novel technique which has widespread applications in the system optimizations. The intelligent control strategy provides robust adaptive response with varying parameters like non-linearity, load disturbances. The basics of PSO algorithm are illustrated in[]. By applying PSO PI, PID controllers to the hybrid system the results obtained are compared with conventional PI, PID, and GA PI, PID controllers respectively. Simulated results show that gains obtained from PSO has improved dynamic performance than the conventional and GA controllers. The PSO controller also had better response for transients during load disturbances.

II. PROPOSED HYBRID MODEL

The proposed hybrid model block diagram is illustrated in the Fig. 1. The parameters of the hybrid model are tabulated in table.1. The hybrid system is a combined model of wind turbine system, diesel generator, fuel cell (Fc), aqua electrolyzer (Ae), solar thermal and solar photovoltaic, and battery energy storage model. The load demand supplied is the summation of all the output powers form wind, solar, fuel cell and battery storage system. As wind is a varying system the fluctuations are absorbed by the aqua electrolyzer system producing the hydrogen gas which is taken as fuel for Fc system. The mathematical modeling of the hybrid system involves first order transfer functions of as shown in this section.

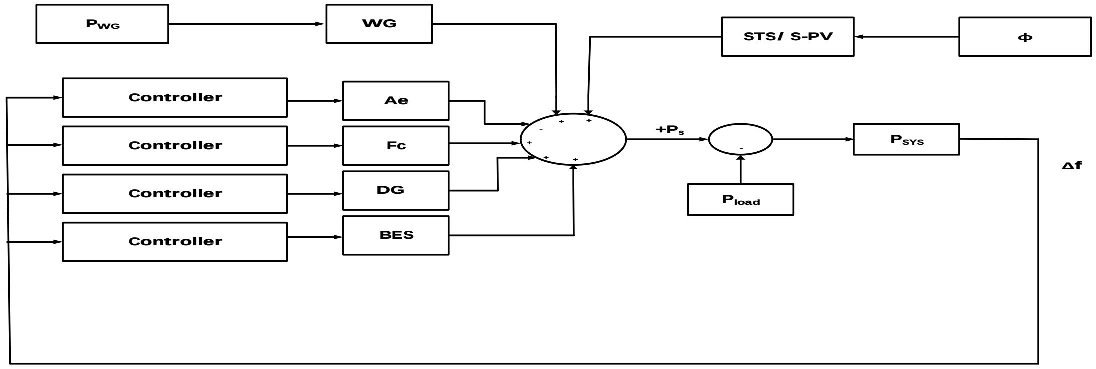

Fig.1 Block Diagram of Hybrid power system model

Table 1 Parameters of proposed hybrid model:

Gains		Time constants (s)	
K_{WG} =1.0	K_{DG} =1/300	T_{WG} =1.5	T_{DG} =2
$K_{S\text{-}PV}$ =1	K_{FC} =1/100	$T_{S\text{-}PV}$ =1.8	T_{FC} =4
K_{BES} =-1/300	$K_{STS\text{-}S}$ =1.8	T_{BES} =0.1	$T_{STS\text{-}S}$ =1.8
$K_{STS\text{-}T}$ =1	K_{Ae} =-1/500	$T_{STS\text{-}T}$ =0.3	T_{Ae} =0.5

A. *Wind Turbine Generator Model*

Wind is a naturally available fuel and can be used to produce clean and sustainable power. As the speed of the wind varies with time we cannot rely on the system directly as all the systems we use require constant power supply which can be achieved by speed regulation. The output depends on the wind speed at that instant. The wind turbine generator characteristics are better explained in [].

As discussed earlier wind is a varying system and has non linearity. The output of the system is mainly controlled by regulating the pitch angle and yawn angle. When a pitch angle controller is used it impacts the utility grid frequency, thus results in varying power between maximum or rated power, and zero power. The pitch angle non-linearity is limited by the boundaries which are affected by the variation in wind speed. We can represent the higher order system into simplified first order lag as[16] .

$$G_{WG}(s) = \frac{K_{WG}}{T_{WG}S+1} \quad (1)$$

B. *Solar-Thermal Model*

Solar energy is abundantly available in the nature in the form of light; this energy once harvested can deliver a reliable power to the system which is clean energy. In the recent trends solar and solar towers are two research topics in solar thermal power systems. This system can be effortlessly hybridized with other systems like wind, diesel, fuel cell, etc. solar power plants occupy larger areas in parabolic with collectors blending in unidirectional path for working fluid through pipes located at the focus of the parabola to heat. The exchange of power is in the form of steam, as the working fluid is heated to higher temperatures (393 ^{0}C). The steam generated by the heat transfer equipment is used to drive the turbine shaft generating the electrical power. Solar power tower use high-temperature heat from concentrated solar radiation by focusing the radiation on the heat exchanger. The system design has large numbers of heliostats (sun-tracking mirrors) to reflect the incident sunlight onto the heat exchanger. The heat transfer fluids (water or other fluids) heated by solar thermal energy in the receiver heats water to generate high temperature steam (up to 560 ^{0}C) to drive the shaft generating electricity.

Till date the tabulated results show that the efficiency of this system is 13% and the efficiency of the collector and heat exchanger system is approximately 70% as in[10].

In the recent years with improvement in technological constraints the solar thermal power industry is rapidly emerging as a new trend. With 17.54 GW of concentrating solar power plants being developing around the world. The reduced first order lag transfer function for the solar thermal power model as.

$$G_{STS}(s) = \frac{K_{STS-S}}{T_{STS-S}S+1} * \frac{K_{STS-T}}{T_{STS-T}S+1} \quad (2)$$

C. Solar Photovoltaic Model

In present eco system, clear energy is produced through the resources available in nature one among them is solar photovoltaic model. The energy present in the form of photons in the sunlight is absorbed and converted into electrical energy using semi-conductors and power electronic devices. With an increase in the worlds energy demand, the advancement in the technological trends has promoted use of solar PV system which has reduced the overall investment (PV module, inverters, cables, fitting, manpower and abundantly available fuel) considerably there by gaining more and more visibility which would be one of the main renewable energy sources for the future electricity supply. The characteristics of a PV model are illustrated in [13]. The output of the solar PV system is DC which is to be converter to AC using a semi-conductor device dc/ac converter. The maximum power output of the solar PV system depends on the given irradiance and cell-surface temperature, the best performance of the PV system is expected at the peak point of the V-P curve. To track the maximum power point where output is maximum can be calculated using various maximum power point tracker (MPPT) techniques as discussed in[15]. The power output that varies with given irradiance and cell surface temperature is given by [16]

$$P_{S-PV} = \eta S\phi[1-0.005(T_a+25)] \quad (3)$$

Where,

η - Conversion efficiency of PV array (generally between 9-12%)

S - Measured area of PV array (=4084m^2)

ϕ - Solar radiation (KW/m^2)

T_a - Ambience temperature in degree Celsius

The value of P_{S-PV} is bounded by the constraints like conversion efficiency, measured area, solar radiation and ambience temperature which are constants.

For low order frequency domain analysis we represent the system as reduced first order lag transfer function as [16].

$$G_{S-PV}(s) = \frac{K_{S-PV}}{T_{S-PV}S+1} \quad \textbf{(4)}$$

D. Diesel Generator Model

Diesel generators are the mostly used generation systems off grid, the torque produced in the machine drives the synchronous generator machine producing the electrical output. In diesel system the output power directly depends on the rotor shaft speed which is inversely proportional to the load demand. With varying load demands the rotor dynamic response are effected, it is important that the prime mover has better and fast dynamic responses with good capabilities for disturbance rejection.

The diesel system is consider to be nonlinear because of the time varying non linearity, this non linearity of time varying with dead time between the injection and production of mechanical torque between the turbine system. Engine model describes the fuel consumption rate as a function of speed and mechanical power at the output of engine. The transfer function which determine this relation between the rate at which the fuel is consumed to the mechanical power generated at the shaft is illustrated in[]. The simplified first order transfer function for the Diesel system with time varying non linearity is given by [16].

$$G_{DG}(s) = \frac{K_{DG}}{T_{DG}S+1} \quad \textbf{(5)}$$

E. Aqua Electrolyzer Model

Aqua electrolyzers are mainly designed in the power system model to absorb the rapidly fluctuating output power from wind and solar thermal system, which generate the hydrogen required by the fuel cell system by electro conducting water and decomposing it into hydrogen and oxygen. The hydrogen generated is stored in a storage tank which is fuel for FC system. The electro conduction of water is achieved passing current through the aqueous solution from two conducting electrodes. The transfer function model for the aqua electrolyzer can be expressed by [16].

$$G_{Ae}(s) = \frac{K_{Ae}}{T_{Ae}S+1} \quad (6)$$

A typical AE system consists of various number of power converters, the time constant of the system is very small [3].

F. Fuel Cell Model

The power generated in this system is through series of electro chemical reactions between hydrogen and oxygen. Fuel cell is used as a substitute to conventional generators, such as diesel generators, where the power produces is clean, sustainable, noise free and free from onsite pollutants. The output of a typical fuel cell is a DC voltage which should be converted to AC for grid usage through semi-conductor devices such as dc/ac converters. For large usage, large numbers of fuel cells are to be connected in series and parallel circuits forming a Fuel cell stack. The developers of this technology claimed of having high efficiency than those traditional combustion technologies. The only drawback of fuel cell is the fuel we use for power generation, even though available freely in nature in combined form it is more expensive that compared to other conventional energy sources like coal, oil and natural gas. The higher order function of the system consists of non-linearity, thus we consider a low order lag transfer function for analyzing the low frequency domain model and is given as[].

$$G_{Fc}(s) = \frac{K_{Fc}}{T_{Fc}S+1} \quad (7)$$

Table 2: Simulation conditions for each case:

Case	sub-systems	simulation time	operating conditions
1	WG, STS, DG, Ae, Fc, BES and load	200	P_{WG} = 0.5 P.u at 0 < t <40 s 0.4 P.u at t > 40 s P_{STS} = 0.36 P.u at 0< t <40 s 0.18 P.u at t > 40 s P_L = 1 P.u at 0 < t < 80 s 1.1 P.u at t > 80 s
2	WG, S-PV, DG, Ae, Fc, BES and load	200	P_{WG} = 0.5 P.u at 0 < t <40 s 0.4 P.u at t > 40 s P_{S-PV} = 0.2 P.u at 0< t <40 s 0.1 P.u at t > 40 s P_L = 1 P.u at 0 < t < 80 s 1.3 P.u at t > 80 s

G. Battery Energy Storage Model

To maintain the grid for a short time period to regulate the fluctuation due to the non-conventional systems in the grid, we use the storage system. The fluctuations in the grid power even for a short time causes adverse effect of the load connected to the grid. These fluctuations can be regulated by providing an alternative solution which is possibly storage of wind energy. Battery energy storage systems are considered to be very advantageous due to their very good characteristics such as large energy density, fast access time, we can store large amount of wind energy. During sudden loss in the grid, the BESS can supply the system with large amount of electric power for a short period of time or large amount of electric power for longer time period to the grid. BESS model consists of bulk battery bank integrated with power converter devices to form an autonomous utility grid. By integrating number of banks we can achieve higher power capacity models. The transfer function model of the BESS model is represented in the first order form as []

$$G_{BES}(s) = \frac{K_{BES}}{T_{BES}S+1} \quad (8)$$

III. PARTICLE SWARM OPTIMIZATION

In the recent years many soft computing were developed based on different animals and particles behaviors that are available in nature, which were proved to be effective in analyzing and unraveling problems. Particle Swarm Optimization (PSO) is one such novel population based technique, developed in 1995 by Dr. Russel Eberhart and Dr. James Kennedy, Inspired by the swarming and

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collaborative behavior of the flock of birds or fish schooling, when analyzed PSO with evolutionary computation techniques such as Genetic Algorithm (GA) it shares many similarities. The technique is better understood once we know the behavior of birds when searching for food in an open environment. Unlike GA, PSO has no operator for evolution like cross over or mutation. In PSO the particles are known as potential solution, there fly through the problem space searching for the solution. PSO simulates the behaviors of flock of birds searching for food. Let us consider a group of birds randomly searching for food in an area the total food available is one piece, not all birds know the location of food in that area, but they would know how far the food is located with iteration, effective way to reach the food will be following the bird nearest to the food. We use this scenario to better understand the PSO optimization problems. In PSO optimization, in problem each single solution in the search place known as particle. The fitness value of all the particles is calculated using fitness function to optimize the problem, the direction in which they move depends on the velocity and position of the particle in the problem space. The algorithm begins with initializing a random population initially; with these initial values we try to determine the best values among the population. Once we determine the best values for the population known as 'P best', we then determine the best value among these local values and call it as 'G best' where Pbest is the best fitness value achieved so far by the particles and Gbest is the best value tracked by PSO so far obtained by any particle in the population. Once these two values are determined then the values are updated for the next iteration and again same procedure is followed until we obtain the best optimized values of the particle. Once the Pbest and Gbest are determined, we use these values to calculate the velocity and position of particle using mathematical expressions. Once determined, the algorithm is repeated for many iterations until the criterion is met.

Table 3a: Gains of PI controller

Gains	conventional values		GA values		PSO values	
Case	case 1	case 2	case 1	case 2	case 1	case2
Pi controller						
K_{PAe}	-37.765	128.458	43.13781	199.724	82.75	454.99
K_{IAe}	-78.728	165.030	95.61633	14.2427	53.50	165.03
K_{PFc}	-42.32	-346.161	-49.1506	- 1093.392	-19.3669	-756.594
K_{IFc}	-31.22	-125.781	-64.892	-235.783	-64.892	-890.493
K_{pDG}	0.924	438.806	1.10444	761.7839	1.799	18.806
K_{IDG}	12.12	249.846	12.16335	307.2137	27.336	149.846
K_{PBES}	-68.3613	-883.791	-80.98984	-1233.7437	-60.112	-143.394
K_{IBES}	-51.8013	-222.807	-81.40701	-299.7437	-23.839	-78.134

Table 3b: Gains of PID controller

Gains	conventional values		GA values		PSO values	
Case	case 1	case 2	case 1	case 2	case 1	case2
Pi controller						
K_{PAe}	-3.25	-127.354	-38.25	-116.36	-51.5119	-930.234
K_{IAe}	1.32	124.337	13.32	83.9926	30.5922	-179.234
K_{DAe}	-3.32	-111.232	-3.23	-90.0618	-5.5998	-180.234
K_{PFc}	26.4087	-121.383	-26.4087	292.9134	-44.0688	189.234
K_{IFc}	-2.3063	-72.515	-1.22	-74.1479	-13.8233	-60.836
K_{DFc}	-25.2087	-227.43	-48.33	-224.6159	-69.0625	-115.236
K_{pDG}	23.2187	132.383	-13.2187	-340.888	-32.8662	-200.07
K_{IDG}	-33.2187	-102.33	-33.2197	-182.8237	-62.974	-129.524
K_{DDG}	-22.4187	261.221	-52.418	331.5912	93.2550	215.4321
K_{PBES}	12.45	41.163	12.42	148.2045	0.3086	92.54
K_{IBES}	-15.89	-29.343	-15.89	-81.849	96.3875	61.3017
K_{DBES}	-4.33	- 34.312	-8.4187	-23.086	-17.4479	21.5987

The steps of the PSO PID controllers are summarized as follows:
Step 1: Create the initial population for initializing the optimization for parameters (K_p,K_i,K_d). Each parameter in the problem area is a particle thus the velocity and position represents the solution to the problem.
Step 2: The objective function considered here for minimizing frequency deviations is integral square error (ISE), we calculate the J values using matlab model.
Step 3: Evaluation of the fitness function. The degree of fitness is evaluated based in the criterion. Since PSO is a minimization function, the objective function is the fitness function.
Step 4: Generating the Pbest and Gbest values for the initial iteration the values are updated for the next iterations and the final values for updating the velocity and position.
Step 5: Replace the present population with a new set of population.
Step 6: On reaching the final criterion terminate; else go to step 2.
In PID controller design method, the most common objective function are integral absolute error (IAE) , integral of time weight square error (ITSE), integral square error (ISE), etc. here in this model we have considered Integral Square Error (ISE) as our objective function to reduce the frequency deviations.

$$J = \int_0^{\alpha} (\Delta f)^2 \, dt \text{ ---------------------------()}$$

Minimize J
Subjected to
$K_p^{min} < k_p < k_p^{max}$
$K_i^{min} < k_i < k_i^{max}$
$K_d^{min} < k_d < k_d^{max}$

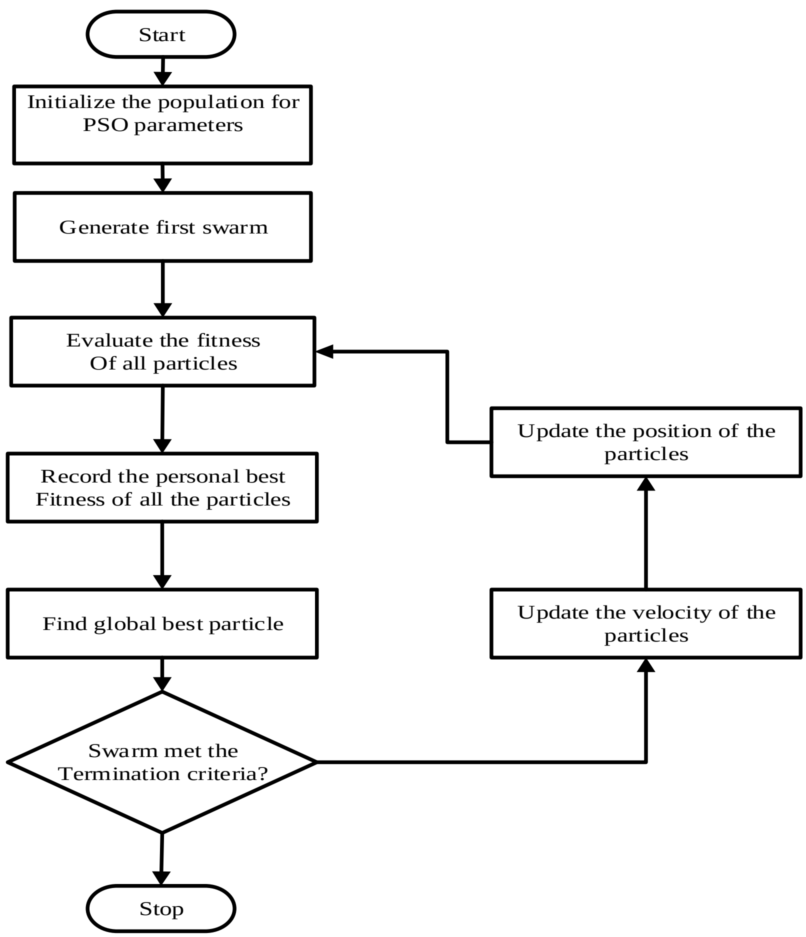

Fig 2. Flowchart representing PSO algorithm.

The minimization of the objective function is implemented to determine the optimal parameters of PID controller. The gains of PI can be calculated in a similar manner. PSO is a simple computational algorithm and has been employed successfully in this field of science and technology. However, the scope of the present work is to compare the completion of PSO with GA and conventional one. This has been performed using MATLAB tool for PSO in Simulink considering the following parameters in table 2.

IV. SIMULATION AND RESULT ANALYSIS

In this module, dynamic performance of the proposed hybrid model is analyzed for simulations in time domain. By defining various operating points and disturbance conditions are presented with optimum gain settings of conventional, GA and PSO based PI and PID controllers respectively. The conventional optimization approach we considered here is ISE criterion where only one parameter is varied at a time keeping rest all parameters the same, for one complete iteration .we have considered the following two cases, as shown in table 2 are considered for case studies.

A. Time Domain Analysis case 1

In this case study, we consider the below conditions for wind, solar and load analysis, during $0 \leq t \leq 40s$, the average wind power and solar irradiation power is kept 0.5PU and 0.36PU respectively after 40s, wind and solar power are suddenly reduced down to 0.36PU and 0.18PU respectively. Load demand during $0 \leq t \leq 80s$ is maintained at 1PU, after 80s the load demand suddenly elevates to 1.1PU. The deviation in the load demand to the generation is attuned by the Fuel cell, diesel, BES through controllers since generation from solar and wind is constant. Total power generated can be expressed by

$$P_S = P_{WG} + P_{STS} - P_{Ae} + P_{Fc} + P_{DG} + P_{BES}$$

Due to the sudden variations in the load demand, and variations in power outputs of solar and wind systems, there is a fluctuation in the system frequency at power level. This deviation in the power frequency is controlled by the controllers (PI/PID) adjusting the system outputs automatically such that the error in the frequency deviation is minimized.

The system gains for the controllers are to be calculated through computational intelligence and conventional controllers, the gains of the conventional and GA based controller are calculated in [16] and are directly considered for the hybrid system. The new gain values are calculated using PSO optimization technique, we observed that the performance of the PID controller is best amongst PI and PID controllers for both conventional and GA, for studies in terms of peak transient deviation, settling time and steady state.

B. Time Domain Analysis Case 2

In this case study, we consider the below conditions for wind, solar and load analysis, during $0 \leq t \leq 40s$, the average wind power and solar irradiation power is kept 0.5PU and 0.36PU respectively after 40s, wind and solar power are suddenly reduced down to 0.36PU and 0.18PU respectively. Load demand during $0 \leq t \leq 80s$ is maintained at 1PU, after 80s the load demand suddenly elevates to 1.1PU. The deviation in the load demand to the generation is attuned by the Fuel cell, diesel, BES through controllers since generation from solar and wind is constant. Total power generated can be expressed by

$$P_S = P_{WG} + P_{STS} - P_{Ae} + P_{Fc} + P_{DG} + P_{BES}$$

Due to the sudden variations in the load demand, and variations in power outputs of solar and wind systems, there is a fluctuation in the system frequency at power level. This deviation in the power frequency is controlled by the controllers (PI/PID) adjusting the system outputs automatically such that the error in the frequency deviation is minimized. In this case we have considered a solar PV system instead of solar thermal system, where the remaining conditions remain the same for both the models.

The system gains for the controllers are to be calculated through computational intelligence and conventional controllers, the gains of the conventional and GA based controller are calculated in [16] and are directly considered for the hybrid system. The new gain values are calculated using PSO optimization technique, we observed that the performance of the PID controller is best amongst PI and PID controllers for both conventional and GA, for studies in terms of peak transient deviation, settling time and steady state.

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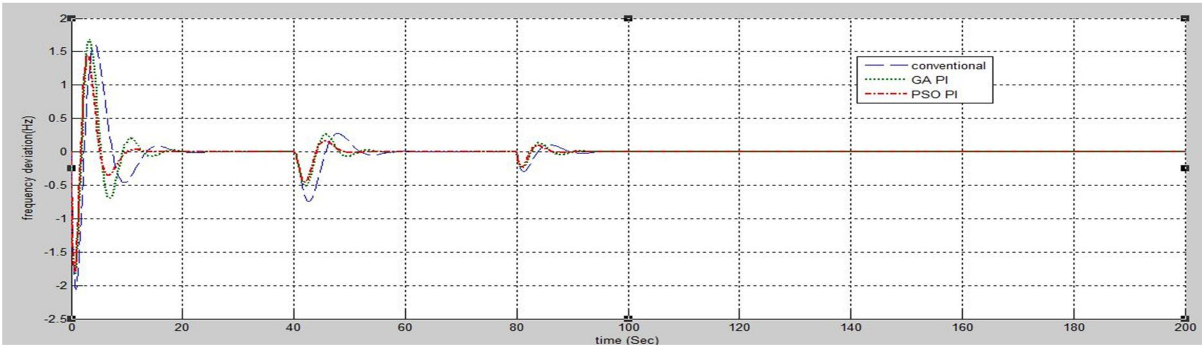

Fig 3: output of case 1 for conventional GA and PSO based PI

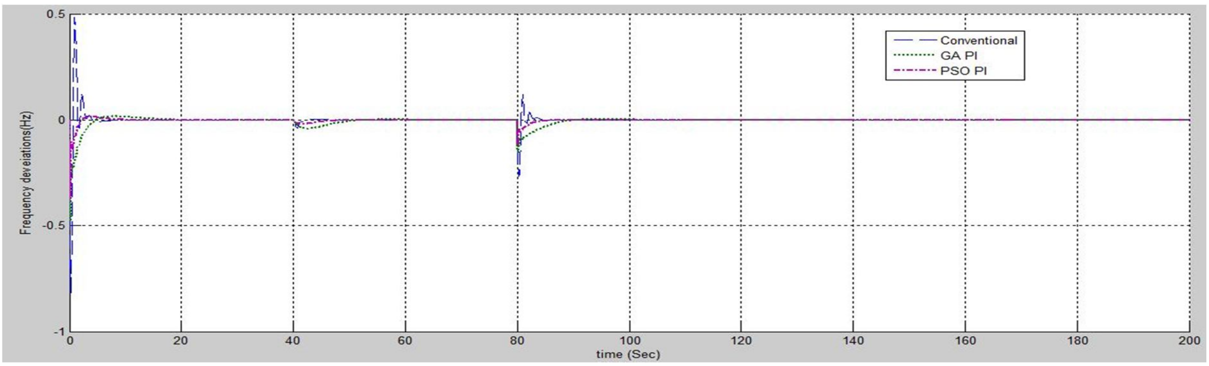

Fig: 4 output of case 2 for conventional GA and PSO based PI

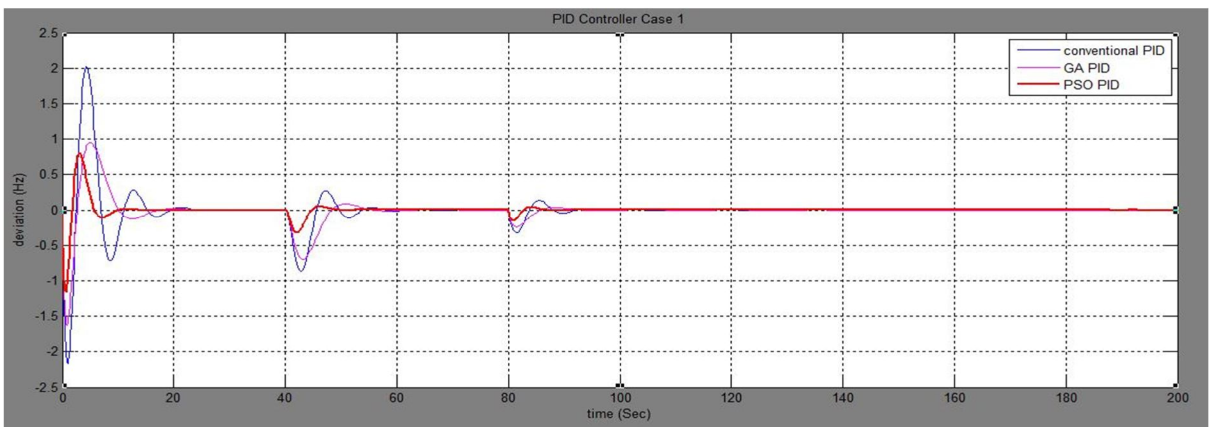

Fig 5: output of case 1 for conventional GA and PSO based PID

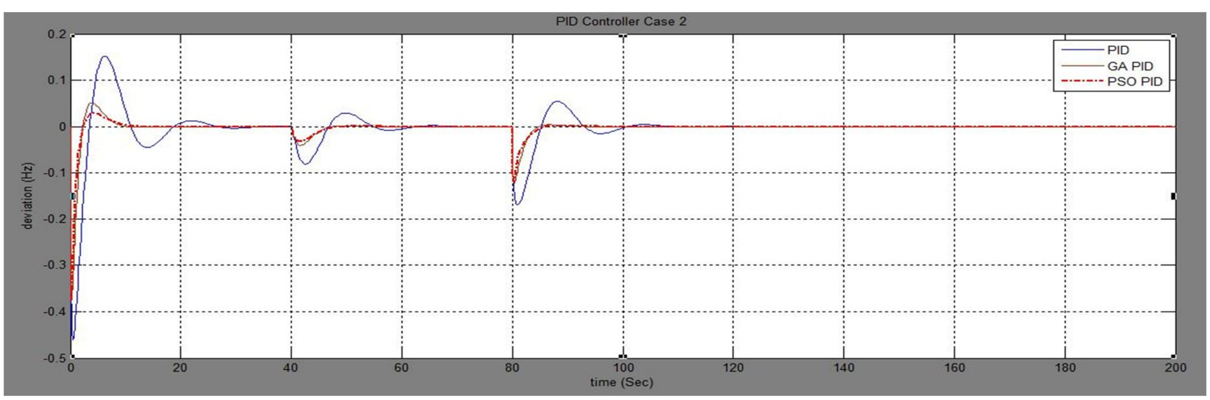

Fig 6: output of case 2 for conventional GA and PSO based PID

V. CONCLUSION

To uphold the stability in the system, the frequency deviations in the system are to be delimited to the nominal values. This work is done by an automatic generation control system which can eliminate the disparity in supply and demand under fluctuating power conditions in load and generation. In this paper, we have presented an autonomous hybrid model consisting of Wind turbine generator (WG), solar photovoltaic (S-PV), diesel generator(DG),fuel cell(FC), battery energy storage system (BES), solar thermal power system(STPS),ultra capacitor(UC), and aqua electrolyzer (AE) . Fuel cell input is attained from the aqua electrolyzer system which generates hydrogen which is energy for fuel cell. The models for the above generation and storage systems are selected to simulate the significant performance of projected hybrid system. In order to maintain stability i.e., to reduce the frequency deviations due to mismatch in power because of abrupt variations in generation and load, a controller is to be designed to regulate the output power form deviating (PI/PID). Conventional methods were used to calculate the gains and verify the performance of the controllers, along with these computational techniques such as GA and PSO were also applied. Analyzing the dynamic behavior of each controller in time – domain performance of each controller is observed in isolated operating modes. On observing the responses PID is more dependable amongst PI and PID controller which are evaluated based on the study in terms of deviations due to peak transients and settling time. Further, it is observed that the gains of the controllers calculated through Computational techniques were performing as better controllers than their counterparts. However, in all the cases, the PSO based PID controller achieved better results than the conventional and the GA based controllers. From the simulation results, it is witnessed that PSO based technique is more reliable for automatic generation control.

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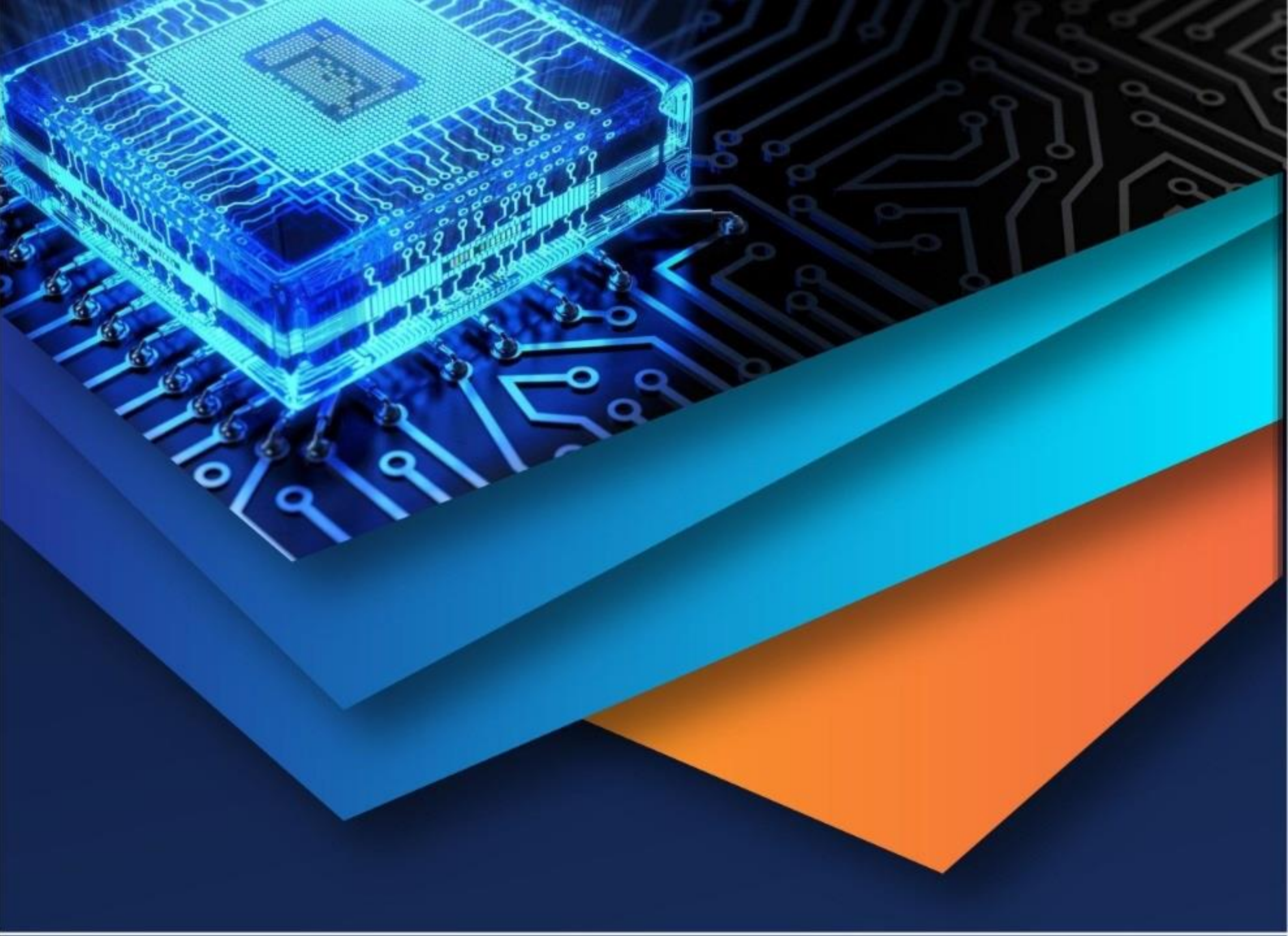

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