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Optimum Power Production of Small Hydropower Plant (SHP) using Firefly Algorithm (FA) in Himreen Lake Dam (HLD), Eastern Iraq

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Abstract: In developing countries, the amount of electrical power production is lower than the request of power or load. Therefore, sustaining the stability of optimum power production system becomes a problem. Sometimes, the development of the correct quantity of load demand is necessary in order to keep the system of power production steady. Thus, the addition of Kaplan turbine into Small Hydropower Plant (SHP) is verified to explore its applicability. This study focuses on the improvement of optimization model by applying particle swarm optimization and firefly algorithm methods in order to get a stable power production utility at its maximum level. Furthermore, it investigates on the minimization of utility loss in power production from the hydropower systemn which is done by optimizing the variables of operation control in the hydropower plant at Lake Himreen-Diyala Dam. The variables mentioned are net turbine head, rate of water flow and power production which had been gathered in the data during a research throughout a 10 years period. Moreover, this study investigates the uncertainties of input and output operation of small hydropower plant, the designing of the entire 3570 experiments and the data collected from the observation on the performance of the nonlinear plant model. The results obtained from these two methods, namely Firefly Algorithm (FA) and Particle Swarm Optimization (PSO) are compared. The inferences for general comparisons are created through several behavior indicators. The behavior indicators illustrate that FA's performance is better than PSO's performance in some fields. At the end, the results show the strength of FA as well as its efficiency and superiority.

Key words: Himreen Lake Dam, small hydropower plants, particle swarm optimization, firefly algorithm, swarm intelligence, power production optimization

INTRODUCTION

Hydropower golden age was set in the first half of the 20th century before oil control gained its dominance in the provision of energy. Several growth republics gradually began to get rid of traditional energy sources that existed in oil, coal and natural gas (Hammid *et al*., 2016). In the present as power demand keeps growing all day, more generation resources and various grid constructions are needed. While the network load is increasing, the generators that are attached to a hydro-turbine begin to be sluggish. This condition leads to the change of the output through the reduction of electrical power frequency. Consequently, the entire system of the hydro-turbine would collapse; this situation is called blackout or cascaded failure (Hejazi, 2016). Usually, the observations made on the reliability of generation systems regard the resource of energy for the power production as continuously available. This indicates that in general, even one cause of the power production deficit leads to the destruction of electricity generation in power plants. During hydropower production when the reservoir is sufficient to generate the energy, the abundance of power production adheres to the rule of the rate of water flow, hence, this model of hydro-turbine is right (Abdulkareem *et al*., 2016; Elsayed *et al*., 2016).

The quotation from many biological organizations as well as arrangements to plan and process several various types of optimization algorithms have been incorporated in both theoretic learning and real-life applications. The development is employed to adjust the parameters of these algorithms. These methods are inspired by the cooperative performance amongst animal communities as well as the other collective colonies and societies of insect. These societies have the outstanding ability to resolve optimization problems successfully and they are

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gathered in Swarm Intelligence (SI) (Bhushan and Pillai, 2013). The optimization techniques are separated into two main parts: deterministic and stochastic techniques which are employed for objective and restriction functions. The deterministic techniques are tracked and categorized to constantly generate the fixed regular solutions for optimum points when the algorithm begins under the similar primary conditions. Conversely, the stochastic methods are categorized by taking one or more elements randomly. The similar problem is suggested and overcome under the same initial conditions. This might not result to the similar optimum solutions. Firefly Algorithm (FA) is commonly regarded as a meta-heuristic algorithm and it is associated with the second part of the optimization techniques (Francisco *et al*., 2014). From the past two decades up until now, there have been some discoveries on algorithms such as particle swarm optimization (Sasikala and Ramaswamy 2012), differential evolution (El-Ela *et al*., 2010), bat algorithm (Bin *et al*., 2002), firefly algorithm (Ali *et al*., 2016) and Cuckoo search (Nguyen and Vo, 2016). These algorithms have emerged and displayed a large amount of possible solutions to difficult engineering optimization problems. Among all of these recent algorithms, the firefly algorithm is significantly effective in solving multi-modal, global optimization problems (Yang and He, 2013).

A leading and lagging traditional regulator construction is chosen to the power system's advantages due to a shortage of security in the general system. The choice was made through certain adjusted or flexible construction methods. The main problem of regulator parameter regulation is that it is a complicated application. Additionally, stability problems are caused by the traditional power system. The traditional methods have suffered from the problems of sluggish calculation. As the optimum result may not be obtained, the operation of research is expected to be hindered in minimum local value. Therefore, a plenty of traditional methods have been introduced to assist a design in solving stability problems. It's obligatory to sustain the hydropower system under the limits of reliability for a constant production of power source to the customers without influence from the general system. However, the recent problem lays in the entire system of hydropower which should be reprogrammed to minimize the loss in power production utility. This is one of the goals of optimum power problem in traditional methods. Even so, it is not adequate in resolving this problem, especially when non-linear and complex strategies are recently added into any part of the system, turning it into a non-convex optimization. This thwarts their capability to make convergence towards global minimum point. Hence, the maximum utilization power generation is created. It is very difficult to establish power production at the optimum level in an electrical power plant because of the unexpected variant of power demand.

The objective of this project is to employ both of Firefly Algorithm (FA) and Particle Swarm Optimization (PSO) into the hydropower plant located in Lake Himreen dam. This action is performed in order to create an effective solution to optimization power problem as well as an actual solution to operational problems which is suitable for both cases of irrigation provider and hydropower generation. Moreover, the objective of the mathematical function is to specify the maximum or the minimum values which may be subjected to restrictions on its variables due to the diversity of real-life applications. Additionally, the objective of power system production is to find out its restrictions and to perform an optimization by controlling specific variables of the power system. The test outcomes of both algorithm methods are obtained. Then, a comparison is made between the validation results of FA method and the validation results of PSO methods in order to display the possibilities and the superior points of the proposed algorithm. Firefly Algorithm (FA) would provide the solution to power system problems which offers some superiority points and improved behavior to general results.

Small Hydropower Plants (SHP): The hydro-turbine obtains mechanic hydropower and mechanically changes it into rotation power. Then, the turbine is connected to an electric power generator. Actually, the turbine efficiency depends on the turbine's power, its type, fluid percentage, etc. Kaplan turbine is observed to ensure that its efficiency reaches the maximum rate of water flow. Its efficiency will prove the appeal of this kind of turbine for a river with a variant in the management of the water flow rate (Borges and Pinto, 2009; Baghani, 2016). The unit of the power generator in a hydropower plant relies on four factors which are gravity acceleration, the flow rate of water, the height of the water drop and the general efficiency as illustrated in Eq. 1:

$$P = g \cdot Q \cdot H \cdot \eta \tag{1}$$

Where:

P = Generated Power (kW)
g = Gravity acceleration (m^2/sec)
Q = Water flow rate (m^3/sec)
H = Net head of turbine (m)
η = Efficiency of hydropower plant

In general, the electrical power generators employed in Small Hydropower Plant (SHP) are synchronous machines which generate electrical power by alternating the electric current. This synchronous machine has been strongly linked with the turbine shaft to convert the mechanical rotation energy into electrical power (Prenc *et al*., 2015). The rate of water flow through discharge gates is a suitable factor of optimization's problem and it relies on the relevance of the hydro-turbine capacity in the reservoir as well as the water height in the reservoir (hydro-turbine net head). The hydropower production structure is regarded as the essential basics for an accurate modeling of the optimization problem in Small Hydropower Plants (SHP). The structure which builds the hydropower system provides the direction of a smooth water flow through the hydro-plant. During the production of the optimized power of the hydro-turbine, the relation between the rate of water flow and power production is complicated and non-linear; it relies on the unit numbers of operation. It is getting more complicated because the system general loss relies on all of the discharge units of the plant. The characteristics and conditions of non-linearity method relies on linear programming success where one of the solutions to production path is in various numeral amounts with linear programming model (M-Dawam and Ku-Mahamud, 2016).

Particle Swarm Optimization (PSO): PSO mimics the action of bird grouping. Assume the general strategy; bird grouping is randomly looking for unknown regions as places for eating. However, there is only one area for eating left in the chosen regions. Even so, all of the birds could not pinpoint the location of the eating area. They only recognize the distance between the eating areas through the iteration on the distance amount. The main plan of this optimization is to discover the eating area. The active way for this is to go after the member which is nearby the eating area. PSO inherits from this strategy and employs it to resolve optimization problems. Furthermore, PSO assumes that every particular solution is a "bird" in the research work. It's named as a particle. All of these particles include a fitness value which is properly estimated to be optimized by fitness solution. These particles also include wide range of velocity which controls the particle's rapidity. The particles rush over the extent of the area through sequence of present optimal particles (Bhushan and Pillai, 2013; Rezk and Fathy, 2016).

PSO operation: PSO is created by using a collection of particles which are as solutions. Afterwards, this operation looks for the ideal situation by performing updates on the power generators. During the update process, each particle targets for the best or superior values during every iteration. The first value is the best solution and it is known as fitness. Then, the fitness value is kept and labeled as "p-best". The other best value is erased after the particle swarm optimizer is obtained by any of the particles within the population. The best value is a global best and labeled as "g-best". Every particle within the population participates in this operation because it lives next to or beside the location of the operation. The best value is the local or personal best, labeled as "p-best". When two of the best values are discovered, the particle performs updates on its velocity (v_i) and positions (x_i) as illustrated mathematically in Eq. 2 and 3 (Ibrahim *et al*., 2017):

$$v_i^{t+1} = wv_i^t + c_1 \times rand \times (pbest_i - x_i^t) + c_2 \times rand \times (gbest - x_i^t) \quad (2)$$

$$x_i^{t+1} = X_i^t + V_i^{t+1} \quad (3)$$

v_i^t is velocity particle while i is at iteration t and it should be placed in field Eq. 4:

$$V_{min} \leq V_i \leq V_{max} \quad (4)$$

x_i^t is the present location of particle i at iteration t. Meanwhile, $pbest_i$ represents p-best in proxy i at iteration t and gbest represents the best solution under this limit. Generally, the inertia's weight (w) is fixed depending on the formula in Eq. 5:

$$W = W_{max} - \left[\frac{W_{max} - W_{min}}{ITER_{max}}\right] \quad (5)$$

Where:

w = The factor of inertia's weight
W_{max} = The highest amount of weighting factor while
W_{min} = The lowest amount of weighting factor
$ITER_{max}$ = The highest iterations number and ITER is the current iteration number (El-Sawy and Aamer, 2016)

Algorithm of multi-objective optimization: The detailed description of PSO algorithm is drawn for multi-objective optimization after the population is formed at the beginning of the operation. Then, according to the assessment on the fitness values of all elements, it is very necessary to create the prime archive. During every iteration of inertia's weight factor, the possibilities of inertia's weight, the learning factors and the operator's should be computed. Afterwards, some particular operators are changed randomly. The operation's procedure is shown in the flow chart in Fig.1 (Kahourzade *et al*., 2015).

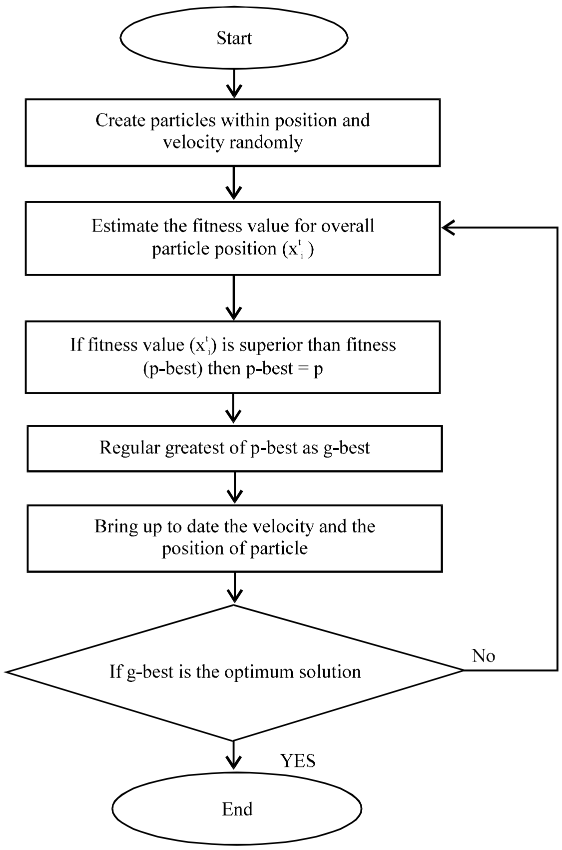

Fig. 1: Flowchart of PSO algorithm execution

Pseudo code for PSO: There are the basic steps of PSO algorithm execution which is shown in Fig. 1:

- The algorithm execution begins with the prime values of swarm size (P) and the acceleration amount of C1 and C2
- The prime position and velocity of each particle (solution) within the population (swarm) are created randomly
- Within the population, the velocity of each solution is estimated by computing its identifying fitness value
- The solution of personal or local best (p-best) and the solution of global best (g-best) are prepared

There are a lot of repeated steps until the results fulfill the outcome's: during each iteration (t), the position of each particle (x^t_i) is validated as illustrated in Eq. 3 while the velocity of each particle (v_i) is validated as illustrated in Eq. 2.

Within the population, each solution is estimated and the new solution's values, namely personal or local best (p-best) and global best (g-best) are specified. This process is repeated until the results fulfill the outcome's standard. The best solution under this limit is created (Vaisakh *et al.*, 2013; Chansareewittaya and Jirapong, 2015; Verma and Mukherjee, 2016).

MATERIALS AND METHODS

Fireflie's behavior and operation: Firefly Algorithm (FA) is an empirical algorithm inspired from the flashing of light from fireflies. This algorithm was established by Xin-She Yang, at Cambridge University in 2007. A lot of fireflies create frequent light flashes and have various light flashing dynamic. Firefly algorithm is an effective local survey in which the brightness of light flashes is related to its objective function. Parameters of fireflie's algorithm such as the constancy of attractiveness and randomization, perform an essential task in specifying the optimum solution in the survey (Gope *et al.*, 2016). These parameters are significantly necessary for the computation of the convergence rapidity and FA algorithm's performance. FA has three main concepts that have been pursued from the fireflie's activities amongst one another.

In general, all fireflies are unisexual. They will move individually towards fireflies which are brighter and more attractive without relying on their sexual role.

The grade of a firefly's attractiveness has a direct proportion to the brightness of its light. The brightness may be reduced due to increase of the distance between fireflies. This is because their lights are absorbed by the air formed within the distance. It moves around randomly when it doesn't come across one that is brighter or more attractive.

Therefore, the objective function is specified by the firefly's brightness or the intensity of the firefly's light (Naidu *et al.*, 2013).

Mathematical model of Fireflies Algorithm (FA) optimization: In a condition which displays the barriers of the highest FA optimization, the brightness (I) of a firefly is determined by two particular positions (x) which are marked as 'I (x) α f (x)'. This is because the distance between fireflies and their level of attractiveness (β) are proportional to each other. This depends on the distance of fireflies (r_{ij}) from the earth and the fireflie's variations (jth). Light intensity reduces with the increase of space between the fireflies because the light is absorbed into the environment. Thus, 'β' changes with absorption rate which inversely depends on the square law as illustrated in Eq. 6:

$$I(r) = \frac{I_s}{r^2} \tag{6}$$

I(r) represents the light intensity within a space (r) and it has the same light intensity in the source space (Babaeizadeh and Ahmad 2016, Azimi and Bashiri, 2016).

Since, a firefly's attractiveness is directly proportional to the light intensity, it is recognized and distinguishable amongst neighboring fireflies. Therefore, the relation between the level of firefly's attractiveness (β) and the size of space (r) is illustrated in Eq. 7:

$$\beta = \beta_0 e^{-\gamma r^2} \quad (7)$$

In the Fig. 7, β_0 is represents a firefly's attractiveness level at r = 0. γ represents the constancy of environmental absorption which the regulates the rate of light intensity reduction. The motion of the firefly which is attracted to the brighter firefly 'j' is labeled as 'I' as illustrated in Eq. 8:

$$X_i^{t+1} = X_i^t + \beta_0 e^{-\gamma r_{ij}^2}(X_j^t - X_i^t) + \alpha_t \varepsilon_i^t \quad (8)$$

The creation of the second part of the Eq. 8 is due to the firefly's attraction towards the brighter firefly. Meanwhile, randomization (α_t) is included on the last third part of this formula. This symbol represents the parameter of randomization and (ε_i^t is the symbol of the dispersed vector numbers, achieved from the regular supply and delivery made at specific time 't' (Gope *et al*., 2016). For both fireflies 'i' and 'j', the space (r) between them is calculated as illustrated in Eq. 9:

$$r_{ij} = \sqrt{\sum_{k=1}^{d}\left(x_{i,k} - x_{j,k}\right)^2} = \left\| x_i - x_j \right\| \quad (9)$$

Based on the Fig. 2, 'r_{ij}' refers to the space between fireflies 'i' and 'j' and they are placed at 'x_i' and 'x_j', respectively. This space is known as the Cartesian space. Meanwhile, '$X_{i,\ K}$' is the k^{th} element of the third-dimensional axis 'x_i' created by firefly 'i^{th}' under 2D condition (Guerraiche *et al*., 2015). When most of the generation is almost finished, the fireflies are classified depending on their brightness and the superior firefly group is discovered from each category. Finally, the fireflies start moving according to their groups. Additionally, the intensity of brightness of all fireflies is recently improved with the information provided in fitness function for each group. Moreover, when the procedures are performed on the groups, the firefly with the maximum level of brightness indicates the highest value of fitness. This is established as the optimal solution to optimization problems (Babaeizadeh and Ahmad, 2016).

Execution of Firefly Algorithm (FA): Four of the parameters in Firefly Algorithm (FA) are labeled as 'α_0, β_0, γ_0' while 'n' represents the population size. The parameters of FA are adjusted to carry out the execution of the optimal solution to optimization problems and the calculation of fireflie's number. The problem in regards to

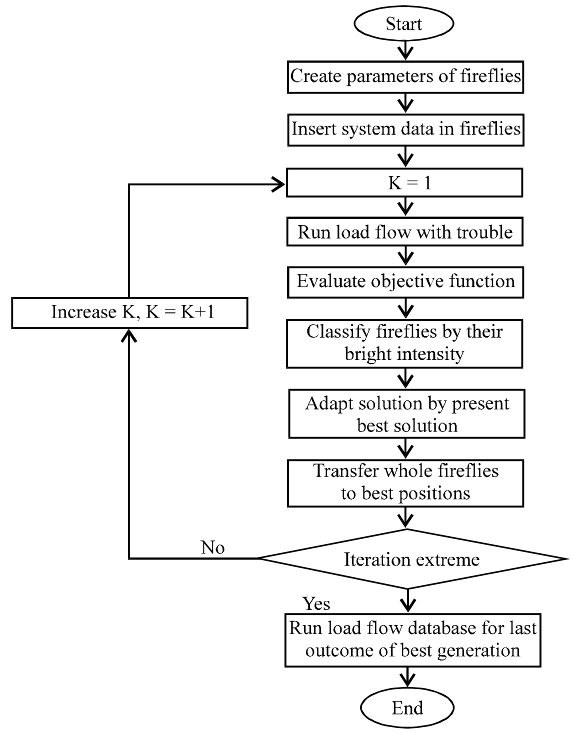

Fig. 2: Flowchart of firefly algorithm execution

the level of brightness or light intensity is resolved using the same approach as the fitness function's approach. Classification of FA according to the intensity of brightness provides the best solution which results to the suggested outcomes. At this point, the optimal solution of system rearrangement results to the problem. A comparison between each step of firefly algorithm in terms of its efficiency is made. As the procedure is displayed in the flow chart in Fig. 2 (Chiranjeevi *et al*., 2016).

Pseudo code of firefly algorithm: The fundamental steps of firefly algorithm are as follows:

Algorithm 1:

- FA initialization
- The problem elements
- The fireflie's number
- The maximum number of iteration
- The selected values of α, β, γ and n
- Counter (k) of iteration = 0
- The increment of iteration counter is k = k+1
- During every calculation of the fitness value, compute the fireflie's fitness using the fitness function as in Eq. 1 and match the light intensity of each firefly to the ones with the same light intensity
- During each calculation; classify the fireflies according to their light intensities and identify the firefly with the highest light intensity
- The difference of intensity of light produced by fireflies depends on the space between them
- The fireflie's movements depend on their attractiveness which is based on their light intensities and the regulation of parameter
- If the stopping criteria are not found go back to the second step Otherwise, proceed to the next step
- Choose the firefly with the highest light intensity and observe the particles of the light

Firefly's Algorithm (FA) characteristics: As the researches on firefly algorithm are made and recent options have appeared, all of them indicate that firefly algorithm is superior to other algorithms. There are some factors contributing to the efficiency of the firefly's algorithm. One of them is the involvement of the analysis on firefly algorithm's structure. It's based on swarm intelligence, thus, it has more benefits related to swarm intelligence compared to other algorithms. Generally, a simple study on parameters proposes that plenty of PSO options such as accelerated PSO (APSO) are the particular conditions required for firefly algorithm while $\gamma = 0$ (Balachennaiah *et al*., 2016).

Anyhow, FA has two main benefits, compared to different algorithms; the voluntary distribution and the capability of treating with multimodality. Furthermore, FA depends on the range of fireflie's attraction towards light intensity and their attractiveness when separated by certain space. It indicates the fact that the entire population of fireflies can be smoothly categorized into sub-collections and every collection can properly gather in crowds with each form being near to each other. The result of the global best can be discovered easily amongst all of these forms. Additionally, this distribution increases the fireflie's ability to discover the total amount of optimal values instantaneously, especially when the size of the population is appropriately greater than the number of forms. Scientifically, $1/\sqrt{\gamma}$ regulates the average space between fireflies within a firefly's collection that can be recognized by neighboring fireflie's collections. Thus an entire firefly population can be divided into sub-collections with specified average space. Strictly in the crucial status when $\gamma = 0$, the entire firefly population won't be distributed. In general, the distribution capability created is appropriate for the greater non-linear form and problems of multi-modal optimization (Guerraiche, 2015). Moreover, the parameters of FA can be adjusted to regulate the inconsistent changes in iterations progress. With FA parameters, convergence values can also be accelerated through adjustments on these parameters. These benefits of FA contribute to its flexibility in solving optimization problems, clustering and organizations as well as combinatorial optimization (Ameli *et al*., 2013; Kahourzade *et al*., 2015).

Climate scenarios and flow rate variation in hydropower production: It is highlighted that temperature level and rainfall have been the influences of the rate of water flow since, the previous months. This is probably because the temperature level and rainfall from the previous period affect the rate of water flow in the next period. In addition, the rate of water flow would be higher due to climatic conditions during the previous period (Kostic *et al*., 2016). The cases of water flow rate were investigated in order to build the operational constraints of winter hydropower. From 1985-2010, the operation of hydropower plants stopped 36 times. The 29 out of all the times when it was shut down lasted for 1-2 h. The longest duration of the "shutting down" state was 6 h. Based on this information, the investigation regarding a set of "shutdown" periods of hydropower plant and the shutdown of the upstream hydropower plants was conducted.

The stability of the ice cover downstream is influenced by the condition of the environment surrounding the hydropower plant upstream. The reason of several shutdown issues is due to the limited supply of water upstream during the period of shutdown. The water supply is provided in order to stop the occurrence of ice breakup as well as flood problems downstream in the regulation permit (Dorn *et al*., 2016; Timalsina *et al*., 2016).

Case study and area: Province of Diyala/Iraq had been frequently exposed to a series of major floods along the Diyala River. The floods occurred five times, between year 1946 until 1986. This kind of natural disaster usually leads to human life loss and property damage in the vicinity of the rivers. It also results to the large scale damage in agricultural regions. Thus, the main purpose of the Himreen Dam is to put flood under control to provide irrigation, produce hydropower. The study area was located in Himreen town in the province of Diyala/Iraq as illustrated in Fig. 3. The Himreen Dam is a dam, situated at the end of the Himreen mountain range which contains Himreen Lake. It is located about 100 km Northeast of Baghdad, Iraq. It was built to control the water flow along Diyala River. The specifications of this dam are as follows: Dam Length; 3360 m, maximum height: 40 m, the amount of dictation; 3.65 million m^3 of dirt, mud, consisting of pulp deaf, this is to fill the origin of a concrete quantity; 150,000 m^3 of liquefied water.

The construction of this dam was conducted between year 1986-1991 by the Yugoslav company, GIK Hidrogradnja (of Sarajevo, now Bosnia-Herzegovina). Furthermore, all the equipment of the Himreen hydropower plant such as gates, turbines, generators were fully supplied by the Yugoslav companies. This hydropower plant consists of two units with a total installation capacity of 50 MW. The type of turbine used is Kaplan; K5S-3.8/3.686 and the type of generator used is three phase synchronous with permanent magnet included.

Dataset collection: This small hydropower plant is located in Diyala/Iraq in the Himreen Lake Dam (34.066, 44.957;

Fig. 3: Himeen Lake Dam

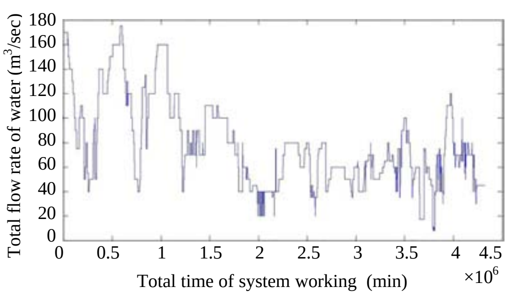

Fig. 4: Chronological flow rate of water

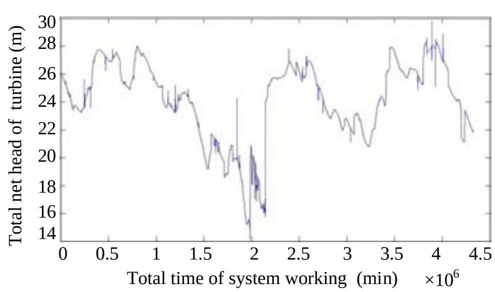

Fig. 5: Chronological net head of turbine

Fig. 3). It serves to produce electrical power to fulfill the needs of the people in this area. The measurements of the parameters including net head, water flow rate and power production were obtained within a 10 years period. The data had been collected from 1st January 2005-31th December 2015. This duration is acceptable and it includes all seasons. These covered all the different possibilities in the work variables, since all the historical data was taken out and studied on a daily basis. This

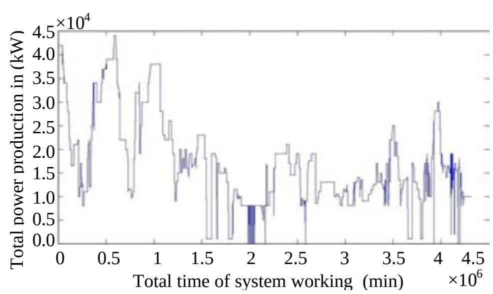

Fig. 6: Chronological power productions

historical data was checked by two ministries (the two ministries of water and electricity resources in Iraq), since the dams and hydropower plants are two facilities related to these ministries. Therefore, the data used was reliable as it had been checked in two specific destinations.

All of the data were carefully used and no raw data was deleted or neglected. The data regarding the days where power transmission lines were cut off was an exception. As the time of the cut-off did not exceed the one-month duration, the data on this matter were not taken into account. The chosen dam covered the ranges of stable irrigation channels and drains with rates of water flow ranging from 8-175 m^3/sec as shown in Fig. 4. T net heat of turbine ranged from 14.17-29.84 m as shown in Fig. 5. Meanwhile, the power production, ranging from 0-44000 kW is shown in Fig. 6. In addition, the value of generation is zero due to the small number of maintenance workers. Besides, they are less experienced in regards to power production safety. This can be proven by how they left the turbine

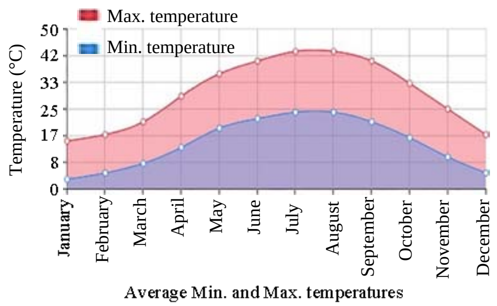

Fig. 7: Average min and max climate temperatures at work site (Hammid *et al*., 2016)

to work in default mode with no power production or water flowing through it within few short periods

The weather all over Iraq is considered as pleasantly warm; the surrounding temperature is higher than 45°C during the summer season. On the other hand, the regular temperature dropped to 5°C during the winter. However, there was no duration for snow and frost as shown in Fig. 7. With this, the shutdown of Himreen hydropower plant did not occur and it could work continuously for throughout the year (Hammid *et al*., 2017).

The data on the production of Small Hydropower Plant (SHP) had a complex and non-linear relation. There were probably some irregularities in the data. Furthermore, the measurement of data variables was changed. This created the values of unrelated variables. In this data collection, the parameter included classified variable data and fixed data according to the input-output of the power rule in Eq. 1. The power rule referred to the net head of the turbine (m) and the rate of water flow (m^3/sec) that was regarded as variable input. Moreover, the efficiency of hydropower plant (%) and ground acceleration (fixed value = 9.81) were regarded as fixed input. The output variable data represented the actual power generation (kW). Then, the number of data on input-output equaled to 3570 rows in MS-Excel. After that, the preprocessed data set was analyzed statistically and classified into 5 columns in a matrix chronological order. Finally, the modeling and the matrix were arranged according to the variables of power rule shown in Eq. 1.

The main reason of the power production's high reliability was the performance of Himreen Lake Dam. Besides, hydropower plant was placed on the dam instead of the river. In spite of the high reliability of the power production in this hydropower plant, it was unstable due to the changes in load demand and the rate of water flow to the turbine. This study represents the rate of water flow in the dam and net head as variables of hydro turbine input. Meanwhile, the unit of power production in generator is represented as variables of output through optimization model. As for the experimental data (net head, water flow rate and power production) regarding specific locations in Himreen Lake Dam, hydropower plant was used as one of the variables of input-output parameters. Experimental mathematical analysis was conducted on dependable input and output values of hydropower plant.

RESULTS AND DISCUSSION

In this study, only the constrained generated power were checked and taken into account, according to the main restrictions. There were various limitations on the operation of power generator on both maximum and minimum level. An observation was also conducted on two input parameters. This refers to the rate of water flow, ranging from 8-175 m^3/sec as shown in Fig. 4 and the net head of turbine, ranging from 14.17-29.84 m as shown in Fig. 5. Moreover, based on the observation, the amount of power output production barely reached 44000 kW. Sometimes, the amount of power production dropped to zero and there was a wide variation of power production as shown in Fig. 6.

As shown in Eq. 1, all input and output data were arranged according to this function which is used for all historically measured input-output data used in this study. Equation 1 was used as a mathematical formula for the description of MATLAB codes which were created in the real observed data. After the implementation of the statistical analysis stage, the execution and application of Firefly Algorithm (FA) and Particle Swarm Optimization (PSO) were performed. However, these two algorithms were not simply generated that illustrated in Fig. 1 and 2, respectively by MATLAB Software.

Since, the creation of FA and PSO depends on their historical data, the input and output data collected during this study were analyzed statistically. These two methods were built to be specialized in 4 inputs and 1 output which originated from fitness function. Clearly, the evaluation of the plant behavior was based on some of the main variables. From the past up until now, there has been no rule for selecting the superior techniques from Swarm Intelligence (SI). The correct way of selecting the superior techniques is through trial and error. Therefore, the execution of each model will be checked so that, the structure of its right behaviour will be clearly seen. In this

Table 1: Optimum input parameters for two algorithms employed on non-linear measured models

Objective	Optimum net head in (m)	Optimum flow rate m^3/s
PSO	29.839632	174.988194
FA	34.84000	115.159889

study, there were some attempts of optimizing power production using the R2015a Version (The Mathworks Inc.) of the MATLAB Software package. The FA and PSO techniques were modeled to accomplish the superior fitness level of fitness function which was identified by Eq. 1. All the models were executed by a computer with the following properties:

- CPU: CoreTM i7-2620 M
- Processor: 2.70 Ghz
- RAM: 8.00 GB

The well-known optimization methods such as Particle Swarm Optimization (PSO) as well as another one is a Firefly Algorithm (FA) have also been considered here in the similar difficult, so as to make comparison between results with the two both diverse optimization methods to solve optimum power production problem. The 500 is maximum iterations have been considered for FA. The 3000 is maximum iterations have been considered for PSO as illustrated in Table 1 and 2, respectively.

PSO and FA algorithms adjustment is executed in two stages; firstly input data to both algorithms. Secondly, velocity convergence of each particle choice of the superior foundation of the fitness function which is equal to the power function group. It is executed for the choice of operation of the superior Firefly algorithm and PSO and made the update in each step to ensure the rate of convergence at a superior rate. The fitness function has been getting for the problem of optimization is the progress of the stability index after employment the governor and controller also in the power system.

From power generated function that applied on PSO and firefly algorithms, PSO is starting the power generation which has ranged from 41000 up to 49000 kW as illustrated in Fig. 8. And the FA is starting the power generation which also has range from 37600 up to 37700 kW as illustrated in Fig. 9. In PSO method, the approximate maximum best fitness and approximate minimum best fitness were 49010 and 42737, respectively which equals to power generation function. In FA algorithm, the exact maximum best fitness and exact minimum best fitness were 37746 and 36676, respectively which equals to power generation

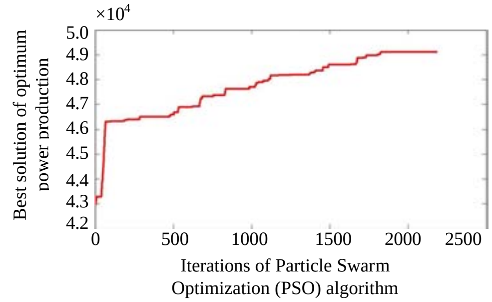

Fig. 8: Convergence graph of PSO algorithm

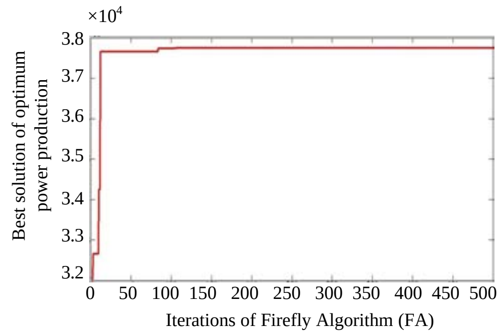

Fig. 9: Convergence graph of FA algorithm

function. Figure 8 and 9 illustrate the relative study of two algorithms base of diverse Himreen Lake Dam (HLD) which non-linear measured model (X-axis is iteration numbers and the Y-axis is optimum power generated by kW).

In the main case, the best result achieved when 500 iterations are done by using the FA optimization method has been made a comparison with the PSO other optimization methods. Results in Table 2, illustrates that all power production rearranging in a founded solution of FA is less than the results obtained by basing solution of PSO. Moreover, the mathematical test function or fitness function value is the best solution that has been done from the power generation equation as illustrated in Eq. 1. Since, it includes power sensitivity analysis in algorithms selection function, it covers all over probabilities and it contains all function parameters.

It is clear that has the FA generated values of the fitness function included the lower standard deviation than the dependency runs compared of the PSO. Furthermore, the best values or maximum values of fitness functions for entire check test problems completely which is obtained by the FA are nearby the global optimal values, Thus, FA might exactly get to the

Table 2: Optimum power production from two algorithms employed on non-linear measured models

N = iterations	Optimal power generated by PSO (KW)	N = iterations	Optimal power generated by FA (kW)
10	42734	1	36676
250	46120	50	36876
500	46769	100	36976
750	47225	150	37664
1000	47538	200	37764
1250	48067	250	37764
1500	48326	300	37764
1750	48542	350	37764
2000	48612	400	37764
2250	48743	450	37764
2500	48979	500	37764
3000	49010	550	37764

global optimal value of the power generation function in the check test table. Both of two algorithms have been showed for a similar number of population which is 3570. In the case of fitness function (power function), FA almost gets to the optimum point and it does not exceed the optimum point as illustrated in Fig. 9. While, PSO is exceeding the observed maximum point but in a much too long time as illustrated in Fig. 8.

The performance of the FA convergence method which is illustrated in Fig. 9 can be actually realized that throughout the algorithm the fitness value converges after 100 iterations turn out to be steady. On the contrary, the performance of the PSO convergence method which is illustrated in Fig. 8 cannot realize any period for steady case due to increasing values throughout all periods of iteration the algorithm. As a result, a comparison must be getting into the relationship between the suitable convergence and computational time. Thus, there is a faraway convergence of PSO method which may be a reason to obstruct the fitness function and lead it in local values. It can be prevented by swarm size increment but the computation time will be greater than before also.

So, as to estimate the algorithm accomplishment and illustration the advantage and efficiency of both suggested algorithm, the total execution and ran both of them are 10 times. Now ‘step numbers’ means a whole number of time steps of optimization algorithm and ‘iteration number’ period is employed for getting sequentially earlier estimates the solution of our own specified problem.

From the numerical data which aforesaid, it can investigate the model performance of PSO method. As its population depends on optimization methods and the fitness function values which are extremely nonlinear as plotted in Fig. 8, thus the results of fitness values of PSO oscillation in each iteration obviously because inner loop which is inside of PSO algorithm does not compare every individual (particle) population within all entire population thoroughly. Therefore, the maximum best fitness is staying approximately in the range of 48000-49000 and the minimum best fitness is approximately staying in the range of 40000-41000. It can also investigate the model performance of FA method. Although, its population depends on optimization methods and fitness function values which are extremely nonlinear as potted in Fig. 9, the results of fitness values of FA endure to be stable in each iteration obviously because inner loop which is inside of FA algorithm certainly compare every individual (particle) population within all entire populations throughout the operation and sustain the same sizing value in every iteration process ranges. Therefore, the maximum best fitness is exactly staying on the value of 37746 and the minimum best fitness is exactly staying in value of 36676. Peculiarly inner loop which is inside of FA algorithm has got a strong point to get a much better solutions in every iteration. But inner loop which is inside of PSO algorithm is giving one best solution in every iteration. Thus, the population of this system is more than 3570 items; the result of final iteration execution of 3570 time in PSO case to equal to one iteration execution time in FA case. Because of a high PSO output variety, FA regard as a high efficiency than PSO method and it achieves the solution with higher convergence accuracy every iteration.

The parameters of FA can be adjusted to regulate the random changing in iterations progress, thus convergence values can also be accelerated by adjusting these parameters. Although, PSO provides more values of power generation through fitness function compared to FA method but FA method revenues less computational time and faster response than PSO to accomplish the objective. In PSO, the velocity vector confirms local utilization ability. Furthermore, the difficulty of PSO is that it has suffered from the faraway convergences in initial periods and it wants more parameters tuning than FA method. These characteristics properly make PSO very difficult to resolve some particular optimization problems.

CONCLUSION

The availability of powe generation in Small Hydropower Plant (SHP) is essential to ensure the availability of energy which is related to the rate of water flow and the generator unit. To ensure the availability of the accurate modeling of SHP, it is necessary to identify some components of the hydropower plant such as turbine's and generator's properties, the net head of the turbine and the rate of water flow within a long-term duration. In this research, a successful execution of Firefly Algorithm (FA) and Particle Swarm Optimization (PSO) has been accomplished on non-linear power function. With this, the stability of power production utility at its maximum level was obtained and the loss of power production in the hydropower system was minimized by optimizing the control of operation variables in the hydropower plant at Himreen Lake Dam Diyala. The analysis of the daily data set was influenced by the net turbine head and rate of water flow. These elements of the hydropower plant functioned as the input and the power was produced as the output. The daily data set was modeled based on the actual observed daily data throughout 2005-2015. Thus, the experimental results were indicated by the compression FA with PSO which is discovered, the better for this proposed work specifically. It's owing to the benefits of the meta-heuristic process of FA which is comprehensively cleaning the searching area to discover the optimal solution for combinatorial optimization correctly. The FA is not only containing the improvement operation related to present area but it's containing the enhancement amongst its specific another area from the earlier steps. Moreover, FA is a stochastic algorithm which depends on attracting and light intensity of common performance of fireflies and its function has a unique behavior to solve the certain restricted of optimization problems.

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