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Application of TLBO Algorithm Optimized PID Controller to Analyse Small Hydropower Plant

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***Abstract*— The issues of climatic change and raise in load demand day by day has led to the search of alternative sources which are renewable, economic as well as eco-friendly in nature. Small hydropower has become a better option to modify the energy scenario of the world and India. This paper is an approach to design off-grid and grid connected model of small hydropower plant in MATLAB/SIMULINK. The PID and FOPID controllers are used and the result is compared for both. TBLO and ATBLO algorithm is adopted to optimize PID parameters value to maximize output power and so as to get synchronised with the system and to enhance the response of the system. In this paper, the proposed TBLO and ATBLO optimized PID controller and FOPID controller is used. The islanding operation of SHP is performed to analysis the transient behaviour of the system..**

***Index Terms*— Small Hydro Power Plant (SHP), Proportional-Integral-Derivative (PID) controller, Teaching-Based Learning Optimisation (TBLO) algorithm, Renewable Energy Resources (RES).**

I. INTRODUCTION

In the present scenario, renewable energy source plays an important role to meet the fast-growing load demand. The increasing overuse of renewable energy technologies worldwide because of global warming and decreasing supply of fossil fuels[1]. Renewable energy is now coming in world focus. Researchers consider RES as promising energy sources. Some countries have more than one renewable energy resource and therefore have made policies to increase the utilisation of RES for the electrical power generation[1]. However the efforts for generating electricity are faced with several challenges including availability of certain power source to cover demand, power fluctuation, and power quality. Thus by combining more than one renewable energy source into a system can overcome the problem of power availability to meet demand in certain times [2].
Considering the global concerns for RES, many countries have started on the mission to reduce greenhouse gas emissions by increasing the part of renewable energy in their total energy matrix[3]. Hydropower is not only a sustainable and renewable source of energy but it is highly flexible and its storage capacity helps in improving stability of grid and supports disposition of other discontinuous renewable energy sources like wind and solar power[4]. Many renewable energy are not presently economically viable for some developing

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countries[5]. Small hydro power plants, solar and wind energy system helps in meeting the objectives of climate change. The run-of the- river (ROR) hydroelectricity is free from carbon dioxide or other greenhouse gas emissions and is an environmental friendly technology. In hydroelectric plant has a hydro turbine with a non-linear, non-stationary multivariable system which means its characteristics differ much with the uncertain load over it and which causes a problem in designing an efficiently reliable controller[6].Furthermore, hydropower plants have profitable benefit for the plant operator. Although, the investment in the construction of plant is high, there is low operating cost which urges high efficiency in cost. Hence, with less installed power, there is a decrease in cost efficiency for small hydro power plant[7].The large-scale hydro power generation is affected by site location, capital costs, location of dams, lengthy development time etc. However, these problems are solved by Small Hydro Power (SHP) developments[5].

II. LITERATURE SURVEY

The literature survey has been made for this proposed work is through various IEEE journals, science direct journals, research papers, books, relevant websites, technical notes etc. In the literature survey, the power system stability and control and its basics have been described in [7], [8]. The various types of excitation system, their various component and composition are discussed by Lee et al. [9]. K. Kimet.al [10], proposed a technique to tune PID controller for excitation system. L. Tenorio[11]has discussed the different type of model for hydraulic-turbine, their components and their control, and also specific model of hydraulic turbine and governor used for hydropower plant.The detailed survey on the development analysis has been evaluated in [12], [13]. The Small hydropower plant application and its advantages are focused in [14]. Here the different algorithms are used and the simulation Result and discussion is done and finally the conclusion has been discussed in this proposed work.

A. System description

To study the dynamic response of the system, it is important to model the power system accurately. Hydraulic turbine, excitation system and its governor system can affect the power system performance so its modelling can help in studying the dynamic response of the system. The elemental block diagram of a Hydraulic-Turbine governor system is shown in Fig. 1. The complete model of the proposed work is divided into several small modules shown in Fig. 1; they are speed governor, hydraulic turbine, generator, excitation system etc. Linear model of hydropower system is useful for studying tuning of control system by applying linear analysis tools (frequency response, eigen value etc.) but cannot be used for the studies related to large power output and frequency variation. The shortcomings of linear model are rectified by nonlinear model assuming an elastic or non-elastic water column which is mostly used under the condition of large power output and frequency fluctuation. Regarding simulation of dynamic characteristic or response of hydraulic turbine, the model based on operation curves and parameter recognition for characteristics of hydraulic turbine is preferred more apart from that the characteristic and operation curves are difficult to obtain [15].

III. CONTROLLER

In hydroelectric system many equipment connected are sensitive to frequency variation. So, we need to control the speed of the system. Regulating the amount of water entering the turbine runner is a conventional method of regulating and maintaining constant speed to drive the generator and for regulating the power output[16]. The governor finds the error in speed between actual and desired values which cause changes in the turbine output. It is performed so that the system load comes into equilibrium with the output of generating unit at the desired speed[17].To improve the system stability and to minimize the overshoot and undershoot the controllers are used to minimize the steady state error to zero or near to zero, we can use different controller such as P, PI, PID, and fuzzy logic controller. In our proposed work, controller is deployed at two different subsystems one is at speed governor and another is at excitation system. It is previously declared in above section, our proposed work deals with the PID controller and the hybrid Fuzzy PI controller. The PID controller assists in maintaining the stability of the isolated system. It is helps in bringing the speed or frequency and the voltage phasor nearer to their reference value, thus aids the synchronization process. The PID controller enhances the transient response and thus reduces the error amplitude with each oscillation and then output is ultimately settles to a final desired value. Thus during a transient response, for hydro turbine application, the system frequency is controlled within 48Hz-53Hz limit, otherwise the over or under-frequency protection will trigger and trip off the Distribution Generation and stop the Distribution Generation's operation so as to prevent the chance of out of phase recloser[16]. PID controllers give better stability margin[17].

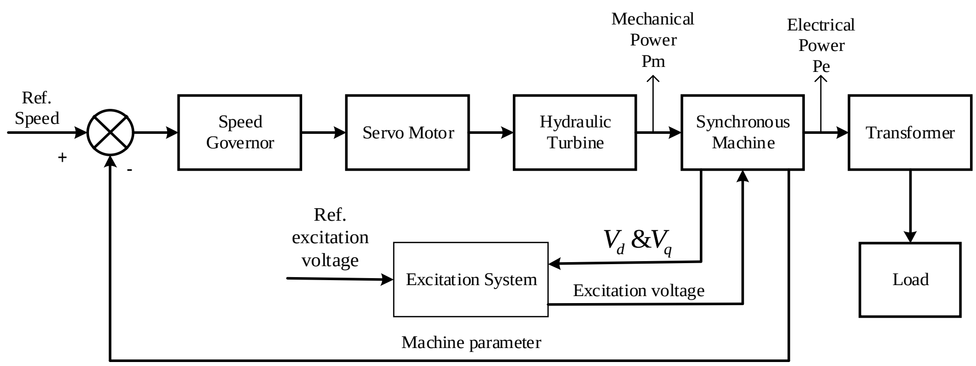

Fig. 1 Block Diagram Of Hydraulic Governor-Turbine System

A. PID Controller

A PID controller (Proportional-Integral-Derivative controller) measures the error between a measured variable and a desired reference value. It tries to reduce the error by adjusting the controller parameters. PID controllers use a three basic behaviour types or modes: P - Proportional, I - integrative and D – derivative. The transfer function of PID controller is as follows:

$$c(t) = K_p e(t) + K_i \int e(t)dt + K_d \frac{d}{dt} e(t) \quad (1)$$

Where,

K_p is gain coefficient of proportional controller;

K_i is gain coefficient of integral controller;

K_d is gain coefficient of differential controller;

e(t) is the error signal i.e. difference between present and reference value.

The equivalent transfer function in Laplace domain of PID controller:

$$C(s) = K_p E(s) + K_i E(s) / s + K_d E(s) s \quad (2)$$

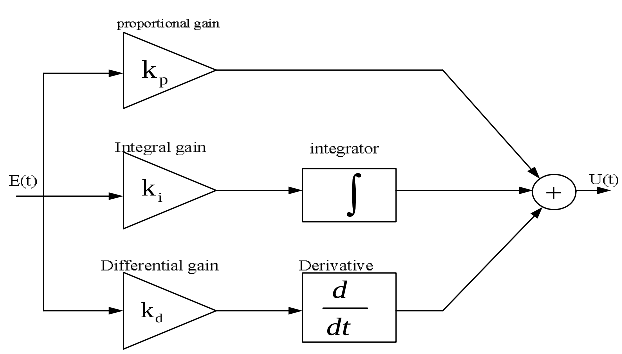

Fig. 2Transfer Function Model Of PID Controller

The simplified block diagram of a PID block employed in the automatic voltage regulator control loop is shown in Fig. 3[18]. The PID block along with, the system loop gain K_G gives a flexible term quite for fluctuations in system input voltage in the power converting bridge [18], [19].The proportional gain or action in PID produces a control action proportional to the error signal and thus affects the rate of rise after a modulation has been introduced into the control loop.

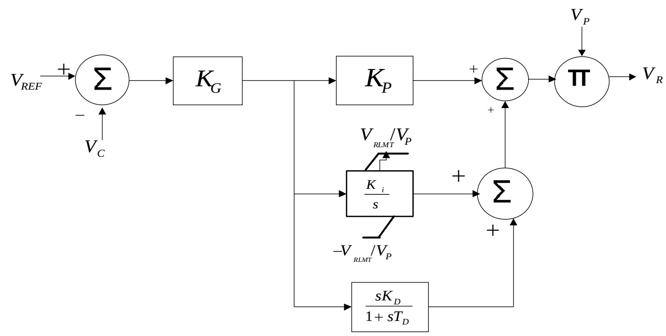

Fig. 3 Simplified Block Diagrams Of Automatic Voltage Regulators

The integral action output depends on the integral of the error. The integral response of a continuous control system, changes continuously in the direction so as to minimize the error, until the error is restored to zero. The derivative action output depends on the rate of change of error.

IV. Teaching Learning Based Optimization Technique (TLBO)

A. Fundamentals of Teaching Learning based Optimization Algorithm

In this paper TLBO algorithm is used to tune the controller parameters to control the active power balance between load and demand. Teacher and learners are the two important components of the algorithm. There are two vital means of learning which are a teacher and learners. In teaching phase, the teacher tries to increase themean result of his students (learners) by his capability. The output in TLBO algorithm is treated in terms of grades or results of the learners and the output which is the best solution depends on the quality or capability of teacher. Therefore the teacher is treated as a highly educated person who teaches the learners in order that they can obtain better results or score in form of the marks obtained by them. Furthermore, learners acquire knowledge by interacting with each other which helps them in betterment of their results[20].A mathematical model is formed and applied for the optimization of an unconstrained non-linear continuous function, to develop a novel optimization technique called Teaching–Learning-Based Optimization (TLBO). TLBO[2], [21]is also a population based method which uses a population of solutions to arrive at a global solution. In this optimization algorithm a group of learners is considered as population and different design variables are considered as different subjects which are offered to the learners and learners' result is equivalent to the 'fitness' value of the optimization problem. In the whole population the best solution is considered as the teacher. The functioning of TLBO is divided into two parts, 'Teacher phase' and 'Learner phase'.

V. Particle Swarm Optimization Algorithm (PSO)

The Particle swarm optimization is type of evolutionary algorithm introduced by Kennedy and Eberhart in 1995. PSO is population-based stochastic search/optimization technique which is capable to handle the non-differential objective function and does not get trapped in local minima point[23], [24]. The PSO algorithm is a set of particles (considered as the optimization variables) called X_i, where i means i^{th}particle. These are a set of variable value that create a swarm and which diffuse in the search space with a distinct particle velocity V_i. Each particle consists of individual best value $p_{best}$and the swarm consist a global best value g_{best}. According to these individual best p_{best} and global best $g_{best}$the value of particles and its velocity is updated using equation shown below:

$$V_i^{(j+1)} = W * V_i^{(j)} + C_1 * rand_1 * \left(pbest_i^{(j)} - X_i^{(j)}\right) + C_2 * rand_2 * (gbest^{(j)} - X_i^{(j)}) \quad (7)$$

$$X_i^{(j+1)} = X_i^{(j)} + V_i^{(j+1)} \quad (8)$$

where,$V_i^{(j+1)}$is the velocity of thei^{th}particle at j^{th}iteration; W is the weighting function;$C_1$and$C_2$are positive weighting factor; $rand_1$and $rand_2$are random number between zero to one;$pbest_i^j$is the individual best of the i^{th}particle inj^{th}iteration;$gbest_i^j$is the global best in j^{th}iteration; $X_i^{(j)}$is the variable value asi^{th}particle in j^{th}iteration. The coefficients are$C_1 = C_2$=2.05 and W=0.7 taken inproposed algorithm.

VI. RESULTS AND DISCUSSION

The TLBO & PSO algorithm is used in the proposed work to tune the conventional PID controller. The transient behavior of the isolated 1.3-MVA Small-Hydro power plant is analyzed through the voltage stability. The maximum number of population and iterations are taken 30 and 100 respectively for both optimization techniques. The objective function for the algorithm is ITAE of the sum of the error signal of both excitation and governor system.The Optimal values of the gain of conventional PID controller are shown in Table-1.

Table-1The optimal value of gain of proposed controller

Algorithm	Gain	Optimal values of Gain	
		Governor System	Excitation System
PSO	K_p	1.7082	0.2095
	K_i	1.3472	0.1978
	K_d	1.2628	0.6202
TLBO	K_p	0.7123	0.2895
	K_i	0.0286	0.1109
	K_d	1.1508	0.0145

The TLBO gives the better results than the PSO algorithm. The terminal voltage (pu) and output electrical power (pu) for the proposed work is shown in Figs. 4 and 5.It can be seen that the TLBO will give better result than PSO with PID controller. It provides less overshoot and gives the faster response to the system to settle down quickly with less settling time.

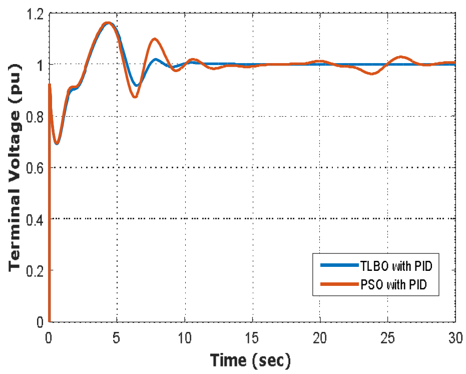

Fig. 4 Terminal Voltage Vs Time

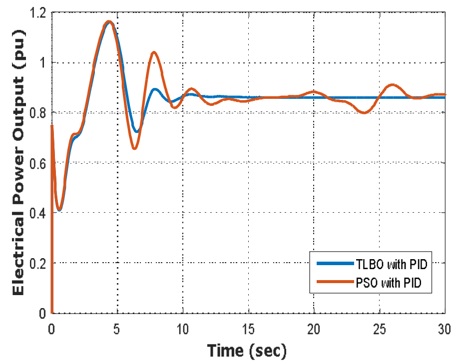

Fig. 5electrical Power Output Vs Time

VII. CONCLUSION

The proposed work uses the two optimization technique named as TLBO and PSO to analyze the transient behavior of the system and improve the voltage stability of the system. It can be observed that the TLBO provides a better optimal solution of conventional PID controller than the PSO algorithm. TLBO offers better controller parameter and give less undershoot and overshoot in terminal voltage and electrical power output waveform and very less settling time as compared to PSO. So the results obtained that the controller parameters of conventional PID optimized by the TLBO algorithm yield better transient response.

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