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Identifying the key factors for chiller system collaborative service design

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ABSTRACT

This paper applies the Analytical Hierarchy Process (AHP) in calculating the weights and uses Cause–Effect Grey Relational Analysis (CEGRA) to rank system performance based on multiple criteria evaluation. AHP is compared with CEGRA in ranking the alternatives, thus achieving improved environmentally friendly system performance. This paper uses the TFT-LCD chiller in Taiwan to measure the model's reliability and validity through comparison with the traditional strengths and weaknesses assessment. Businesses should cooperate with collaborative vendors and apply the service science management concept to improve performance and reduce energy waste.

1. Introduction

The greenhouse effect is a key factor leading to global warming [1–3]. Alternative energy sources can replace high cost energies, which is the key energy consumption factor in the flat panel display industry [4]. Chiller energy savings were accomplished in the past by creating a multitude of pipeline installations after chiller heat recovery [5]. Reducing mechanical cooling or electrical heating requirements can significant energy savings [6]. This approach can improve current energy efficiency in a limited way. Importing collaboration means that businesses and venders share a common goal in helping each other professionally, through exchanging knowledge in an integrated process model that improves value and creates more efficiency [7,8]. Fig. 1 shows the general chiller.

According to the relevant literature of chiller system, Niu et al. [9] proposed the four different heating systems to replace the conventional heating, ventilating and air-conditioning (HVAC) systems. Shi et al. [10] proposed the CFD (Computational Fluid Dynamics) to condensing unit air management modeling on the chiller system performance. Fan et al. [11] employed heating, ventilating and air conditioning (HVAC) systems to solve the optimal chiller loading problem and decrease computational costs.

Collaborative design can design and plan chiller installation and enhance the various supply chain member's design input, improving clarity in the information exchange to speed up the process efficiency [12–14]. This study used the Analytic Hierarchy Process (AHP) to assess chiller efficiency [15], with the Cause–Effect Grey Relational Analysis (CEGRA) to determine the key impact factor [16,17]. The AHP and CEGRA decision-making method for constructing an evaluation method provides decision-makers or administrators with a valuable reference for evaluating chiller collaborative service performance in TFT-LCD industries, thus improving applicability for both academic and commercial purposes.

2. Theoretical overview

"Energy savings and carbon reduction" are now global issues. The El Niño-Southern Oscillation (ENSO) causes extreme weather, such as floods and droughts, in many regions of the world. Developing countries are generally dependent upon agriculture and fishing, particularly those bordering the Pacific Ocean, and are the most affected by ENSO [1–3].

An air dehumidification system is an efficient way to supply fresh air [18] and reduce the carbon footprint. Fresh air with energy recovery measures is the key equipment [19]. Zhang and Niu [20] proposed a pre-cooling Munters environmental control (PMEC) cycle combines with chilled-ceiling panels to predict the desiccant cooling system performance [21,22]. Zhang and Niu [23] proposed that an hour in advance dehumidification/ventilation in summer can save energy.

The TFT-LCD industry uses alternative energy sources that can replace high cost energies [4]. According to the relevant literature, the facility equipment energy use survey ratio determined that facility equipment, electricity consumption and electricity accounts for about 49% of the energy used. Chiller facility equipment accounts for about 35% of the electricity. The Make-up Air Unit (MAU) uses about 23% of the facility equipment electricity [6]. The MAU is installed to capacity due to increased

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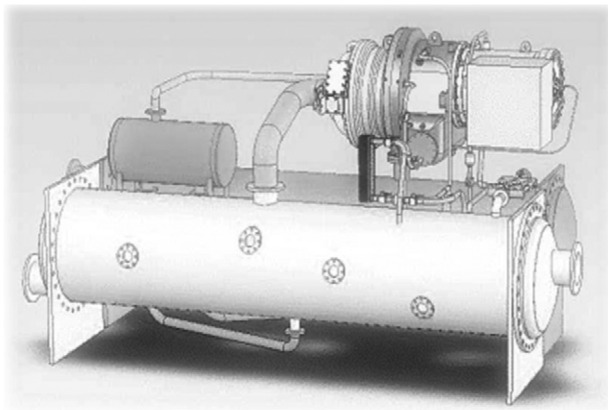

Fig. 1. Chiller.

collaborative design and installation when planning heat exchanger coil path installation. MAU, because of service science, combines collaborative service technologies and uses heat recovery air handling to increase the demand for different services from a saved supply of both ice water and warm water.

The collaborative design concept stems from continuous acquisition and life-cycle support (CALS), concurrent engineering and collaborative engineering. Antony provided collaborative design, allowing the high-tech industry to gain a competitive advantage [7]. Collaboration provides a pre-integrated system that provides stable operation and command operations. Both the external and disturbance variables will be correlations between the corresponding operations [12]. Collaboration can provide a low-cost [24], open architecture and ongoing maintenance for quickly addressing system variations. Centralized integration service firms provide chiller installation and route planning according to experts from both sides, changing equipment needs by planning dual-ice temperature use. The MAU supply and dry coil can improve chiller efficiency and consume relatively less power.

This study proposes an evaluation method that combines AHP and CEGRA for chiller system [18,19] save energy [9,23] in Taiwan's TFT-LCD industries. AHP is used to obtain the relative criteria weights [15]; with the CEGRA approach used to rank the overall system performance [20–22] based on multiple criteria evaluations [16]. The AHP and CEGRA decision making method for constructing an evaluation method can provide decision makers or administrators with a valuable reference for evaluating TFT-LCD industry chiller collaborative service performance.

3. Research methods

3.1. Analytic Hierarchy Process

AHP is a structured technique for dealing with complex decisions. As a decision making method that dissects a complex multi-criteria problem into a hierarchy [25], AHP is also a measurement theory that prioritizes the hierarchy and consistency of subjective data provided by a group of decision-makers. AHP creates a matrix framework and a local priority vector that can be derived as an estimate of the relative importance associated with the elements (or components) being compared by solving the following formulae:

$$A \cdot w = \lambda_{\max} \cdot w \tag{1}$$

where A is the pair-wise comparison matrix, w is the eigen-vector, and $\lambda_{\max}$ is the largest eigen-value of A.

Saaty proposed utilizing a consistency index (*C.I.*) and consistency ratio (*C.R.*) to verify the comparison matrix consistency [25]. *C.I.* and *R.I.* are defined as follows:

$$C.I. = \frac{\lambda_{\max} - n}{n - 1}, \tag{2}$$

$$C.R. = \frac{C.I.}{R.I.}, \tag{3}$$

where *R.I.* represents the average consistency index over numerous random same order reciprocal matrices entries. If $C.R. \le 0.1$, the estimate is accepted; otherwise, a new comparison matrix is solicited until $C.R. \le 0.1$.

3.2. Cause–Effect Grey Relational Analysis

Deng initiated Cause–Effect Grey Relational Analysis (CEGRA) which is predicated based on cause–effect incidences and comparisons [26]. The evaluation method combines AHP and CEGRA for collaborative service design chiller system [18,19] can save energy [9,23] and reduce carbon footing [20–22]. Under this, this study definition and algorithm of the method are shown below:

(1) The orientation of exploiting the resource space.

Let the $(EP\ \ \mathcal{F}, X)$ be an exploited resource space, provided that $EP\ \ \mathcal{F}$ is equipped with mapping functions, as

$$EP\ \ \mathcal{F}: \quad \text{Resources} \rightarrow \text{efficacies}\,(\nu) \tag{4}$$

(2) Data category.

The data is a data resource or other resource that possesses information $\theta\,(d)$

$$\theta(d) = \{\nu(\cdot), \text{value}; s(\cdot), \text{sign}; p(\cdot), \text{polarity}; b(\cdot), \text{background}; c(\cdot), \text{connotation}\}$$

or else, there is no resource, only a digit.

Let $dec_o(\cdot)$ be the entirety of complete information in decision making for event o. We thus have the following data category.

$$\text{Decision making data}, \theta(d) \in dec_o(\cdot) \tag{5}$$

(3) Patterns in Grey Resource Theory.

Let the situation $S = (a, b)$ be a pattern in GRT provided that $S \in \mathcal{S}$.

$$\mathcal{S} = \{S_{de}, S_{rat}, S_{aut}, S_{gra}, S_{GM} \ldots\} \tag{6}$$

$S_{ij} = (a_i,\ b_j) \rightarrow S_{ij} = S_{GM}$ (grey modeling pattern), $a_i \rightarrow$ decision-maker; $b_j \rightarrow$ resource.

The pattern S in S is then said to be an unbiased truth, provided that

$$(a, b) = (b, a) \tag{7}$$

(4) Cause–effect contrasting incidences.

In cause–effect space (P_{cau}, P_{eff}), only individuals that present cause–effect incidence exhibit a cause–effect relationship. There is no need to contrast the irrelevant individuals. In fact, incidence is essential to contrast. This study uses the cause–effect contrasting incidence.

First let α, β be contrasted individuals, $\alpha, \beta \in P$, $\mu = \Delta = \alpha - \beta$ stands for the comparison gene and $\Delta = \Delta_{0i}(k) = \left|\chi_0(k) - \chi_i(k)\right|$ for the series comparison, where $\Delta \rightarrow 0$ means melt; $\Delta \rightarrow \infty$ means irrelevant.