

12TH IEEE/PES TRANSMISSION & DISTRIBUTION
CONFERENCE AND EXPOSITION

HOW GOOD IS YOUR SUBSTATION GROUND SYSTEM
WEDNESDAY SEPTEMBER 25, 1991
ROOM #W108, PANEL # 37

DETERMINING CONDITION OF GROUND SYSTEM COMPONENTS

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I APPRECIATE THE OPPORTUNITY TO SHARE WITH YOU TODAY
SOME OF THE THINGS THAT MY COMPANY IS DOING TO VERIFY THE
CONDITION OF OUR SUBSTATION GROUND GRID.

VIRGINIA POWER IS ONE OF SEVERAL SUBSIDIARIES OF
DOMINION RESOURCES, INC. OUR SERVICE AREA COVERS
APPROXIMATELY TWO THIRDS OF VIRGINIA AND OUR SISTER COMPANY,
NORTH CAROLINA POWER SERVES THE NORTH EAST PORTION OF NORTH
CAROLINA. TOTAL SYSTEM CAPABILITY IS ABOUT 15,000 MEGAWATTS
WITH RECENT PEAK DEMAND OF ALMOST 13,000 MEGAWATTS. OUR
ENERGY SOURCES ARE 38% NUCLEAR, 40% COAL, 18% PURCHASED AND
INTERCHANGED, AND 4 % OTHER. WE HAVE APPROXIMATELY
1,780,000 CUSTOMERS. OUR MAJOR TRANSMISSION SYSTEM VOLTAGES
ARE 500KV AND 230KV. OUR PRIMARY DISTRIBUTION VOLTAGE IS
34.5KV GROUNDED WYE.

A. DESIGN STANDARD

BRIEFLY, WE FOLLOW THE IEEE GUIDE 80 FOR OUR
SUBSTATION GROUND GRID DESIGN AND USE THE EPRI SUBSTATION
GROUNDING ANALYSIS COMPUTER - SGSYS PROGRAM FOR
DETERMINATION OF GRID SPACING, GROUND ROD LOCATIONS, ETC.

YEARS AGO WE USED MOSTLY THE EXOTHERMIC TYPE WELDED
CONNECTIONS. DURING THE LAST 10 YEARS WE HAVE TRIED ALMOST
EVERY TYPE OF CONNECTOR. TODAY WE ARE IN THE PROCESS OF
GOING BACK TO THE EXOTHERMIC TYPE OF WELDED CONNECTIONS AT
EACH CROSS POINT OF THE GRID AND ALSO TO THE ROD. BOLTED
CONNECTIONS CONTINUE TO BE MADE TO EACH ITEM OF EQUIPMENT
IN AT LEAST TWO LOCATIONS AND TO EACH STEEL STRUCTURE.

RECENTLY, WE CHANGED FROM 7 STRAND HARD DRAWN #4/0 COPPER
TO 19 STRAND SOFT DRAWN # 4/0 COPPER CONDUCTOR. THIS CHANGE
WAS MADE SOLELY BECAUSE IT IS MUCH EASIER TO INSTALL. THERE
WAS SOME CONCERN ABOUT CORROSION ON THE 19 STRAND CONDUCTOR,
HOWEVER WE BELIEVE THIS WILL NOT BE A PROBLEM FOR OUR SOIL
CONDITIONS.

SEVERAL YEARS AGO WE BECAME CONCERNED ABOUT THE INTEGRITY OF OUR GROUND CONNECTIONS. THERE ARE TWO MAJOR AREAS OF CONCERN; (1) PERSONNEL SAFETY, AND (2) PROTECTION OF THE EQUIPMENT AGAINST VOLTAGE TRANSIENTS AND NEUTRAL SHIFT CONDITIONS DURING FAULTS ON THE SYSTEM. OUR COMPANY IS NOTED FOR BEING A LEADER IN THE INDUSTRY FOR "LOW EQUIPMENT BIL LEVELS." THIS ALSO INCREASES THE IMPORTANCE OF GOOD GROUNDS. MOST IF NOT ALL THE PROBLEMS SEEM TO BE WITH LOOSE OR DEFECTIVE CONNECTIONS, NOT THE CONDUCTORS OR THE RODS. WE HAVE ALSO DISCOVERED SEVERAL CASES WHERE THE CONDUCTORS HAVE BEEN CUT DUE TO CONSTRUCTION IN THE AREA.

B. HIGH CURRENT TEST PROCEDURE

FOR THESE REASONS WE ADOPTED A "HIGH CURRENT TEST" PROCEDURE TO VERIFY THE CONDITION OF OUR GROUND CONNECTIONS. THIS TEST IS PERFORMED ON ALL NEW STATIONS BEFORE ENERGIZING AND EVERY EIGHT YEARS THEREAFTER.

I. THE FOLLOWING EQUIPMENT IS NECESSARY.

1. A. C. HIGH CURRENT SOURCE; CAPABLE OF PRODUCING 300 AMPERES CONTINUOUSLY, WITH METERS, VARIAC, ETC. SIMILAR TO MODEL GTS-300 MANUFACTURED BY EIL INSTRUMENTS., INC. SPARKS, MD, 21152
2. CLASS TWO RUBBER GLOVES FOR OPERATORS.
3. CLIP ON AMMETER
4. CABLES
5. PERMANENT MARKERS TO IDENTIFY GROUND RISERS.

II. SAFETY CONSIDERATIONS

1. CLASS TWO RUBBER GLOVES SHALL BE WORN BY ALL EMPLOYEES OPERATING THE HIGH CURRENT TEST SET AND /OR CONNECTING AND DISCONNECTING THE HIGH CURRENT TEST LEADS.
2. BEFORE DISCONNECTING ANY GROUND, BE SURE TO PARALLEL IT WITH AN APPROVED # 2/0 TEMPORARY GROUND. KEEP IN MIND TO NEVER " OPEN - CIRCUIT" THE GROUND CURRENT PATH FROM THE TRANSFORMER NEUTRAL OR ANY OTHER EQUIPMENT WHICH MAY HAVE CURRENT FLOW INTO THE GROUND GRID.
3. HAZARDOUS VOLTAGE AND CURRENT MAY EXIST IN SUBSTATION GROUNDING SYSTEMS AT ANY TIME. IF A GROUND RISER OR GROUND GRID CONNECTION IS FOUND TO BE LOOSE OR DEFECTIVE, THEN A SHUNT GROUND MUST BE PLACED IN PARALLEL WITH THE DEFECTIVES CONNECTION BEFORE REPAIRS ARE STARTED. THE SHUNT GROUND SHALL BE PLACED WITH APPROVED LIVE LINE TOOLS OR CLASS TWO, OR EQUIVALENT, RUBBER GLOVES.

III. TEST PROCEDURES

1. FIRST CONNECT THE TWO HIGH CURRENT TEST LEADS TOGETHER AND PASS THREE HUNDRED AMPS THROUGH THE LEADS. RECORD THE VOLTAGE DROP FOR REFERENCE.
2. USE THE TRANSFORMER NEUTRAL AS A REFERENCE GROUND WHEN AVAILABLE.
3. CONNECT ONE HIGH CURRENT LEAD TO THE REFERENCE GROUND ABOVE GRADE BUT BELOW ANY BONDING CONNECTION OR CLAMP.
4. CONNECT THE OTHER HIGH CURRENT LEAD TO THE GROUND RISER TO BE TESTED.
5. INCREASE THE VOLTAGE ON THE TEST SET UNTIL THREE HUNDRED AMPS FLOW THROUGH THE TEST LEADS AND RECORD THE VOLTAGE DROP ON THE TEST SET. THE VOLTAGE DROP WILL RISE APPROXIMATELY ONE VOLT MORE THAN THE REFERENCE "LEAD VOLTAGE DROP" RECORDED ABOVE FOR EACH FIFTY FEET OF STRAIGHT LINE DISTANCE FROM THE REFERENCE POINT TO THE TEST POINT.
6. USING A CLIP ON AMMETER MEASURE THE AMOUNT OF CURRENT FLOWING IN THE GROUND RISER BELOW THE TEST LEAD TO THE GROUND GRID AND THE AMOUNT OF CURRENT FLOWING IN THE GROUND RISER ABOVE THE TEST LEAD TO THE CONNECTED EQUIPMENT OR STRUCTURE. RECORD THE READINGS ON THE TEST SHEET. ON EQUIPMENT WITH SINGLE GROUNDS, AT LEAST 200 AMPS SHOULD FLOW DOWN TO THE GROUND GRID. ON SOME GROUNDS OF THIS TYPE, 100 AMPS WILL FLOW BACK TO THE GRID THROUGH FOUNDATION BOLTS, CONDUITS, ETC.
7. IF THE CURRENT FLOWS AND OR VOLTAGE DROP IS NOT IN ACCORDANCE WITH THE ABOVE THEN THE GROUND RISER SHOULD BE EXCAVATED, THE CAUSE OF THE HIGH RESISTANCE DETERMINED AND CORRECTED.
8. IN LARGE STATIONS IT MAY BECOME NECESSARY TO ADD EXTENSION LEADS TO THE HIGH CURRENT TEST LEADS OR RELOCATE THE TEST SET. IN WHICH CASE A PREVIOUSLY TESTED GROUND RISER MAY BE USED AS A NEW REFERENCE GROUND.

ON EQUIPMENT WITH MULTI GROUNDS, AT LEAST HALF OR 150 AMPS OF THE TEST CURRENT SHOULD FLOW TO THE GRID. IF THE CURRENT TO THE GRID IS LESS THAN 150 AMPS, DISCONNECT THE GROUND FROM THE EQUIPMENT (SEE CAUTION ABOVE) AND AGAIN PASS 300 AMPS THROUGH IT. IF THE GROUND PASSES 300 AMPS AND THE VOLTAGE DROP DOES NOT INCREASE MORE THAN .5 VOLTS OVER THE PREVIOUS LEVEL, CONSIDER THE GROUND SATISFACTORY.

C. OBSERVATIONS

WE ARE AWARE THAT THE ABOVE PROCEDURE DOES NOT WORK WELL TO FIND ALL QUESTIONABLE CONNECTIONS DUE TO OTHER NORMAL A. C. CURRENTS PRESENT IN THE GROUND CONDUCTORS WHEN THE STATION IS IN SERVICE. WE ARE WORKING ON A NEW TEST SET USING D. C. RATHER THAN AN A. C. VOLTAGE SOURCE. THIS METHOD WOULD ALLOW US TO CALCULATE AND OR MEASURE THE ACTUAL CIRCUIT RESISTANCE AND THUS FIND HIGH RESISTANCE CONNECTIONS.

OUR NORTHERN DIVISION HAS 365 SUBSTATIONS TRANSFORMERS. RECENT TEST FOUND 67 TRANSFORMER LOCATIONS WHERE THE CURRENT PASSING THROUGH THE NEUTRAL GROUND WAS LESS THAN THE TOTAL CURRENT PASSING THROUGH THE TANK GROUNDS. THIS IS MOST LIKELY DUE TO THE FACT THAT THE NEUTRAL IS BONDED TO THE TANK WITH MULTIPLE TANK GROUNDS. OUR STANDARD DISTRIBUTION IS SOLID GROUNDED WYE CONNECTIONS WITH ALL NEUTRALS; FROM THE CIRCUITS AND THE TRANSFORMERS CONNECTED DIRECTLY TO THE GROUND GRID. WE DO NOT USE A NEUTRAL BUS, AS SUCH, EXCEPT IN THE CASE OF SINGLE PHASE TRANSFORMERS.

IN AT LEAST TWO OF THESE STATIONS WE ARE IN THE PROCESS OF REPLACING THE EXISTING GRID DUE TO THE DETERIORATED CONDITIONS OF THE CONNECTORS DISCOVERED BY THIS TEST PROCEDURE. FROM THIS PROJECT IN ADDITION TO THE OTHER CHANGES TO OUR STANDARDS WE HOPE TO BE ABLE TO IMPROVE OUR SUBSTATION GROUNDING SYSTEM.

WE HAVE SEVERAL STATIONS WITH TERRACED GROUND ELEVATIONS AND OR STATIONS WHERE MAJOR ADDITIONS HAVE TAKEN PLACE. WE HAVE DISCOVERED, IN MANY OF THESE LOCATIONS, A LACK OF BONDING OF THE GROUNDS BETWEEN THE TWO AREAS. THIS WAS DISCOVERED WHEN TEMPORARY PERSONAL PROTECTIVE BONDING CONDUCTORS WERE USED TO BOND BETWEEN THESE SEPARATE AREAS.

WHERE NEW ADDITIONS ARE ADDED OFTEN THE EXISTING GROUND GRID IS CUT TO ALLOW NEW FOUNDATIONS, CONDUIT RUNS, ETC. WE HAVE FOUND CASES WHERE THE NEW STRUCTURE GROUNDS WERE NOT ADEQUATELY CONNECTED TO THE EXISTING GROUND GRID. THERE HAVE BEEN CASES WHERE CONTROL CIRCUIT GROUNDS ATTEMPTED TO PASS HIGH GROUND CURRENTS AND ACTED AS FUSIBLE LINKS, BURNING IN TWO.

OVER THE YEARS, SEVERAL TYPES OF GROUNDING HARDWARE HAVE BEEN USED ON OUR SYSTEM, RANGING FROM MECHANICAL, TO COMPRESSION, TO EXOTHERMIC TYPE CONNECTIONS. DIFFERENT TYPES REQUIRE DIFFERENT TOOLS, DIES, ETC FOR PROPER INSTALLATION. OFTEN, BECAUSE OF OUR TOOL STANDARDS WE DID NOT HAVE AVAILABLE, THE PROPER TOOL TO INSTALL A CERTAIN TYPE COMPRESSION CONNECTOR. THIS, PERHAPS HAS CONTRIBUTED TO THE CAUSE OF SOME OF THE POOR CONNECTIONS WE HAVE FOUND. CROSS REFERENCE TABLES ARE AVAILABLE, HOWEVER I BELIEVE AT LEAST PART OF OUR PROBLEM WAS THE SEVEN STRAND HARD DRAWN COPPER CONDUCTOR MENTIONED EARLIER.

OTHER PROBLEMS ARE IN CLEANING THE MUD, WATER DROPLETS, ETC PRIOR TO MAKING AN EXOTHERMIC TYPE CONNECTION.

THERE IS ALSO A CONCERN FOR THE THREADED CONNECTIONS BETWEEN SECTIONAL COPPER CLAD GROUND RODS. OTHER TYPE CONNECTIONS INCLUDING EXOTHERMIC ARE BEING EVALUATED. FIELD TEST ARE ALSO PRESENTLY UNDERWAY ON DIFFERENT TYPES OF GROUND RODS. DIFFERENT DIAMETER RODS, DIFFERENT MATERIALS AS WELL AS DIFFERENT TYPE SPLICES ARE BEING EVALUATED.

D. GROUND GRID GENERAL REQUIREMENTS

1. EIGHTEEN INCHES DEEP AND EXTEND THREE FEET OUTSIDE STATION FENCE LINE. #4/0 19 STRAND SOFT DRAWN COPPER.
2. MAXIMUM GRID SPACING SHOULD BE 50 FEET, MINIMUM WILL NORMALLY BE 5 FEET.
3. OPTIMUM ROD SPACING FOR LOWERING THE GROUND RESISTANCE IS 2 TIMES THE LENGTH OF THE RODS.
4. A MINIMUM OF TWO 6 FOOT RODS SHOULD BE USED AT EACH ROD LOCATION.
5. GRAVEL SHOULD BE AT LEAST 3 INCHES DEEP.
6. GROUND GRID RESISTANCE FOR LARGE DISTRIBUTION AND TRANSMISSION STATIONS SHOULD BE 1 OHM OR LESS. SMALLER STATIONS SHOULD BE LESS THAN 5 OHMS.

REFERENCE: HIGH-CURRENT METHOD OF TESTING GROUND GRID INTEGRITY, BY A. S. GILL, P.E. "NETA WORLD." MR. GILL IS A SENIOR ENGINEER WITH THE NUCLEAR REGULATORY COMMISSION.

VIRGINIA POWER SUBSTATION OPERATING GUIDELINES AND WORK PROCEDURES, ELECTRIC OPERATIONS DEPARTMENT.