REVISED CHANGE ORDER

INVESTIGATION OF VOLTAGE HARMONICS AND UNBALANCE IN TRANSMISSION NETWORK

SEC Project No: S0602

Prepared for

Saudi Electricity Company (SEC)
Riyadh, Saudi Arabia

Prepared by

Center for Engineering Research

Jamada'I 1426 H
June 2005 G

SUMMARY

This revised change order has been prepared in response to a letter from Saudi Electricity Company (SEC), Riyadh, dated 01-062005 for changing the scope of the work related to the project entitled *"Voltage Unbalance: Causes, Effects and Mitigation Techniques"* (Project No. CER2256, SEC Project No: S0602). Communication regarding changing the scope of the work of this proposal is presented in ***(Appendix A).***

In response to the request of Saudi Electricity Company, the aim of this study is to evaluate existing harmonic and unbalance levels, identify different causes of voltage harmonics and unbalance in the transmission system and to suggest suitable remedial actions if levels of measured harmonic or unbalance voltage exceed the recommended limits identified by international standards such as IEEE Std. 519-1992, IEEE Std. 1159-1195 Std, and IEC Std. 61000-3-6. Results of this study are expected to contribute in improving the transmission line performance.

The work will involve review of standards, field measurements, and collection of data from SEC, on the substations selected by SEC. Measurements will be conducted at selected (total number of 30) substations in the eastern and central regions of the Kingdom. Computer simulations will also be performed to analyze the transmission network performance to detect the sources which may contribute to line voltage harmonics and unbalance and to evaluate the proposed remedial measures, if voltage harmonic or unbalance exists in the transmission network.

The Center for Engineering Research of the Research Institute and the Electrical Engineering Department of the King Fahd University of Petroleum & Minerals (KFUPM) are qualified to conduct the study. The team has conducted many projects in the area of power system quality for various clients. They have fully equipped laboratories and computational facilities and a scientific and professional staff with extensive experience in electrical power engineering.

The change order will be completed within fifteen working months after signing the contract at a lump sum cost of SR 850,886 (Eight hundred and fifty thousand, eight hundred and eighty six Saudi Riyals). ***This budget includes all previously received payments.***

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SECTION 1 INTRODUCTION

This change order has been prepared in response to a request from Saudi Electricity Company (SEC), Riyadh, for changing the scope of the work related to the project entitled *"Voltage Unbalance: Causes, Effects and Mitigation Techniques"* (Project No. CER2256, SEC Project No: S0602). Communication regarding changing the scope of the work of this proposal is presented in ***(Appendix A).***

The presence of voltage harmonics in the power system could decrease the capacity and/or overload equipment due to the additional heating effect of the harmonic current. It could also cause the protective relays to misoperate, resulting in inadvertent power interruptions. With proliferation in the application of large capacity, non-linear, devices such as variable speed drives and thyristor controlled devices (TCRs and SVCs) by both the electric utilities and their customers, problems associated with the presence of harmonics in the power system are thus of increasing concern.

Causes of voltage unbalance can be categorized into two classes: functional and structural. The former refers to power system faults. The latter refers to the asymmetrical transformer winding impedances, asymmetrical transmission impedances possibly caused by incomplete transposition of transmission lines, and blown fuses of three-phase capacitor banks. Under unbalance conditions, the power system incurs more losses and heating effects and is less stable because when the phases are balanced, the system is in better position to respond to emergency load transfers.

This change order aims is to investigate the voltage harmonics and unbalance problems in the existing transmission network in eastern and central regions and their remedial measures.

SECTION 2 OBJECTIVES

The overall objectives of this change order are to characterize and analyze harmonics and voltage unbalance on the transmission systems of SEC and to investigate possible mitigation technique for systems which may encounter voltage harmonics and\or voltage unbalance problems. The specific objectives are the following:

1. Characterize existing voltage harmonic and unbalance levels in bulk transmission system in Central and Eastern regions of SEC.

2. Analyze the transmission network performance to detect the sources which contribute to voltage harmonics and line voltage unbalance.

3. Investigate alternative mitigation techniques for voltage harmonic and unbalance problems in transmission line if they exist.

SECTION 3 DISCUSSION OF THE PROBLEM

3.1 DESCRIPTION OF THE PROBLEM

Saudi Electricity Company (SEC) is concerned with characterizing the harmonic voltage and unbalance levels which exists in the transmission network.

A number of large capacitor banks and Static VAR Compensators (SVC) are installed\planned in SEC transmission network for reactive power compensation and voltage support. Also, large non-linear loads, such as Hadid, are connected directly to the transmission network. Characterizing harmonic levels is important to assess the impact of large capacitor banks, SVC and connected non-linear loads on the existing levels of harmonic voltage. If the existing harmonic voltage exceeds the internationally accepted limits, a remedial measure should be investigated to alleviate any technical problems which may appear as a direct result of exceeding the acceptable harmonic levels.

Asymmetrical transformer winding impedances, asymmetrical transmission impedances, possibly caused by incomplete transposition of transmission lines, and blown fuses of three-phase capacitor banks are the most probable causes for voltage unbalance in transmission network. To alleviate technical problems caused by voltage unbalance, SEC needs to assess if they encounter any voltage unbalance in the transmission network and the possible causes of the voltage unbalance if it exists.

3.2 APPROACH TO THE PROBLEM

The voltage harmonic and unbalance study involves several tasks. The proposed work will involve review of standards related to voltage harmonic and voltage unbalance, collection of data from SEC for selected typical substations in the eastern and central regions of the Kingdom and field measurements will also be carried out on these substations. Computer simulations will be conducted to quantify harmonic and unbalance voltage levels at the selected substations, the specific activities that will be carried out in order to identify and investigate the voltage unbalance and recommend mitigation techniques are as follows:

- Conduct measurement for harmonics and voltage unbalance for 30 substations distributed as follows: monitoring 3 lines connecting 6 380kV substations, monitoring 5 lines connecting 10 230kV substations, and monitoring 7 lines connecting 14 115/132kV substations. All substations and lines will be identified by SEC. SEC technicians will do the measurements after being instructed by KFUPM team. KFUPM team will make field demonstration for SEC technicians on three substations sites one at 380 KV, one at 230 KV, and one at 115 or 132 KV

- For parts of the transmission networks which experience voltage harmonics and (or) unbalance problems, the research team will model the transmission system to analyze the transmission network performance and to detect the

sources which contribute to line voltage unbalance and (or) harmonics. ***This analysis will be done for five locations worst measurements are obtained***.

- The research team will investigate alternative mitigation techniques for voltage harmonics and unbalance problems if they exist in any parts of the Transmission Network under consideration

SECTION 4 STATEMENT OF WORK

The work involved is divided into the following Tasks:

4.1 TASK 1: MOBILIZATION, LITERATURE SURVEY, AND DATA COLLECTION

- Literature survey on the related voltage harmonic and unbalance standards and publications.
- Prepare a list of the required data which include: utility short circuit capacity and X/R ratio at the concerned bus, transformers MVA ratings, X/R ratio and percentage impedance, ratings of the capacitor banks, measurement or estimation of the harmonic source current …etc.
- Order the power quality analyzers.
- Obtain permission to measure sites.
- Collect data on substation, transmission lines, and bulk load data

4.2 TASK II: MEASUREMENTS

- Conduct measurements at the selected six 380kV substations which are connected with three lines.
- Conduct measurements at the selected ten 230kV substations which are connected with five lines.
- Conduct measurements at the selected fourteen ***132/115 kV*** substations that are connected with seven lines.
- Analyze the measurements obtained.

4.3 TASK III: SIMULATION STUDIES

- Enter data for the simulation software, the simulation cases (limited to a maximum of five locations) will be identified with consulting with SEC.
- Perform simulation studies for the selected locations. ***Voltage harmony and unbalanced simulation studies will be carried out using CYME software***.

- Analyze simulation results.

4.4 TASK IV: REMEDIAL MEASURES

- Compare existing harmonic and unbalance levels against international standards such as IEEE Std. 519-1992 and IEC Std. 61000-3-6.
- Recommend remedial measures if harmonic or voltage unbalance problems exist.
- Perform simulation to insure the effectiveness of the proposed remedial measure.

4.5 TASK V: REPORTING

- Monthly progress letter
- Three quarterly progress reports
- Final report

SECTION 5 DELIVERABLE ITEMS

A: KFUPM/RI will provide the following items to SEC:

1. List of items required from SEC.
2. Questionnaire for data collection.
3. A monthly letter and quarterly progress reports for the entire duration of the project, stating the work performed and the percentage completion compared with the overall project schedule.
4. The final report, in both digital and paper form (Five copies).
5. A presentation to Company management on the findings of the project.
6. ***Harmonic analyses with accompanying software at the end of the studies***.

B: KFUPM/RI will receive the following items from SEC:

1. Access to the substations where measurements are to be carried out. ***These substations should not be shutdown***.
2. Single line diagrams for the selected substation
3. Substation equipment and Transmission line data in electronic format.
4. Bulk load data in electronic format

5. Two technicians to assist in measurement stage.

Table 5.1. Project deliverable items list:
Items to be provided by KFUPM/RI.

Item	Description	Quantity	Delivery (in working months)
1.	List of items required from SEC.		
2.	Data collection list	1	End of 1st working month
3.	Monthly letter	10	End of months 1,2,4,5,7,8,10,11,13,14
4.	Quarterly progress reports	3	End of months 3 , 6 , 9,12
5.	Final report	5	End of month 15
6.	***Harmonic analyses with accompanying software at the end the studies***	1	15

Table 5.2. Project deliverable items list:
Items to be provided by SEC.

Item	Description	Quantity	Delivery (in working months)
1.	Access substation sites	1	1
2.	Single line diagrams for the selected substation	1	2
3.	Substation equipment and Transmission line data in electronic format.	1	2
4.	Bulk load connected to Transmission Network data in electronic format	1	2
5.	Two technicians to assist in measurement stage.	1	2

Prior to contract signature, the calendar dates for start and end of the project as well as for all deliverables (PDIL) shall be determined. A schedule showing all these dates as well as a payment schedule shall be part of the contract documents at the time of contract signature. Any subsequent changes during project execution shall be made by mutual agreement and will be accomplished by means of a change order.

SECTION 6 SCHEDULE

The proposed research project will be carried out over a period of ***15*** working months. A schedule of the tasks outlined in this proposal is shown in Figure 6.1.

The Research Institute will be closed for annual vacation from mid of July to the end of August and for the Eid holidays. The locations of these holidays in the work schedule will be determined at the time of signing the contract.

SECTION 7 MANAGEMENT PLAN

A joint team from the Research Institute and the Department of Electrical Engineering will conduct the proposed study. Participating from the Research Institute will be the KFUPM/RI Center for Engineering Research. The work shall be coordinated by the project team as per a project coordination chart (Figure 7.1).

Dr. Ibrahim O. Habiballah is expected to be the project manager and will be responsible for the day-to-day management aspects of the project. Specifically, he will be responsible for:

1. The technical quality of the work,
2. The timely and comprehensive reporting of work progress and results,
3. The timely completion of individual tasks and of the entire project,
4. The control of costs, and
5. The coordination of the work of the project team.

The following personnel will be involved in conducting this study:

1. Dr. Ibrahim Habiballah, Associate Professor, KFUPM/EE.
2. Dr. Ibrahim El-Amin, Professor, KFUPM/EE.
3. Dr. Abu Hamed M. Abdur-Rahim, Professor, KFUPM/EE.
4. Dr. Tarek Abdel-Galil, Research Engineer-III, KFUPM/RI.
5. Mr. Mohammed Arif Abdul-Majeed, Research Engineer-III, KFUPM/RI, and
6. Mr. Farid M. Kandlawala, lecturer, KFUPM/EE.

The resumes of the personnel who will be associated with this project are given in Appendix B.

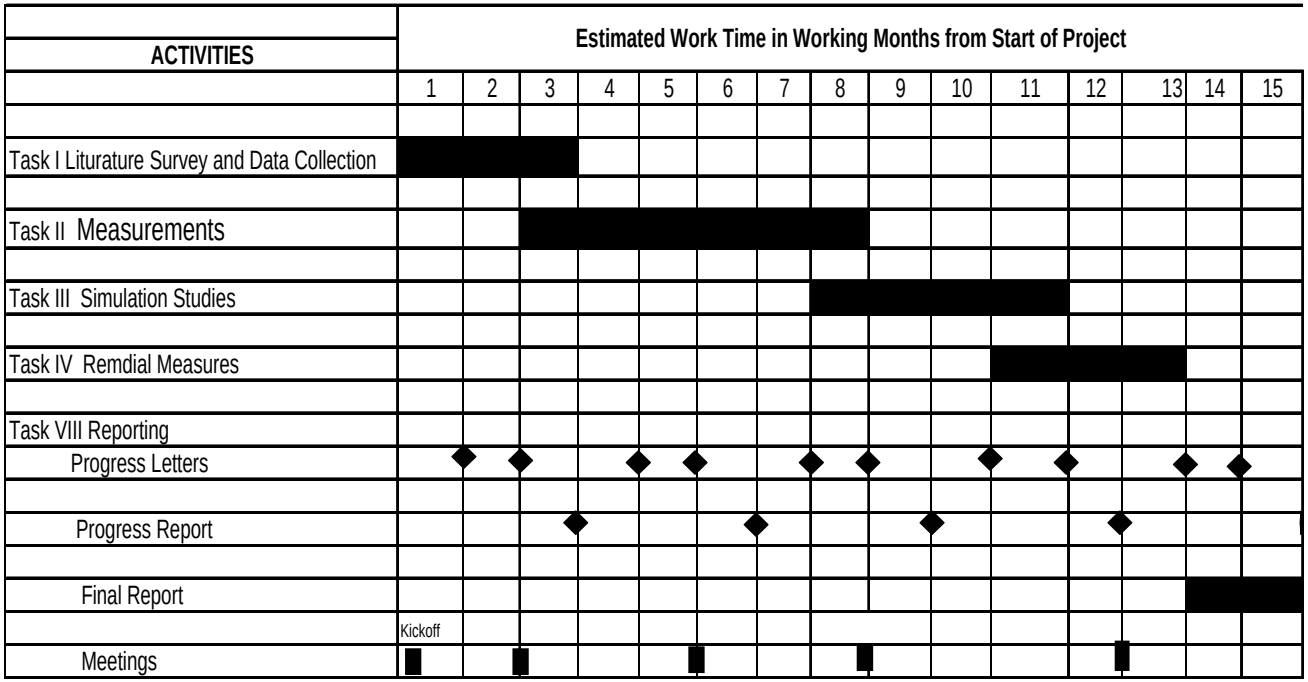

Figure 6.1. Work schedule.

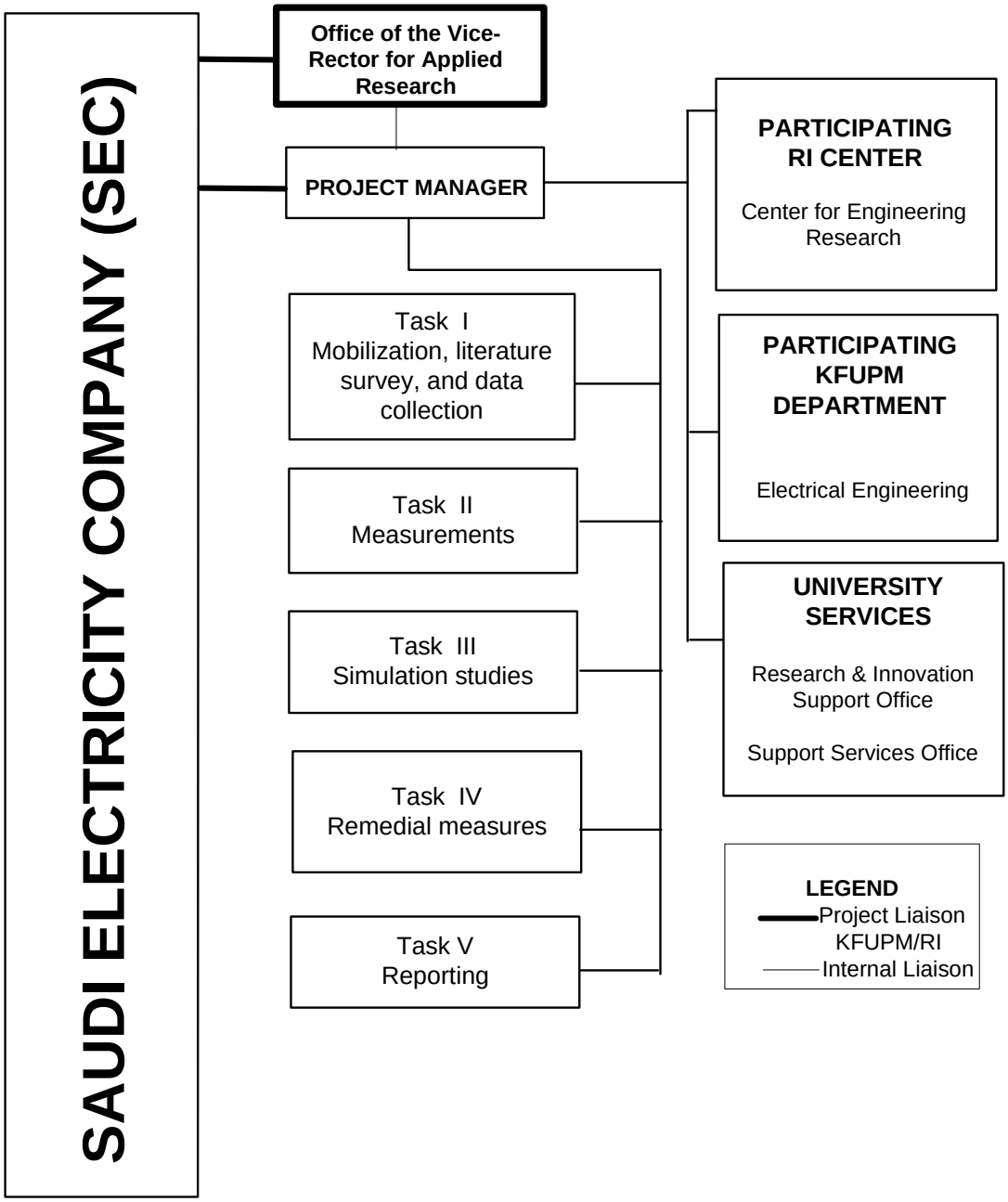

Figure 7.1. Project coordination chart

SECTION 8 COST

The proposed work will be performed at a lump sum price of SR 850,886 (Eight hundred and fifty thousand, eight hundred and eighty six Saudi Riyals). This proposal and the price quoted herein are valid for a period of 90 days from the date of its submittal. The cost breakdown of different items is as follows:

Item	Cost
Manpower	325,886
Services	20,000
Travel	155,000
Equipment	320,000
Software	30,000

SECTION 9 GENERAL TERMS AND CONDITIONS

The services and products described in this proposal are offered under the General Terms and Conditions of the Saudi Electricity Company as given in the request for proposal.

SECTION 10 RESOURCES AND FACILITIES

10.1 RELATED PROJECT EXPERIENCE

The researchers in the Energy System Section of the Center for Engineering and the faculty of Electrical Engineering Department have extensive experience in power systems analysis, power system planning, and power related issues.

The researchers from KFUPM are conducting a project entitled "Voltage Dip Study of Jubail Industrial Area" under the sponsorship of Saudi Electricity Company – Eastern Region Branch, Dammam. The overall objectives of this study were to identify the characteristics, causes, and effect of voltage dip incidents occurring on 230 kV and 115 kV network in Jubail industrial area. The study involved review of international standards and practices in characterizing and mitigating voltage dips. The study also involved comparing the results of the study with the international standards and practices.

Some major projects conducted by the Electric Power Group are as follows:

- Voltage Dip Study for Jubail Industrial Area, sponsored by Saudi Electricity Company, Eastern Region Branch, Dammam.
- MYAS – SEC-WRB Electrical Interconnection Study, sponsored by Royal Commission for Jubail and Yanbu, Yanbu.

- ♦ SCECO West - SCECO Central Interconnection Study, sponsored by Zedan Consultants, Al-Khobar.
- ♦ Renewable Energy Power Supply for A Remote Settlement, sponsored by KACST, Riyadh.
- ♦ Refinery Residue Reduction Using Three Power Generation Options, sponsored by Saudi Aramco, Dhahran.
- ♦ Frequency Conversion at the Military Factory in Al-Kharj, sponsored by the Military Industries Corporation, Riyadh.
- ♦ Peak Load Reduction by Load Management, sponsored by KACST, Riyadh.
- ♦ Electric Energy Trading Benefits among Mashreq Arab Countries, sponsored by the Arab Fund, Kuwait.
- ♦ Feasibility Study of Mashreq Arab Countries' Power Systems Interconnection, sponsored by the Arab Fund, Kuwait.
- ♦ Electrical and Physical Properties of Saudi Arabian Soils, sponsored by KACST, Riyadh.
- ♦ Feasibility Study of GCC Countries' Power Systems Interconnection, sponsored by the GCC Secretariat, Riyadh.
- ♦ A Master Plan Study of Saudi Arabia's EHV Transmission Requirements, sponsored by KACST, Riyadh.
- ♦ High Voltage Insulator Performance in Saudi Arabia sponsored by the General Electricity Corporation, Riyadh.

10.2 SPECIAL RESOURCES AND FACILITIES

The Electric Energy System Section have Dranetz Power Platform meter to conduct power quality measurements. The Dranetz Power Platform meter can provide the order and level of harmonic contents of voltage and current waveforms. It can also calculate the total harmonic distortion (THD) and the K-factor. The meter also provides the graphical display of the voltage or current waveform. It uses a FLICKER TASKCARD for the voltage flicker measurements. The card provides the capability to measure and monitor the voltage and current waveform for flicker calculations.

ELECTRIC POWER SYSTEM SIMULATION LABORATORY

The electric power system simulation laboratory has facilities for conducting a wide range of engineering studies in areas such as:

- Generation capacity planning,
- Network analysis and planning,

- Generation reliability analysis,
- Power system production costing,
- Interconnection studies,
- Power system transients,
- Energy interchange studies,
- Load management studies, and
- Energy conservation studies.

The following software packages are utilized to conduct these studies:

CYME Conducts electrical network simulation such as load flow, fault analysis, transient stability, power quality, motor starting, grounding mat, audible noise, relay coordination, and cable ampacity studies.

EMTP Calculates the impact of electromagnetic transients such as those caused by lightning and power apparatus switching. The results are analyzed for abnormal behavior and corrective measures are evaluated.

PSIM Simulates the operation of an electric power system to determine energy production costs. The energy produced by the power plants as well as the fuel requirements can be calculated. The results may be utilized to perform generation planning and/or evaluate alternative generation plans. PSIM may be utilized to provide economic results for power system expansion planning. Interconnected systems energy trading transactions can also be evaluated.

MAREL Assesses the reliability of an electric power system. It calculates standard reliability indices, which can be used to develop generation expansion plans. Standard indices such as LOLE, EENS, and area deficiencies are generated. MAREL can also be used to compare the reliability indices of alternative generation expansion plans. Simulation of single-area as well as interconnected power systems can be conducted.

ELECTRIC POWER ENGINEERING

The Electric Power Engineering group provides consulting services and conducts research in the areas of electric power systems and high voltage engineering. Its activities cover all aspects of generation, transmission, and utilization of electric power and many types of high voltage equipment tests. Major clients served by the power group include electric utilities, governmental organizations and private industrial establishments.

The group has expertise in electrical network-related studies such as generation capacity planning, transmission network analysis, reliability evaluations, power system interconnection, production costing, harmonics analysis, transients, and electric energy conservation. The group has well-equipped computational facilities

for carrying out such studies. A high voltage laboratory is utilized by the group to undertake research and provide services in high voltage equipment testing and insulator contamination studies.

The electric power group has completed several client-funded projects. Some of the recent ones include: refinery residue reduction with three power generation options, peak load reduction by load management, frequency conversion at an industrial complex, and energy trading benefits among countries in the region.

Two laboratories support the work of the electric power group:

- Power System Computer Simulation Laboratory
- High Voltage Measurements Laboratory

APPENDICES

APPENDIX-A

REQUEST FOR PROPOSAL

APPENDIX-B

RESUMES OF PROJECT PERSONNEL

DR. IBRAHIM OMAR HABIBALLAH

Dr. Ibrahim Omar Habiballah is an Associate Professor of Electrical Engineering Department and manager of the Energy Systems Section in the Research Institute at King Fahd University of Petroleum & Minerals. He received his Ph.D. from University of Waterloo, Canada in 1993, M.S. from King Fahd University of Petroleum & Minerals, Saudi Arabia in 1987, and B.S. from King Abdul-Aziz University, Saudi Arabia in 1984.

Since joining KFUPM in January 1984, he taught several undergraduate and graduate courses in electrical, power systems, power transmission, and electrical machines. He conducted many seminars locally and internationally in the related areas of power systems. He advised and co-advised over ten master theses and over fifteen senior projects. He has supervised and co-supervised over fifty summer training and co-op students.

He has acted as the principal investigator or co-investigator of more than ten sponsored projects:

- "Feasibility Study of Frequency Conversion" for the Military Factory Complex in Al-Kharj, 1997.
- "Refinery Residue Reduction with Three Power Generation Options" for Saudi Aramco, 1998.
- "Testing High Voltage Insulators" for Al-Najim, 1999.
- "Inspection of High Voltage Insulator Test Sites" for the Electricity Corporation, 2000.
- "Feasibility Study for Energy Conservation of KFUPM's Residential and Academic Buildings" for King Fahd University of Petroleum & Minerals, 2000.
- "Test and Evaluation of Harmonics and Flicker Levels at HADEED", for Hadeed Co., 2001.
- "Evaluation of Strategic Master Plan for Restructuring and Commercializing the Saudi Electricity Sector", for SEC, 2002.
- "Evaluation of Strategic Master Plan for Restructuring and Commercializing the Saudi Electricity Sector",
- "The benefits of Interconnecting MAYS with SCECO West", for The Royal Commission of Jubail and Yanbu, 2002.
- "Voltage Dip Problems in the Jubail Industry Area", for SEC-ERB, (in progress).

Dr. Habiballah's areas of interest include power systems in general, power system state estimation, power system optimization and partitioning of large power networks, HV insulators, power quality, co-generation, restructuring, and energy conservation. He has published over thirty five journal and conference papers and authored / co-authored over ten technical reports.

DR. IBRAHIM EL-AMIN

Dr. El-Amin is a Professor of Electrical Engineering at the King Fahd University of Petroleum and Minerals.

He received his Ph.D. and M.Sc. degrees from the University of Manchester in 1978 and 1975, respectively, in electrical engineering with specialization in power systems. He obtained his B.Sc. degree in electrical engineering from the University of Khartoum, Sudan in 1971.

Since joining KFUPM in 1978, Dr. El-Amin has taught undergraduate and graduate courses in electrical power systems and electrical machines, and has been actively involved in both basic and applied research in the area of power systems. His research interests include power systems, DC transmission, power electronics, and the integration of alternative energy sources into power networks.

Dr. El-Amin was an active member of the research team which conducted the projects, “Feasibility Study for Arabian Gulf States Interconnection” and “Mashreq Arab Countries’ Interconnection Study”.

Dr. El-Amin has published several technical papers and reports. He is a senior member of IEEE (USA) and an associate member of IEE (UK). Dr. El-Amin is currently serving as a reviewer for the International Journal of Energy Systems.

DR. ABU HAMED M. ABDUR-RAHIM

Dr. Abdur-Rahim is a Professor of Electrical Engineering at the King Fahd University of Petroleum and Minerals.

He received his Ph.D. in Electrical Engineering from the University of Alberta, Edmonton, Canada in 1972. His Ph.D. research was in the area of power systems and control theory. He obtained his B.Sc. degree in electrical engineering from the University of Engineering and Technology, Dhaka, Bangladesh in 1966.

Since his Ph.D., Dr. Abdur-Rahim has worked at the Bangladesh University of Engineering and Technology, the University of Alberta, the University of Strathclyde (UK), the University of Bahrain and the KFUPM. At the KFUPM, he has taught undergraduate and graduate courses in electrical power systems, electrical machines, control systems, etc. He has been actively involved in both basic and applied research in the area of power systems. His general research interests include power systems stability, control and optimization. Dr. Abdur-Rahim is involved in the research of FACTS system and application of fuzzy-logic and neural networks to power system dynamic studies. Presently he is working on robust control of power systems. Dr. Abdur-Rahim has published a good number of technical papers and reports. He is a senior member of IEEE (USA) and a Fellow of the IE (Bangladesh). Dr. Abdur-Rahim was an active member of the research team, which conducted the following projects.

- "Control of HVDC Links in Power Systems". Research Sponsored by the K.F. University of Petroleum and Minerals. Duration of project: March 1981 - February 1983.

- "Control Design for Large Power Systems: A Case Study on SCECO East". A Saudi Arabian National Center for Science & Technology (KACST) Project, July 1982 - June 1984.

- "Feasibility Study for Interconnection of Arabian Gulf States Electrical Power Systems". Project Sponsored by Gulf Co-operation Council, 1984 -1986.

- "A Master Plan Study of Saudi Arabia's Extra High Voltage Transmission Requirements". Saudi Arabian National Center for Science & Technology (KACST) Project, 1984 -1985.

- "Robust Shunt Connected FACTS Devices for Power System Damping Improvement", Research sponsored by King Fahd University of Petroleum & Minerals. Start date: December 2002.

- "Voltage Unbalance: Causes, Effects and Mitigation Techniques", Sponsored by Saudi Electric Company. Start date: Feb 2003.

DR. TAREK ABDELGALIL

Dr. Tarek Abdelgalil received the B.Sc. and M.Sc. degrees from Ain-Shams University, Egypt, and the Ph.D. degree from the University of Waterloo, Waterloo, Ontario, Canada, all in electrical engineering in 1992, 1998, and 2003, respectively. After his graduation, he has worked as a Post-Doctoral fellow at University of Waterloo, where he was involved in conducting funded research projects related to power quality and distribution system operation. Presently, he is with the Research Institute-King Fahd University Petroleum and Minerals working as Research Engineer (III). His research interests are in the area of the operation and control of distribution systems, power quality analysis, application of Artificial Intelligence algorithms in power system, high voltage and insulation systems. Dr. Tarek has authored and co-authored more than 25 referred journal and conference papers which are related to power quality and distribution system performance.

During his academic carrier, he has worked on many funded projects such as "Power quality standards", "Effect of extremely low frequency-electromagnetic fields on electric utility workers", "Environmental effect on polymer insulators properties", and "Partial discharge detection in cables using statistical methods

Dr. Tarek Abdelgalil is a member of the IEEE and a member of the Association of Professional Engineers of Egypt. He is a reviewer of technical papers for the IEEE Transaction on Power Delivery, the IEEE Transaction on Power System, IEEE Power Engineering Letters, and Elsevier Digital Signal Processing Journal.

MR. MOHAMMED ARIF ABDUL-MAJEED

Mr. Mohammed Arif Abdul-Majeed is Research Engineer III in the Center for Engineering Research at the Research Institute.

He obtained his MS in Electrical Engineering from King Fahd University of Petroleum and Minerals (KFUPM) in 1985 and BE from Nagpur University, Nagpur, India, in 1980.

In May 1981, Mr. Abdul-Majeed joined the Maharashtra State Electricity Board (MSEB), Nagpur, India, and was responsible for the erection and commissioning of high voltage substations. In April 1982, he joined KFUPM to pursue a graduate program in electrical engineering. As a graduate student, he participated in two externally funded research projects, namely:

A Master Plan Study of Saudi Arabia's Extra High Voltage Transmission System Requirements.

Feasibility Study for Interconnection of Arabian Gulf States Electric Power Systems.

Since joining the Research Institute in June 1985, he has actively participated in many research projects related to power systems and high voltage engineering, prominent among them are:

i. Peak Load Reduction by Load Management.

ii. Voltage Dip Study in Jubail Industrial Area.

iii. MYAS – SEC-WRB Electrical Interconnection Study.

iv. SCECO-West – SCECO-Central Electrical Interconnection Study.

v. Evaluation of Electric Energy Trading Benefits within Mashreq Arab Countries.

vi. High Voltage Insulator Performance in the Kingdom of Saudi Arabia.

He has co-authored several technical reports and published several technical papers in refereed technical journals and proceedings of national and international conferences.

MUHAMMAD FAREED KANDLAWALA

Muhammad Fareed Kandlawala received the M.Sc. degrees from the King Fahd University of Petroleum & Minerals Dhahran, Saudi Arabia, in 2001, the B.E degree from N E D University of Engineering & Technology, Karachi, Pakistan, in 1997, all in Electrical Engineering. From 1997 to 1998, he was with Sh. Wilayat Ahmad & Sons, Karachi as a Technical Sales Engineer. He joined the Electrical Engineering Department at King Fahd University of Petroleum & Minerals in 1998 as Research Assistant. He is currently a Lecturer in the same Department. He is a author or co-author of 7 paper in international journals and conferences. Mr. Kandlawala received 2nd best research award on his M. Sc. Thesis in 2002 in the "AIBTAKAR" competition at King Fahd University of Petroleum & Minerals, Dhahran, KSA.

He is a Life time member of the Pakistan Engineering Council (PEC).

He has participated in the following projects as a team member:

1. Fast Track project on Robust shunt connected FACTS devices for power system damping improvements, [Dec. 2002 - Dec. 2004]

2. SEC-RI project on Voltage unbalance: Causes, Effects & Mitigation Techniques, Project reference # CER 2256 [March – June 2003].

His research interests include Robust Control, Applications of Control Techniques in Power Systems, and FACTS.