HEURISTIC ALGORITHMS CONSTRUCTION TO COMPENSATE REACTIVE POWER DISTRIBUTION NETWORK FOR THE RAY

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ABSTRACT

About a Heuristic search methods for reactive power compensation for radial distribution networks, which receive cost savings is maximized. The method is a technique that is done from the technical concept of the present and Heuristic for better results. The method was developed and applied to three-phase system. The results of this method are compared with previous methods to show its advantages. New algorithm is implemented through technical change to obtain the position, the optimal capacitor size.

Keywords: *heuristic algorithm, reactive power compensation, cost savings is maximized, the optimal capacitor size, the optimal capacitor position*

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1. Introduction

The installation of capacitors on distribution level is essential for controlling power flow, improve system stability, adjustable power factor, power management and minimum pressure loss in system. Therefore, the need to find solutions to locate and install capacitors capacity aims minimum losses (power loss, power) for maximum savings function. The solution to determine the position can be classified as follows: Analysis, Programming of, Search and basic artificial intelligence (AI-based). Artificial intelligence algorithms including genetic algorithms, expert systems, neural networks and fuzzy logic [9], [10], [11], [12], [13], [14].

Heuristic techniques [6], [5] that the rules were developed through intuition, experience and evaluation. Heuristic algorithms for fast and relevant results, this leads to reduce the search space and can lead to a near-optimal solutions with high reliability [4].

Heuristic algorithms are applied to reduce the loss of distribution system [6], [8]. In the document [6] have given methods to evaluate the change in loss in net restructuring. Document [8] also provides methods of reconstruction algorithms heuristic system overload wired route.

Materials [2] introduced heuristic algorithm to reduce the loss by the method of identifying the download button. The button is determined by identifying the first branch in the system on which the loss caused the greatest resistance. First button is the button to download the most influential causes of losses in that branch (this button is selected). The capacity of a capacitor bank is worth making the loss of the system is minimal. The above process will be implemented for the next button until the loss reduction achieved within the range allowed. This method does not guarantee cost function is minimum or maximum saving function.

Document [3] introduced a method was developed from the literature [2] to overcome the shortcomings in reducing losses and costs. However, this method is not a desired result.

Document [5] provides a method to reduce losses to a minimum by installing a capacitor bank at the optimum position. Disadvantages of this approach are to ignore cost-benefit analysis that this will affect the cost of capacitors and power savings.

The work in this paper is to develop the technology to the previous heuristic. Introducing the Heuristic has been made, then introduce heuristic algorithms that give better results, this technique can be viewed as the sum of the previous Heuristic for the installation of capacitor banks in distribution networks the beam. A heuristic algorithm is introduced through transformation techniques to locate, the optimal capacity of the capacitor.

2. To build the formula

2.1. Survey the distribution of reactive power

Density function of reactive power normalization f(x) $\mathbf{f(x)=\frac{Q(x)}{Q_\Sigma}}$

Among them:

Q_Σ: total reactive power.

x: distance is measured along the most copper.

Q(x): reactive power in x.

The function of reactive power normalization F(x) $\mathbf{F(x)=\sum f(x)}$

2.2. Construction of reduced power loss

From the graph distribution of reactive power, we assume that the function of reactive power is a continuous function as shown in Figure 10.

Power loss caused by the reactive component should be calculated using the formula:

$$\mathbf{P_Q=\frac{1}{U^2}.\int_0^1 (Q_\Sigma.F(x))^2 r.dx}$$

Among them: r - resistance of copper wire the entire route.

Power loss reduction by the reactive component causes

$$\mathbf{\Delta P_Q = P_Q - P_{Qb}}$$

$$\mathbf{\Delta P_{Qb}=\frac{1}{U^2}.\left(\begin{array}{l}\int_0^1 (Q_\Sigma.F(x))^2 r.dx-\int_0^{x_1}\left([Q_\Sigma.F(x)]-\sum_{j=1}^{k}Q_{bj}\right)^2.r.dx\\ -\sum_{i=1}^{k-1}\int_{x_i}^{x_{i+1}}\left([Q_\Sigma.F(x)]-\sum_{j=i+1}^{k}Q_{bj}\right)^2.r.dx-\int_{x_k}^{1}(Q_\Sigma.F(x))^2 r.dx\end{array}\right)}$$

2.3. Construction of reduced energy loss

We have:

$$\mathbf{A_{ht}^{Q}=\int_0^{\tau} P_Q(t)dt}$$

Among them:

PQ (t) is the power loss caused by the reactive components change over time.

τ is the time average maximum capacity; $\mathbf{\tau=\left(0,124+\frac{T_{max}}{10^4}\right)^2.8760}$

So reducing the energy losses of the system when the reactive power varies with a cycle time of the survey are:

$$\mathbf{\Delta A_{Qb}=\int_0^{\tau}\Delta P_{Qb}(t)dt}$$

Change the value $\mathbf{\Delta P_{Qb}}$ above we obtain:

$$\Delta A_{Qb} = \frac{1}{U^2}.\left(\begin{array}{l} \int_0^{\tau}\left(\int_0^1 \left[Q_\Sigma(t).F(x)\right]^2 r.dx - \int_0^{x_1}\left([Q_\Sigma(t).F(x)] - \sum_{j=1}^{k} Q_{bj}\right)^2 .r.dx - \right. \\ \left. - \sum_{i=1}^{k-1}\int_{x_i}^{x_{i+1}}\left([Q_\Sigma(t).F(x)] - \sum_{j=i+1}^{k} Q_{bj}\right)^2 .r.dx - \int_{x_k}^{1}\left[Q_\Sigma(t).F(x)\right]^2 r.dx \right) dt \end{array}\right)$$

3. Maximum saving function ΔS

Locate the capacitor to set the function ΔS peak.

$$\Delta S = K_P.\Delta P + K_A.\Delta A - K_C.\sum_{i=1}^{n} Q_{bi}$$

3.1. Locate the capacitor set

We do:

$$\frac{\partial S}{\partial x_i} = K_P.\frac{\partial \Delta P}{\partial x_i} + K_A.\frac{\partial \Delta A}{\partial x_i} = 0$$

- At the component : $K_P.\frac{\partial \Delta P}{\partial x_i}$

We are:

$$\frac{\partial \Delta P_{Qb}}{\partial x_i} = \frac{1}{U^2}.\left(2.r.Q_\Sigma.Q_{bi}.\left(F(x_i) - \sum_{j=i+1}^{k}\frac{Q_{bj}}{Q_\Sigma}\right) - r.(Q_{bi})^2\right)$$

with $\sum_{j=i+1}^{k}\frac{Q_{bj}}{Q_\Sigma} = 0$ khi $j > k$

- At the component : $K_A.\frac{\partial \Delta A}{\partial x_i}$

We are:

$$\frac{\partial \Delta A_{Qb}}{\partial x_i} = \frac{\tau}{U^2}.\left[2.r.Q_\Sigma.Q_{bi}.\left(K_f.F(x_i) - \sum_{j=i+1}^{k}\frac{Q_{bj}}{Q_\Sigma}\right) - r.(Q_{bi})^2\right]$$

with $\sum_{j=i+1}^{k}\frac{Q_{bj}}{Q_\Sigma} = 0$ khi $j > k$

Change the value ∂ΔP, ∂ΔA on the expression:

$$\frac{\partial S}{\partial x_i} = K_P.\frac{\partial \Delta P}{\partial x_i} + K_A.\frac{\partial \Delta A}{\partial x_i} = 0$$

$$F(x_i) = \frac{K_P + K_A.\tau}{K_P + K_A.\tau.K_f}.\left(\frac{Q_{bi}}{2Q_\Sigma} + \sum_{j=i+1}^{k}\frac{Q_{bj}}{Q_\Sigma}\right)$$

With $\sum_{j=i+1}^{k}\frac{Q_{bj}}{Q_\Sigma} = 0$ khi $j > k$;

$$\delta = \frac{K_p + K_A.\tau}{K_p + K_A.\tau.K_f}$$

According to the above expression, we define the position of the capacitor bank to put maximum savings function ΔS.

3.2. Determining the value of storage capacitor

We do:

$$\frac{\partial S}{\partial Q_{bi}} = K_P.\frac{\partial \Delta P}{\partial Q_{bi}} + K_A.\frac{\partial \Delta A}{\partial Q_{bi}} - K_C = 0$$

- At the component : $K_P.\frac{\partial \Delta P}{\partial Q_{bi}}$

We are:

$$\frac{\partial \Delta P_{Qb}}{\partial Q_{bi}} = \frac{1}{U^2}.\left(2.r.\int_0^{x_i} Q_\Sigma.F(x).dx - 2.r.x_i.\sum_{j=i}^{n} Q_{bj} - 2.r.\sum_{k=1}^{i-1} Q_{bk}.x_k\right)$$

with $\sum_{k=1}^{0} Q_{bk}.x_k = 0$

- At the component : $K_A.\frac{\partial \Delta A}{\partial x_i}$

We are:

$$\frac{\partial \Delta A_{Qb}}{\partial Q_{bi}} = \tau.\frac{1}{U^2}.\left[2.r.K_f.\int_0^{x_i} Q_\Sigma.F(x).dx - 2.r.x_i.\sum_{j=i}^{n} Q_{bj} - 2.r.\sum_{k=1}^{i-1} Q_{bk}.x_k\right]$$

with $\sum_{k=1}^{0} Q_{bk}.x_k = 0$

Change the value ∂ΔP, ∂ΔA on the expression:

$$\frac{\partial S}{\partial Q_{bi}} = K_P.\frac{\partial \Delta P}{\partial Q_{bi}} + K_A.\frac{\partial \Delta A}{\partial Q_{bi}} - K_C = 0$$

$$Q_{bi} = \frac{Q_\Sigma.\alpha}{x_i - x_{i-1}}.\int_{x_{i-1}}^{x_i} F(x).dx - \sum_{j=i+1}^{n} Q_{bj}$$

With **i = 2÷n** when **i =1**; $\sum_{j=i+1}^{n} Q_{bj} = 0$ when j > n

$$Q_{b1} = \frac{Q_\Sigma.\alpha}{x_1}.\int_0^{x_1} F(x).dx - \sum_{j=2}^{n} Q_{bj} - \frac{\beta}{x_1}$$

$$\alpha = \frac{K_p + K_A.\tau.K_f}{K_p + K_A.\tau} = \frac{1}{\delta};\ \beta = \frac{U^2.K_C}{2.r.[K_p + K_A.\tau]}$$

According to the above expression, we find the value of capacitor banks for maximum savings function ΔS.

3.3. Algorithm to determine how much and where to install capacitors to reduce power loss and power

Step 1: From the diagram, the data of the system determine the length, the distance of each node in the routing wire load uniformly standardized.

Step 2: Determination of reactive power normalized F(x).

Step 3: Select a location for gathering x_n, define $F(x_n)$.

Step 4: Determine Q_{bn} :

$$Q_{bn} = \frac{2.F(x_n).Q_\Sigma}{\delta}$$

Step 5: Determine x_{n-1} to achieve optimal Q_{bn} and x_n value, this means that the target area between A_n, B_n are equal.

- Determination of the g_n

$$F(g_n) = \frac{Q_{bn}}{\alpha.Q_\Sigma}$$

- Draw lines (1) by g_n and parallel to F(x).
- Select the x_{n-1} for $A_n = B_n$ area.

Step 6: Determine:

$$Q_{bn-1} = \frac{2.Q_\Sigma.F(x_{n-1})}{\delta} - 2.Q_{bn}\,.$$

Step 7: As Step 5, x_{n-2} defined as follows:

- Identify g_{n-1}:

$$F(g_{n-1}) = \frac{Q_{bn-1} + Q_{bn}}{\alpha.Q_\Sigma}$$

- Draw lines (2) by g_{n-1} and parallel to F(x).
- Select the x_{n-2} for $A_{n-1} = B_{n-1}$ area.

Step 8: Make turns as the above steps until the position x_1.Then determine the

$$Q_{b1} = 2.Q_\Sigma.\frac{F(x_1)}{\delta} - 2.\sum_{j=2}^{n} Q_{bj}$$

- Identify g_1: $F(g_1) = \dfrac{Q_{b1} + \sum_{j=2}^{n} Q_{bj} + \dfrac{\beta}{x_1}}{\alpha.Q_\Sigma}$
- Drawlines (n) by g_1 and parallel to F(x).
- Compare the last two areas A_1 and B_1, will be the case as follows:
  - If $A_1 = B_1$ or misleading in a given range, the algorithm stops. The result is determined.
  - If $A_1 > B_1$: recording step 3, choose x_n positions far more power and repeat the other steps.
  - If $A_1 < B_1$: recording step 3, choose x_n positions near the source over and repeat the other steps.
- When changing the position x_n toward the last load that can not find the optimal value is:

- Choose the location x_n at the load end, Q_{bn} to change the value $F(g_n)$ makes $A_n = B_n$

- Perform to step 6.

4. Results

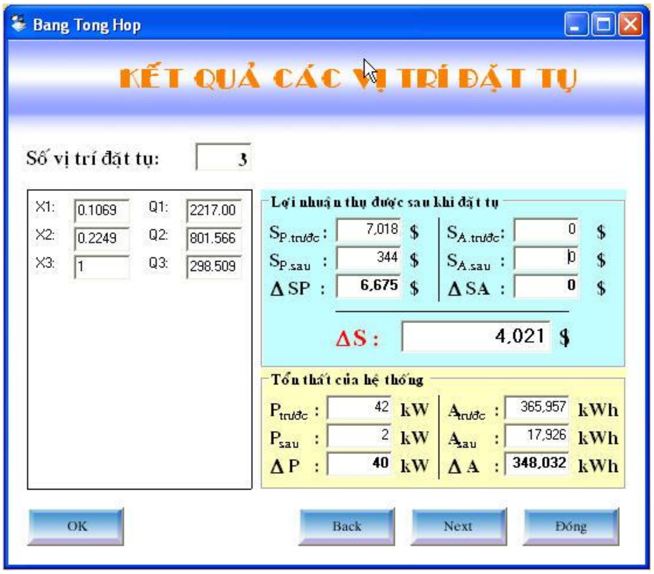
4.1. Route wires first

For such systems [26]

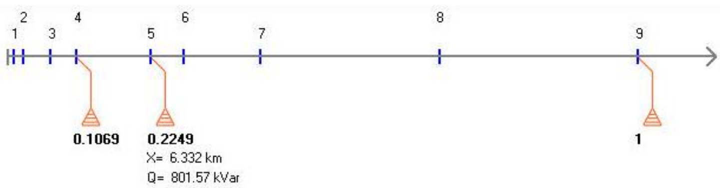
The algorithm	Capacitor placement	Storage capacitor (kvar)	The total capacity capacitor (kvar)	Losses after compensation kW
[2]	4; 7; 9	4050; 300; 600	4950	547.3
[3]	4; 8; 9	3750; 300; 600	4650	546.3
[22]	4; 5; 8; 9	3750; 1650; 300; 600	6300	587.8
[23]	4; 5; 9	3600; 1950; 750	6300	589.2
[24]	3; 4; 5; 9	3300; 2100; 1650; 600	7650	587.3

[25]	2; 3; 5; 9	3900; 3300; 2100, 600	9900	580.5
[26]	4; 5; 9	1350; 1950; 450	3750	539.5
Proposed algorithm	**4; 5; 9**	**2217; 802; 299**	**3318**	**524.9**

The results of the proposed algorithm



Position and size of the capacitor has been converted

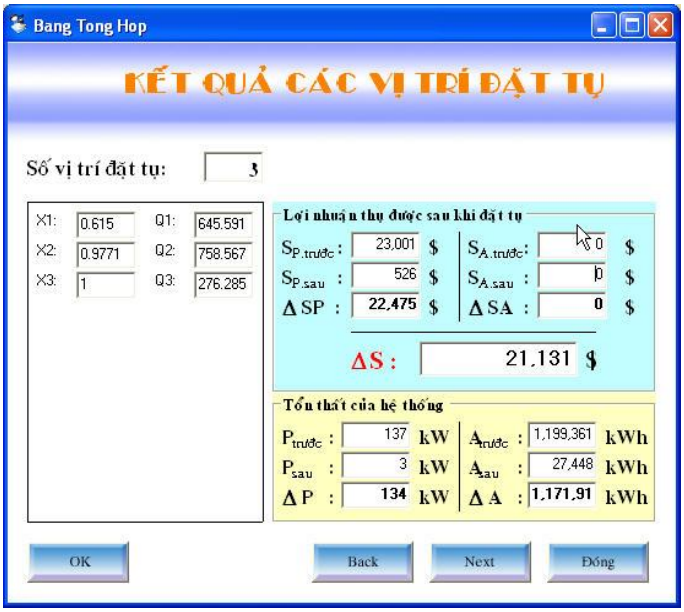


4.2. Route wire second

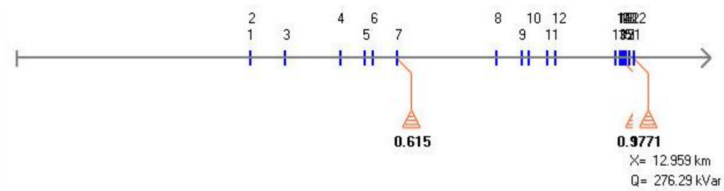
For such systems [26]

The algorithm	Capacitor placement	Storage capacitor (kvar)	The total capacity capacitor (kvar)	Losses after compensation kW
[2]	8; 22	450; 1350	1800	116.2
[3]	8; 22	450; 1200	1650	113.5
[22]	6; 8; 14	450; 450; 900	1800	111.6
[23]; [25]	4; 22	900; 900	1800	111.5
[24]	1; 22	900; 1200	2100	114.7
[26]	6; 14	600; 1200	1800	112.8
Proposed algorithm	**7; 15; 22**	**646; 759; 277**	**1682**	**111.5**

The results of the proposed algorithm



Position and size of the capacitor has been converted



5. Conclusion

Using modern mathematical methods: Heuristic algorithms for the construction of new efficient than the current maximum profit for the installation of capacitors on radial distribution systems. The results can be summarized as follows:

- Can be used as a module heuristic algorithm for solving reactive power compensation.

- Solve the reactive power compensation by increasing the value of ΔS function simply and efficiently.

- Heuristic algorithms can suggest practical applications for the examination of the power system

Direction of future development:

- Research complete algorithm to calculate the effect of voltage, installation costs with each capacitor.

- Further research on the ability to deliver medium voltage grid.

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XÂY DỰNG GIẢI THUẬT HEURISTIC ĐỂ BÙ CÔNG SUẤT PHẢN KHÁNG ĐỐI VỚI MẠNG PHÂN PHỐI HÌNH TIA

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TÓM TẮT

Bài báo này giới thiệu một phương pháp tìm kiếm heuristic để bù công suất phản kháng cho mạng phân phối hình tia, qua đó nhận được chi phí tiết kiệm là cực đại. Phương pháp là một kĩ thuật được thực hiện từ những khái niệm của kĩ thuật heuristic hiện tại và cho ra kết quả tốt hơn. Phương pháp được phát triển và áp dụng vào hệ *thống ba pha. Kết quả của phương pháp này được so sánh với những phương pháp trước để cho thấy ưu điểm của nó. Thuật toán mới được thực hiện thông qua kĩ thuật biến đổi để thu được vị trí, dung lượng tụ bù tối ưu.*

Từ khóa: *giải thuật heuristic, bù công suất phản kháng, cực đại chi phí tiết kiệm, tối ưu dung lượng tụ bù, tối ưu vị trí tụ bù*

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