RISK MODEL FOR ELECTRICAL AND INSTRUMENTATION INSTALLATION FOR POWER GENERATION SYSTEM ONBOARD SHIP

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To my beloved wife and children

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ABSTRACT

Installation of electrical and instrumentation of power generation system onboard ship is not without risk. Risks exist in many stages of the installation process and may lead to system failure. For decades it has been accepted by all the installation engineers representing the shipowner, the shipyard, the equipment manufacturer and the classification society that risk from each of the six main installation stages namely site preparation (P1), installation of prime mover and alternator (P2), cabling works including laying and termination (P3), installation of instrumentation equipment and accessories (P4), system interfacing and integration (P5) and system testing and commissioning (P6) is remote and independent. Separate contractors are engaged for each of the first four stages and without the knowledge that risk from one stage may be connected to the next immediate stage and may finally accumulate to cause total system failure. Data were collected using questionnaires and analysed using Statistical Package for Social Science (SPSS). Descriptive analysis is used to determine the level of risk, Pearson Chi Square method is used to check risk dependency and Pearson r^2 method is used to check correlations between risks. The aim is to verify the correct sequence of installation stages, their levels or risk, risks' dependencies and correlations and finally develop the failure model for the installation process. The research has verified and later validated using data from Bunga Seroja ship that P1, P2, P3, P4, P5 and P6 are in that right order. The respondents agree that risks for P1, P2, P3 and P4 are low (mean of 1.71 to 2.10 corresponding to "Agree" on the Likert scale used) while P5 and P6 are high (mean of 2.0 and 1.73 respectively). Risk on P2 is dependent on risk on P1, P3 is dependent on P2, P4 is dependent on P3, P5 is dependent on P4 and P6 is dependent on P5. There are strong correlations between the risks as indicated by the relatively high r^2-value between P1 and P2 is 0.648, 0.774 between P1 and P3, 0.684 between P1 and P4, 0.654 between P2 and P3, 0.676 between P2 and P4, 0.673 between P3 and P4 and 0.519 between P5 and P6. The model developed indicates that the installation process will fail when P5 or P6 fails.

ABSTRAK

Pemasangan sistem penjanaan kuasa elektrik dan instrumentasi di atas kapal adalah berisiko. Risiko wujud dalam banyak peringkat proses pemasangan dan boleh menyebabkan kegagalan sistem. Berdekad lamanya, jurutera-jurutera pemasangan yang mewakili pemilik kapal, limbungan, pengilang perkakasan dan badan klasifikasi menerima bahawa risiko dari setiap peringkat pemasangan utama iaitu penyediaan tapak(P1), pemasangan penggerak utama dan alternator(P2), kerja-kerja kabel termasuklah pemasangan dan penamatan(P3), pemasangan perkakasan instrumentasi dan aksesori(P4), sistem pengantaramukaan dan penyepaduan(P5) dan pengujian sistem dan pentauliahan(P6) bebas dan terpisah. Kontraktor yang berasingan ditugaskan bagi empat peringkat pertama pemasangan. Tanpa menyedari, risiko pada satu peringkat mungkin berkait dengan peringkat yang berikutnya dan akhirnya boleh menyatu dan menyebabkan kegagalan menyeluruh. Data dikumpulkan melalui borang soal selidik dan dianalisa menggunakan perisian Statistical Package for Social Science (SPSS). Analisis deskriptif digunakan bagi menentukan tahap risiko, kaedah Pearson Chi Square digunakan untuk memeriksa kebergantungan risiko dan kaedah Pearson r^2 digunakan untuk memeriksa hubungkait antara risiko. Matlamatnya untuk mengesahkan urutan peringkat pemasangan yang tepat, tahap-tahap risiko, kebergantungan dan hubungkait antara risiko dan akhir sekali menghasilkan model kegagalan bagi proses pemasangan. Kajian mengesahkan bahawa P1, P2, P3, P4, P5 dan P6 adalah urutan yang tepat. Responden bersetuju risiko bagi P1, P2, P3 dan P4 adalah rendah (min 1.71 ke 2.10 bersamaan "Setuju" pada skala Likert), manakala risiko bagi P5 dan P6 adalah tinggi (min masing-masing 2.0 dan 1.73). Risiko P2 bergantung pada risiko P1, P3 bergantung pada P2, P4 bergantung pada P3, P5 bergantung pada P4 dan P6 bergantung pada P5. Hubungkait yang kuat antara risiko ditunjukkan oleh nilai r^2 yang berbanding tinggi diantara; P1 dan P2 iaitu 0.648, P1 dan P3 iaitu 0.774, P1 dan P4 iaitu 0.684, P2 dan P3 iaitu 0.654, P2 dan P4 iaitu 0.676, P3 dan P4 iaitu 0.673 dan diantara P5 dan P6 iaitu 0.519). Model yang terhasil menunjukkan proses pamasangan akan gagal bila P5 dan P6 gagal.

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LIST OF ABBREVIATIONS

AVR	Automatic Voltage Regulator
CDF	Cumulative distribution function
D1	Minor degrade failure minor crack
D2	Major degraded failure large crack
DNA	Do not Agree
EFCS	Electrical Flight Control System
F1	Failure due to degradation
F2	Shock failure
FMEA	Failure Modes and Effect Analysis
GSAM	General service Administrative Acquisition Manual
Hz	Frequency
ITW	Illinois Tools Works
MA	Moderately Agree
MBPC	Model based prediction control
MSB	main switch board
MTTF	Mean time to failure
N	The number of components (engines)
OFC	Oscillatory Failure Cases
OK	Good state.
P(f)	1 – P(s), the probability that one component fails.
P(F)	1 – P(S), the probability that the system fails.
P(s)	The probability that one component is successful
P(S)	The probability that the system (the entire) is successful

P1	Site Preparation
P2	Prime Mover and Alternator installation
P3	Cabling works
P4	Instrumentation and accessories installation
P5	Interface and integration
P6	Testing and commissioning
PDF	Probability density function
PMS	Power Management System
$R(t)$	The probabilistic reliability function, $R(t)$.
SA	Strongly Agree
SPSS	Statistical Package for Social Science
TTF	Time to Fail
UIC	Ultrasonic Inspection car
VSA	Very strongly agree
$z(t)$	The probabilistic failure rate function $z(t)$.

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CHAPTER 1

INTRODUCTION

1.1 Background

This thesis reports a study to develop a failure model for the installation of electrical and instrumentation system for power generation onboard ship. Ensuring the successful installation for electrical and instrumentation for power generation system onboard ships has been of great concern to ship owners as it is crucial to the safe operation of the vessels. Installation of electrical and instrumentation for power generation system onboard vessel is not without risk and each risk may lead to undesirable consequences on the vessel's operation, maintenance and commercial performance. Research on detailed installation process and the associated level of risk needs further attention to minimize the risk of failure. Risk associated with the installation process need to be studied and identified in ensuring successful implementation of electrical and instrumentation installation of power generation on board ship. Premature failure of electrical and instrumentation system during ship operation is a major concern.

Poor workmanship during installation could result in fatal failure to the power system onboard ship. For example failure of wiring could cause damage to other ship system and ignited flammable material within the close proximity and could result in the loss of life and property.

CHAPTER 1

INTRODUCTION

1.1 Background

This thesis reports a study to develop a failure model for the installation of electrical and instrumentation system for power generation onboard ship. Ensuring the successful installation for electrical and instrumentation for power generation system onboard ships has been of great concern to ship owners as it is crucial to the safe operation of the vessels. Installation of electrical and instrumentation for power generation system onboard vessel is not without risk and each risk may lead to undesirable consequences on the vessel's operation, maintenance and commercial performance. Research on detailed installation process and the associated level of risk needs further attention to minimize the risk of failure. Risk associated with the installation process need to be studied and identified in ensuring successful implementation of electrical and instrumentation installation of power generation on board ship. Premature failure of electrical and instrumentation system during ship operation is a major concern.

Poor workmanship during installation could result in fatal failure to the power system onboard ship. For example failure of wiring could cause damage to other ship system and ignited flammable material within the close proximity and could result in the loss of life and property.

Therefore research on risk and failure for electrical and instrumentation installation process during installation process will have significant impact for ship operation. It plays as an important starting point towards maintain a system with minimum risk. It also allows installation-related risks to be closely observed and monitored during system installation.

It is a normal practice, yet optional, for engineering practitioners in industry to use Failure Modes and Effect Analysis (FMEA) to address risk. FMEA (Teoh et al., 2004) is quality improvement and risk assessment tool commonly used in industry. FMEA captures design and process failure information. Additionally, model based prediction control (MBPC) have been proposed by Clarke *et al.* (1987) Camacho *et al.* (1995) and Hansen (2000). MBPC is claimed as able to control risk of failure by further improving the resistant to faults, safety, reliability and durability of all machinery components, as well as to decrease overall operational costs. Risk model for electrical and instrumentation installation of power generation system is to prove similar objectives based as MBPC.

Investigative effort on risk associated with electrical and instrumentation installation process has not been the focus of system manufacturer, supplier, shipyard or even ship owner. This research is also a guide to study, capture risk data related to installation process for electrical, and instrumentation installation of power generation system onboard ship. A failure model should be developed to show which of the installation subprocesses are likely to contribute to total system failure.

1.2 Problem statement

System failure during the installation of electrical and instrumentation (E&I) installation for power generation onboard ship is to be avoided as it can directly cause delay to ship construction and financial implication. System failure during ship operation originating from installation problems could lead to similar effects. Therefore, risk elements associated with the installation of electrical and instrumentation installation for power generation needs to be identified and the individual risk level recognised.

A failure model showing the process of installing electrical and instrumentation system for power generation onboard ship detailed with risks level and their interrelationship will assist installation and supervision engineers on site. Supervision focus can be directed to critical stages of the installation process so that risk can be minimized and system failure can be avoided.

1.3 Objectives of study

The objectives of the research is to develop a risk model for electrical and instrumentation installation of power generation system onboard ship that identifies the related risk elements such as component damage, malfunction, and premature and total system failure, describes the statistical correlation between risk elements and indicates critical sub processes and path of possible system failure.

1.4 Scope of study

The scope of this research covers installation process starting from the generator being brought to site for actual installation until the completion of system integration process between the prime mover and alternator (generator) and main switch board (MSB) for electrical power distribution. Risk data covers risk type and risk level for each of the subprocesses of installing electrical and instrumentation for power generation system onboard ship.

The methodology of developing the failure model is based on failure models developed by others but there have been needs to adapt and combine the various models into one unified system model. Model presentation is using the waterfall model that illustrated using Boehm’s waterfall model.

The failure model described by a flow chart also intends to differentiate the steps and process during the installation of electrical and instrumentation for power generation system onboard ship.

1.5 Significance of study

The failure model and its protocol include six main steps:

i. Site preparation – foundation of the prime mover and alternator
ii. Prime mover and alternator placement onto the bedplate and foundation
iii. Cabling works includes the termination of cables to each individual system and field devices.
iv. Instrumentation and accessories, fixing of the pressure sensors, temperature sensors input, gauges, salinometer, input and output controllers.
v. Interface and integration of electrical and mechanical system to the control system
vi. Testing and commissioning of the power generation system for power distribution.

The model developed is a tool to identify the risk and failure categories that is fundamental to various electrical and mechanical equipment installation processes. This generic risk model for electrical and instrumentation installation for power generation system onboard ship, is suitable to be applied to other machineries installation process. As such the research finding will become a useful tool to confirm the risk model for electrical and instrumentation installation of power generation system onboard ship. Young engineers can use the failure model as a tool for supervising and monitoring the installation process of the power generation system and guide them to be efficient in managing the project. The research will have significance impact to the engineers during installation process, preventive measure, cause, consequences and recovery.

1.6 Research framework

The research approach is based upon established failure modeling concepts, for which risk elements are identified to help eliminate and rectify inference elements to avoid fatal failure of installation. Thus, model-driven techniques enriched with known problems based on literature, experience and expert advised representation are the important ingredients. In depth analysis has been injected for the identification, interpretation and adaptation of the proposed model.

The installation failure model has been developed with reference to existing concepts used for various industries and applications such as the waterfall concept, spiral model concept, v-model and dual-v model. The model developed has not been limited to one but rather the combination of various failure modeling concepts suitable for electrical and instrumentation for power generation onboard ship.

The research adopts the failure modeling approach used by Cushing et al, (1993) and as below:

i. Identifying potential failure during installation process mechanisms (chemical, electrical, physical, mechanical, structural or thermal processes leading to failure); failure sites; and failure modes.

ii. Identifying the appropriate failure model and their input parameters, including those associated with material characteristics, damage properties, relevant geometry at failure sites, manufacturing flaws and defects, and environmental and operating loads.

Building up the model has been based on published information, and also experience and expert advice captured using survey questionnaire. It is the instrument and tools to identify the risk element and critical point during the installation process that can post a major risk to the system. Due consideration has been given to failure analysis done by previous researchers some of which are based on experiment or lab test, especially for electrical component or equipment. Majority of these failure models are the reliability failure model, aging failure model, maintenance and operation of the equipment and instrumentation for electrical system. Almost none has been developed to study the failure model for the installation of electrical and instrumentation installation of power generation system onboard ship. Lab test and experiment as the common practice to study the reliability of the equipment for electrical and instrumentation system is not the approach selected. Observation for the characteristic and reliability of the equipment based on the experiment set criteria defined for the test. The result and model shown from the experiment by Banerjee & Cheung (1997) is an excellent resemblance of what has been developed.

1.7 Thesis Structure

This thesis consists of six chapters and followed by references and appendices. Chapter 1 explains the overview of this research that outlines the objective, the problem statement, scope of the study and significance of study. Chapter 2 discusses the relevant literature pertaining to failure model. Chapter 3 describes the methodology and tools to develop the failure model. Chapter 4 outlines the result and report based the study, experience and expert advice. Chapter 5 and Chapter 6 each discusses and concludes the study on failure model developed for electrical and instrumentation installation for power generation onboard ship. The appendices contain some terminology, detail about the survey questionnaire and reports.

REFERENCES

Aalen, O., (1995), Phase Type Distributions in Survival Analysis, Scandinavian Journal of Statistic, Vol. 22, pp. 447-463.

Abu, M.S, and Tasir, Z, (2001), Pengenalan Kepada Analisis Data Berkomputer SPSS 10.0, Venton Publishing, Kuala Lumpur.

Ådnanes, A.K, (2003), Maritime Electrical Installations and Diesel Electric Propulsion, *Tutorial Report*, ABB AS Marine.

Banerjee, K. and Cheung, N, (1997), High-Current Failure Model for VLSI Interconnects Under Short-Pulse Stress Conditions, IEEE ELECTRON DEVICE LETTERS, Vol. 18, No. 9, September.

Ben-Haim, Y, (2005), .Lecture Notes on Probabilistic Failure Model, Faculty of Mechanical Engineering, Israel Institute of Mechanical Engineering.

Bukowski, J. V, Rouvroye, J. and Goble, M. W, (2002), Social Research Theory, Methods and Techniques,

Camacho, E.F., and Bordons, C., (1995), Model Predictive Control in the Process Industry, Springer-Verlag.

Centurion Generic Power system Incorporation, (2008), Centurion Generic Power system Inc, Part No. 0G8679, Revision C (05/22/08), Catalog No. IM-ASPCA-S-01, U.S.A

Clarke, D.W., Mohtadi, C., and Tuffs, P.S., (1987), Generalized predictive control - Part I: The Basic Algorithm, Automatica, 23(2), Page 137-148.

Cooke, R.M, (1996), The Design of Reliability Data Bases. Part I. Review of standard design concepts, Reliability Engineering and System Safety, Vol. 51, No. 2, pp. 137-146,

Crowder, M .J, Kimber, A.C, Smith, R.L, and Sweeting, T.J, (1991), Statistical Analysis of Reliability Data, Chapman and Hall, London.

Cushing, M. D, Mortin, T. S, and Malhotra, A., (1993), Comparison of Electronics-Reliability Assessment Approaches, *IEEE Transactions on Reliability*, Vol. 42, No.4, pp. 542-546.

Elavsky, T, (2007), A Condensed Guide to Automation Control System Specification, Design and Installation, Part 1: System Identification and Safety: Automation Direct, www.automationnotebook.com

Five Star Products Inc., (2009), MARINE EPOXY CHOCK High Performance (Highly Chemical Resistant Epoxy Coating Horizontal Applications) Product Guide (07/01/09) American Owned & Operated.

Gavrilov, L. A. and Gavril, N. S., (2006), Models of Systems Failure in Aging, Handbook of Models for Human Aging

Gavrilov, L. A., and Gavrilova, N. S. (2006). Reliability theory of aging and longevity. Handbook of the Biology of Aging, 6, 3-42.

GSAM (Guideline for Successful acquisition & Management of Software) Handbook, (2003), Chapter 14.4: System Integration, Testing & Acceptance.

Hansen, J.F., (2000), Modeling and Control of Marine Power Systems, Doctor Thesis, Norwegian University of Science and Technology, Department of Engineering cybernetics, Trondheim, Norway.

Hokstad, P., Langseth, L., Lindqvist, B.H. ogVatn, J., (2005), *Failure modeling and maintenance optimization for a railway line*. International Journal of Performability Engineering 1(1): 51-64,

Icemaster Fischer Panda, (2005), Marine Generator Panda PMS 8 'mini' E-TEC 120V – 60 Hz, Fischer Panda Installation Manual: Installation, Maintenance, and Troubleshooting.

Illinois Tool Works (ITW), (2004), Standard Chock Design for Integral Gas Compressor Engines Bulletin No. 643E, Page 3.

Kling, A. (2009), AP Statistical Lecture, *http://arnoldkling.com/apstats/failure.html*., unpublished.

Knudsen, J.K., and Smith, C.L., (2002), Estimation of System Failure Probability Uncertainty Including Model Success Criteria, PROCEEDINGS OF THE 6TH INTERNATIONAL CONFERENCE ON PROBABILISTIC SAFETY ASSESSMENT AND MANAGEMENT (PSAM).

Kohler Power System, (2009), Kohler Power SystemMarine Generator set Operation and Installation Manual, TP-5592 7/96a, unpublished.

Krejcie, R.V., and Morgan, D.W., (1970), Determining sample size for research activities, Educ Psychol Meas.

McClave, J.T., Benson, P.G. and Sincich, T., (2001), Statistics for Business and Economics. , Prentice-Hall, Inc., Upper Saddle River, New Jersey 07458.

Rausand, M. and Høyland, A., (2004), System Reliability Theory - Models, Statistical Methods.and Applications, 2nd Edition.

Rigdon, S. E., and Basu, A. P., (2000), Statistical Methods for the Reliability of Repairable Systems, Wiley, New York

Siegel, S. and John C.N, (1988), Nonparametric Statistics for the Behavioral Sciences, Second Edition, McGraw-Hill, United States of America.

Sørensen, A. J., Ådnanes, A. K., Fossen, T. I. and Strand, J. P., (1997), A New Method of Thruster Control in Positioning of Ships Based on Power Control, Proceedings of 4th IFAC Conference on Maneuvering and Control of Marine Craft (MCMC'97), pp. 172-179, Brijuni, Croatia.

Teoh, P.C., and Case, K., (2004), Modelling and Reasoning for Failure Models and Effects Analysis Generation, Proc. Instn Mcch. Engrs Vol. 218 part B: J. Engineering Manufacture, IMcchE.

Wärtsilä, (2006), Wartsila 50DF Project Guide Lib Version: a1416, unpublished.

Zukarnain, Z, (2001), Analisis Data Menggunakan SPSS Windows. Universiti Teknologi Malaysia, unpublished.