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A Comparative Study of Hybridization Methods of Particle Swarm Optimization (PSO) Family for Network Reconfiguration

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Abstract: Electric power distribution loss and reliability are major concerns in power system as the demand of electrical energy by customers keep increasing from day to day. Distribution Network Reconfiguration (DNR) is one of the methods that can be applied in the system to minimize the power loss in the existing distribution network. This project proposed the comparative study between the meta-heuristics PSO family that consists of traditional PSO and hybrid PSO; EPSO and REPSO. The performance on the power loss, computing time and total cost saving has been applied to the algorithm. A comprehensive performance analysis has been applied on IEEE 33 bus distribution system by using the simulation in the MATLAB environment. The proposed technique has been integrated as well as the real power losses along with computation time in the network system offers also been investigated and justified. From these studies, the best PSO Family algorithm that excels in performance of power losses reduction, computation time and total cost save has been determined. Thus, distribution network reconfiguration can certainly be utilized to greatly assist in conserving the expenditure, decreasing the power losses as well as increase the quality and even the reliability of electrical power system throughout Malaysia installation.

Key words: PSO, PSO, Malaysia, IEEE, installation

INTRODUCTION

Electricity distribution companies constantly require improvements in service and an appropriate reduction in the cost of the system. Since the distribution system is the biggest section in a power system area, by finding the best optimal method that can reduce the power losses that at the same time influences the cost and crucially also leading to significant energy saving. Due to that several the heuristic techniques utilized by experts to resolve the optimization issue and Particle Swarm Optimization (PSO) is one of the algorithms that applied to the distribution system to reconfigure the network. Many researchers had enhanced the classical PSO algorithm with other heuristic algorithm such as Differential Evolution (DE) and Evolutionary Programming (EP) that produces hybrid PSO which is more powerful and produce more efficient performance to solve optimization problem. However, there is a lack of research that has been reported on the performance of these hybrids PSO families; Particle Swarm Optimization (PSO), Evolutionary Particle Swarm Optimization (EPSO) and Rank Evolutionary Particle Swarm Optimization (REPSO). The comparative studies of performance of power loss reduction, computation time and validate the cost saving after hybrid method of PSO family applied to the network reconfiguration need to be done to verify the effectiveness of the algorithms when applied at the network in Malaysia.

To reduce power loss as the demand of electrical energy is increasing day by day. The techniques of monitoring systems such local and manual control of capacitor, sectionalizing switches and voltage regulator are generally dealing throughout nearly all of the distribution system network. To improve the efficiency of the electrical network, there are several techniques that can be applied in the system and the reconfiguration of the distribution network is one of the method (Nath and Rana, 2011). The method is performed by opening the sectionalizing switches that usually closed and closing the tie switches that normally open to maintain the feeder in radial network (Kashem *et al*., 2000; Subburaj *et al*., 2006). Energy loss reduction analysis on distribution network reconfiguration also had been done by Taleski and Rajicid (1997), Yang and Guo (2008). The energy loss estimation method based on readily available data studies was conducted in Azizipanah-Abarghooee.

Initially, Particle Swarm Optimization (PSO) was presented in 1995 as a brand new heuristic method by Kennedy and Eberhart (1995). However, the original main objective of their research was to graphically simulate the social behavior of bird flocks as well as fish schools. As the investigation about PSO advanced, they found out that along with certain modifications, their social behavior model can serve as a powerful optimizer. Evolutionary

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Particle Swarm Optimization (EPSO) had been introduced by Miranda and Fonseca (2002) to be implemented in power system. The ability of EPSO application to reduce power losses has been proved in (Liu *et al*., 2011; Murthy, 2009).

Aside from that, in the year of 2014 (Sulaima *et al*., 2014) a new hybridization method Rank Evolutionary Particle Swarm Optimization (REPSO) which is the combination of ranking idea in Evolutionary Programming (EP) in conventional PSO in order to obtain a quicker solution had been tested on the IEEE-33 bus system. The exact ranking idea in REPSO offers remarkable outcome in picking the ideal topologies switches along with faster computational time frame for distribution network optimization.

The comparative studies between three types of particle swarm optimization (PSO, EPSO and REPSO) had been done (Jamian *et al*., 2012) on distributed generator sizing. The research exposes the fineness of REPSO more than PSO and EPSO in DG sizing.

Hence, the important of reconfiguration to the distribution system as it maintains the reliability of the system by reducing the losses has been discovered. PSO is a type of heuristic method that had been evolving from day by day that can be applied in distribution network reconfiguration to reduce the power losses. From the research that had been done there were still no comparative studies that shows the performances of PSO Family (PSO, EPSO and REPSO) in network distribution reconfiguration for the energy loss reduction and cost reduction improvement.

MATERIALS AND METHODS

Mathematical formulation and constraints: The needed for there configuration of the distribution system in this study is tominimize the power losses in the distribution network system. Therefore, the expressions that can relate to the objective are as follows:

$$\text{Minimize } f1(x, v) = \Sigma_{i=1}^{n} \text{ Lossesi} \quad (1)$$

Where:

n = The number of branches
x = The continuous control variable
v = The discrete control variable
Losses = The power losses at classified at i branch

The voltage constraints: In order to maintain the power quality of the system, the voltage magnitude should be based on within its particular limits:

$$V_{min} \leq V_{bus} \leq V_{max} \quad (2)$$

The particular limit for voltage at each bus is within 1.05 and 0.95 (±5).

Power flow constraints: Each and every branch in the power flow has its own permissible range. This range should be followed clearly and the constraints are strictly lies within it.

Radial configuration constraints: The constraints of the radial configuration should be considered to avoid any excess of current flow through the system. Therefore, in order to ensure the radial network to be maintained, several constraints must be taken into account. Several standard rules have been adopted for selection of switches. Those switches that do not belong to any loop, connected to the sources and contributed to a meshed network have to be closed.

Energy losses cost reduction analysis: The energy losses that had been obtained were transformed into form of cost by referring the System Average Interruption Duration Index (SAIDI) obtained from Energy Commission for medium voltage which is between 6.6-33 Kv annually. With the assumption of the system operates for the whole year. From the SAIDI data the average operation of the system for 1 day on average is calculated as 23.846 Hours.

To obtain the energy loss:

$$\text{Energy(kWh)} = \text{Total power(kW)} \times \text{Hour(h)} \quad (3)$$

To obtain the loss cost average for one day of operation the values of obtained were multiplied with the average selling price:

Total Loss Cost (RM) = Energy(kWh)
Electricity Average Selling Price (sen/kWh)

Particle swarm optimization family

Particle Swarm Optimization (PSO): The choreography of a bird flock when they seek for food has inspired Kennedy and Eberhart in 1995 to develop PSO. The birds will move to the food within selected speed and position. P_{best} and G_{best} can be concluded as the movements they have created are primarily based upon their experiences along with their friend's experience. Since it possesses individual velocity. While $V_{(i+1)}$ denoted as new velocity and the new position that denoted as new position $x_{(i+1)}$ could be acquired through the function listed below show in Fig. 1 and 2.

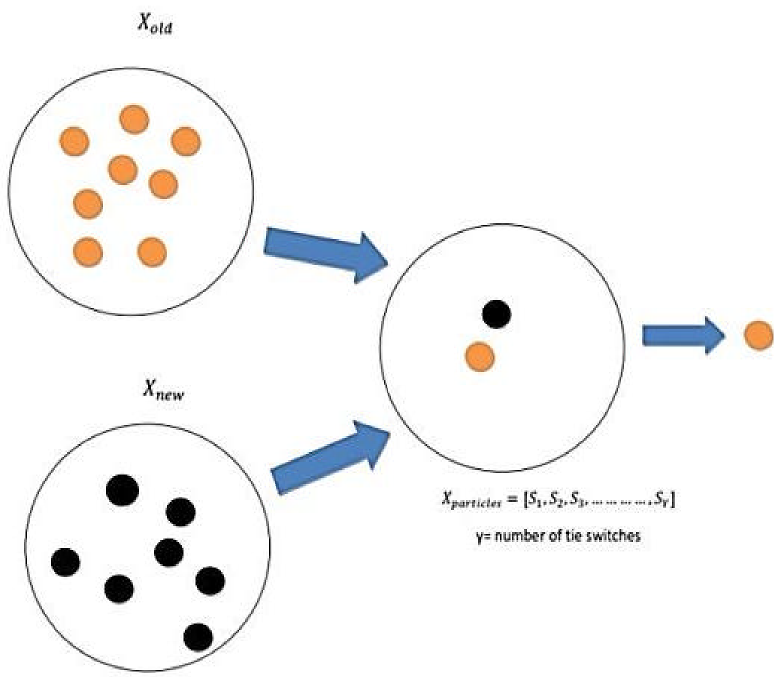

Fig. 1: Particle Swarm Optimization (PSO) impementation on DNR concept

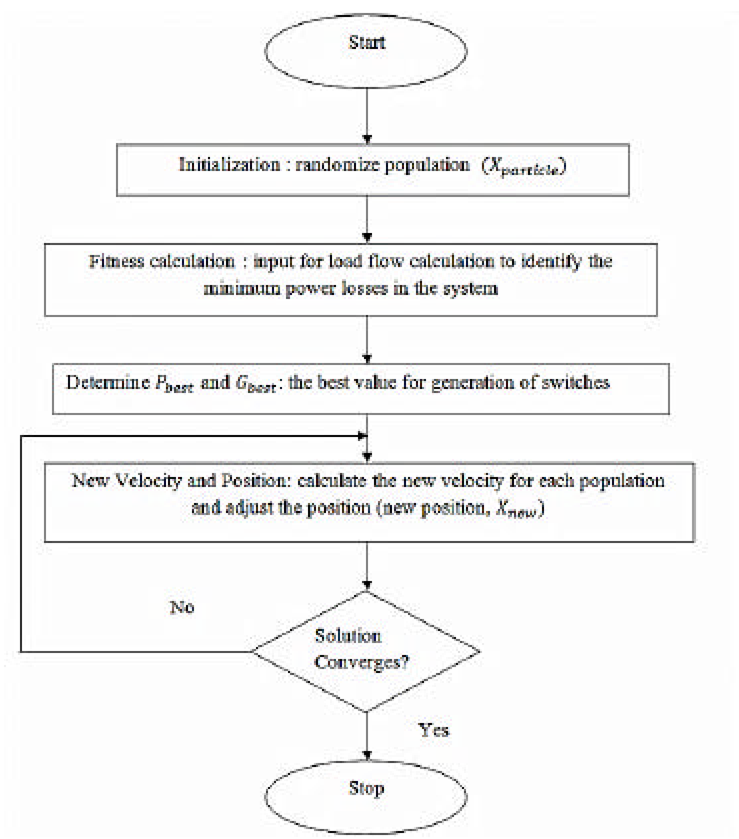

Fig. 2: Implementation of PSO in network reconfiguration

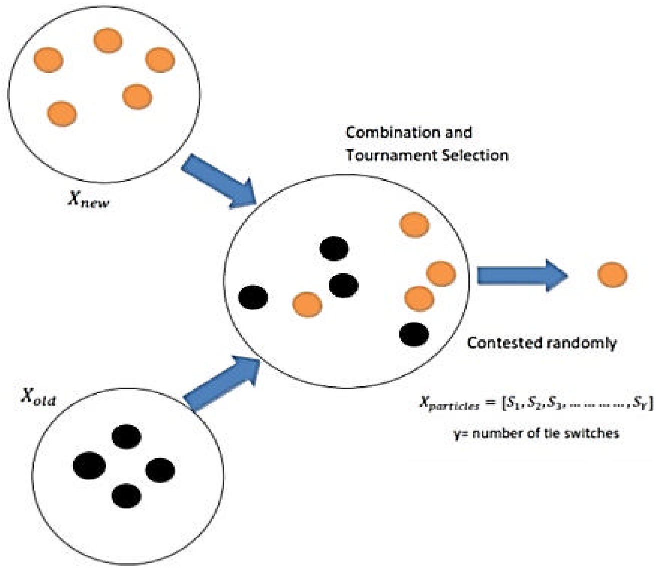

Fig. 3: Evolutionary Particle Swarm Optimization (EPSO) implementation of DNR concept

$$v_{(i+1)} = \omega V_i + c_1 r_1 (P_{best} - x_{\rightarrow}) + c_2 r_2 (G_{best} - x_i)$$
$$x(i+1) = v(i+1) + x_i$$

Where:

ω = Inertia weight
c_1 = Acceleration constant
r_1 and r_2 = Random values between 0 and 1

In PSO algorithm:
Initialization-for the randomize population (x)
REPEAT:
Calculate the fitness (f(x))
Calculate the and for all the population
Find the new velocity for each population
Adjust the position
Is the requirement fulfilled? If no, REPEAT
If yes, END

Evolutionary Particle Swarm Optimization (EPSO): The ability of Evolution Programming (EP) for distribution network reconfiguration for power losses configuration had been reported in (Delbem *et al*., 2005; Song *et al*., 1997; Hsiao, 2004). However, the result of power loss minimization is not optimal when compared to the traditional PSO method. Evolutionary Particle Swarm Optimization (EPSO) has been unveiled by Miranda and Fonseca (2002) merged the evolutionary programming idea to the PSO algorithm to resolve the optimal problem efficiently. Presently there are numerous researches that demonstrated EPSO tend to be efficient and accurate with successful application of the power system as mentioned in Energy Commission. The efficient of EPSO in distribution network reconfiguration has been reported by Sulaima *et al*. (2013) where it's shown the optimum results that produces lesser power loss compared to the traditional PSO (Fig. 3 and 4).

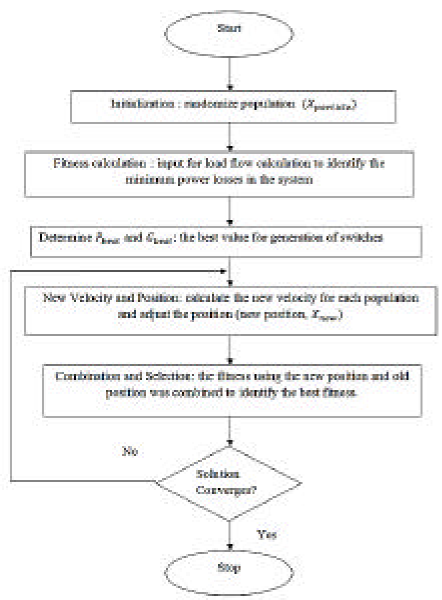

Fig. 4: Implementation of EPSO in Network Reconfiguration

Rank Evolutionary Particle Swarm Optimization (REPSO): The application of REPSO in Distribution Network Reconfiguration had been reported by Sulaima *et al*. (2014a, b) where between in particles

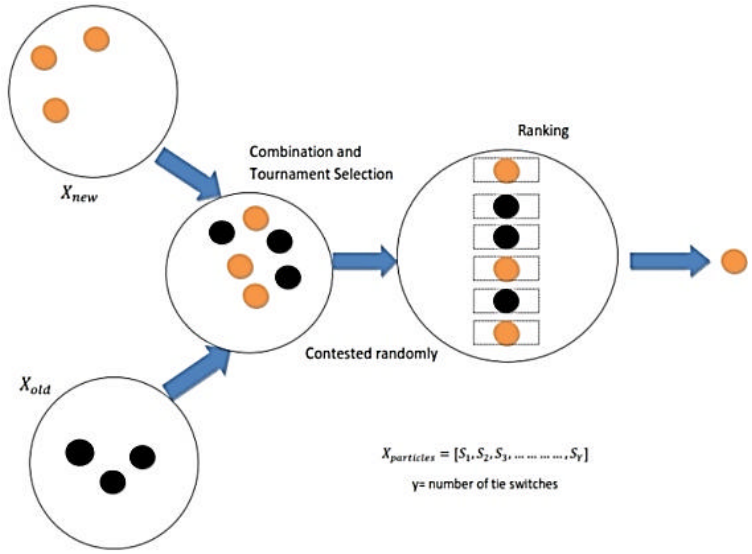

Fig. 5: Rank Evolutionary Particle Swarm Optimization (REPSO) implementation of DNR concept

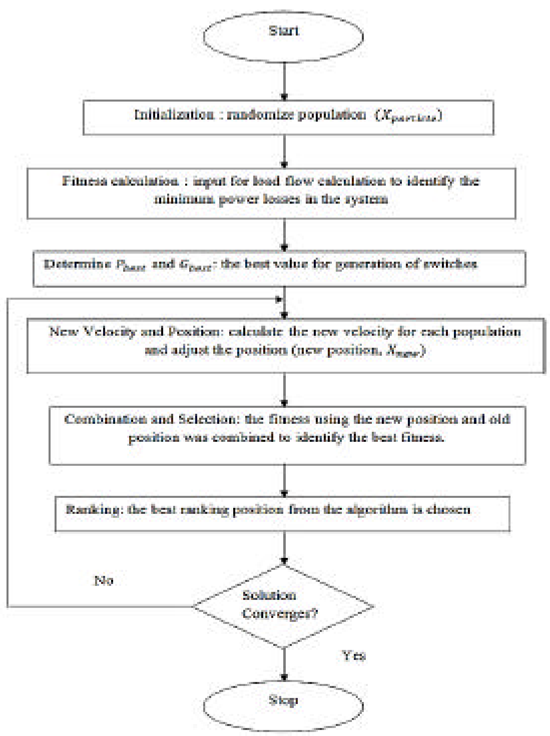

Fig. 6: Implementation of REPSO in network reconfiguration

in a population, the unfilled position that they left will be exchanged by others particles and the best particles will shift to the new position.Through applying principle of combination, ranking as well as a selection method in Evolutionary Programming (EP), REPSO make the particle move faster to the optimal solution. Different via EPSO, the strategy of competition/tournament in EP may possibly result in the 'lucky' particles to continue to be in the system considering that the particle is going to be compared randomly. Therefore, there will be several probabilities for that 'lucky' particle to stay in the system. As a result, REPSO will overcome this problem as well as produce quicker convergence in comparison to PSO and even EPSO. The circulation process of the unique algorithm is as follows Fig. 5 and 6.

RESULTS AND DISCUSSION

Throughout this research, all the data and programming should be written and noted so that the entire work becomes easier. For this entire network, the data are taken from the network performance on a test system 33 kV IEEE test system. As the data is completely inserted into the data network, the proposed method consists of REPSO programming which consists of PSO and EPSO programming will be simulated into the MATLAB for analyzing the result. In order to verify either the power losses are really minimized or not, the comparison between the conventional results and the simulation results has been done. For the sectionalizing switches, the original switches opene dareat 33, 34, 35, 36 and 37. Never theless, after the recon figuration is done, the section alizings witches openedare different for PSO, EPSO and REPSO algorithm Table 1 and Fig. 7-12.

Table 1 shows the results for four cases consists of original initial network that maintain its radial configuration with the open tie line, PSO algorithm, EPSO

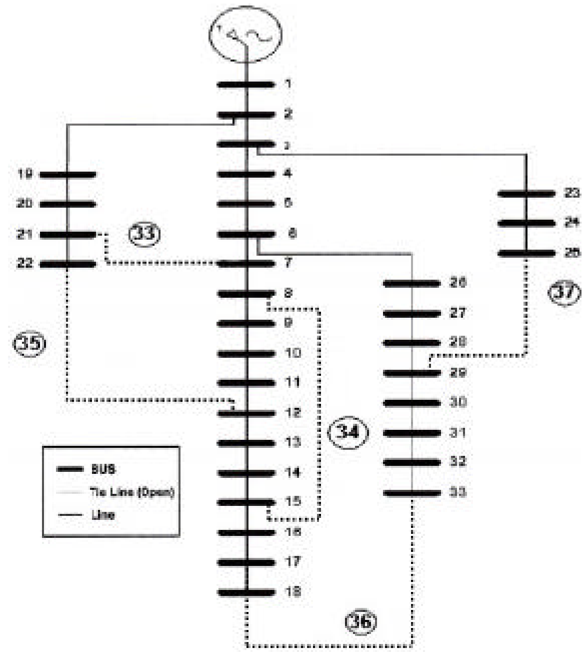

Fig. 7: The 33 bus radial initial configuration

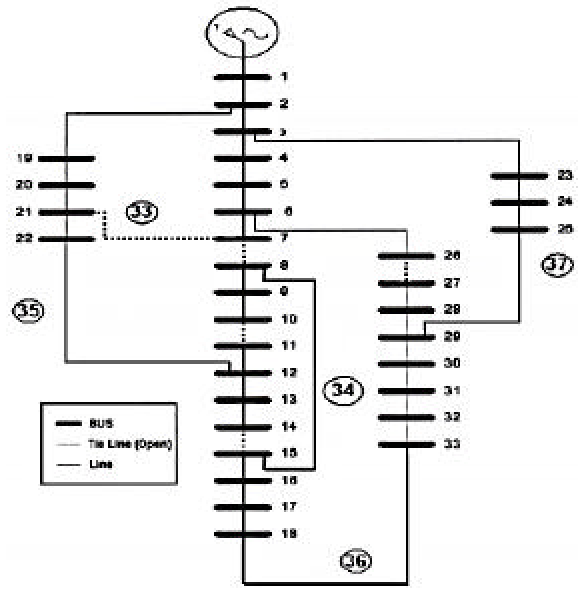

Fig. 8: The radial network after reconfiguration by using PSO

algorithm and REPSO algorithm. From the result that had been obtained, it shows the minimization of power losses in distribution system when applied to PSO Family algorithms. In case 2, the traditional PSO the power loss, reduce by 26 kW which is 13.22% lesser than the initial losses followed by EPSO that reduce by 44.2 kW that 21.81 lesser than initial and REPSO that shows superior optimization on the system that reduce the power losses by 77.4 kW which is 38.18% more than the initial losses. The REPSO algorithm also monopolies the computation times for all three PSO family when it recorded shorter times that is 11.59 sec followed by EPSO; 21.60 sec and PSO; 30.39 sec correspondently (Fig. 13-15).

From the result that had been obtained from the simulation of the power loss. It has been proven the greater amount of power loss reduction contributed to

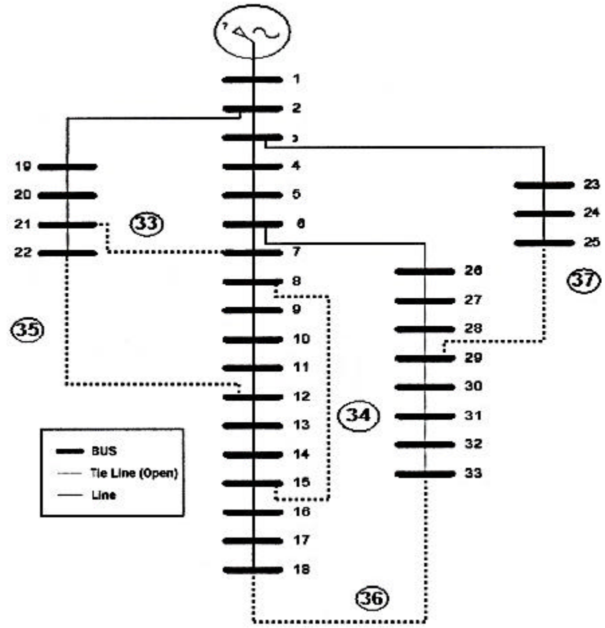

Fig. 9: The radial network after reconfiguration by using EPPSO

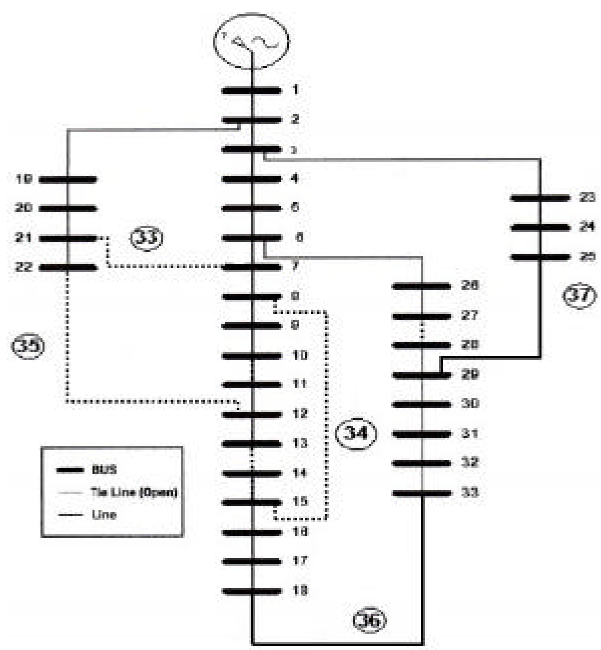

Fig. 10: The radial network after reconfiguration by using EPPSO

Table 1: The analysis results for 33-bus test system for three cases

Parameters	Case 1: Original initial network	Case 2: Afters reconfiguration using PSO	Case 3: After reconfiguration using EPSO	Case 4: After reconfiguration with Algorithm
Switch to be opened	33,34,35,36,37	14,26,7,10,33	27,33,34,35,13	9,17,33,28,34
Total power loss (kW)	202.7	175.90	158.5	125.30
Loss reduction (kW)	-	26.80	44.20	77.40
Percentage of loss reduction (%)	-	13.22	21.81	38.18
Computational time (s)	-	30.39	21.60	11.59

Table 2: The summary of analysis results for 33-bus radial IEEE test system

Algorithm	Total power losses (kW)	Computation time (sec)	Total annual cost save (RM)
PSO	175.9	30.39	78, 843.65
EPSO	158.5	21.60	130, 772.20
REPSO	125.3	11.59	227, 701.60

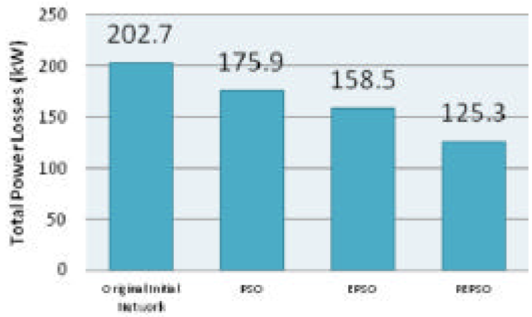

Fig. 11: The comparison of total power loss reduction between PSO, EPSO and REPSO algorithm

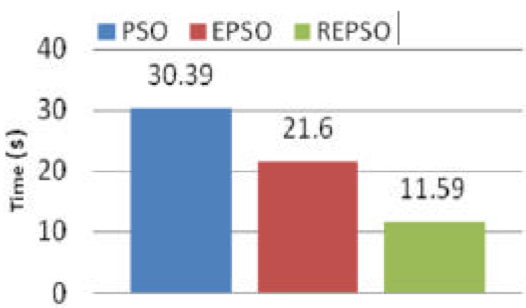

Fig. 12: The comparison of computation time between PSO, EPSO and REPSO algorithm

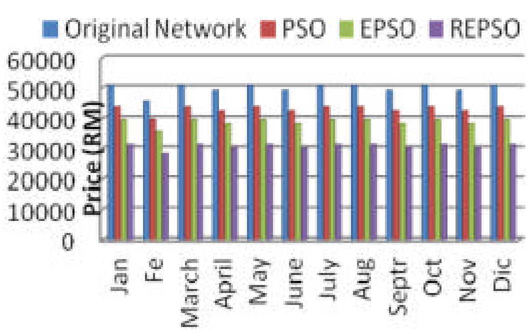

Fig. 13: Total cost loss by month with original network and PSO Family algorithm apply on the 33-bus radial IEEE test system

higher total cost saves. The data obtained from the SAIDI, total power losses and average selling price had

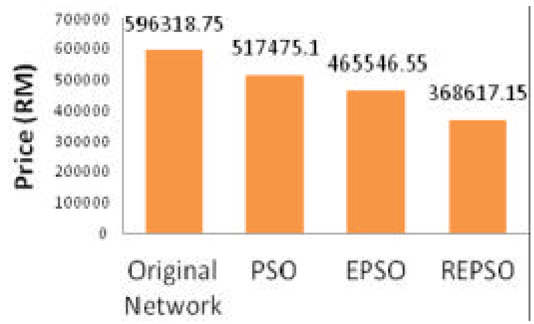

Fig. 14: Total annual cost operation with original network and PSO Family algorithm apply on the 33-bus radial IEEE test system

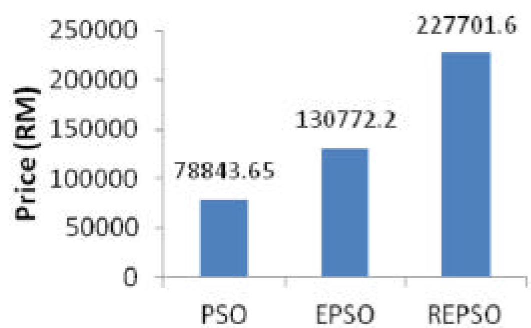

Fig. 15: Total cost saves when PSO Family algorithm applies to33-bus radial IEEE test system

been merged in the calculation of best total cost save state that when applying REPSO on the systems saves RM 227, 701.6 followed by EPSO that save RM 130, 772.2 and PSO that save RM 78, 843.65 (Table 2).

CONCLUSION

The main objective of these studies is to compare the performance of hybrid method of PSO Family when applied on network reconfiguration for power loss minimization. From the simulation and analysis that had been conducted, it shows the superiority of REPSO compared to other optimization PSO Family which is traditional PSO and EPSO in power loss, computation time and total cost save. Without performing any recon figuration, the power and cost loss in the distribution system will be high. Thus, it will affect the reliability of the distribution system. Through distribution network reconfig uration, these problems can be solved in order it helps in improving power system performance and distributi on network for planning purpose.

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