

**ROBERT A. HANNA, Ph.D., P. Eng.,
FIEEE, FIET, FIEC, C. Eng.,
Designated Consulting Engineer
Recipient of 2020 IEEE Canada McNaughton Award
Past President IEEE Canada and IEEE Director (Region 7) 2006-2007**

SKILLS & EXPERIENCE

Over forty five years of experience in project engineering, Adjustable Speed Drives (ASDs) selection and implementation, Complex investigation into electrical equipment failure, Due diligence studies, Expert Witness, Power system studies including arc flash, emergency/UPS for critical load and power quality studies for industry, commercial and utilities. He has been retained and completed advanced engineering work in all six Continents. In January 2020 received the prestigious McNaughton award. He is a registered Professional Engineer in the provinces of Ontario and Alberta. Summary of completed projects include the following:

1. Prepared a white paper on medium voltage adjustable speed drives.
2. Expert Witness and Failure Analysis of 10 medium voltage Adjustable Speed Drives in Chemical Industry up to 30 MVA rating.
3. Electrical design work, technical specifications, commissioning and interface with the Utility for a second electric storage facility in Ontario rated 2.5 MW. This plant was placed in service in September 2020
4. Conducted complex investigation into failures of four medium voltage adjustable speed drives for pipeline applications at several stations. Produced comprehensive reports outlining findings and recommendations.
5. Design review and engineering for 1.75 MW electric storage facility in Ontario.
6. Conducted complex investigations into utility power failure resulting in shutdown of two major oil refineries.
7. Conducted starting analysis and computer modelling for 13.8 kV, 25000 HP synchronous motor under normal and abnormal utility conditions for a large chemical plant in Ontario. Prepared a report with recommendations.
8. Conducted power system studies including short circuit, coordination, arc flash and harmonic for the Arctic Navy patrol ship.
9. Conducted design review and power system studies for a battery storage facility.
10. In-house electrical consultant for the first of its kind 1 MW electric storage facility installed on the Toronto Island. The work involved engineering design, equipment selection, power system studies and commissioning. The system involves converting electrical energy into mechanical during off-peak hours using motor/compressor and store the compressed air in accumulators installed at Lake bed level. During on-peak hours, the stored mechanical energy is converted back into electrical via expander/generator and supplied to Toronto Hydro.
11. Completed, for a large oil company, a complex electrical failure analysis and field measurements of three slow speed 17500 HP, 13.8 KV brushless Synchronous motors driving reciprocating compressors. All failures were rotor related that made predicting the failures very challenging. The first motor suffered a cracked shaft that had to be replaced. The second experienced arcing amortisseur bars and the third shorted field winding.

12. Completed for a large manufacturer, a comprehensive study on manufacturers' experiences with isolating transformer for medium voltage adjustable speed drives. This is the first of its kind survey that involved preparing a three segments questionnaire that covered gathering technical specification, protection, transformer performance, operating experience, sourcing challenges and purchasing requirements for the next five years.
13. Conducted comprehensive study for a major pipeline company on arc mitigation techniques in industry and produced a report covering pros and cons of each technology, retrofitting, implementation challenges, operational and field experience and costing.
14. Completed arc-flash, short circuit and coordination studies for two commercial facilities and provided PPE labels.
15. Reviewed, for a large chemical plant, the impact of adding 50 MVAR, 138 KV capacitor bank on existing plant operation with and without a co-generation plant.
16. Investigated field excitation failure for slow speed 25000 HP brushless synchronous motor for compressor application in a chemical plant.
17. Completed a complex power quality study for the largest steel mill in North America that was placed in service in late 2010 and has several medium voltage large adjustable speed drives for cold and hot strip mills. The work covered electrical equipment failure, snubbers' failure, harmonic study and power quality measurements.
18. Conducted complex investigation to address incompatibility issues of 12 km, nine conductors sub sea umbilical cable connecting three offshore 1500 HP adjustable speed drives to electrical submersible pumps (ESP) for oil drilling application.
19. In October 2010 led international technical delegates to India on renewable energy. Met with governments' official, manufacturers of solar and wind turbine, utilities and end users.
20. Conducted field measurements and harmonic computer study for large induction furnace to ensure harmonic compliance to IEEE 519 standard.
21. Completed complex investigation into arc-flash medium voltage switchgear failure for two large pumping stations. The equipment was less than 6 months in service. Also, conducted detailed review of seven 5000 HP motor protections, operating practices and field testing.
22. Conducted due-diligence study covering comprehensive technical evaluation of a large manufacturer of medium voltage adjustable speed drive up to 15000 HP and wind turbine inverter. The project covered preparing detailed questionnaire covering all 10 manufacturing departments, conducting interviews and preparing a report.
23. Completed conceptual design, engineering specification and equipment selection for 500 KW emergency generator for commercial site.
24. Completed conceptual design study for renewable energy using solar power rated 50 KW and 100 KW for commercial facility in Ontario. Prepared overall installations cost and justification.
25. Conducted magnetic wedges failure analysis for 7500 HP motor driving reciprocating compressor.
26. Design review, field measurements and Multilin relay protection setting for eight 7500 HP motors for compressor station
27. Prepared engineering specification for two 3000 HP adjustable speed drives for soft starting several 7500 HP motors.
28. Conducted for a capital investment firm a "due diligence" study of a major manufacturer of power quality equipment, prepared a report and made recommendations.
29. Prepared engineering specification, design, installation and commissioning of 160 KVA UPS for data processing centre.
30. Provide ongoing engineering support to a critical data processing centre covering system upgrade, adding new servers, resolving power quality issues, emergency generator testing, variable frequency drives, annual maintenance work and coordination with hydro for supply reliability.
31. Conducted computer modeling and harmonic analysis for Niagara Tunnel facility project that included the world's largest hard-rock tunnel boring machine (TBM) to ensure compliance to IEEE Standard 519-1992 as stipulated by Hydro One.
32. Conducted comprehensive review of implementation plan, justifications, methodology and overall cost for replacing obsolete electrical equipment in a large Petro-Chemical plant involving over 10

- substations. The work includes installing multifunctional relays and modern switchgear - to be carried out during scheduled process unit shutdown
33. Provided expert opinion and investigation into a litigation case involving the repair work and performance of DC motors for Bay Area Rapid Transit (BART) system. The work included conducting temperature rise tests for DC series motors.
 34. Conducted failure analysis, protection review and system engineering of a 25000 HP Adjustable Speed Drive for starting and speed control of three synchronous motors for compressor applications. This IGBT based ASD rating was considered the first of its kind at 11KV directly connected to synchronous motor.
 35. Investigated serious torsional vibration problem with 8500 HP slip ring recovery drive. Conducted detailed torsional study, harmonic and vibration measurements.
 36. Provided building construction management for a new 30,000-ft² data processing centre as well as design and commissioning of emergency back up system.
 37. Provided expert opinion for a litigation case involving the performance and repair work for DC traction motors for large subway system. Conducted motor failure analysis and motor temperature rise testing.
 38. Provided comprehensive training for large automotive plant in Ontario covering rectifier, drives and harmonics. Conducted power quality study for paint plant, field measurements and addressed a long-standing noise problem.
 39. Conducted investigation into operating history, repair work, motor protection and field measurements of three slow speed induction motors each rated 5400 HP for reciprocating compressor application in Petro-Chemical industry.
 40. Conducted power quality study and harmonic measure nets for 25 MW co-generation plant for a Pulp and paper plant.
 41. Conducted system evaluation and power quality measurements of emergency shutdown system for nuclear station in Ontario. Produced a report on the blackout of August 14, 2003 comparing data captured for several locations within Ontario.
 42. Provided expert opinion and a report into a litigation case involving the application of brushless DC drive and dry type transformer.
 43. Power quality study and field measurements for Federal penitentiary in Ontario.
 44. Conducted failure analysis of 3000 HP Load Commutated Inverter (LCI) motor driving slow speed synchronous motor for a mining mill.
 45. Conducted feasibility study for 400 MW steel plant connected to captive power plant located in the Far East with emphasizes on power quality integration issues and corrective measures.
 46. Conducted failure analysis and power quality measurements for UPS system for data processing centre in British Columbia. Carried out Engineering and installation for a new parallel redundant UPS system.
 47. Engineering specification and selection of 19000 HP Load Commutated Inverter (LCI) ASD/motor for compressor application. Carried out factory acceptance tests and issued a report covering the results.
 48. Review and replacement of emergency back up system for two nuclear power stations in Ontario including vendor selection, harmonic field measurements and review all technical specifications. Prepared a report covering field measurements, findings and recommendations
 49. Conducted failure analysis, harmonic study and field measurements into 3500 HP DC drive for fan application for a pulp and paper company.
 50. Conducted power quality measurements and analysis at 27.6 KV level for an electric utility in Ontario to determine the quality of incoming power supply and impact on customer operation.
 51. Conceptual design, engineering specification, selection and implementation of one 3500 HP, and two 1750 HP Medium Voltage ASD, motor and control house for exhaust fan application for the mining industry.
 52. Conducted field measurements and an investigation into 2x4000 HP GE DC drive flashover for a hoist application for a mining company.

53. Conducted comprehensive computerized harmonic study for a 125 MW Petro-Chemical plant in Alberta having ASD type load to ensure compliance to harmonic guidelines of TransAlta/System Administrator and to IEEE 519-1992 standard. Also, conducted harmonic field measurements.
54. Conducted a feasibility study for selecting three 12000 HP Cycloconverters versus Load Commutated Inverter (LCI) drives for a production hoist application for the deepest mine in North America.
55. Conducted comprehensive design review, power quality field measurements and failure analysis for the normal and emergency backup power system at the control building for the first electronic toll road (407ETR) in North America as well as for the Area Control Centre, Pearson International Airport, NAV CANADA.
56. Provide technical expertise for a very large Petro-Chemical project in Alberta. This involved 400 MW Co-generation plant, specification and selection of 5 Medium Voltage ASDs with the largest being 7500 HP for extruder application, selection large electrical equipment and perform power quality assessment for the entire facility to comply with the utility harmonic requirements.
57. Engineering specification, selection and implementation of the first medium voltage ASD for an extruder application in North America rated 2500 HP.
58. Performance evaluation and testing of two 5000 HP MV ASDs for gas pumping station.
59. Engineering specification and selection of 13000 HP motor for a mixer application.
60. Selection and implementation of (2x2500 HP, 2x1500 HP) medium voltage ASDs for compressor and pump applications.
61. Study of users' and manufacturers' experience with medium voltage ASDs for induction motors in North America.
62. Rehabilitation of 10 MVA main substation.
63. Development of power quality meter for harmonic and power measurements.
64. Harmonic analysis and ASDs selection for a new car plant
65. Voltage disturbance and harmonic analysis for a food processing plant-having 35 ASDs to alleviate nuisance drives tripping caused by transient over voltages.
66. Conceptual design for 25 MW Co-generation Project.
67. Conducted several investigations into low voltage ASDs and associated motor related problems.
68. Survey of users' experience with ASDs rated 500 HP and above in Ontario. The findings were presented in a symposium sponsored by several large utilities in Canada.
69. Harmonic analysis and filter design for Pearson International Airport, Terminal 3.
70. Investigation of harmonic notching problems for a very large data processing centre backed up by three 500 KVA UPS's and 2,000 KW emergency generator.
71. Engineering design, equipment selection, harmonic analysis and commissioning of over 130 AC and DC ASDs installations for newspaper production plant, Vaughan, Ontario.
72. In-plant preventative maintenance procedure covering high and low voltage switchgear, UPS, emergency generator motors, ASD's, transformers and cables.
73. Design and specification for two 22,000 HP, 6,000 rpm, LCI drive installation at chemical plant. Conducted field harmonic measurements and the findings were published in IEEE conference.
74. Conducted several feasibility studies for energy saving programs across Canada. Invited speaker for Ontario Hydro (1987), Nova Scotia Power ((1988), BC Hydro (1990), TransAlta (1991) and Ontario Hydro (1992) on adjustable speed drive applications.
75. Plant wide automatic re-acceleration system for 150 motors for a refinery using PLC system, and the findings were published in IEEE conference.
76. Conducted short circuit and relay co-ordination studies. Teaching electrical machines, power systems and power electronics.

EDUCATION

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| 1977 | Ph.D. | Electrical Engineering Department, Imperial College of Science & Technology, University of London, England |
| 1973 | M.Sc. (Distinction) | Electrical Engineering Department, Queen Mary College, University of London, England |

PROFESSIONAL AFFILIATIONS

Member of the Association of Professional Engineers Ontario, Canada	1981
Senior Member of Institute Electrical & Electronic Engineers (SMIEEE), USA	1988
Fellow Member of Institute of Electrical Engineers (FIEE), UK	1993
Designated Consulting Engineer, Professional Engineers, Ontario	1995
Vice-Chair of 48 th IEEE Petroleum & Chemical Industry Conference, Toronto	2001
Member of the Association of Professional Engineers, British Columbia, Canada	2001
Member of the Association of Professional Engineers, Alberta, Canada	2001
Chair, IEEE Toronto Section	2002-03
Fellow Member of Institute Electrical & Electronic Engineers (FIEEE)	2004
Chair, 18 th IEEE Canadian Conference on Electrical & Computer Eng. (CCECE 04)	2004
Fellow Member of Engineering Institute of Canada (FEIC)	2006
Past President of IEEE Canada & IEEE Director (Region 7)	2006-07

MANAGEMENT COURSES

Problem Solving / Decision Making; Effective Presentation; Situational Leadership;
Interaction Management; Management Guide to Loss Control; Business Writing for Reports.

PUBLICATIONS

1. Hanna, R.: Power Quality Challenges in Industry, The McNaughton Lecture, IEEE/CCECE 2020, September 02, 2020, London, Ontario.
2. Lawrence, R., Hanna, R.A., Lockley, W, Paes, R.: "Standard Updates For Adjustable-Speed ac Drives" IEEE Industry Applications Magazine, Volume 24, No.1, January/February 2018, page 42-51
3. Lawrence, R., Hanna, R.A., Lockley, W, Paes, R.: "IEEE Standard 1566-2015 Performance of Adjustable Speed AC Drives Rated 375 kW and Larger" PCIC/IEEE, Industry Application Society, 63rd Annual Conference, September 2016, Philadelphia, Pennsylvania. Awarded 2nd Best paper.
4. Bapat, A., Hanna, R.A., Panetta, S.: "Advanced Concepts in High resistance Grounding" PPIC/IEEE, Industry Application Society, 61st Annual Conference, June 2015, Milwaukee, Wisconsin, page 15-24.
5. Bapat, A., Hanna, R.A & Panetta, S.: "Advanced Concepts in High resistance Grounding" PCIC/IEEE, Industry Application Society, 59th Annual Conference, September 2012, New Orleans, Louisiana, page 223-230.
6. Hanna, R.A. & Schmitt, D.W.: "Failure Analysis of 7500 HP Induction Motors Driving Reciprocating Compressor with Three Years in Service" IEEE Industry Applications Magazine, July/August 2012, Vol 18, No. 4, page 40-46.
7. Schmitt, D.W & Hanna, R.A.: "Mechanical and Electrical Challenges of Large Induction Motors Driving Reciprocating Compressors With Three Years Service", 2010 Gas Machinery Conference (GMC), Phoenix, Arizona.
8. Hanna, R.A. & Schmitt, D.W.: "Failure Analysis of 7500 HP Induction Motors Driving Reciprocating Compressor with Three Years in Service" PCIC/IEEE, Industry Application Society, 57th Annual Conference, September 2010, San Antonio, Texas, page 281-286.
9. Endrejat, F., Hanna, R.A. & Shultz, J.: "Ensuring Availability of a Large Adjustable Speed Drive for Process Gas Compressor Application Rated 11 KV, 15.5 MW (20778 hp)" IEEE Transaction on Industry Application, Volume 46, No. 5, September/October 2010, page 1843-1849.
10. Endrejat, F., Hanna, R.A. & Shultz, J. : "Ensuring Availability of a Large Adjustable Speed Drive for Process Gas Compressor Application Rated 11 KV, 15.5 MW (20778 hp)" PCIC/IEEE, Industry Application Society, 56th Annual Conference, September 2009, Anaheim, California, page 133-139.

11. Murray, D., Dickin, J., Hanna, R.A., & Morin, T. : “High Resistance Grounding – Avoiding Unnecessary Pitfalls” IEEE Transaction on Industry Applications, Volume 45, No. 3, May/June 2009, page 1146-1154.
12. Hanna, R.A. & Ezer, D: “Minimizing Plant Interruption Caused by Line Disturbances Using Active Voltage Conditioners” Webinar May 21, 2008, IEEE Canada.
13. Murray, D., Hanna, R.A. Dickin, J., & Morin, T. “High Resistance Grounding – Avoiding Misapplication of TVSS and UPS System.” Electricity Today Magazine, April 2008, Volume 20, No. 3, page 12.
14. Murray, D., Dickin, J., Hanna, R.A., & Morin, T. “High Resistance Grounding – Avoiding Unnecessary Pitfalls.” PCIC/IEEE, Industry Application Society, 54th Annual Conference, September 2007, Calgary, Alberta, page 39-47.
15. Hanna, R.A., Klinowski, P. & Hiscock, W: “Failure Analysis of Three Slow Speed Induction Motors For Reciprocating Load Application” IEEE Transaction on Industry Applications, Volume 43, No. 2, March/April 2007, Page 429-435.
16. Hanna, R.A., Klinowski, P. & Hiscock, W: “Failure Analysis of Three Slow Speed Induction Motors for Reciprocating Load Application” PCIC/IEEE, Industry Application Society, page 239-245, 52nd Annual Conference, September 2005, Denver, Colorado.
17. Hanna, R. A.: “What Can We Learn About AC Systems from Monitoring Batteries?” INFBAT Conference, Toronto, September 2003.
18. Hanna, R.A., Ezer, D. & Penny, J: Discussion “AVC for Industrial Plants” IEEE Transaction on Industry Applications, Volume 39, No. 4, July/August 2003Page 1211-1213.
19. Ezer, D., Hanna, R.A & Penny, J: “Active Voltage Correction for Industrial Plants” IEEE Transaction on Industry Applications, Volume 38, No. 6, Nov/ December 2002, page 1641-1646.
20. Hanna, R.A: “Power Quality, Who’s Responsible – Utility or Facility” 3rd Power Quality Conference, Toronto, Canada, November 2001.
21. Penny, J.; Hanna, R.A. & Ezer. D: “Active Voltage Correction for Industrial Plants” PCIC/IEEE, Industry Application Society, 47th Annual Conference, page 253-259 September 2001, Toronto, Ontario.
22. Dickin, J.; Hanna, R.A; Randall & S.; Dedeurwaerder, C.: “Challenges Encountered when Expanding a World Class Petrochemical Facility”, IEEE Transaction on Industry Applications, 2001 July/August, Volume 37, Number 4, Page 1109-1119.
23. Hanna, R.A. & Randall, S: “Medium Voltage Adjustable Speed Drive Retrofit of an Existing Eddy Current Clutch Extruder Applications”, IEEE Transaction on Industry Applications, 2000 November/December, Volume 33,Number 6, page1750-1755.
24. Dickin, J.; Hanna, R.A.; Randall & S.; Dedeurwaerder, C.: “Design Challenges Encountered when Expanding a World Class Petrochemical Facility”, PCIC/IEEE, Industry Application Society, 47th Annual Conference, September 2000, page 103-114, San Antonio, Texas.
25. Hanna, R.A. & Randall, S.: “Use of Adjustable Speed Drives for Extruder Applications”, PCIC/IEEE, Industry Application Society, 46th Annual Conference, September 1999, P241,San Diego, California.
26. Hanna, R.A. & Prabhu, S: “Medium Voltage Drives-Users’ and Manufacturers’ Experiences”, IEEE Transaction on Industry Applications, 1997 November/December, Volume 33,Number 6.page 1407
27. Hanna, R.A.: “Low Voltage & Medium Voltage ASDs: Application Considerations”, 5th Annual Pulp & Paper Conference, September 1997, Sudbury, Ontario.
28. Hanna, R.A. & Prabhu, S: “Medium Voltage Drives-Users’ and Manufacturers’ Experiences”, PCIC/IEEE, Industry Application Society, 43rd Annual Conference, September 1996, page 115-123, Philadelphia, Pennsylvania.
29. Hanna, R.A. & Luscombe, J.: “Survey of Users Experience with Adjustable Speed Drives”, PCIC/IEEE, Industry Application Society, 40th Annual Conf., Sept 1993, page 271-277 St.Louis, Mo.
30. Hanna, R.A. Bulmer, P. & Kohistani, R.: “Minimizing Refinery Upset during Power Interruptions Using PLC Control ”, IEEE, Industry Application Society. 39th Annual Conf., 1992 Petroleum and Chemical Industry Conference, September 1992, page 185-195, San Antonio, Texas.
31. Hanna, R.A.: “Survey of Users’ Experience with Adjustable Speed Drives rated 500 HP and Above”, 1992 Canadian Utility Trade Alley Symposium, June 1992, Toronto, Ontario.

32. Hanna, R.A.: "ASDs Application Consideration", Dupont Canada Workshop, May 1992 Canadian Utility Trade Alley Symposium, June 1992, Kingston, Ontario.
33. Hanna, R.A.: "Effects of Harmonics on Power System Equipment and Loads" Third Alberta Exposition and Conference on Power Quality, October 1991, Calgary, Alberta.
34. Hanna, R.A.: "ASDs - Their Applications, Types and Harmonics Behaviors" , Showcase 90 Seminar sponsored by BC Hydro, Vancouver, February 1990 (Invited speaker)
35. Hanna, R.A.: "Harmonics and Technical Barriers in Adjustable Speed Drives" - IEEE Transaction on Industry Applications, 1989 September / October, Volume 25, Number 5. Page 894-900.
36. Hanna, R.A.: "Harmonics and Technical Barriers in Adjustable Speed Drives" - 24th Industry Applications Conference, October 1989, Page 1632-1640, San Diego, California
37. Hanna, R.A.: "Adjustable Speed Drives - Effects of Harmonics on Power System Equipment and Loads", symposiums on energy efficient motors and adjustable speed drives, sponsored by Nova Scotia Power and Canadian Elect. Assoc., Halifax, September 1988, (Invited speaker).
38. Hanna, R.A.: "Harmonics and Technical Barriers in Adjustable Speed Drives" - IEEE / PCIC, 35th Annual Petroleum and Chemical Industry Conference, September 1988, page 165, Dallas, Texas.
39. Hanna, R.A.: "Harmonics and Technical Barriers" - Symposium on Electrical Variable Speed Drives, Sponsored by Ontario Hydro and the Ontario Ministry of Energy, Toronto, April, 1987, (Invited speaker).
40. Hanna, R.A. & MacDonald, D.C.: "The Six-Phase Power System" - IEEE Transaction on Power Apparatus and System, August 1983, page 2600, Volume PAS-102, Number 8.
41. Hanna, R.A., MacDonald, D.C. & Allen, P.H.G.: "The Six-Phase Generator and its Associated Transformer" - Fourteenth Universities Power Engineering Conference, Loughborough University of Technology, England, April 1979.
42. Hanna, R.A., Ph.D Thesis, January 1978, University of London, Imperial College of Science & Technology, Department of Electrical Engineering. "The Six-Phase Two-Circuit Synchronous Generator and Its Associated Transformer.
43. Hanna, R.A., M.Sc Dissertation, December 1973, University of London, Queen Mary College, Department of Electrical Engineering. "Asynchronous Operation of AC Generator with and without Rectifier in Field Circuit. [PDF]

10/ 2020