

시스템 별 주요 측정값 조사

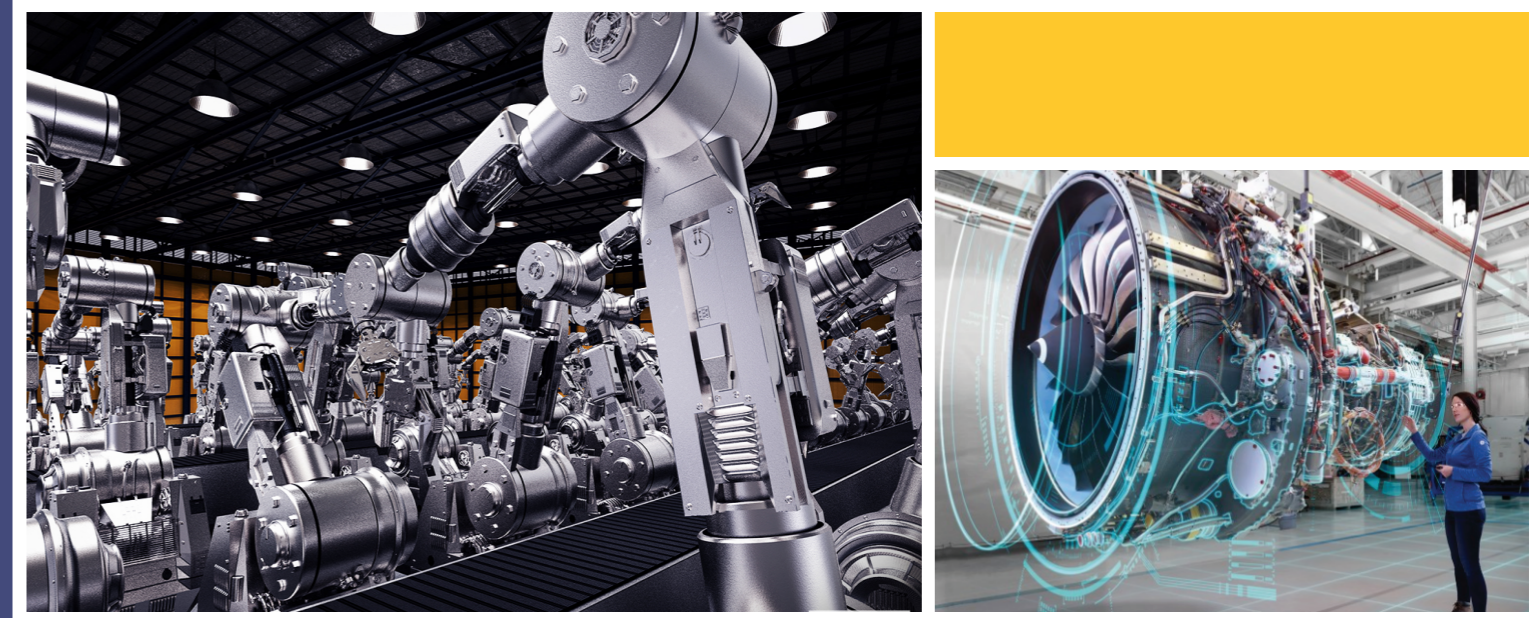
| 핵심설비부 | 고장부품 | Vibration | Thermography | Oil Analysis | Process Parameter | Performance | Acoustic Monitoring | Electrical Monitoring |
|---------|-----------------------|-----------|--------------|--------------|-------------------|-------------|---------------------|-----------------------|
| 에너지/전원부 | Power supply | D | P | D | - | - | - | D |
| | Transformer | D | - | M | - | - | M | M |
| | Energy storage system | - | M | - | - | - | - | M |
| 유공압부 | Cylinder | P | M | M | - | - | P | - |
| | Valve | D | P | - | D | M | M | - |
| 제어부 | PLC | - | - | - | - | - | - | D |
| | Inverter | - | D | - | - | - | - | D |
| | Switch | - | - | - | - | - | - | D |
| | Cable | - | - | - | - | D | D | D |
| 구동부 | Motor | M | M | - | M | M | D | M |
| | LM Guide | D | - | - | - | - | D | - |
| | Hydraulic supply | M | M | M | M | M | - | - |
| 동력전달부 | Reducer | M | - | M | - | M | D | D |
| | Ball screw | D | D | - | D | - | - | D |
| | Chain & Belt | P | - | - | - | - | P | - |
| | Gear | M | - | M | - | D | D | D |
| | Bearing | M | M | M | - | - | M | D |
| 가공부 | Mechanical tool | M | - | - | M | M | D | D |
| | Electrical tool | - | - | - | - | - | - | - |

M: Mature and commonly applied in industrial applications. (Ref: ISO 13379-1: CM and D of machines-Data interpretation and diagnostics techniques)
 D: Under development and some initial applications.
 P: Promising and potential.

지능형 생산설비 고장예지관리 핵심기술 개발

Development of Core Technologies for
Fault Prognostics and Management of Smart Manufacturing Systems

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(10067284, 지능형 생산설비 고장예지관리 핵심기술 개발)

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스마트공장 6대 핵심설비 고장예지관리 표준 아키텍처

| No. | 핵심설비부 | 세부 No. | 고장부품 | 고장모드 | 측정값 | 특성인자 | 고장진단 기법 | | 고장예지 기법 | | 고장부품 추가설명 | | | | | | | | |
|--------|-------------------------------|-----------------|--------------|---|--|---|---|---|--|--|--|---|--|-------------------------|--|---|---------------------|---|------------------------------|
| | | | | | | | 롤/물리 기반 | 데이터 기반 | 롤/물리 기반 | 데이터 기반 | | | | | | | | | |
| 1 | 에너지/전원부 | 1) | Power supply | 단락 | 진동 | TDF [1], FDF [1] | - | Back propagation NN [95], Random forest [96] | Equivalent series resistance process modeling [159] Physics-based component aging models [160] Particle Filter [161] | Simple state-based method [162] Gaussian Process Regression [163] | 전원 공급장치 | | | | | | | | |
| | | 2) | Transformer | 단락 | 가스 | DGC [2] [3] | Fuzzy logic [97][98][101], Association rule-mining (ARM) classifier [105] | k-NN [99] Back propagation NN [99] ANN [101] Multi-layer SVM [100][101] Gene expression programming (GEP) [101] | Perks' Hazard Function [164] Population prediction model [165] Bayesian Particle Filter [166] | Logistic Regression [167] | 변압기 | | | | | | | | |
| | | | | 부분방전 | 부분방전 | FDF [4] [5] | | | | | | | | | | | | | |
| 기계적손상 | 임피던스 | R, L, C [6] [7] | 진동 | TDF, FDF [8] [9] [10] [11] | | | | | | | | | | | | | | | |
| 3) | Energy storage system | 단락 | 임피던스 | R, L, C [12] | Discrete event system model [102], Residual generation by Kalman filter (KF) [103], Extended Kalman filter (EKF) [104], Thermal modeling [105] | Functional SVM [106], Correlation assessment [107] | Extended Kalman Filter [168][169] Particle Filter [170][171][172] | Gaussian Process Regression [173] | 배터리 등 | | | | | | | | | | |
| | | | 전압 | TDF [13] | | | | | | | | | | | | | | | |
| 2 | 유공압부 | 4) | Cylinder | 마모 | 진동 | TDF [14] | Thermodynamic process modeling [108] | RBF kernel SVM [109], k-NN [109], Back propagation NN [109][110], ANN [111][112], Genetic NN [112] | Kernel Regression [174] | 유공압 실린더 | | | | | | | | | |
| | | | | | 오일 | empirical parameters [15] | | | | | | | | | | | | | |
| | | | | | 온도 | TDF [16] | | | | | | | | | | | | | |
| | | | | | 저항 | TDF [16] | | | | | | | | | | | | | |
| 5) | Valve | 마모 | 진동 | entropy [17], SF [18] empirical parameters [19] [20] | Probabilistic NN [113], NN ensemble [114], ANN [115] | Particle Filter [175][176] Kalman Filter [177] Valve fluid flow mode [178] Gamma process model [179] | Neural Network [180] | 각종 밸브류(Gate, Angle, Pneumatic 등) | | | | | | | | | | | |
| | | | AE | TDF [21] | | | | | | | | | | | | | | | |
| | | | 음향 | SF [18] | | | | | | | | | | | | | | | |
| | | | 압력 | PV Diagram [22] | | | | | | | | | | | | | | | |
| 크랭크 속도 | TDF [23] | | | | | | | | | | | | | | | | | | |
| 3 | 제어부 | 6) | PLC | 오작동 | system on/off | - | Petri-net [116], State transition diagram [117] | Bayesian network [118] | - | 컨트롤러류 | | | | | | | | | |
| | | 7) | Inverter | 단락 | 전압 | TDF [24] [25] | Fuzzy logic [119] Residual generation by mixed logical dynamic (MLD) model [120] Current residual vector [121] | Multilayer perceptron network [122] Genetic NN [123] | Particle Filter [161] | Gaussian Process Regression [163] Weibull General Renewal Process [181] | 인버터, 컨버터 등 | | | | | | | | |
| | | 8) | Switch | 단락 | 전압 | TFDF [26] | Residual generation by extended Kalman filter (EKF) [124] sensor fault model [125] | Back propagation NN [126] Elman NN [126] Fuzzy c-means (FCM) [126] | Particle Filter [161] Crow-AMSA model [182] | Gaussian Process Regression [163] | 리미트, 릴레이, 푸쉬, 센서 등 | | | | | | | | |
| | | 9) | Cable | 단락 | 가스 | TDF [27] | Electric arc model [127], High-impedance fault model [128] | Self-organizing map algorithm [129] | General Path model [183] | A Sliding-window Regression [184] Support Vector Regression [185] | 전원 케이블 | | | | | | | | |
| 기계적 특성 | hardness [27] [28] | | | | | | | | | | | | | | | | | | |
| 전압 | TDF [29], FDF [28] [29] | | | | | | | | | | | | | | | | | | |
| 임피던스 | R, L, C [28] [29] | | | | | | | | | | | | | | | | | | |
| 4 | 구동부 | 10) | Motor | 단락 | 전류 | FDF [30] [31], profile [32], TDF [33] | Stator and rotor faulty model [130] Swing-angle model [131] | Hebbian-based unsupervised NN [132] RBF kernel SVM [133] | Particle Filter [186] | Hidden Markov Model [187][188] Recursive Least Square [189] Neural Network [190] | 모터, 펌프 등 | | | | | | | | |
| | | | | | 전압 | TDF [33], FDF [34], phase [35] residual error [36] | | | | | | | | | | | | | |
| | | | | | 전력 | FDF [34] [37] | | | | | | | | | | | | | |
| | | | | | 토크 | profile [35], FDF [38] | | | | | | | | | | | | | |
| | | | | | 자속 | FDF [39] [40] | | | | | | | | | | | | | |
| | | | | | 진동 | FDF [41] | | | | | | | | | | | | | |
| | | | | | 임피던스 | TDF [36] | | | | | | | | | | | | | |
| | | | | | 온도 | TDF [42] | | | | | | | | | | | | | |
| | | | | | 11) | LM Guide | | | | | | 마모 | 진동 | FDF [43] [44] | Linear rotor bearing kinematic model [134], High frequency resonance technique (HFRT) [135][136] | - | - | - | - |
| | | | | | 12) | Hydraulic supply | | | | | | 누유 | 온도 | TDF [45] [46] [47] | Frequency response diagram (FRD) [137][138] | Multilayer back propagation NN [139] | Kalman Filter [191] | - | 공압/유압 압축탱크 |
| 점도 | TDF [45] | | | | | | | | | | | | | | | | | | |
| 진동 | TDF [47], FDF [46] | | | | | | | | | | | | | | | | | | |
| 유량 | TDF [48] | | | | | | | | | | | | | | | | | | |
| 오염도 | TDF [45] | | | | | | | | | | | | | | | | | | |
| 5 | 동력전달부 | 13) | Reducer | 마모 | 진동 | SF [49], FDF [50] [51] [52] [53] [54] | - | Transductive SVM [140] | - | - | LM, TM Guide 등 | | | | | | | | |
| | | | | | 자기장 | TDF [55] | | | | | | | | | | | | | |
| | | | | | 음향 | TDF [56] | | | | | | | | | | | | | |
| | | | | | AE | energy [57] | | | | | | | | | | | | | |
| | | | | | 전력 | TDF [58] | | | | | | | | | | | | | |
| | | | | | 14) | Ball screw | | | | | | 마모 | 진동 | FDF [59], backlash [60] | Residual generation by Kalman filter (KF) [141] | Self-organizing map algorithm [142] Coefficient of variation [143] | - | - | Ball screw, Gamisole guide 등 |
| | | | | | 전류 | empirical parameters [61] | | | | | | | | | | | | | |
| | | | | | 속도 | empirical parameters [61] | | | | | | | | | | | | | |
| 15) | Chain & Belt | 단락 | 진동 | TDF, FDF | Kernel SVM [144], ANN [144] Self-adaptive growing NN [145] | - | - | - | Chain & Timing/V - belt 등 | | | | | | | | | | |
| 16) | Gear | 마모 | 진동 | empirical parameters [62], TFDF [63], energy [63] [64] [65] | | | | | | Residual generation by autoregressive (AR) filter [146] | Wavelet SVM [147], Multimodal deep support vector classification [148], Proximal SVM [149], ANN [149][150], c5.0 [149] | Particle Filter [192] Fast crack propagation model [193] Lineare Kalman Filter [194] Paris Law [195] | Back Propagation Neural Network [196] Hidden Markov Model [197] | 각종 기어류 | | | | | |
| 자기장 | TDF [55] | | | | | | | | | | | | | | | | | | |
| 음향 | TFDF [64] | | | | | | | | | | | | | | | | | | |
| 17) | Bearing | 마모 | 진동 | TDF [67] [68] [69] [70] [71], FDF [72] [73] | Kernel SVM [151], Wavelet SVM [152], One-class v-SVM [153], ANN [151], Paris Model [202][203] Fuzzy lattice classifier [154], Decision tree [154] | Kalman Filter [198][199] Particle Filter [200][201] Paris Model [202][203] LP & IH Model [204] | Neural Network [205][206][207][208] Support Vector Regression [209][210][211][212] Recursive Least Square [213] Gaussian Process Regression [214] Hidden Markov Model [215] | 롤러, 볼, 편심 베어링류 | | | | | | | | | | | |
| AE | TDF [74] [75] | | | | | | | | | | | | | | | | | | |
| 음향 | energy [68] [76] [77] | | | | | | | | | | | | | | | | | | |
| 전류 | TDF [78], FDF [79], TFDF [80] | | | | | | | | | | | | | | | | | | |
| 추파수 | FDF [81] | | | | | | | | | | | | | | | | | | |
| 18) | Mechanical tool | 마모/변형 | 절단힘 | empirical parameters [83] [84], TDF [85] [86] [87] [88] | Mechanistic force model [155] | Hidden Markov model (HMM) [156] | Saucer's local linear model [216] | Continuous Hidden Markov Model [217] Mixture of Gaussias Hidden Markov Model [218] Nerural Network [219][220] Support Vector Regression [221][222] Bayesian random sample path approach [223] | 기계적 가공 Tool (엔드밀, 절삭날, 연마구 등) | | | | | | | | | | |
| 진동 | TDF [87], FDF [88] [89] | | | | | | | | | | | | | | | | | | |
| 전류 | TDF [90] | | | | | | | | | | | | | | | | | | |
| 표면거칠기 | RMS [91] [92] | | | | | | | | | | | | | | | | | | |
| AE | TDF [93] [94], FDF [93] [94] | | | | | | | | | | | | | | | | | | |
| 19) | Electrical tool | 마모/변형 | 전압 | TDF [88] | If then rule [157] | Recurrent NN [158] | - | - | 용접건 등 | | | | | | | | | | |
| | | | 진동 | TDF, FDF | | | | | | | | | | | | | | | |

Nomenclature
DGC dissolved gas concentration
TDF time domain feature(s)
FDF frequency domain feature(s)
TFDF time-frequency domain feature(s)
SF statistical feature(s)
empirical parameters
hardness

H2, CH2, CO, CH2, C2H2, CH4, C2H6, C3H8
Root Mean Square(RMS), Time Domain Reflectometry(TDR), peak, Negative Sequence Current, Negative Sequence Voltage, Variance of autocorrelation modal current envelope, cooling ability, Pressure rise coefficient, Debris production, change of magnetic flux, negative-sequence impedance
Frequency Domain Reflectometry(FDR), Rotor Slot Harmonics(RSH), Stator slot sideband frequency, air-gap torque, NA4, NA4*, NA4 reset, MSA, MBA, PMA, N84, BPG, FTF/BPF, FTF/BFI, BFI, Defect frequency, induction motor current, harmonics and sidebands, partial discharge, Harmonics, Residuals
Wavelet coefficient, oxygen consumption measurement, Hilbert spectrum
IPCA(index of particle coverage area) (cylinder)
Laplacian Mahalanobis-Taguchi system, regression models, linear observer model & threshold
inverse tensile compliance, insulation hardness