Real and Reactive Power Flow Allocation in Deregulated Power System Utilizing Genetic-Support Vector Machine Technique

M. H. Sulaiman[1], M. W. Mustafa[2], O. Aliman[3], S. N. Abd. Khalid[4], H. Shareef[5]

Abstract – *This paper presents a technique to allocate the real and reactive power flow in deregulated power system environment by incorporating the hybridization of Genetic Algorithm and Least Squares Support Vector Machine (Genetic-SVM). The idea is to use GA to find the optimal values of hyper-parameters of LS-SVM and adapt a supervised learning approach to train the LS-SVM model. The manipulation of proportional sharing method (PSM) is utilized as a teacher. Based on converged load flow and followed by PSM for power flow allocation procedures, the description of inputs and outputs of the training data are created. The Genetic-SVM model will learn to identify which generators are supplying to which loads. In addition, the equivalent transmission model will be discussed in reactive power tracing methodology together with the concept of virtual load for both real and reactive power tracing methods. In this paper, 5-bus system and 25-bus equivalent system of southern Malaysia are used to show the effectiveness of the proposed method. The comparison with other method is also given.*

***Keywords**: Deregulation, Genetic Algorithm, Least Squares Support Vector Machine, Proportional Sharing Method*

Nomenclature

A_P	Distribution matrix of real power
A_P^{-1}	Inversion of matrix A_P
A_Q	Distribution matrix of reactive power
A_Q^{-1}	Inversion of matrix A_Q
P_i	Total through power of bus *i*
P_j	Total through power of bus *j*
α_i	Set of buses supplying directly to bus *i*
$\|P_{j-i}\|$	Magnitude of power flow at line *j-i*
Q_i	Total through power of bus *i* (reactive power)
Q_j	Total through power of bus *j* (reactive power)
$\|Q_{j-i}\|$	Magnitude of reactive power flow at line *j-i*
P_{Lk}	Load at bus *k*
Q_{Dk}	Reactive load at bus *k*
P_{Gi}	Generation bus *i*
P_{LVk}^{m}	Virtual load at bus *k* for line *m*
nline	The total lines that attached to bus
$Loss_{i-j}^{Gi}$	Contribution of generator *i* to line loss *i-j*
V_i	The voltage at sending end
V_j	The voltage at receiving end
I_{i-j}	The current through the line *i-j*
G_i	The original generator at bus *i*
G_{Qk}	Displacement reactive power produced by shunt admittance
Qsh	Number of shunt admittance
$\beta \in R$	Lagrange multipliers

I. Introduction

Power allocation or power tracing problem become one of the active topics among electrical power engineers and researchers. The important of this topic is significant because by knowing the contribution of individual generators to loads and losses, difficult charging of electricity tariff schemes could be resolved in deregulation environment. Moreover, the information of generators' shares in meshed power network is vital in congestion management. Nevertheless, the problem arises since all transactions have to share the same transmission network concurrently. Thus the power tracing algorithm which has ability to guarantee open access to all system users and working efficiently is needed to solve the problem.

In the last decades, several power flow tracing algorithms haven been proposed in literature. It started by the introduction of proportional sharing principle that has been proposed by Bialek [1], [2]. However, the method proposed has a drawback in handling the transmission losses by introducing fictitious nodes on every lossy branch to make the system lossless. This will cause the distribution matrix [1] become larger and messy. The graph method that uses searching technique to determine the power flow from any generators to loads has been proposed in [3]. The concepts of graph method and proportional sharing principle have been adopted in [4], where the technique is called proportional tree method (PTM).

A modified topological generation and load distribution factor has been proposed in [5]. This method uses a decouple power flow to overcome the losses problem and also the equivalent model of a line in their power tracing algorithm. In reactive power flow tracing, the effects of line charging to the original generators and loads are integrated. However, the actual contributions from individual generators to lines and loads have been ignored.

The circuit theory approach in determining the real and reactive power flow allocation also has been proposed in [6], [7]. In [6], the concept of superposition theorem has been proposed. However, the tracing methodology is applied for small system only (4 bus and 6 bus-systems). If the method is tested for a larger system, the results may be varied and not so accurate, especially for reactive power flow allocation. Reference [7] uses circuit theory method for tracing the transmission usage allocation in bilateral trade power system.

The incorporation of Artificial Intelligence (AI) techniques also have been utilized in power tracing problem. Khalid *et al.* has proposed an Artificial Neural Network (ANN) technique to trace the transmission usage in bilateral power system [8]. The method in [7] is utilized as a teacher before ANN is incorporated in their tracing methodology. Real power flow allocation using Genetic Algorithm (GA) has been proposed in [9]. The problem of this method is GA will gives multi-solution results which is sometimes the result is far from the expected result and very time consuming.

This paper proposes a new technique to allocate the real and reactive power transfer from generators to loads by implementing the hybridization of Genetic Algorithm (GA) and Least Squares Support Vector Machine (LS-SVM), namely Genetic-SVM. The new power allocation method is based on manipulation of convention in [1], the introduction of virtual load concept (for real and reactive power allocation) and the equivalent transmission model (for reactive power allocation) [5] before incorporating Genetic-SVM into power allocation problem.

II. Proportional Sharing Method (PSM)

This paper presents the manipulation of the PSM that proposed in [1], [2] by introducing a virtual load concept, where the loss at each transmission line is removed and attributed to the sending end bus. The concept of virtual load will be applied in real and reactive power tracing methodologies, which are presented in the next sub-sections.

II.1. Real Power Flow Allocation

The development process of proposed method can be illustrated with a small power network with AC power solution as shown in Fig. 1. To apply this concept, the test system must be constructed into lossless system. This paper proposes a different point of view how the lossless system can be obtained, which is by removing the loss at each line and that particular loss is attributed to the sending end bus as a virtual load. The proposed modification is depicted in Fig. 2.

After lossless system is constructed, PSM is applied, which is the distribution matrix is created as follows [1]:

$$[\quad] = \begin{cases} 1 & for \quad i = j \\ -\ _{ji} = -\dfrac{|P_{j-i}|}{Pj} & \quad j = \in \alpha_i \\ 0 & otherwise \end{cases} \tag{1}$$

From distribution matrix A_P, the shares of generators to the loads and losses (virtual loads) can be calculated as follows:

$$P_{Lk}^{Gi} = \frac{|P_{Gi}|}{P_i} \sum_{k=1}^{n} [\quad]_{ik} \cdot P_{Lk} \tag{2}$$

$$P_{LVk}^{Gi} = \frac{|P_{Gi}|}{P_i} \sum_{k=1}^{n} [\quad]_{ik} \left(\sum \quad \right) \tag{3}$$

Finally, the individual generators' contribution to line loss can be obtained as follows:

$$Loss_{i-j}^{Gi} = \frac{Loss_{i-j}}{P_{LVk}^{m}} \cdot P_{Gi} \tag{4}$$

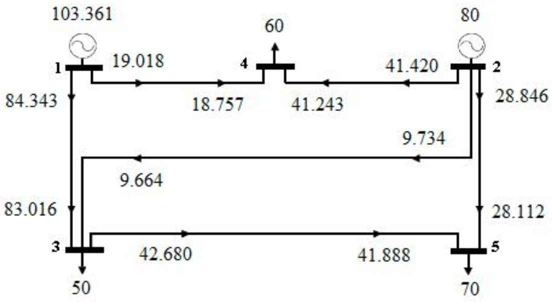

Fig. 1. 5-bus test system with the real power flows in MW

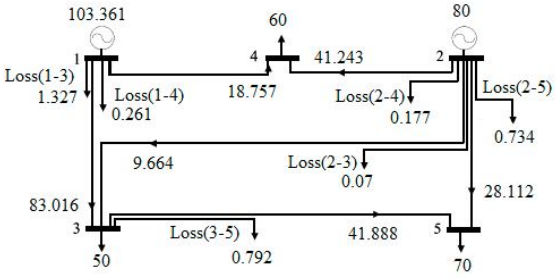

Fig. 2. Lossless system with attributed losses to the sending end bus (virtual load)

II.2. Reactive Power Flow Allocation

Before proceed to the concept of PSM for reactive power tracing, the equivalent π model of a line is introduced. Although the transmission losses of reactive power depend on line charging, it is also possible to displace the reactive powers G_{Qi} and G_{Qj} produced by shunt admittances $B_{sh/2,i-j}$ into nearby buses as follows [5]:

$$G_{Qi} = V_i^2 B_{sh/2,i-j} \tag{5}$$

$$G_{Qj} = V_j^2 B_{sh/2,i-j} \tag{6}$$

Fig. 3 shows this equivalent model of line *i-j*. From Fig. 3, it can be seen that line *i-j* has the reactive power absorption due to reactance X_{i-j} as follows:

$$Loss_{i-j} = I_{i-j}^2 X_{i-j} \tag{7}$$

To make the system lossless, same as real power allocation technique, each of reactive losses is attributed to its sending end and treated as virtual load. The virtual load and displacement reactive power concepts are illustrated in Figs. 5-6.

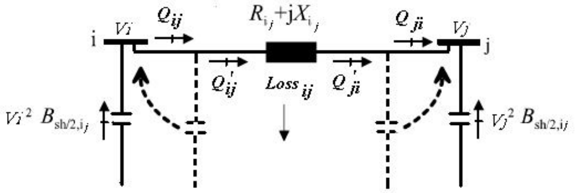

Fig. 3. Equivalent model of line *i-j*

Fig. 5 shows the test system after introducing equivalent transmission model of line. It can be seen that the integration of the generators with the reactive powers by shunt admittances and the contribution of charging megavars to the loads. The integration of generators, $G_{i(int)}$ for each generator can be obtained as follows [5]:

$$G_{i(\quad)} = \,_{,} + \sum_{n\in Qsh} G_{Qk,n} \tag{8}$$

Fig. 6 shows the lossless system of this test system. It can be seen that the loss at each transmission line has been attributed to the sending end bus and treated as additional load. After the lossless system is constructed, PSM is applied, where the distribution matrix, A_Q is created as follows:

$$[\quad] = \begin{cases} 1 & for \quad i = j \\ -_{ji} = -\dfrac{|Q_{j-i}|}{Qj} & j = \in \alpha_i \\ 0 & otherwise \end{cases} \tag{9}$$

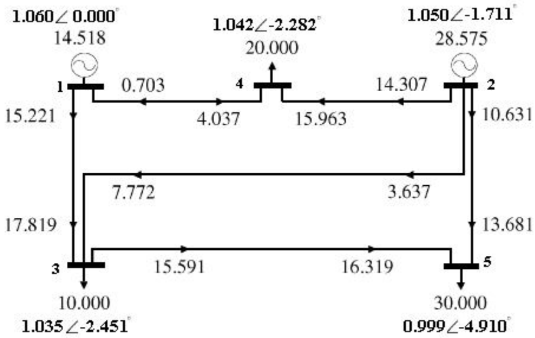

Fig. 4. 5-bus test system with the bus voltages and the reactive power flows in MVar

From matrix A_Q, the shares of generators to loads, $Q^{Gi(int)}_{Dk}$ can be calculated as follows:

$$Q_{Dk}^{Gi(\quad)} = \frac{|Q_{Gi(int)}|}{Q_i} \sum_{k=1}^{n} [\quad]_{ik} \cdot Q_{Dk} \tag{10}$$

To obtain the contribution of original reactive generator to each load, the following expression is used:

$$Q_{Dk}^{Gi} = \frac{G_i}{G_{i(int)}} \cdot Q_{Dk}^{Gi(\quad)} \tag{11}$$

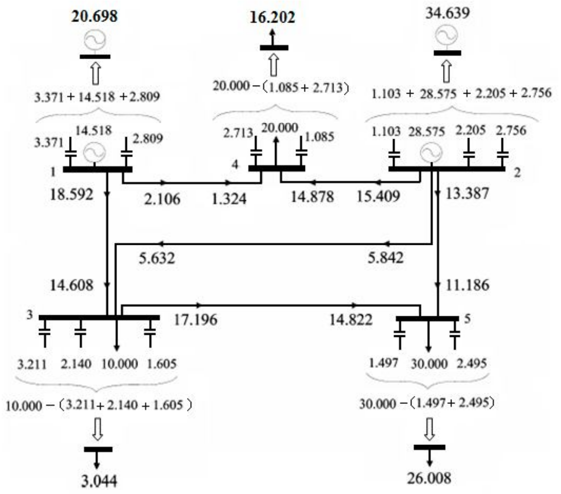

Fig. 5. Reactive power flows in MVar after applying equivalent model line

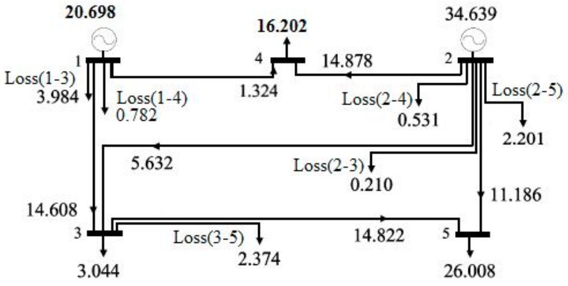

Fig. 6. Lossless system with attributed losses to the sending end bus (virtual load)

To trace the contribution of original reactive generators to reactive losses, the same technique of equations (3) and (4) are adopted and followed by the partition technique expressed in equation (11).

Vectors $P^{Gi}{}_{Lk}$ and $Q^{Gi}{}_{Dk}$ then are used as a target in the training process of proposed hybrid Genetic-SVM technique.

III. Function Estimation Using LS-SVM

Support vector machine (SVM) is known as a powerful methodology for solving problems in nonlinear classification, function estimation and density estimation. SVM has been introduced within the context of statistical learning theory and structural risk minimization. Least squares support vector machine (LS-SVM) is reformulations from standard SVM [10] which lead to solving linear Karush-Kuhn-Tucker (KKT) systems. LS-SVM is closely related to regularization networks and Gaussian processes but additionally emphasizes and exploits primal-dual interpretations [11].

In LS-SVM function estimation, the standard framework is based on a primal-dual formulation. Given N dataset $\{\quad\}_{i=1}^{N}$, the goal is to estimate a model of the form:

$$y(x) = \quad {}^{T}\,(\quad) + \quad + e_i \tag{12}$$

where $x \in {}^{n}, \ \in R$ and $\varphi(\,): R^n \rightarrow R^{n_h}$ is a mapping to a high dimensional feature space. The following optimization problem is formulated:

$$\min_{w,b,e} J(\quad) = \frac{1}{2} \quad {}^{T} \quad + \gamma \frac{1}{2} \sum_{i=1}^{N} e_i^2 \tag{13}$$

$$\text{s.t. } y_i = \quad {}^{T}\,(\quad) + \quad + e_i,\ i = 1,\ldots,N.$$

With the application of Mercer's theorem [10] for the kernel matrix $\boldsymbol{\Omega}$ as $\Omega_{ij} = (\quad) = \varphi(\quad)^{T}\varphi(x_j)$, *i, j=1,..,N* it is not required to compute explicitly the nonlinear mapping φ(.) as this is done implicitly through the use of positive definite kernel functions K [11].

From the Lagrangian function:

$$\zeta(\quad \beta) = \frac{1}{2} \quad {}^{T} \quad + \quad \frac{1}{2} \sum_{i=1}^{N} \quad {}^{2} + \\ -\sum_{i=1}^{N} (\quad + \quad + \quad - \quad) \tag{14}$$

Differentiating (5) with *w, b, e_i and β_i*, the conditions for optimality can be described as follow:

$$\begin{cases} \dfrac{d\zeta}{dw} = \quad \rightarrow \quad = \sum_{i=1}^{N} \beta\,\varphi(x_i) \\ \dfrac{d\zeta}{db} = \quad \rightarrow \sum_{i=1}^{N} \quad = 0 \\ \dfrac{d\zeta}{de_i} = \quad \rightarrow \quad = \quad = 1,\ldots,N \\ \dfrac{d\zeta}{\beta} = 0 \rightarrow \quad = \quad {}^{T}\,(\quad) + \quad + e_i \end{cases} \tag{15}$$

By elimination of w and e_i, the following linear system is obtained [14]:

$$\begin{bmatrix} \quad & \quad \end{bmatrix} \begin{bmatrix} \quad \end{bmatrix} = \begin{bmatrix} \quad \end{bmatrix} \tag{16}$$

with $y = [y_1,\ldots,y_N]^T$, $\beta = [\beta_1,\ldots,\beta_N]^T$. The resulting LS-SVM model in dual space becomes:

$$y(x) = \sum_{i=1}^{N} \beta K(\quad) + b \tag{17}$$

Usually, the training of the LS-SVM model involves an optimal selection of kernel parameters and regularization parameter. For this paper, the RBF Kernel is used which is expressed as:

$$K(\quad) = e^{-\frac{\|x-x_i\|^2}{2\sigma^2}} \tag{18}$$

Note that σ^2 is a parameter associated with RBF function which has to be tuned.

IV. Genetic-SVM for Real and Reactive Power Flow Allocation

In order to find the optimal value of regularization parameter, γ and Kernel RBF parameter, σ^2, the hybrid genetic algorithm (GA) with LS-SVM is proposed. Genetic algorithm is a subset of evolutionary algorithms that model biological processes to solve the optimization problems. GA approach can be divided into two: binary and continuous. For this paper, continuous GA is selected since it has an advantage in the accurate representation of the continuous parameter. Each chromosome consists of two parameters representing γ and σ^2 in continuous floating numbers that generated randomly. The single point arithmetic crossover method is adapted from the modification of extrapolation and crossover method [12]. The CGA properties to find the optimal γ and σ^2 are as follow:

- Selection: *roulette wheel*
- Crossover probability = 0.9
- Mutation probability = 0.1
- Population = 40

- Maximum iteration = 50

The proposed tracing method is elaborated by designing an appropriate Genetic-SVM model using LS-SVMlab Toolbox [13] for the 25-bus equivalent system of southern Malaysia as shown in Fig. 7. The input samples for training is assembled using daily load curve and performing load flow analysis for every hour of load demand. For this paper, two models of Genetic-SVM are developed for real and reactive power allocation respectively. Input data (D) and target data (T) for real and reactive power allocation problem for each Genetic-SVM models are tabulated in Table I. The flow of GA-SVM is depicted in Figs. 8 and 9.

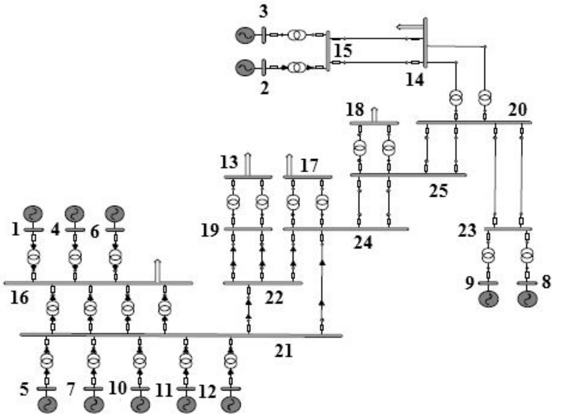

Fig. 7. Single line diagram for the 25-bus equivalent system of southern Malaysia

TABLE I
DESCRIPTION OF INPUTS AND OUTPUTS OF THE GENETIC-SVM MODEL

Genetic-SVM for Real Power Allocation	
Input and Output	Description
I_1 to I_{12}	Real power generation (P_{G1} to P_{G12})
I_{13} to I_{17}	Real loads (P_{d13}, P_{d14}, P_{d16}, P_{d17}, P_{d18})
I_{18} to I_{42}	Voltage magnitude (V_1 to V_{25})
O_1 to O_{60}	12 generators' contribution to each load
Genetic-SVM for Reactive Power Allocation	
Input and Output	Description
I_1 to I_{12}	Reactive power generation (Q_{G1} to Q_{G12})
I_{13} to I_{17}	Reactive loads (Q_{d13}, Q_{d14}, Q_{d16}, Q_{d17}, Q_{d18})
I_{18} to I_{42}	Voltage magnitude (V_1 to V_{25})
O_1 to O_{60}	12 generators' contribution to each load

V. Results and Discussion

V.1. 5-Bus System

Bialek [1], [2] has proposed PSM for power tracing methodology. The same convention is followed with simple manipulation of distribution matrices, A_P^{-1} and A_Q^{-1} to suit the real and reactive power flow allocation purpose.

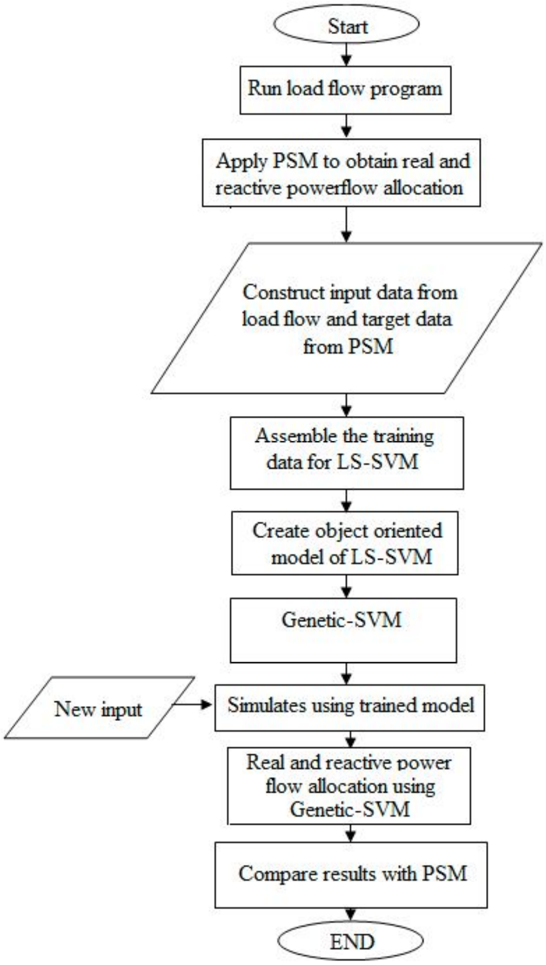

Fig. 8. Flow of proposed method

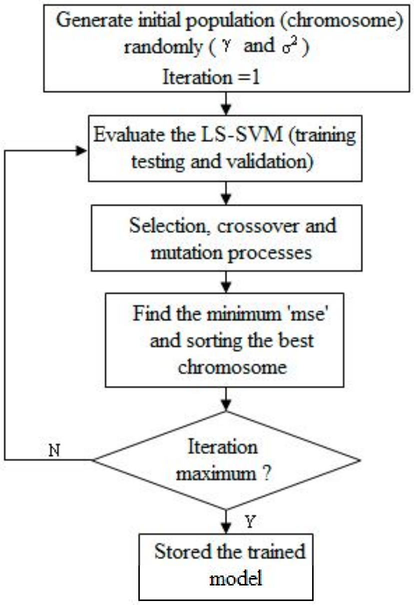

Fig. 9. Flow of Genetic-SVM

In order to verify the veracity of this approach, a numerical calculation is performed for 5-bus system shown in Fig. 1 for real power and Fig. 4 for reactive power.

For real power flow allocation, after obtaining lossless system (Fig. 2), the matrix A_P and A_P^{-1} can be constructed as follow:

$$A_P = \begin{bmatrix} \\ \end{bmatrix}$$

$$A_P^{-1} = \begin{bmatrix} \\ \end{bmatrix}$$

By applying equation (2), the contribution of real power from G1 to load 5, P^{G1}_{D5} is $(103.361/103.361) \times 0.536 \times 70 = 37.52$ MW and the contribution of real power from G2 to load bus 5, P^{G2}_{D5} is $(80/80) \times 0.464 \times 70 = 32.48$ MW. The same procedures can be used to compute the generators' contributions to load buses 3 and 4 as well. Table II shows the result for the real power tracing for this test system using proposed method together with the method that has been proposed in [4].

TABLE II
REAL POWER CONTRIBUTION FROM INDIVIDUAL GENERATORS TO LOADS IN MEGAWATT (MW) FOR 5-BUS SYSTEM

Supplied By	Proposed Method		
	Bus ID		
	3	4	5
G1	44.7863	18.7569	37.5204
G2	5.2137	41.2431	32.4796
Total	50	60	70
		PTM [4]	
G1	44.7863	18.7569	37.5204
G2	5.2137	41.2431	32.4796
Total	50	60	70

It can be seen that the result of proposed method compared well with the result using PTM [4]. This can be expected since PTM uses the same convention of proportional sharing principle.

The same technique can be applied for reactive power tracing methodology. After lossless system is constructed together with the application of displacement megavars, the matrix A_Q is formed as follows:

$$A_Q = \begin{bmatrix} 1 & 0 & \frac{-14.608}{20.24} & \frac{-1.324}{16.202} & 0 \\ 0 & 1 & \frac{-5.632}{20.24} & \frac{-14.878}{16.202} & \frac{-11.186}{26.008} \\ 0 & 0 & 1 & 0 & \frac{-14.822}{26.008} \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

And inverting the matrix A_Q yields:

$$A_Q^{-1} = \begin{bmatrix} 1 & 0 & 0.7218 & 0.0817 & 0.4113 \\ 0 & 1 & 0.2782 & 0.9183 & 0.5887 \\ 0 & 0 & 1 & 0 & 0.5699 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

By applying equation (10), the contribution of reactive power from integrated G1 to load 3, $Q^{G1(int)}_{D3}$ is $(20.698/20.698) \times 0.7218 \times 3.044 = 0.2197$ MVar and the contribution of reactive power from integrated G2 to load bus 3, $Q^{G2(int)}_{D3}$ is $(34.639/34.639) \times 0.2782 \times 3.044 = 0.8469$ MVar. To obtain the original contribution of reactive power from both generators G1 and G2 to load 3, equation (11) is used. The same procedures can be used to compute the generators' contributions to load buses 4 and 5 as well. Table III shows the result for the reactive power tracing for this test system using proposed method together with the method that has been proposed in [6].

TABLE III
REACTIVE POWER CONTRIBUTION FROM INDIVIDUAL GENERATORS TO LOADS IN MEGAVOLT AMPERE (MVAR) FOR 5-BUS SYSTEM

Supplied By	Proposed Method		
	Bus ID		
	3	4	5
G1 (int)	2.197	1.324	10.698
G2 (int)	0.847	14.88	15.31
Total (int)	3.044	16.20	26.01
G1	1.541	0.929	7.504
G2	0.699	12.27	12.63
Total	2.24	13.20	20.13
		Superposition technique [6]	
G1	2.136	8.091	12.393
G2	7.864	11.917	17.634
Total	10.0	20.008	30.027

It can be seen that the total result at row 6 in Table III is same with the reactive load demand after displacement reactive power is applied (refer to Fig. 5). By referring to row 9, the result of actual or original contribution from generators is displayed. For load 3, only 2.24 MVar is contributed from generators 1 and 2, while about 0.804 MVar is supplied by shunt admittances from lines 1-3 and 1-4 for G1 and lines 2-3, 2-4 and 2-5 for G2. The results show the conformity of reactive power tracing with the equivalent transmission model and also the reactive power solution.

Comparison with [6] shows discrepancies with proposed method. This situation has been expected since the effect of line charging megavars that have been taken into account in the proposed method. By referring back to the Fig. 5, the loads are changing due to line charging megavars as introduced in equivalent model of a line. While in [6], the load demand is maintain and the technique is adapting superposition technique into the power tracing. However, by using this technique, sometimes the contribution of individual generators can be exceeding the generation of that generator itself. Thus, the veracity of [6] can be argued.

The purpose of virtual load is to make the system lossless and by applying the same concept of load tracing, the loss allocation now can be allocated since the loss has treated as a load. By applying equation (3), the generators' shares to losses can be traced. Table IV shows the result of loss tracing for real and reactive losses.

TABLE IV
CONTRIBUTION FROM INDIVIDUAL GENERATORS TO LOSSES FOR 5-BUS SYSTEM

From Bus	To Bus	G1 MW	G2 MW	G1(int) MVar	G2(int) MVar	G1 MVar	G2 MVar
1	3	1.328	0	3.983	0	2.794	0
1	4	0.261	0	0.782	0	0.549	0
2	3	0	0.07	0	0.21	0	0.174
3	5	0.709	0.08	1.714	0.661	1.202	0.545
2	4	0	0.18	0	0.532	0	0.438
2	5	0	0.73	0	2.201	0	1.816

V.2. 25-Bus System with Incorporating Genetic-SVM

V.2.1. Training, Validation and Testing Processes

After the input and target of training data have been created, the next step is to divide the data (D and T) up to training, validation and testing subsets. In this case, 48 samples (29%) of the data are used for training, 72 samples (42%) for validation and 48 samples (29%) for testing out of 168 hours. Table V shows the number of samples of training, validation and testing.

TABLE V
THE NUMBER OF SAMPLES FOR TRAINING, TESTING AND VALIDATION SETS

Data Types	Samples (Hour)
Training	(1-24),(145-268)
Validation	(25-72), (121-144)
Testing	(73-120)

The property of regularization parameter, γ and Kernel RBF, σ^2 are decided through the hybrid Genetic-SVM model that has been discussed above. For real power allocation, the final value of γ is set to 962.8178 and σ^2 is set to 16.663. While for reactive power allocation, the final value of γ is set to 986.0975 and σ^2 is set to 17.6567. For real power allocation, the mean square error (MSE) for testing and validation are 2.1468 x 10^{-4} and 2.1449 x 10^{-4} respectively. While for reactive power, the MSE for testing is 3.3715 x 10^{-4} and for validation process is 3.0855 x 10^{-4}. These show that estimation by Genetic-SVM models and the training data points having the similar characteristics.

V.2.2. Pre-Testing

After Genetic-SVM models have been trained in MATLAB based, the next step is to simulate the models. After simulation, the obtained result from the trained model is evaluated with the linear regression analysis. The regression analysis that refers to Generator 12 to load bus 18 for real and reactive power are shown in Figs. 9 and 10 respectively. The correlation coefficient, (R) for real and reactive power allocations are equal to one indicates the perfect correlation between trained Genetic-SVM models with the PSM results.

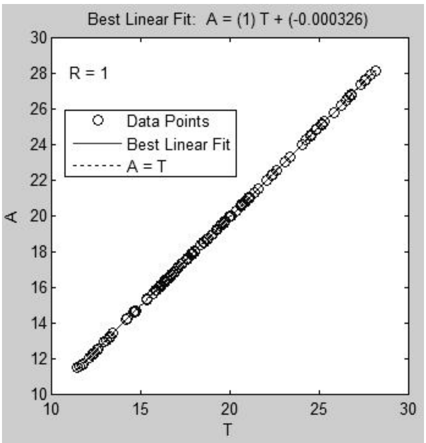

Fig. 10. Regression analysis between Genetic-SVM output and corresponding target for real power allocation

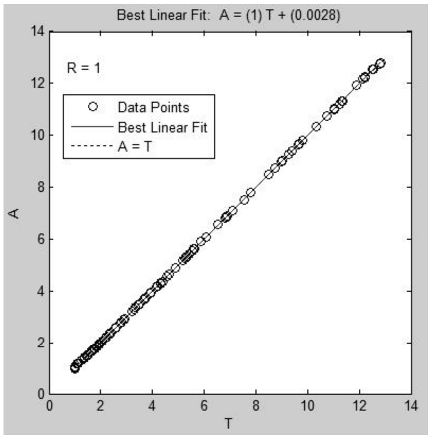

Fig. 11. Regression analysis between Genetic-SVM output and corresponding target for reactive power allocation

V.2.3. Simulation

The case scenario is that real and reactive power at each load is assumed to decrease by 10% from hour 1 to 168, from the nominal trained pattern. This also assumed that all generators also decrease their production proportionally according to the variation of demands. The allocation of real and reactive power from generators to loads using PSM and proposed method on hours 40 out of 168 hours are tabulated in Tables VI and VII respectively.

The results obtained by Genetic-SVM are compared well with the result form PSM. For real power allocation, the largest difference between generators is 0.0053 MW at bus 16 for G4. While for reactive power allocation, the largest difference is 0.0149 MVar at bus 14 for G9. The MSE for the simulation of real and reactive power are 1.76 x 10^{-2} and 1.27 x 10^{-2} respectively.

For real power allocation, it can be observed that the sum of real power contributed by each generator obtained from Genetic-SVM and PSM are in conformity with the actual load demand although there are very small variations in the predicted results from Genetic-SVM. This situation is quite opposite for reactive power allocation. It can be observed that the sum of reactive power contributed by each generator obtained from PSM and Genetic-SVM are unequal to the load demand from load flow analysis which is tabulate in Table VIII. This situation has been expected since the effect of shunt admittances, $B_{sh/2,i\text{-}j}$ that exist at several transmission lines (equivalent transmission model) which also give some contributions to the reactive load demand.

TABLE VI
ANALYSIS OF GENERATORS' CONTRIBUTIONS TO LOADS ON HOURS 40 USING PSM IN MW AND MVAR

Supplied By			PSM		
			Load Bus ID		
MW+*j*MVar	13	14	16	17	18
G1	0	0	100.42+*j*64.12	0	0
G2	0	82.25+*j*61.5	0	0	0
G3	0	82.25+*j*61.5	0	0	0
G4	0	0	89.36+*j*65.01	0	0
G5	3.31+*j*0.73	0	24.10+*j*6.14	33.10+*j*9.0	21.73+*j*4.07
G6	0	0	68.74+*j*52.48	0	0
G7	2.76+*j*0.93	0	20.094+*j*7.78	27.58+*j*11.4	18.12+*j*5.16
G8	0	22.19+*j*0.62	0	0	60.02+*j*6.97
G9	0	18.50+*j*0.80	0	0	50.02+*j*9.02
G10	3.59+*j*1.60	0	26.11+*j*13.45	35.85+*j*19.72	23.54+*j*8.92
G11	3.59+*j*1.60	0	26.11+*j*13.45	35.85+*j*19.72	23.54+*j*8.92
G12	3.86+*j*1.59	0	28.12+*j*13.32	38.61+*j*19.53	25.35+*j*8.84
Total	17.10+*j*6.45	205.20+*j*124.42	383.04+*j*235.761	171+*j*79.35	222.30+*j*51.90
Actual	17.10+*j*10.60	205.20+*j*126.97	383.04+*j*237.387	171+*j*105.98	222.30+*j*137.77

TABLE VII
ANALYSIS OF GENERATORS' CONTRIBUTIONS TO LOADS ON HOURS 40 USING GENETIC-SVM IN MW AND MVAR

Supplied By			Genetic-SVM		
			Load Bus ID		
MW+*j*MVar	13	14	16	17	18
G1	0	0	100.404+*j*64.1386	0	0
G2	0	82.2501+*j*61.5460	0	0	0
G3	0	82.2501+*j*61.5460	0	0	0
G4	0	0	89.3507+*j*65.0204	0	0
G5	3.3095+*j*0.7320	0	24.1019+*j*6.1483	33.0950+*j*9.0050	21.7259+*j*4.0745
G6	0	0	68.7319+*j*52.4934	0	0
G7	2.7579+*j*0.9268	0	20.0851+*j*7.7780	27.5787+*j*11.4009	18.1055+*j*5.1623
G8	0	22.1919+*j*0.6065	0	0	60.0187+*j*6.9754
G9	0	18.4932+*j*0.7835	0	0	50.0156+*j*9.0185
G10	3.5853+*j*1.6023	0	26.1105+*j*13.4511	35.8529+*j*19.7190	23.5367+*j*8.9293
G11	3.5853+*j*1.6023	0	26.1105+*j*13.4511	35.8529+*j*19.7190	23.5367+*j*8.9293
G12	3.8611+*j*1.5866	0	28.1188+*j*13.3187	38.6109+*j*19.5255	25.3473+*j*8.8416
Total	17.099+*j*6.45	205.185+*j*124.482	383.013+*j*235.8	170.99+*j*79.3694	222.286+*j*51.9309
Actual	17.10+*j*10.5976	205.20+*j*126.97	383.04+*j*237.387	171.00+*j*105.976	222.30+*j*137.769

Overall performance of Genetic-SVM can be said very successful since the model's predictions are close to the PSM even just using about 29% from the overall data. Moreover, the Genetic-SVM model computes the results within 227 ms whereas the PSM took about 659 ms to calculate the same real and reactive power allocation. Better computation time is crucial to improve online application.

For that, the Genetic-SVM provides the results in a faster manner with acceptable accuracy. Figs. 12 and 13 show the daily load profile for real and reactive power within one week for different load buses.

TABLE VIII
BUS DATA FOR 25-BUS SYSTEM ON HOURS 40

Bus	Voltage		Load		Generation	
No	Mag. p.u	Angle p.u	Real MW	Reactive MVar	Real MW	Reactive MVar
1	1.05	9.88	0	0	100.42	76.74
2	1.05	8.60	0	0	82.48	72.02
3	1.05	8.60	0	0	82.48	72.02
4	1.05	9.35	0	0	89.36	75.86
5	1.03	11.19	0	0	82.48	32.95
6	1.05	9.16	0	0	68.74	60.75
7	1.04	10.34	0	0	68.74	37.75
8	1.05	19.33	0	0	82.48	31.78
9	1.05	16.99	0	0	68.74	28.70
10	1.05	10.50	0	0	89.36	64.20
11	1.05	10.50	0	0	89.36	64.20
12	1.05	10.83	0	0	96.23	64.73
13	0.99	5.54	17.1	10.60	0	0
14	0.98	4.26	205.2	127.17	0	0
15	0.99	4.61	0	0	0	0
16	0.99	5.05	383.04	237.39	0	0
17	0.91	-1.05	171	105.98	0	0
18	0.89	-2.93	222.3	137.77	0	0
19	0.99	5.85	0	0	0	0
20	0.99	5.35	0	0	0	0
21	1.00	6.21	0	0	0	0
22	1.00	5.87	0	0	0	0
23	0.99	5.52	0	0	0	0
24	0.99	5.22	0	0	0	0
25	0.97	4.04	0	0	0	0

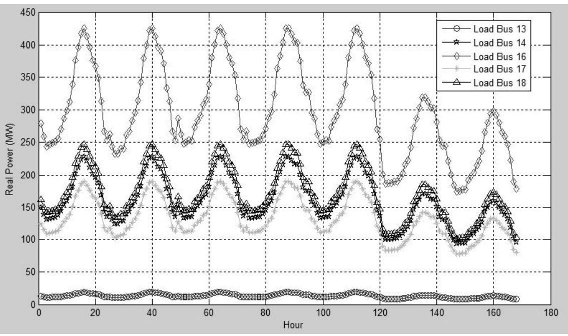

Fig. 12. Daily load curves for real power demand

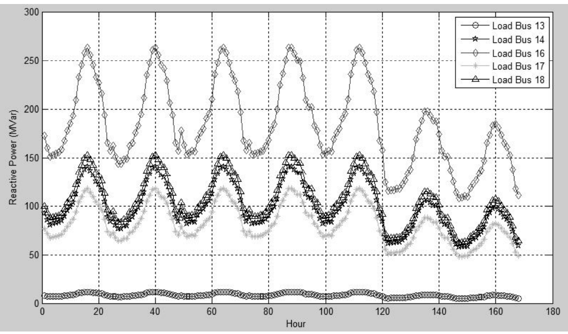

Fig. 13. Daily load curves for reactive power demand

VI. Conclusion

This paper has presented a new methodology to allocate the generators' contributions to real and reactive loads in pool based power system. Initially, the introduction of virtual load concept for real and reactive power allocation and equivalent transmission model for reactive power allocation are proposed before PSM is applied in the tracing paradigm. Then the power allocation procedure is extended by proposing the hybridization of LS-SVM technique with Genetic Algorithm. The developed Genetic-SVM adopts real and reactive power allocation outputs determined by PSM as an estimator to train the model. The results show that Genetic-SVM able to trace the real and reactive power transfer from generators to loads even though just using small amounts of data in training process. The results also show the advantage of Genetic-SVM compared to PSM in term of computational time. Better computational time is crucial to improve online application. Thus, the proposed methodology could be adopted into real application of power system deregulation, especially in pool based market.

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Authors' information

[1]Universiti Malaysia Perlis (UniMAP), Perlis, Malaysia.
[2,4]Universiti Teknologi Malaysia (UTM), Johor, Malaysia.
[3]Universiti Malaysia Pahang (UMP), Pahang, Malaysia.
[4]Universiti Kebangsaan Malaysia (UKM), Bangi, Malaysia.

Mohd Herwan Sulaiman obtained his B. Eng. (Hons) in Electrical-Electronics and M. Eng. (Electrical-Power) from Universiti Teknologi Malaysia in 2002 and 2007 respectively. From June 2002 to June 2005, he held a position as design engineer at RND department of Panasonic AVC Networks Johor Malaysia Sdn. Bhd. He is currently a lecturer at School of Electrical System Engineering, University Malaysia Perlis (UniMAP), Perlis, Malaysia and PhD student in UTM. His research interests are power system deregulation/ optimization and application of AI to power system studies.

Mohd Wazir Mustafa received his B. Eng. Degree (1988), M. Sc. (1993) and PhD (1997) from University of Strathclyde. He is currently an Associate Professor and Head of Department of Power Engineering at Faculty of Electrical Engineering, Universiti Teknologi Malaysia. He is a member of Institution of Engineers, Malaysia (IEM) and a member of IEEE. His research interest includes power system stability, FACTS, wireless power transmission and power system distribution automation.

Omar Aliman received his B. Sc. in Electrical Engineering from Hanyang University, South Korea in 1998 and M. Eng. in Electrical Engineering from Universiti Teknologi Malaysia (UTM) in 2002. He is currently a lecturer at Faculty of Electrical and Electronic, Universiti Malaysia Pahang (UMP), Malaysia. He is a member of IEEE. His research interests include sun tracking control of solar energy applications and embedded generation studies.

Saiful Nizam Abd. Khalid received his BEE (1998), MEE (2000) and PhD (2009) degrees from Universiti Teknologi Malaysia. His current research interests are power system deregulation, application of artificial neural network in power system and power tracing.

Hussain Shareef received his B. Sc with honours from IIT, Bangladesh, MS Degree from METU, Turkey and PhD degrees from UTM, Malaysia in 1999, 2002 and 2007 respectively. His current interests are power system deregulation, power quality and power system distribution automation. He is currently a Senior Lecturer at Faculty of Electrical Engineering and Build Environment, Universiti Kebangsaan Malaysia.