PSO optimized PIDF controller for Load-frequency control of A.C Multi-Islanded-Micro grid system

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***Abstract*— The integration of Renewable Energy Systems is an intricate nonlinear power system, which enlightens severe issues of power system frequency and deviations in tie-line power due to lack of damping factor under dynamically changing loads. The amendment between Power generation-Demands suffers from contingency issue of scarcity of during critical condition of load. This can be easily over coming by the introduction of microgrid with the grid system. In this paper an innovative method is implemented for load frequency control in an ac multi-islanded-micro-grid system by PIDF controller with particle swarm optimization (PSO). Improving power reliability and quality issues, Micro-grids have been discovered as the prime component of smart grid. It also increases the system energy and efficiency. In power system Load frequency control is done by controlling the active power and frequency. On this paper as controller PI, PID and PIDF are used for controlling gains which is optimized by particle swarm optimization technique 'PSO'. Through simulation potency of the frequency control approach is measured.**

Keywords*— *Micro-Grid, Load Frequency Control, Energy Storage System, Solar PV, Wind Turbine Generator WTG, PIDF.

I. INTRODUCTION

Power generation is done from non-renewable fuel source. Day by day the requirement of power generation become more and at the same time there is a depletion in fossil fuel resources. To overcome this challenge now a days there is a huge use of renewable resources such as solar energy, wind energy, biomass etc. [1] acting as a Microgrid. There is another benefit occur by using renewable energy sources is that no greenhouse emission and reduction of air pollution [16].

A Micro-grid is exactly an independent power system restricted to a small geographic area. One or more small size power plants combine a Micro-grid which might also have some means to save energy, such as batteries. These small size power plants are may be generators or RES sources wind and solar energy resources. When there is a heavy demand in the main power grid it gives the backup power. There is a tie line which coupled two Micro-grids. The two Micro-grids consist of a wind power, a solar PV, a synchronous generator, ESS and Load. In working point of view Microgrid may be designated as grid connected mode and Island mode [10-11]. The Microgrid which is working in islanded mode observes enormous frequency control issue under any distrust, that will arise in the Micro grid system [12]. Through several research articles it is observed that maximum unpredictability occurs in the system with wind power model and solar pv model [13,14]. To upgrade genuine and power quality of microgrid system, the energy storage system (ESS) has been clarified in the Micro-grid System [15].

Fig 1 Symbolic diagram of Micro- Grid system

II. CONTRIBUTION

The key features of this article for the analysis of load frequency control of two-area interconnected microgrid system through the following steps:

- The microgrid is formed by combining Conventional Thermal power unit with renewable energy sources like PV arrays, Wind Farms, Diesel Engine Generator (DEG), Energy storage system (ESS).
- Energy storage system (ESS) is included in the MG system to manage generation and load demand.
- The performance of the Microgrid is tested with different controller PI, PID & PIDF using the PSO technique for frequency control.
- The performance of the PIDF controller is compared with other controllers such as PI and PID Controllers to justify superiority.

III. DESIGN OF MICRO GRID

The design of microgrids is carried out including one Thermal power unit with renewable energy sources like WTG, PV together with storage devices battery energy storage system. All the above sources are represented through their transfer function model.

A. Synchronous Generator System

Function of standby synchronous generator is to provide the deficit power to the Micro Grid . It also balances supply and load need. Generally diesel generator is preferred in case of smaller micro grids, But turbine driven generator is preferred in case of larger micro grids.

The transfer function of governor system is

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$$G_g(\text{sys}) = \frac{\Delta P_v(sys)}{\Delta P_g(sys)} = \frac{K_g}{1+sT_g} \quad (1)$$

Where T_g is time constant of the governor and K_g is governor gain constant, whose value is set as 1.
Transfer function of the Turbine system is

$$G_t(\text{sys}) = \frac{\Delta P_m(sys)}{\Delta P_v(sys)} = \frac{K_t}{1+sT_t} \quad (2)$$

Where T_t is time constant of the governor and K_t is turbine time constant whose value is set as 1[2, 3].

B. Solar Photovoltaic system

The solar photovoltaic system made up of from several cells. These cells are may couple series or parallel for delivering required output voltage and current. Correlation between voltage and current is nonlinear in character. By changing solar radiation, the maximal power output of the photovoltaic array can be changed. For getting maximal power in the solar pv model control strategy is needed for utilizing the solar radiation successfully. The output power can be computed by the equation given below

$$P_{pv} = \beta S\varphi[1-0.005(T_a+25)] \quad (3)$$

where β represents the conversion efficiency. S represents area of the photovoltaic array (m^2). φ and T_a represents the solar irradiation (kw/m^2) and ambient temperature respectively (°C).

Transfer function of the solar photovoltaic system could be written as a first order lag [4,5].

$$G_{pv}(\text{sys}) = \frac{\Delta P_{pv}}{\Delta \varphi} = \frac{K_{pv}}{1+ST_{pv}} \quad (4)$$

Where K_{pv} and T_{pv} is the gain constant and time constant reciprocally.

C. Wind power generation system

The normal deviation of wind power output is given by the following equation

$$\delta_w = 0.8\sqrt{P_w} \quad (5)$$

For getting random output fluctuation some manipulation is required in the MATLAB SIMULINK which is derived from the Band-limited white noise block. My wind model is shown below. For finding the output fluctuation on the given wind model the random output fluctuation is multiplied by the normal deviation [6,7].

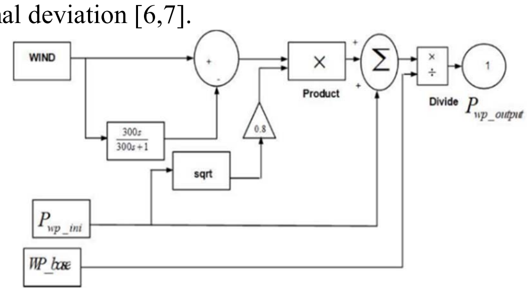

Fig 2 Wind power system Model

D. Energy storage system

The energy storage system (ESS) acts a vital role in valid operation of Micro-grids. It provides deficit energy to power generation subsystems productively to maintain the system stable. It also has the ability to swiftly control the reactive power and active power output with a higher switching frequency by the use of power electronics devices such as MOSFET or IGBT. The major application of energy storage system is it mitigate the harmonics, control the voltage and level the load. It also upgrades both transient stability and dynamic stability by supplying extra damping to power system swings [5]. The transfer function of the energy storage system (ESS) is

$$G_{ess}(sys) = \frac{\Delta \boldsymbol{P_{ess}}}{\Delta \boldsymbol{\omega}} = \frac{\boldsymbol{K_{ess}}}{\boldsymbol{1+sT_{ess}}} \quad (6)$$

Where K_{ess} and T_{ess} are the gain constant and time constant respectively.

E. Power Deviation and system frequency variation

The overall power generation (P_t)of the micro grid system.

$$P_t = P_{sg} + P_{pv} + P_w + P_{ess} \quad (7)$$

ΔP_e is defined as the variation between the overall power generation and power demand reference

$$\Delta P_e = P_t - P_d \quad (8)$$

By changing the net power system frequency can be changed and is determined by

$$\Delta \boldsymbol{\omega} = \frac{\Delta \boldsymbol{P_e}}{\boldsymbol{K_s}} \quad (9)$$

K_s is defined as the system frequency characteristic constant of the micro grid.

In power deviation and system frequency variation there is an inherent time delay presents between the two. Now transfer function for system frequency variation to per unit power deviation can be determined as

$$G_s(\text{sys}) = \frac{\Delta \boldsymbol{\omega}}{\Delta \boldsymbol{P_e}} = \frac{\boldsymbol{1}}{\boldsymbol{K_s(1+sT_s)}} = \frac{\boldsymbol{1}}{\boldsymbol{d+ms}} \quad (10)$$

Where m is defined as the equivalent inertia constant and d is defined as the damping constant of the micro grid.

IV. PIDF CONTROLLER

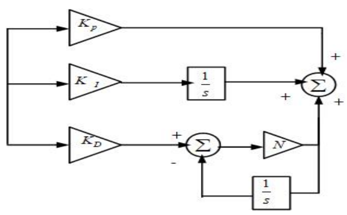

Fig 3 PIDF Controller Model

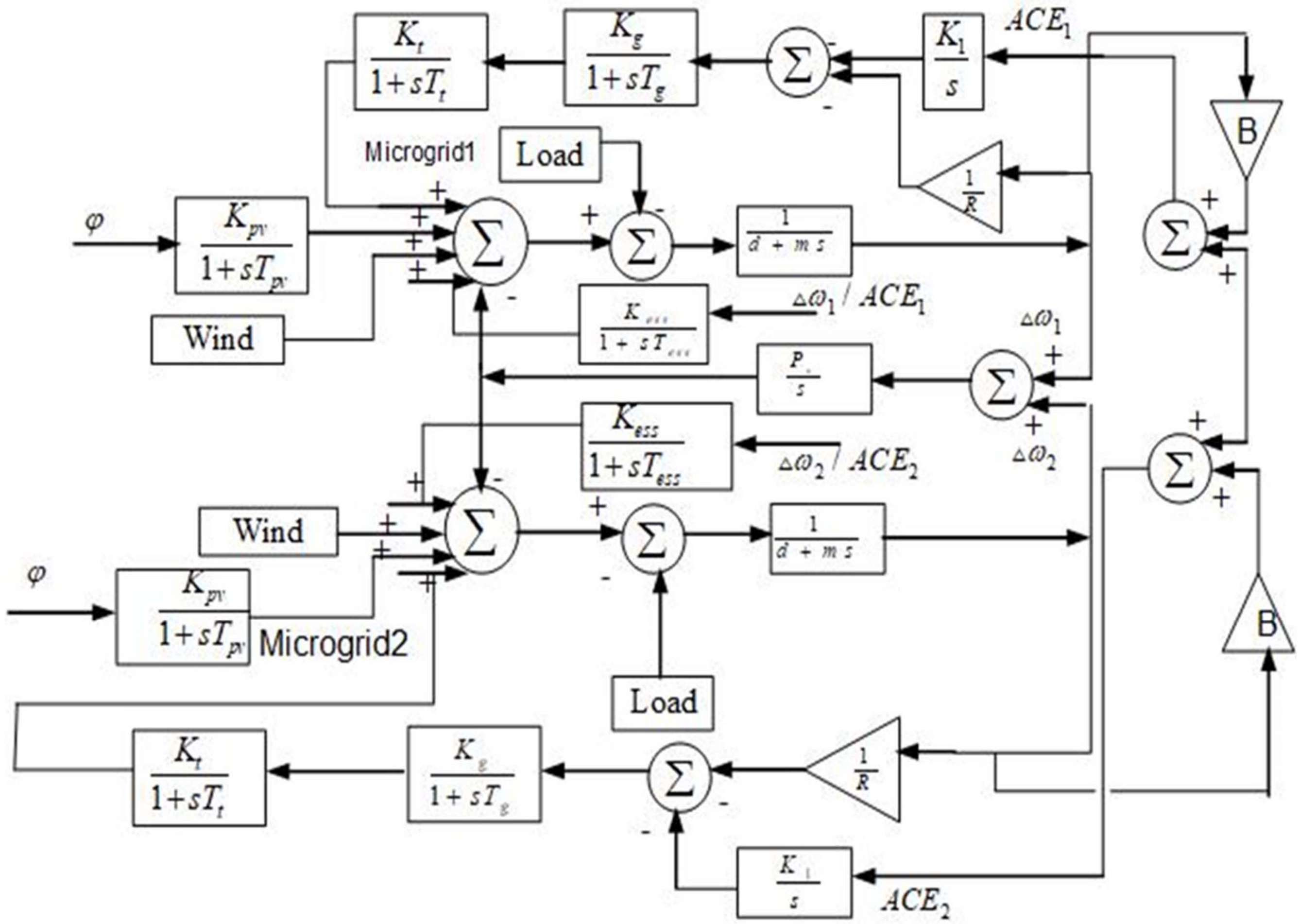

Fig 4 Block diagram of proposed multi-micro-grid system

Normally PID controller is used for giving reliability and perfect system output. This PID controller combines three control operation such as P-mode, I-mode, D-mode. The depletion of oscillation is taken care by the P-mode. Zero steady state error control action is done by I-mode. D-mode is used for making the system faster. Sensors normally create noise, noise is naturally high-rise, which shows high-rise value of derivative of that created noise. Noise is created due to the tie-line. This tie-line power is available in the area control error. Depletion of undesired signal of higher frequency can be done by placing a filter together with the derivative part. As noise has an issue on the derivative part, so a proper tuned filter is implemented in the derivative part. In the model two equal areas are used so two similar PIDF (PID with derivative filer control) controller is implemented. In the above figure i.e. in the Fig 3 PIDF controller model is given.

The Transfer function of the PIDF controller is

$$TF_{PIDN}=K_p+\frac{K_I}{s}+K_D\frac{Ns}{s} \quad (11)$$

V. SIMULATION MODEL

The parameter values of this Island Multi-Micro-Grid system are brought from [2-5, 8-9] and given in the Table-1. The average value of wind power for Micro grid1 and Micro grid2 is kept 0.4pu and 0.3 pu respectively. The average value of solar power for Micro grid1and Micro grid2 is kept 0.2 pu for both. The synchronizing power co-efficient p_s is fixed as 1.5pu.

Table-1 Parameter values of studied Microgrid system

Sl.No.	Parameter	Defination	Micrigrid1	Microgrid2
1	R(pu)	Speed Regulation	0.05	0.04
2	T_g(s)	Governor time constant	0.1	0.1
3	T_t(s)	Turbine time constant	0.4	0.4
4	T_{pv}(s)	Solar pv time constant	1.5	1.4
5	$T_{ess}(s)$	ESS time constant	0.1	0.1
6	K_{ess}	ESS gain constant	-10	-8
7	K_i	Internal gain	5	7
8	B(pu)	Frequency biasing factor	10	12.5
9	m(pu)	Inertia constant	0.8	0.7
10	d(pu)	Damping constant	0.02	0.03

VI. RESULT & ANALYSIS

The time domain simulated results of different responses are acquired in MATLAB 2018 Simulink environment. In regard to this present model of Multi-Micro-Grid system is expanded in MATLAB Simulink environment and the needed programmed of present PSO technique is write down in .m file. The superiority of the proposed PIDF controller with PSO technique is presented by comparing with conventional PI and PID controller. The gains of the above controllers are optimized by PSO Algorithm.

Table-2 PSO Optimized parameters for minimum fitness values

Controller parameters	PI	PID	PIDF
KP1	0.8754	9.5673	7.7021
KI1	4.6160	9.0491	9.9086
KD1	-	3.3180	2.1650
KP2	0.8629	7.9888	3.4955
KI2	0.9315	9.5791	6.0742
KD2	-	1.5922	7.8453
N1	-	-	138.7217
N2	-	-	145.1917

A. Output Result of $\Delta\omega_1$

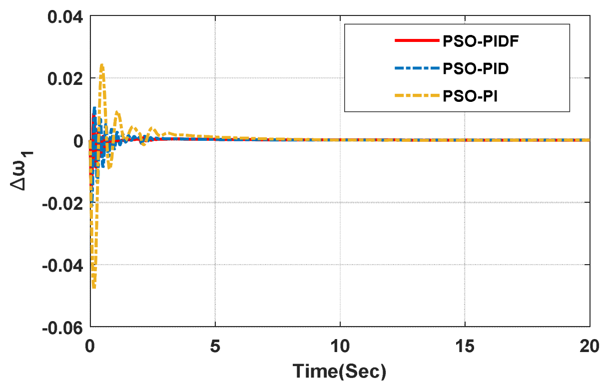

Fig 5 (a)

B. Output Result of $\Delta\omega_2$

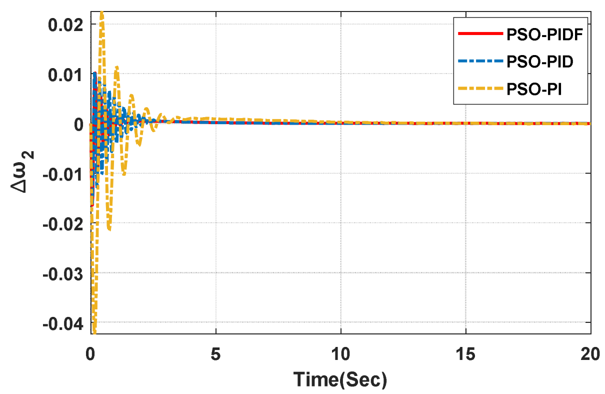

Fig 5 (b)

C. Output Result of $Pess_1$

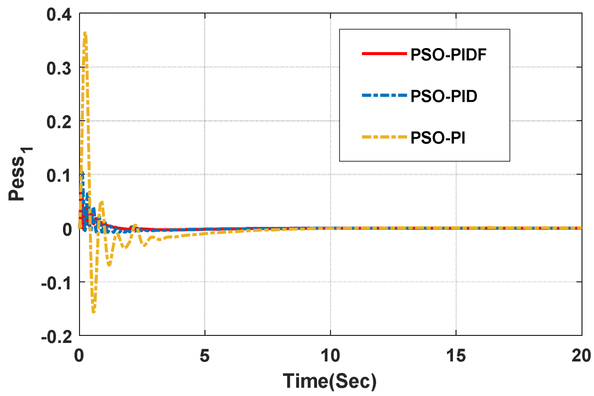

Fig 5 (c)

D. Output Result of $Pess_2$

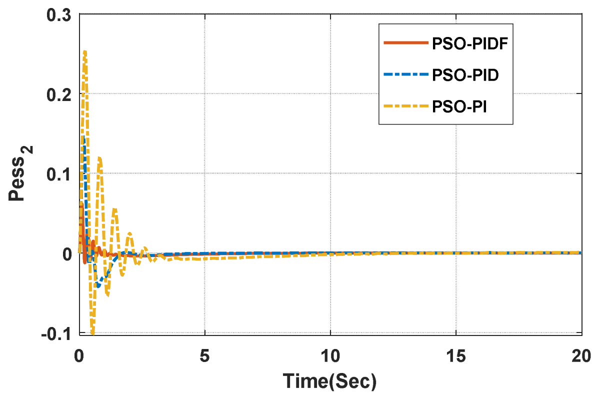

Fig 5 (d)

E. Output Result of Tie-Line Power

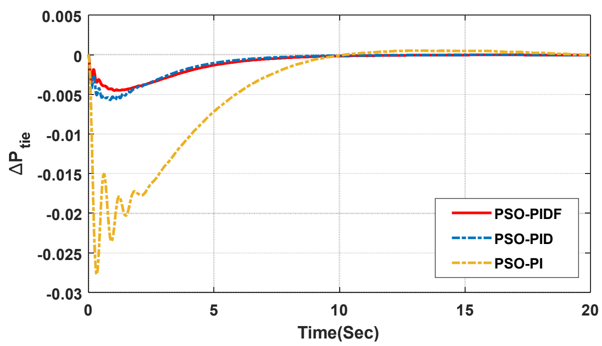

Fig 5 (e)

- In Fig 5 (a) the control of frequency occurs in micro-grid1. The PIDF controller is the superiority controller between the conventional PID and PI controller. The settling time of PIDF controller is 3.1872sec which is better in comparison with 3.8239sec (PID) and 5.0602sec (PI).

Table-3 PERFORMANCE INDICES OF DIFFERENT RESPONSES DUE TO DIFFERENT CONTROLLERS

Controller	**PI controller**			**PID controller**			**PIDF controller**		
Performance	***Over shoot in pu***	***Under shoot in pu***	***Settling time in Sec***	***Over shoot in pu***	***Under shoot in pu***	***Settling time in sec***	***Over shoot in pu***	***Undershoot in pu***	***Settling time in Sec***
$\Delta\omega_1$	.0244	-.0481	5.0602	.0105	-.0213	3.8239	.0084	-.0158	3.1872
$\Delta\omega_2$	.0224	-.0423	6.2782	.0104	-.0164	3.6148	.0101	-.0160	2.1532
P_{ess1}	.3652	-.1575	6.3755	.1043	-.0079	5.8915	.0670	-.0033	5.0211
P_{ess2}	.2535	-.1038	7.7380	.0584	-.0138	5.2162	.0616	-.0125	5.1576
ΔP_{tie}	.0005	-.0277	13.1031	0	-.0057	10.4668	0	-.0045	8.8917
ITAE	0.1756			0.0397			0.0266		

- In Fig 5 (b) the control of frequency occurs in Micro-grid2. The PIDF controller is the superiority controller between the conventional PID and PI controller. The settling time of PIDF controller is 2.1532 sec which is better in comparison with 3.6148 sec (PID) and 6.2782 sec (PI).
- Fig 5 (c) shows the output result of energy storage system of micro grid1. The PIDF controller is the superiority controller between the conventional PID and PI controller. The settling time of PIDF controller is 5.0211 sec which is better in comparison with 5.8915 sec (PID) and 6.3755 sec (PI).
- Fig 5 (d) shows the output result of energy storage system of micro grid2. The PIDF controller is the superiority controller between the conventional PID and PI controller. The settling time of PIDF controller is 5.1576 sec which is better in comparison with 5.2162 sec (PID) and 7.7380 sec (PI).
- Fig 5 (e) shows the output result of tie-line power of micro grid1and micro-grid-2. The PIDF controller is the superiority controller between the conventional PID and PI controller. The settling time of PIDF controller is 8.8917 sec which is better in comparison with 10.4668 sec (PID) and 13.1031 sec (PI).

- The ITAE value of PIDF controller is also better in comparison with the other two conventional controller PID and PI i.e. 0.0266,0.0397,0.1756 respectively.

- From the above result and analysis PIDF controller gave better settling time, over shoot, under shoot and ITAE value in comparison with other two conventional controller PID and PI which is shown in the Table-3.

VII. CONCLUSION

The article approaches load frequency control of Multi-Micro-Grid system by proposing PSO algorithm for PIDF controller.

- In this paper different classical controller like PI, PID & PIDF controller are used for stabilizing the frequency, energy storage system and tie-line power dynamics of two area interconnected system.
- To make it easy an interactive behavior-based nature stimulated optimization algorithm called particle swarm optimization (PSO) technique is implemented to optimize the parameters of different controllers along with PI, PID & PIDF controller.

Comparison of different controller shows that PIDF controller gives superior dynamic response than other two PID and PI controllers which is shown in Table-3.

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