IMPLEMENTATION ISSUES IN RENOVATION AND MODERNIZATION OF OPERATIONAL THERMAL POWER PLANTS IN INDIA

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by

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Dedicated

To

My Father

CERTIFICATE

This is to certify that the thesis titled "IMPLEMENTATION ISSUES IN RENOVATION AND MODERNIZATION OF OPERATIONAL THERMAL POWER PLANTS IN INDIA" being submitted by Ms. Purnima Barjatya to the Indian Institute of Technology Delhi, (India) for the award of the degree of Doctor of Philosophy is a bonafide record of the research work carried out by her under my guidance and supervision and has fulfilled the requirements for submission of this thesis, which to the best of my knowledge has reached the requisite standard. The results contained in this thesis have not been submitted either in full or in parts to any other University or Institute for the award of any degree or diploma.

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PURNIMA BARJATYA

ABSTRACT

Infrastructure development is a dynamic process; it is multidisciplinary in nature and involves various resources. With the continuous increase in the power demand, there is an inevitable requirement of increasing the supply of power to reduce this demand supply gap.

Almost 70 percent of thermal power plants in India were set up during the late nineties and have been facing the problems of declining efficiency and as recommended by the Central Electricity Authority of India (CEA, 2016) are due for renovation and modernization (R&M). Based on the R&M programme of the Government of India (GoI), CEA in 2013 found units with 36,000 MW of capacity to be over 25 years old, which should either be renovated or retired. In the National Perspective Plan of the CEA under the 12th five-year plan, R&M works for 65 units were identified amounting to approximately 17000 MW. However, the investors and utilities faced many challenges during the planning and implementation of these projects that derailed the objectives of the project and as a result, only 37% of the projects were actually completed on time (CEA 2013). Even though R&M projects were initiated in the mid-nineties and were successful in improving plant efficiency, the actual implementation has not been satisfactory and the reasons for such unsatisfactory performance have not been reported anywhere nor seem to have been documented. Various studies carried out in the past have highlighted one common concern of the poor and deteriorating efficiencies of the thermal power plants in India. However, none of these studies could provide solutions to improve efficiencies of the plants or even check reasons for such deterioration thereof. This motivated the researcher to take up the study in the area of R&M of existing thermal power plants in India.

The aim of the research was to develop a risk management framework to ensure effective implementation of R&M projects, which would act as a tool for utilities, to plan such projects in an efficient manner and ultimately lead to an increase in efficiency of thermal power plants. The research also aimed at generating some standard guidelines for managing the risks identified for ensuring better implementation of the R&M projects in India.

The research included the study of 35 operational thermal power plants, which have undergone R&M at different stages of their life. The study period considered was of ten years between 2006-2016. The Malmquist Productivity Index (MPI) technique of Data Envelopment Analysis (DEA) was used to carry out an efficiency study. The study revealed that even though the overall plant productivity was declining over the ten year time period (2006-2016), the change in the technology/R&M in these plants over the years has contributed positively in enhancement of the plant efficiency. A questionnaire survey and factor analysis approach was therefore undertaken to identify the key risks associated with the implementation of R&M projects in India. Six key risks significantly affecting the rate of implementation of R&M projects in India were identified which included *contractual risks; funding risks; planning risks; regulatory risks; market related risks* and *manpower related risks*. In the study 3 out of 6 risks were found to be the most significant, these are namely, *the contractual risks, planning risks, and manpower related risks.*

These risk factors were then taken up for further analysis and preparation of the risk model using structural equation modelling (SEM) to help the utilities and other stakeholders to understand the interdependencies of risks and their cumulative impact on the rate of implementation of R&M projects. The study also develops strategies for dealing with the key risks associated with implementation of R&M projects in India.

A case study approach was adopted to capture the experiences of various stakeholders and to understand their concerns, challenges and success strategies while planning, managing & implementing R&M projects at national & international level through which the industry best practices were identified. Meetings and consultations with stakeholders were also conducted for formulation of strategies. These industry best practices were taken forward to develop a strategic framework for better implementation of R&M projects, which was subsequently validated by the industry experts before it could be recommended for use. As a result, the study establishes the significance of R&M in the life span of a thermal power plant and its impact on plant efficiency and identifies the major risks faced by various stakeholders during planning and implementation of R&M projects in India. The proposed interdependency risk management model is a significant outcome of the study, which can act as a guideline for various stakeholders for proactive planning for project risks associated with R&M projects in India. Furthermore, the strategic framework for timely mitigation of risks associated with effective planning, management and implementation of R&M projects is a unique contribution made by this study to help utilities effortlessly manage such projects.

Key Words: Thermal power plants, Renovation & Modernization, technological efficiency, Total productivity factor, risk management, strategic framework

सार

अवसंरचना विकास एक गतिशील प्रक्रिया है; यह प्रकृति में बहुआयामी है और इसमें विभिन्न संसाधन शामिल हैं। बिजली की मांग में निरंतर वृद्धि के साथ, इस मांग आपूर्ति अंतर को कम करने के लिए बिजली की आपूर्ति में वृद्धि की एक अनिवार्य आवश्यकता है।

नब्बे के दशक के उत्तरार्ध में भारत में लगभग 70 प्रतिशत थर्मल पावर प्लांट स्थापित किए गए थे और घटती दक्षता की समस्याओं का सामना करना पड़ रहा था और जैसा कि सेंट्रल इलेक्ट्रिसिटी अथॉरिटी ऑफ इंडिया (सीईए, 2016) द्वारा सिफारिश की गई है, नवीकरण और आधुनिकीकरण (आर एंड एम) के कारण है। भारत सरकार (आरओआई) के आरएंडएम कार्यक्रम के आधार पर, 2013 में सीईए ने 36,000 मेगावाट क्षमता वाली इकाइयाँ 25 साल से अधिक पुरानी पाईं, जिन्हें या तो पुनर्निर्मित या सेवानिवृत्त किया जाना चाहिए। 12 वीं पंचवर्षीय योजना के तहत सीईए की राष्ट्रीय परिप्रेक्ष्य योजना में, 65 इकाइयों के लिए आरएंडएम कार्यों की पहचान लगभग 17000 मेगावाट की गई थी। हालांकि, निवेशकों और उपयोगिताओं को इन परियोजनाओं की योजना और कार्यान्वयन के दौरान कई चुनौतियों का सामना करना पड़ा जो परियोजना के उद्देश्यों से निकले थे और परिणामस्वरूप, केवल 37% परियोजनाएं वास्तव में समय पर पूरी हुईं (सीईए 2013)। भले ही आर एंड एम परियोजनाएं नब्बे के दशक के मध्य में शुरू की गईं और संयंत्र की दक्षता में सुधार करने में सफल रहीं, वास्तविक कार्यान्वयन संतोषजनक नहीं रहा है और इस तरह के असंतोषजनक प्रदर्शन के कारणों को कहीं भी रिपोर्ट नहीं किया गया है और न ही ऐसा लगता है कि दस्तावेज किए गए हैं। अतीत में किए गए विभिन्न अध्ययनों ने भारत में थर्मल पावर प्लांटों की खराब और बिगड़ती क्षमताओं की एक आम चिंता को उजागर किया है। हालांकि, इन अध्ययनों में से कोई भी पौधों की क्षमता में सुधार करने या इस तरह के बिगड़ने के कारणों की जांच करने के लिए समाधान प्रदान नहीं कर सका। इसने शोधकर्ता को भारत में मौजूदा ताप बिजली संयंत्रों के अनुसंधान और विकास के क्षेत्र में अध्ययन करने के लिए प्रेरित किया।

अनुसंधान का उद्देश्य आर एंड एम परियोजनाओं के प्रभावी कार्यान्वयन को सुनिश्चित करने के लिए एक जोखिम प्रबंधन ढांचा विकसित करना था, जो उपयोगिताओं के लिए एक उपकरण के रूप में कार्य करेगा, ताकि इस तरह की परियोजनाओं को एक कुशल तरीके से योजना बनाई जा सके और अंततः थर्मल पावर प्लांट की दक्षता में वृद्धि हो सके। अनुसंधान का उद्देश्य भारत में आर एंड एम परियोजनाओं के बेहतर कार्यान्वयन को सुनिश्चित करने के लिए पहचाने गए जोखिमों के प्रबंधन के लिए कुछ मानक दिशानिर्देशों का निर्माण करना है।

अनुसंधान में 35 परिचालन ताप बिजली संयंत्रों का अध्ययन शामिल था, जो उनके जीवन के विभिन्न चरणों में आर एंड एम से गुजरे हैं। माना जाता है कि 2006-2016 के बीच अध्ययन की अवधि दस वर्ष थी। मैल्मक्विस्ट प्रोडक्टिविटी इंडेक्स (MPI) तकनीक का डेटा एनवेलपमेंट एनालिसिस (DEA) एक दक्षता अध्ययन करने के लिए इस्तेमाल किया गया था। अध्ययन से पता चला कि भले ही कुल संयंत्र उत्पादकता में दस साल की समयावधि (2006-2016) से अधिक गिरावट आ रही थी, लेकिन वर्षों से इन पौधों में प्रौद्योगिकी / आरएंडएम में परिवर्तन ने संयंत्र की दक्षता बढ़ाने में सकारात्मक योगदान

दिया है। एक प्रश्नावली सर्वेक्षण और कारक विश्लेषण दृष्टिकोण इसलिए भारत में अनुसंधान एवं विकास परियोजनाओं के कार्यान्वयन से जुड़े प्रमुख जोखिमों की पहचान करने के लिए किया गया था। भारत में आर एंड एम परियोजनाओं के कार्यान्वयन की दर को प्रभावित करने वाले छह प्रमुख जोखिमों की पहचान की गई, जिनमें अनियंत्रित जोखिम शामिल थे; धन का जोखिम; जोखिम की योजना बना; नियामक जोखिम; बाजार से संबंधित जोखिम और जनशक्ति से संबंधित जोखिम। अध्ययन में 6 में से 3 जोखिमों को सबसे महत्वपूर्ण पाया गया, ये हैं, संविदात्मक जोखिम, योजनागत जोखिम, और जनशक्ति के अन्य जोखिम।

इन जोखिम कारकों को तब आगे के विश्लेषण और जोखिम मॉडल की तैयारी के लिए संरचनात्मक समीकरण मॉडलिंग (एसईएम) का उपयोग करके उपयोगिताओं और अन्य हितधारकों को जोखिम और अनुसंधान परियोजनाओं की कार्यान्वयन की दर पर निर्भरता और उनके संचयी प्रभाव को समझने में मदद करने के लिए लिया गया था। यह अध्ययन भारत में अनुसंधान एवं विकास परियोजनाओं के कार्यान्वयन से जुड़े प्रमुख जोखिमों से निपटने के लिए रणनीति भी विकसित करता है। विभिन्न हितधारकों के अनुभवों को पकड़ने और राष्ट्रीय और अंतर्राष्ट्रीय स्तर पर अनुसंधान एवं विकास परियोजनाओं की योजना, प्रबंधन और कार्यान्वयन करते समय उनके हित, चुनौतियों और सफलता की रणनीतियों को समझने के लिए एक दृष्टिकोण अध्ययन दृष्टिकोण अपनाया गया, जिसके माध्यम से उद्योग सर्वोत्तम प्रथाओं की पहचान की गई। हितधारकों के साथ बैठकें और परामर्श भी रणनीतियों के निर्माण के लिए किए गए थे। इन उद्योगों को आर एंड एम परियोजनाओं के बेहतर कार्यान्वयन के लिए एक रणनीतिक रूपरेखा विकसित करने के लिए सर्वोत्तम प्रथाओं को आगे बढ़ाया गया था, जिसे बाद में उद्योग के विशेषज्ञों द्वारा उपयोग के लिए अनुशंसित किए जाने से पहले मान्य किया गया था। नतीजतन, अध्ययन एक थर्मल पावर प्लांट के जीवन काल में आरएंडएम के महत्व को स्थापित करता है और पौधों की दक्षता पर इसके प्रभाव और भारत में आरएंडएम परियोजनाओं की योजना और कार्यान्वयन के दौरान विभिन्न हितधारकों द्वारा सामना किए गए प्रमुख जोखिमों की पहचान करता है। प्रस्तावित अन्योन्याश्रयता जोखिम प्रबंधन मॉडल अध्ययन का एक महत्वपूर्ण परिणाम है, जो भारत में अनुसंधान एवं विकास परियोजनाओं से जुड़े परियोजना जोखिमों के लिए सक्रिय योजना के लिए विभिन्न हितधारकों के लिए एक दिशानिर्देश के रूप में कार्य कर सकता है। इसके अलावा, अनुसंधान और विकास परियोजनाओं के प्रभावी नियोजन, प्रबंधन और कार्यान्वयन के साथ जुड़े जोखिमों के समय पर शमन के लिए रणनीतिक ढांचा इस तरह के उपयोगिताओं को आसानी से ऐसी परियोजनाओं का प्रबंधन करने में मदद करने के लिए इस अध्ययन द्वारा किया गया एक अनूठा योगदान है।

मुख्य शब्द: थर्मल पावर प्लांट, नवीनीकरण और आधुनिकीकरण, तकनीकी दक्षता, कुल उत्पादकता कारक, जोखिम प्रबंधन, रणनीतिक ढांचा

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ABBREVIATIONS

BEE	Bureau of Energy Efficiency
BHEL	Bharat heavy electricals limited
BTPS	Barauni Thermal Power Station‘s
BCC	Banker, Charnes and Cooper
BSEB	Bihar State Electricity Board
BTG	Boiler, generator and turbine
BAU	Business as usual
CFI	Comparative fit index
CCR	Charnes, Cooper and Rhodes
CRS	Constant return to scale
CEA	Central electricity authority
CERC	Central electricity regulatory commission
CRISIL	Credit Rating Information Services of India Limited
DEA	Data envelopment analysis
DPR	Detailed project report
DMU	Decision making unit
ESP	Electrostatic precipitator
EFA	Exploratory factor analysis
EFFCH	Efficiency change

FA	Factor analysis
GCV	Gross calorific value
GSECL	Gujarat State Electricity Corporation Limited
GOI	Government of India
KMO	Kaiser-Meyer-Olkin
KBUNL	Kanti Bijlee Utpadan Nigam Ltd
MPI	Malmquist productivity index
MYT	Multi-Year Tariff
MAHAGENCO	Maharashtra Power Generation Corporation Ltd.
MPPGCL	Madhya Pradesh power generating company limited
MOP	Ministry of Power
MCDM	Multi-criteria decision making
NTPC	National Thermal Power Corporation
O&M	Operation & maintenance
ONGC	Oil and Gas Corporation
PCA	Principal component analysis
PECH	Pure technical efficiency change
PLF	Plant load factor
PIE	Partnership in Excellence
R&M	Renovation & modernization
RMSEA	Root mean square error of approximation
RLA	Residual life analysis
ROR	Rate of return
SEB’S	State Electricity Boards
SWOT	Strengths, weakness, opportunities and threats

SEM	Structural equation modelling
SERC	State electricity regulatory commission
SECH	Scale efficiency change
SFA	Stochastic frontier analysis
TFPCH	Total factor productivity change
TPE	Techno Prom Export
UPRVUNL	Uttar Pradesh Rajya Vidyut Utpadan Nigam Limited
VRS	Variable return-to-scale
WBG	World Bank Group

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GLOSSARY

AUXILIARY POWER CONSUMPTION: The amount of energy, which is consumed by auxiliary equipment of the generating units.

COAL BASED THERMAL POWER PLANT: Plants, which produce electricity by burning coal in a boiler to produce steam. The steam produced, flows into a turbine, which spins a generator to create electricity.

COMPETITIVE BIDDING:A transparent process adopted by different authorities for engineering, procurement and services by inviting bids for the project by open advertisements covering the entire scope and specifications required for the project, and the terms and conditions based on which the bids shall be evaluated.

CONSTANT RETURNS TO SCALE (CRS): A scale used in data envelopment analysis (DEA) which indicates if an increase in inputs results in a proportionate increase in the output levels or not.

EFFICIENCY: The ratio between the maximum amounts of output that can be produced by a minimum amount of inputs.

GENERATING STATION means any station for generating electricity, including any building and plant with step-up transformer, or a site intended to be used for a generating station, and any building used for housing the operating staff of a generating station, and where electricity is generated.

INFRASTRUCTURE PROJECT: The basic physical and organizational structures and facilities needed for the operation of a society

LIFE EXTENTION PROGRAM (LE): It is a major event in the life of a thermal power station, as it envisages extension of life over a considerable period of time beyond its designed life.

OPERATION & MAINTAINANCE (O&M): Planning of operation, performing daily operations, plant maintenance, material and resource management and continual improvement.

PLANT LOAD FACTORY (PLF): The ratio between the actual amount of energy generated by a plant to the maximum possible energy that can be generated by the plant working at its rated capacity and for duration of one complete year.

PANEL DATA: The multi-dimensional data frequently involving measurements over time. Panel data contain observations of multiple phenomena obtained over multiple time periods for the same firms or individuals.

PRODUCTIVITY The actual output per unit of input at a particular time.

PURE TECHNICAL EFFIEICENCY (*pech):* *A* measure of how the inputs and outputs are being managed by the DMU/utility/owner.

RESIDUAL LIFE ASSESSMENT (RLA) A systematic study involving destructive and non-destructive tests that help in revealing the remaining life of various critical components of plants and equipment.

RENOVATIONS & MODERNIZATION (R&M): An activity of carrying out repairs, refurbishments and replacement of defective equipment & components to extend the life of the power plant by at least 20 years and to restore the performance parameters to equal or better than the original design parameters.

TOTAL FACTOR PRODUCTIVITY CHANGE *(tfpch):* Measure of how much productivity has grown or declined over a period of time.

VARIABLE RETURNS TO SCALE (VRS): A scale used in data envelopment analysis (DEA) which estimates whether an increase or decrease in plant input or outputs results in a proportional change in the outputs or inputs respectively.

SCALE EFFICIENCY *(sech):* A measure of the capacity of the DMU to optimize the size of resources and the scale of production that will help in attaining the anticipated design production level.