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Application of SMES for Load Frequency Control on Micro Hydro Power Plant Using Ant Colony Optimization A. M. ShiddiqYunus Muhammad Ruswandi Djalal Apollo Musrady Mulyadi Mechanical Eng. Dept Mechanical Eng. Dept Mechanical Eng. Dept Mechanical Eng. Dept State Polytechnic of Ujung Pandang State Polytechnic of Ujung Pandang State Polytechnic of Ujung Pandang State Polytechnic of Ujung Pandang shiddiq@poliupg.ac.id wandi@poliupg.ac.id apollo@poliupg.ac.id musrady_mulyadi@poliupg.ac.id Abstract—This research proposes an additional controller for load frequency control at a micro hydropower plant using PID-SMES.

The PID-SMES parameters are optimized using smart methods called Ant Colony Optimization (ACO), which could find the optimal value of PID-SMES. In this paper, four control approaches are compared which are P, PI, PID, SMES, and PID-SMES. From the simulation results, it can be obtained that overshoot of P controller is -0.0002193, with PI Controller is-0.0002183, with PD Controller is -0.0002139, with PID controller, is -0.0002129, with SMES controller, is -0.0001958, and with PID-SMES, is-4.187e-05.

ACO optimization results obtained fitness function value of 7.15e-09, with 50 iterations. The minimum value of the system performance function at each iteration is plotted on the convergence graph. In the simulation result, it can be concluded that the ACO algorithm could be quickly convergence on the 14th iteration or find the most optimal value at the 9th iteration. The PID-SMES controller proposed in this study has a significant influence on the damping of the oscillation of frequency deviation.

Therefore, PID-SMES is appropriate to be applied to a micro hydropower plant.
Keywords: Micro Hydro, Frequency, SMES, ACO, Overshoot I. INTRODUCTION Stability is a major concern in micro hydro operating systems because, in steady state conditions,

the average velocity for all generators must be the same or in the synchronous state.

The frequency and voltage generated by the micro-hydro generator are greatly influenced by the rotational speed of the generator, the rotational speed of the micro-hydro generator is greatly influenced by the load changes. The electricity burden served by the micro hydro at night will decrease, especially at 23:00. This causes the generator shaft to rotate faster. As a result, the frequency of electricity will increase and endanger consumer electrical equipment.

A control mechanism of micro-hydro is done automatically by arranging the gate opening position so that the incoming water flow can be adjusted with the electrical load. Therefore, to give a better adaptation for the load change, a Load Frequency Control (LFC) is employed. In this paper, the LFC mechanism is designed using Superconducting Magnetic Energy Storage (SMES).

SMES provides energy storage systems that can operate quickly and automatically. However, an optimal optimization of SMES parameters is required for optimal SMES performance. Therefore, in this paper, the Ant Colony Optimization (ACO) method is selected based on its advantages for tuning PID-SMES parameters.

In some previous studies many researchers have discussed the application of SMES on electric power systems, such as in [1-3] which discussed SMES applications on wind turbines. Ref [4] discusses SMES applications on smart grids. The SMES application as a frequency controller in a power system has also been discussed, such as in [5-7], and [8] on thermal power plants.

Optimization of SMES parameters using intelligent methods has been discussed in ref [9], in Ref [10] Fuzzy Logic is used, in Ref [11] Cuckoo Search Algorithm is applied, Ref [12] uses Imperialist Competitive Algorithm, and [13] uses Particle Swarm Optimization. From the aforementioned studies above it can be revealed that SMES could be a suitable option for energy storage and compensator when properly control using a smart method.

In this paper, optimized tuning parameters of SMES using Ant Colony Optimization (ACO) is proposed to control the load frequency deviation in the micro hydropower system. The smart method based on Ant Colony Optimization (ACO) is a method that is inspired by the behavior of ants in finding food sources as a group. The ACO algorithm will work based on the Objective Function, which minimizes Integral Time Absolute Error (ITAE).

Implementation of ACO has also been widely used in other studies, because the results are very optimal in doing computation process, such as in [14] for Power System Stabilizer. Some other examples of storage controls such as Capacitive Energy Storage, also produce good control output [15]. II. SYSTEM MODELING 2.1. Micro Hydro Power Plant A micro hydropower plant is one of the renewable power plants, which utilizes the height difference and the amount of water discharge.

Water discharge can be sourced from irrigation channel, river or waterfalls. This water flow will rotate the turbine shaft to produce mechanical energy. This energy then drives the generator and generates electricity. The best location for the installation of micro hydropower plants is the location that has a source of water whose water flow always flows throughout the year.

Theoretically, the value of electric power that can be generated by a micro hydropower plant depends heavily on the value of the water discharge Q passing through the pipe and also the high waterfall, H. The equation is as follows: 3 [ ] [/]. [ ]. [/] th P W Q m s H m k N kg ? (1) Due to the turbine efficiency and generator efficiency determined by each manufacturer with a value of about 0.85, the real power value of P real generated become lower than Pth. 3 [ ] [/]. [ ]. [/]. .

real turbin gen P W Q m s H m k N kg ? ? ? (2) For pumps used as turbines, the efficiency value is range from 0.6 to 0.8. For cross-flow turbines, the value is ranged from 0.5 to 0.7. While the generator used in micro hydropower plant usually an induction generator, then the servo motor is operated as governor.

To simulate the system under study, MATLAB-SIMULINK program is employed. Fig. 1 shows the configuration of the designed micro hydropower plant. 1 . 1 Tb s ? ? ? ? ? ? ? 2 K . 1 Kg Tg s ? 3 . 1 K T s ? 2 K ? ? . 1 Ks Ts s ? ? ? Figure1. Micro Hydro Block Diagram [11] From the error detection block, signal will forwarded to the servomotor block used as the governor.

In this block, there are parameters that are Ks and Ts. As for the output side of the governor, there is a signal that is fed back as an input value to the governor. Also, the output of the governor is passed to a rate limiter which serves to limit the signal at the highest and lowest saturation value that has been previously determined. The output of this limiter rate is forwarded as input on the water turbine block. Table 1 shows the micro-hydro parameters used in this study.

Table 1. Micro Hydro Parameters [11] Parameters Values Notes Tb 1 Water turbine time response (s) Kg 1 Strengthening the generator regulator (s) Tg 13,333 Response time

induction generator (s) K1 5 Error Detection confirmation constant K2 8,52 Frequency deviation constant K3 0.004 Strengthening Error Detection T 0,02 Time response Error Detection Ts 0,1 The governor's time constant (s) Ks 2,5 Strengthening governor Sg 40 Micro hydropower generator rating (kVA) pf 0,8 Power factor Vg 400/231 Nominal voltage generator (V) ? 1500 Nominal rotational speed (rpm) fg 50 The nominal frequency of micro hydro (Hz) 2.2.

Superconducting Magnetic Energy Storage (SMES) SMES is an equipment that can store and release large amounts of power simultaneously. SMES stores energy in magnetic fields created by DC currents on superconducting coils. SMES consists of superconducting coils, cryogenic cooling systems, and power conditioning systems (PCS) with control and protection functions.

PCS is also referred to a power electronics hub of the SMES coil. Fig. 2 shows the schematic diagram of SMES. Figure 2.SMES schematic diagram [11] In principle, superconductors have near-zero losses at a very cold temperature. The coolant used is Helium liquid which is able to cool to 4 K. PCS is used to transfer energy from the SMES coil to the system.

A PCS uses a dc link capacitor to connect the voltage source from the SMES coil to the system. The working principle of SMES is divided into three, namely the mode of charging, standby mode and discharging mode. The SMES performance setting is performed by adjusting the duty cycle (D) of the converter which in this case uses a Gate Turn Off (GTO) thyristor To effectively control the power balance of the generator, SMES is placed on the bus terminal of the generator.

From some SMES equations of reference, a block diagram of the PID-SMES controller used is shown in Fig. 3. In this study, PID-SMES is installed on a micro hydroelectric power system. The installation of PID-SMES is in the bus terminal of the induction generator when there is a burden of changing the load.

w (+ +) 1+ST I p D K S K SK S ? ? 1+ C DC K ST 1 SM SL p Figure 3. Block diagram of PID-SMES III. ANT COLONY OPTIMIZATION 3.1. Determination of Inter-City Distance The city referred here is the magnitude of the generation value of each plant. Prior to the trip, the distance between the value of the generation of one power plant and the other is calculated first (initialized).

After initialization, the ants are placed in the first city at random. Then the ants will continue their journey from one city to another randomly to the final destination, the last city. Once the journey is over, the location of the cities that the ant has passed through will be used to calculate the solution resulting from the trip. 3.2.

Ant Tour Ants choose a path to be traversed from point r to point s in a journey with probability: k r t N l,s)l,r( )s,r( )s,r(p ? ? ? ? ? ? (3) where matrix (r, represents amoun t of pheromone intensity between points r and s. Then the pheromones will be updated through the following equation:)s,r(y)s,r( )s,r(k ? ? ?? ? ? ? (4) where with 0 <1 the a pheromone, then (1- a) the ration in mones ??k s) the of mones that ants drop on line (r, s). 3.3.

Ants Plot Travel The solution of the ant colony's journey in minimizing the cost of generation is plotted into a graph up to the maximum iteration limit. 3.4. Best Tour Plot Travel with the best solution of the ant colony (minimum generation cost) for each iteration is plotted to the maximum iteration threshold. 3.5. Initialization of Pheromones (Tau Matrix) The tau matrix has a size of n x m, with the number of buses in the system, whereas the number of generator units generated on a scale of 0 to 1 having a 0.01 interval. The value of this matrix will be updated every time the ant colony travels. IV.RESULTS AND DISCUSSIONS The objective function used in this study is to minimize the Integral Time Absolute Error (ITAE).

0 ( ) t ITAE t t dt ? ? ? ? (5) SMES-PID parameters tuned by ACO are Kp, Ki, Kd, Tdci, twi, and Ksmes. The ACO parameter data and the ACO convergence graph are shown in Table 2-3 and Fig. 4. Table 2 ACO Parameter Parameters Values Number of Ants 6 Max Iteration 50 Feromone (Alpha) 0.9

Beta 2 Table3 Results of SMES-PID Optimization with ACO Best Solution Columns 1 through 410.6582 0.4493 0.7216 0.0199Columns 5 through 619.561179.4553 ACO optimization results obtained fitness function value of 7.15e-09, with 50 iterations. The minimum value of the system performance function at each iteration is plotted on the convergence graph shown in Fig. 4. In Fig.

4 it can be seen that the ACO algorithm can quickly converge on the 9th iteration or find the most optimal value at the 9th iteration. Table 4 shows the value of SMES-PID parameter optimization results after tuning by ACO. Table 4 Results of Tuning of SMES-PID Parameters Parameter Limits Results Lower limit Upper limit Kp 0 100 10.6582 Ki 0 1 0.4493 Kd 0 1 0.7216 Tdci 0 1 0.0199 twi 0 100 19.5611 Ksmes 0 100 79.4553 Figure 4. Ant Colony Optimization Convergence Process Fig. 5 shows the micro hydropower plant design used in this study. Fig.

5 shows the micro-hydro model design with PID-SMES controller. Figure 5 SMES Block Diagram As shown in Table 5, the PID-SMES controller where its parameters are also

optimized using the ACO approach is able to obtain more satisfactory response than all previous controllers, where the overshoot on this scheme is -4.187e- 05.

Settling time also shows very good results, because the system returns to steady-state conditions faster than all the proposed control schemes before. Therefore, it can be revealed that the combination of PID-SMES shows more satisfactory performance better than all the control schemes proposed previously. Comparison of the micro-hydro frequency response of all control methods can be seen in Fig. 6. Tabel 5.

Overshoot and settling time value Characteristics Overshoot (pu) Uncontrol -0.0003179 Proportional -0.0002193 Proportional-Integral (PI) -0.0002183 Proportional-Derivative (PD) -0.0002139 Proportional-Integral-Derivative (PID) -0.0002129 Superconducting Magnetic Energy Storage (SMES -0.0001958 PID-SMES -4.187e-05 Based on the comparison of all frequency response shown in Fig 6, it can be concluded that a micro hydropower plant requires a controller to damp frequency oscillation due to load changes. The PID-SMES controller proposed in this study has a significant influence on the oscillation damping for micro-hydro power plants.

With optimal PID and SMES parameters, micro-hydro performance could be more optimal in controlling the dynamics of load changes. Figure 6. Comparison of Micro Hydro Delta Frequency Response V. CONCLUSIONS This research proposes an additional controller for load frequency control at a micro hydropower plant using PID-SMES.

The PID-SMES parameters are optimized using smart methods, called Ant Colony Optimization algorithms, which can find the optimal parameters of PID-SMES. From the simulation results, it is obtained that overshoot on PID- SMES –is 4.11e-05, showing better results compared to the obtained results of P, PI, PD, PID and SMES controller.

The PID-SMES controller proposed in this study has a significant influence on damping the frequency deviation oscillations. Therefore, it is much preferred to be applied to micro hydropower plants particularly for the system with large loads change the experience. REFERENCES [1] A. M. S. Yunus, A. Abu-Siada, and M.

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