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Article

Novel Approach to Energy Management via Performance Shaping Factors in Power Plants

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Abstract: The literature that a lack of integration between the performance shaping factors (PSFs) and the energy management performance (EMP) is one of the critical problems that prevent performance improvement and reduces the power plant's efficiency. To solve this problem, this article aims to achieve two main objectives: (1) Systematically investigate and identify the critical success factors (CSFs) for integration with PSFs and EMP; (2) Develop a novel modelling approach to predict the performance of power plants based on innovative integrated strategies. The research methodology is grounded on the theoretical and practical approach to improving performance. The Newcastle Ottawa Scale (NOS) was used to assess the quality of the literature that met the criteria. To ensure the reliability and accuracy of the proposed model, the researchers developed a hypothesis and evaluated the CSFs via a case study in the Iraqi power plants. The findings of this study succeeded in developing a novel modeling approach to predict the performance by integrating the CSFs of both the PSFs and EMP to increase the positive interaction and energy efficiency of power plants. The results confirmed the validity of the selected hypotheses and verified the positive and important relationship with the success and improvement of the performance in power plants. However, the lack of consistency and balance in the current studies indicates that the performance strategy in power plants did not receive sufficient attention and needs further investigations.

Keywords: Intelligent model; energy policy; energy use; integrated system; energy efficiency; framework

1 Introduction

The green energy management performance of power plants contributes to improving the behavior of companies and enhancing economic participation in the economic sector [1]. However, the performance shaping factors (PSFs) can affect human performance [2]. In the power plants, neglecting PSFs, including human factors, and sustainable integration with workplace energy management performance EMP resulted in an evident weakness in the energy management performance of power plants. Therefore, the integration between CSFs of PSFs and CSFs of EMP remains a research gap and an urgent problem that needs to be solved according to previous studies [3,4]. Poor performance in the industrial sector, especially in the electricity sector, negatively affects the power plant and contributes to the increase in human errors and the weakness of human factors [5]. The literature confirms the need to conduct more studies and investigations related to the performance shaping factors, including the human performance, human factors, and human error in maintaining thermal and gas power plants [6–12]. Additionally, further investigation regarding the CSFs of energy management is required [13–15]. The poor performance is one of the main challenges facing the Iraqi electricity sector [16]. The weakness of leadership practice with the CSFs in the maintenance of Iraqi power plants led to poor performance for both the personnel and energy management performance [17,18].

The performance in power plant facilities often poses significant hazards to the economic systems and power plants; therefore, it is necessary to focus on human factors that are related to risks associated with the consequences of human errors. The risk of mediocre performance is closely related to human errors, which contributes to weak human factors. The failures caused by human errors are roughly two and a half times greater than those attributed to hardware failures. Organizational performance variability can cause many problems such as production losses, ineffective maintenance, and major disasters [19]. PSFs in a power plant are closely related to energy management performance and contribute to a reduction in energy consumption [20]. The literature confirms the need to conduct more studies and investigations on the interaction between the PSFs and EMP and their CSFs in power plants to enhance their performance [21,22]. Previous studies also show a lack of transparency in EMP [23–27]. This study is a supplement and a second part to our other published studies with a new result. No noteworthy studies identified the critical success factors (CSFs) to integrate the energy management performance with the PSFs in power plants. To solve these problems, the researchers investigated the CSFs for the integrating performance and developed a novel model via a case study in the Iraqi thermal power plants to ensure an integrated and sustainable performance. According to the best research knowledge of the authors, this is the first study to systematically investigate the literature to build a predictive novel model that can improve the performance in power plants through a sustainable integration between the PSFs and EMP to overcome the mediocre performance problems of power plants.

2 Methodology

The methodology of this study is based on the theoretical side through a systematic literature review (SLR) to select 145 out of 535 papers that were carefully studied to examine the performance architecture. The practical side matches the results of the systematic investigation of the literature with the opinions of energy experts via a case study in the Iraqi power plants. Strict and transparent procedures were used in this study as recommended in the literature [28], which included planning and exploration, conducting a systematic review, and then writing the report that represents the analysis's output. The research team in this study worked on overcoming the data shortage. The authors created an intelligent framework to increase the performance so that the power plant can profit from the SLR's findings. In addition to that, the authors developed a two-way strategy to increase the dependability based on energy experts and power plants. The search used five scientific digital databases, namely i) Science Direct, ii) Scopus, iii) IEEE Xplorer, iv) Web of Science (WoS), and v) Springer, where relevant articles were downloaded, filtered, extracted, and drafted. The articles that were selected were published between the years 2013 and 2022. Scale (NOS) was used to assess the quality of the literature that met the criteria. The quality assessment was conducted by three authors independently, and a fourth reviewer resolved the disagreement. The outputs of the systematic investigation were employed by conducting a case study and implementing the critical success factors identified and presented to energy experts for evaluation. The partial least squares-structural equation modeling (PLS-SEM) and Statistical Package for the Social Sciences (SPSS) software were used to validate the results.

2.1 CSFs of Performance Shaping Factors (PSFs)

The PSFs were designed to improve the performance under expected and benign conditions, and not in risky scenarios [29]. Furthermore, one of the main problems with the existing PSF taxonomy is that they overlap. PSFs help increase the energy efficiency and the success in energy management of power plants, which has faced several issues. The most significant issue is the personal performance related to awareness, which has resulted in energy waste [30]. CSFs of the PSFs play a large role in diagnosing errors and improving the quality of the performance of the power plant [31,32]. The researchers developed measurement instruments for the performance and suggested using such measures to understand the performance and build theories and models related to the critical factors. Improving the energy management performance through personnel performance success factors has become essential to overcoming hurdles [33–36]. Tab. 1 illustrates the most important CSFs suggested by previous studies and refers to the success factors that got the highest rate, including teamwork (TW) at 19%, followed by commitment (CO) at 17.6%, skills flexibility (SF), motivation (M) with 16.2%, work overload (WO) with time pressure (TP) by 13.7% and top management support (TMS) 3.7%.

Table 1: CSFs of the PSFs that are proposed by previous studies

CSFs of PSFs	Previous studies	NO	%
(TW)	[37–51]	15	19
(SF)	[37,38,40,46,48–56]	13	16.2
(CO)	[37–40,46–51,54,57–59]	14	17.5
(MO)	[38,40,46–49,51,54–57,60,61]	13	16.2
(WO)	[37,41–45,49,54,62–64]	11	13.7
(TP)	[38,40,46–49,51,54–57,60,61]	11	13.7
(TMS)	[40,61,65]	3	3.7
Total		80	100%

2.2 CSFs of Energy Management Performance (EMP)

The literature referred to the role of the performance factors influencing EMP and energy-saving [66]. The elements that affect the PSFs, such as human factors, human errors, and personal qualities, are employed to maximize the operators' performance and energy saving in power plants. Previous studies have helped researchers to identify the critical success factors for the energy management practices that can be integrated with personnel performance. A complex management mechanism with clear roles must be established to reconcile the artificial relationship between some inconsistencies and implement energy efficiency measures. As a result, a full understanding of the role of human factors in energy efficiency and their application can greatly improve the effectiveness of the energy management measures. Tab. 2 refers to the success factors with the highest rate, including teamwork at 7.7%, commitment (CO) at 7.7%, skills flexibility (SF), motivation (MO), risks management (RM) also at 7.7%, continuous improvement (CI) with 11%, policies (PO) 6.1%, and top management support (TMS) by 14%.

Table 2: CSFs of the EMP that proposed by previous studies

CSFs of EMP	Previous studies	No	%
(TW)	[14,67–70]	5	7.7
(SF)	[14,67,68,71,72]	5	7.7
(CO)	[68–71,73]	5	7.7
(MO)	[6,68,69,74,75]	5	7.7
(TMS)	[13–15,67–69,71–73,75–77]	15	23
(RM)	[14,67,71,73,78]	5	7.7
(A)	[14,67,69–73,76]	9	14
(CI)	[13–15,67,73,75,78]	7	11
(PO)	[6,72,76,78]	4	6.1
(CO)	[67,68,74,77,79]	5	7.4
Total		65	100%

3 Integration CSFs for PSFs & EMP

An Integrated Management System (IMS) attempts to integrate all of the organization's systems and processes into one complete framework, enabling an organization to work as a single unit with unified objectives. This Integrate simplifies management, saves time, and increases efficiency by addressing all management system elements [80]. A careful study of the previous literature helped identify the most important indicators of the successful integration of the PSFs with EMP in a power plant. The CSFs that achieved the highest score were selected. Tab. 3 and Fig. 1 provide a comprehensive review of the different evaluation metrics used in managing the performance in the workplace environment and the classification in all the reviewed studies.

Table 3: Integration the CSFs of the PSFs & EMP

CSFs	PSFs		EMP		Integration PSFs & EMP	
	F	%	F	%	F	Total %
(TW)	15	19	5	7.7	20	13.7
(SF)	13	16.2	5	7.7	18	12.4
(CO)	14	17.5	5	7.7	19	13
(M)	13	16.2	5	7.7	18	12.4
(TMS)	3	3.7	15	23	18	12.4
(WO)	11	13.7	-	-	11	7.5
(TP)	11	13.7	-	-	11	7.5
(RM)	-	-	5	7.7	5	3.4
(A)	-	-	9	14	9	6.2

(Continued)

Table 3: Continued

CSFs	PSFs		EMP		Integration PSFs & EMP	
	F	%	F	%	F	Total %
(CI)	-	-	7	11	7	4.8
(EP)	-	-	4	6.1	4	2.7
(LS)	-	-	5	7.4	5	3.4
Total	80	100	65	100	145	100

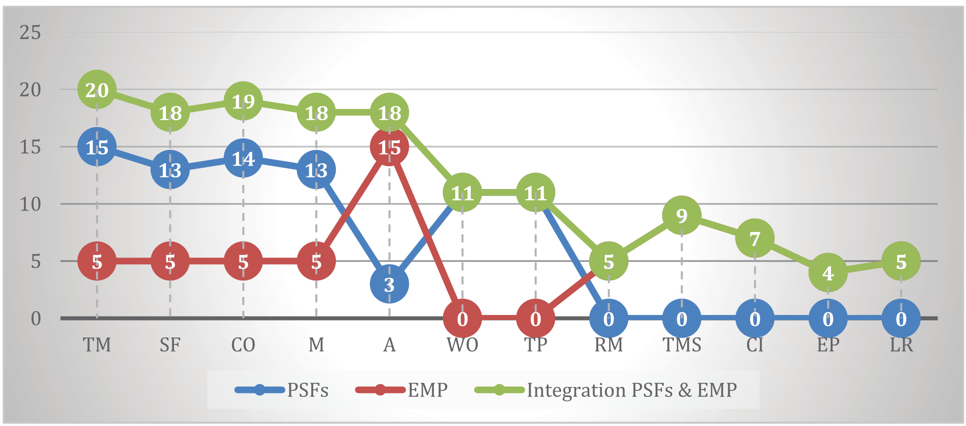

Figure 1: Indicators of CSFs to the integration of the PSFs & EMP

Additionally, no study used all this set of metrics together. The usage variance of these metrics indicates a serious challenge in using a specific set of metrics when evaluating and benchmarking the detection and classification of the performance. However, such varying usage rate of evaluation metrics also suggests that common guidelines exist for evaluating the various metrics and that each guideline applies the metrics that fulfill its objectives.

3.1 Developing a Novel Modelling to Predict Performance

The integrated management system allows the integration of a group of different processes and systems into one intelligent system for continuous improvement, which will help in achieving the organization's goals [81]. This study provides an opportunity to investigate the integration between the CSFs for the PSFs and the CSFs for the EMP to reduce the human errors and improve the human factors in power plants. The CSFs in the performance management and the CSFs in the energy management practices are equally important for integration as these are considered vital for the organizational success and effectiveness. According to the research gaps and open issues identified through comprehensive literature analysis, there is an urgent need to develop a conceptual framework to improve the overall performance and promote positive interaction between the personnel performance and the energy management performance in power plants. The proposed framework consists of three levels.

The first level of the conceptual framework is considered the foundational level. It aims to create internal content that includes establishing strategies and correct planning for the work with the importance of setting the goals for the organization, whether it is an emergency or scheduled, and setting strict and clear work policies with defining the available capabilities. In contrast, the external content within the first level includes considering the risks, government legislation, and taking advantage of the possibility of Industry 4.0. As an output for this level, the CSFs and the performance success indicators identified by this study are used to develop the second level and the integration industry between the performance stages. The second level represents the inputs of the integration stages generated from the previous literature that is analyzed in this study, including the three phases: The first phase refers to the need to improve the culture among workers through several steps, the most important of which is strengthening the leadership, improving the organization's structure with the continued development and training of employees, and encouraging employees to improve their performance through rewards and penalties. The second phase, which is the most important, uses the CSFs for personal performance and energy management performance to be combined into one intelligent management system. The CSFs represent a guiding framework for the power plant for attention and development to make the integration successful. The most important critical factors and success indicators contributing to the integration success have been identified: teamwork, skill flexibility, commitment, motivation, time pressure, awareness, work overload, top management support, and continuous improvement. The third phase is the indicators to measure the success of integrating personnel performance with the energy management performance through a set of indicators. The most important is reducing human errors, increasing energy efficiency and saving, increasing maintenance and operations quality, reducing maintenance failures, etc. The third level includes the PSFs and EMP performance analysis according to the success indicators that were identified in the third phase of the second level. The results of this level are divided into two categories: benefits for power plants, including increased revenue, reduced losses, operations management success, and increased quality of work. The three phases of the proposed framework will help the power plants successfully integrate the personnel performance and energy management performance in an intelligent management system. As a result, a conceptual framework will improve the power plant's overall performance. Fig. 2 refers to the main components of the proposed framework.

3.2 Developing the Performance Algorithms via Case Study

To make this study more robust and reliable, the researchers conducted a case study in one of the Iraqi power plants to test the CSFs that were analyzed from the literature after completing the judgment of the energy experts. The opinion of the energy experts working in the Iraqi power plants was used to confirm the model framework that was developed from the literature.

The researchers considered these power plants an ideal research area for conducting the study due to the Iraqi power plants suffering from multiple problems in performance. The study's data was collected through the opinions of experts and a questionnaire conducted within the power plants and was adopted from [31] and [3]. According to the equation developed to compute the sampling size by [82–84], the number of respondents was 100 with a confidence level of 99 percent from approximately 135 respondents. The study used the five-point Likert scale with the cross-sectional study. Cronbach's alpha of more than 0.7 was utilized to assess the questionnaire's reliability, as recommended by [85]. The PLS-SEM was chosen to predict correlations between components, and SPSS statistical software was utilized to analyze crucial data [86]. Hypotheses were developed according to the CSFs that achieved the highest scores and were recommended by previous studies; as shown in Tab. 3, the hypotheses of the study were established based on integrating the CSFs of the PSFs and EMP in one integrated system as independent variables, including (TW = 13.7%, SK = 12.4%, CO = 13%, M = 12.4%, TMS = 12.4%, WO = 7.5%, and TP = 7.5%). The purpose of these hypotheses is to verify the reliability of the selected factors in enhancing the integrated performance. The four research hypotheses (H1:CO, H2:MO, H3:TM, H4:WO, H5:TP, H6:TMS, and H7:TW) have a positive relationship with the EMP. Furthermore, the measurement model's validity is evaluated using the average variance extracted convergent and discriminant validity (AVE), and the value should be bigger than 0.5 according to [87]. As shown in Tab. 4, the results confirm the validity of the selected hypotheses and confirm the positive and important relationship with the success and improvement of the performance in power plants as shown in Tab. 5.

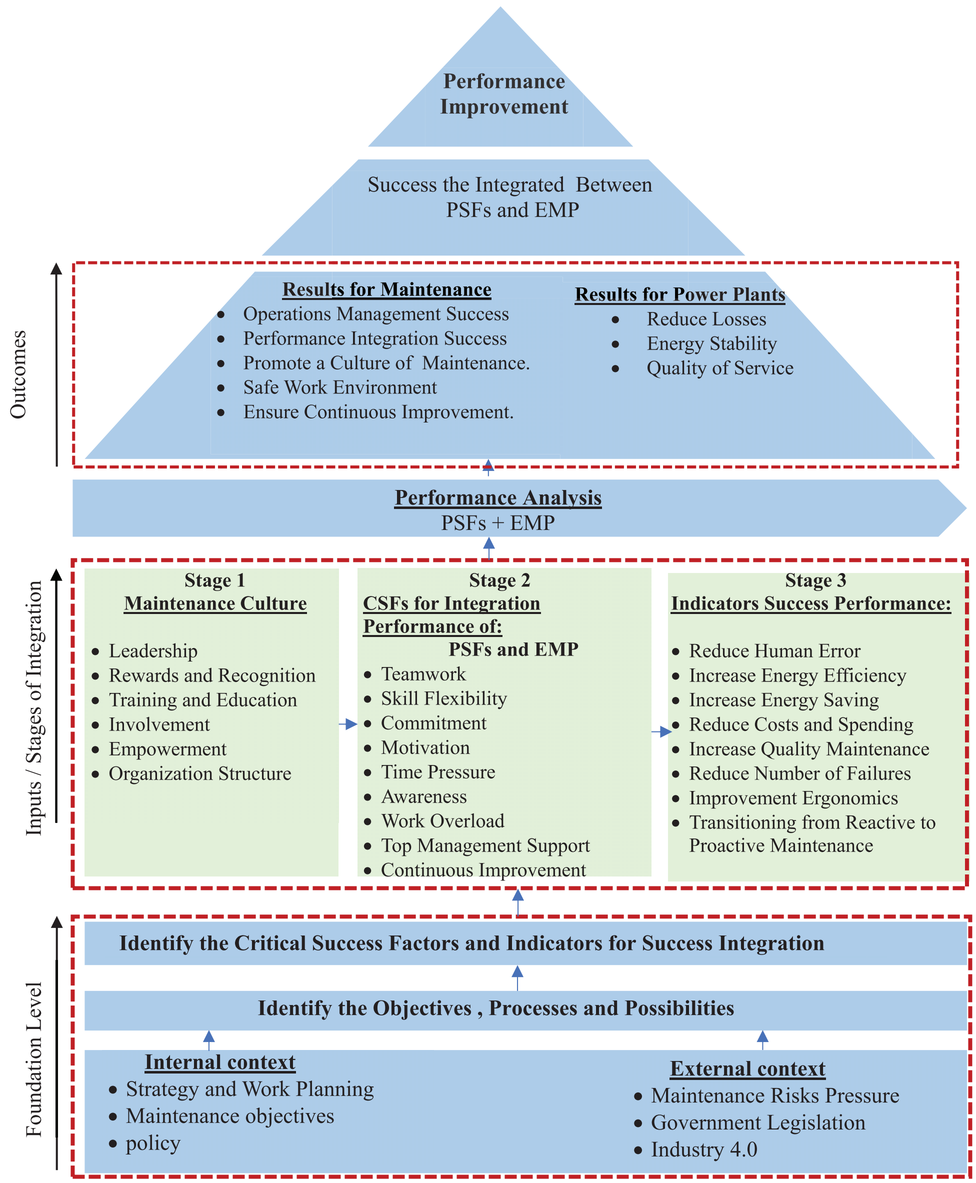

Figure 2: Main strategy of the proposed framework for integrated performance

Table 4: Model validity measurement

SF	CA	CR	AVE	CO	MO	TMS	WO	TP	TMS	TW	EMP
CO	0.721	0.902	0.820	0.930							
MO	0.743	0.855	0.735	0.363	0.820						
TM	0.821	0.760	0.758	0.487	0.658	0.787					
WO	0.856	0.917	0.821	0.586	0.568	0.645	0.758				
TP	0.952	0.845	0.723	0.632	0.514	0.456	0.489	0.787			
TMS	0.905	0.748	0.853	0.489	0.458	0.582	0.610	0.575	0.745		
TW	0.878	0.967	0.726	0.598	0.587	0.420	0.524	0.458	0.552	0.736	
EMP	0.740	0.837	0.735	0.524	0.603	0.411	0.356	0.454	0.520	0.434	0.772

Notes: CR: Composite Reliability; AVE: Average Variance Extracted; CA: Cronbach's Alpha

Table 5: Results of the model testing

H.	Hypotheses	No of items	*P*-values	Cronbach's alpha	Results
H1.	CO has a positive relationship with EMP	7	0.001	$\alpha = 0.721 < 0.01$	Significant
H2.	MO has a positive relationship with EMP	7	0.011	$\alpha = 0.743 < 0.01$	Significant
H3.	TM has a positive relationship with EMP	7	0.003	$\alpha = 0.821 < 0.01$	Significant
H4.	WO has a positive relationship with EMP	7	0.000	$\alpha = 0.856 < 0.01$	Significant
H5.	TP has a positive relationship with EMP	7	0.000	$\alpha = 0.952 < 0.01$	Significant
H6.	TMS has a positive relationship with EMP	7	0.008	$\alpha = 0.905 < 0\ .01$	Significant
H7.	TW has a positive relationship with EMP	7	0.000	$\alpha = 0.878 < 0.01$	Significant

In the regression analysis, the examination of the normality of the data is considered a prior check. For the present research, a workable sample size revealed that the data were normally distributed as the skewness value of all the items was within ±2 and the kurtosis values of all the items were within ±2, which did not fulfill the requirement of a previous study [88]. Furthermore, regression standardized residual histograms and normal probability plots were used to evaluate the normality. Normal data is represented by an asymmetric, bell-shaped curve on the standardized residual histogram and a straight line on the normal probability plots. Although the histogram and p-p plots are normal distribution, the symmetric bell-shaped curve and the straight line showed no significant deviation from normalcy. The results of the standardized regression residual of an independent and dependent variable and normal p-p plot of the regression standard residual are illustrated in Figs. 3 and 4.

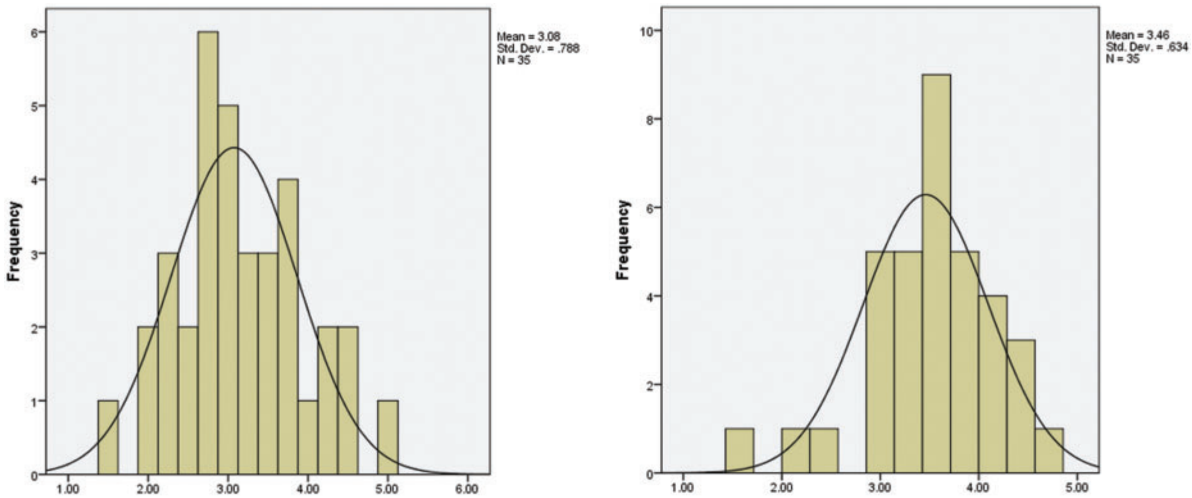

Figure 3: Results of the regression standardized residual

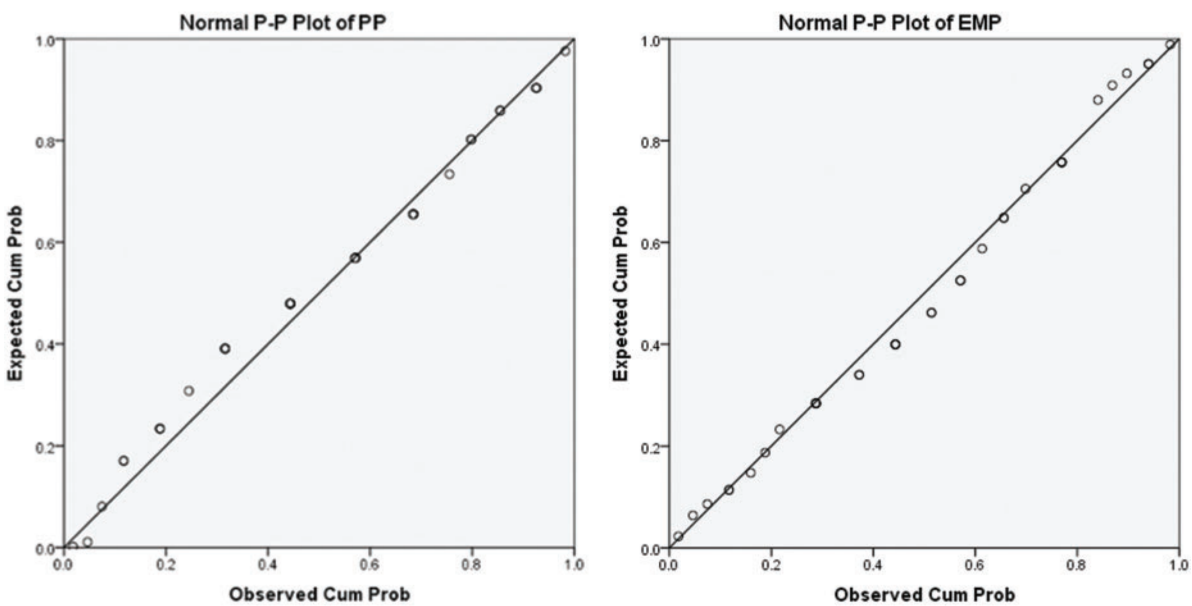

Figure 4: Normal P-p plot of the regression standard residual

4 Conclusion, Limitations, and Future Work

The performance shaping factors are directly responsible for maximizing the energy performance and increasing the financial returns of power plants. The literature showed that the lack of integration between the PSFs and EMP in power plants could lead to poor performance. This study identified the CSFs for PSFs & EMP after analyzing 145 different articles in-depth as a performance success indicator. The systematic review protocol included five databases for 2013–2022 and references that are written in English. On the other hand, as an outcome of the systematic investigation, a new model was developed to improve and integrate the performance within the power plants as a guide that is based on the literature. This study developed research hypotheses that can help researchers in future studies to develop this model according to previous literature. The success factors that achieved the highest scores and were recommended by previous studies are shown in Tab. 3. The hypotheses of the study were established based on integrating the CSFs of PSFs and EMP in one integrated system. The case study in this research confirmed that the Iraqi power plants suffer from significant mismanagement, weak performance, and mediocre performance shaping factors.

Furthermore, the measurement model's validity results were evaluated using the average variance extracted convergent and discriminant validity (AVE). All the results of the AVE that were higher than 0.5 prove that all the models were acceptable, as shown in Tab. 4. The results in Tab. 5 show the validity of the selected hypotheses and prove the positive and important relationship with the success and improvement of the performance of power plants. The data were normally distributed with the skewness value of all the items within ± 2 and the kurtosis values of all the items within ± 2. Research contributions are divided into two categories: Firstly, it is the first study to systematically investigate the literature to identify the CSFs for performance integration to develop a new model to predict the performance; Secondly, it can help reduce the human errors and improve the overall performance of power plants. This study, like any research effort, has many limitations and recommendations for future work as follows:

I. SLR noted that most literature studies on improving the PSFs focused on the industrial sectors and nuclear power plants, with an apparent lack of literature on the thermal and gas power plants. Therefore, this article recommends that more research should be conducted to improve the performance of thermal and gas power plants.
II. Apply the CSFs and the conceptual framework with the proposed hypotheses through a case study in the power plants and other industrial sectors.
III. It is recommended that future studies focus on the organizational culture or leadership style/practice as a mediator or moderator to enhance the EMP implementation and performance.
IV. There has been no relevant research on integrating the CSFs for personnel or PSFs and EMP in Iraqi power plants.
V. Integrating the CSFs of energy management ISO 50001 and service quality improvement within quality management programs is recommended to enhance the energy efficiency and successful implementation of the EMs in power plants.
VI. More investigations in the CSFs represented PSFs including teamwork, work overload, time pressure, motivation, commitment, skill flexibility with the maintenance culture, orleadership style/practice as the mediator or moderator to improve the overall performance to enhance and improve the maintenance procedures is required.
VII. No previous studies used the organizational culture as mediators or moderators with the CSFs to successfully implement the energy management plan. Hence, the article recommends testing these factors with the CSFs.
VIII. The study recommends expanding the research sample using the same methodology in thermal power plants and then comparing the results.

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