PROTECTIVE RELAYING PERFORMANCE REPORTING

WORKING GROUP ON PROTECTIVE RELAYING PERFORMANCE CRITERIA OF THE POWER SYSTEM RELAYING COMMITTEE: R. P. TAYLOR, CHAIRMAN, J. W. INGELSON, VICE CHAIRMAN, P. F. ARNOLD, G. BABCOCK, A. A. BURZESE, J. R. CORNELISON, P. R. DRUM, I. HASENWINKLE, R. JOHNSON, W. J. MARSH, JR., W. M. MELLO, T. J. MURRAY, K. K. MUSTAPHI, S. L. NILSSON, R. ONATE, D. E. SANFORD, L. SCHARF, H. S. SMITH, M. SWANSON, D. TZIOUVARAS, E. A. UDREN, J. A. ZIPP

ABSTRACT

The performance of protective relaying systems is an issue within the electric power industry which has received inadequate attention. The wide variations in relaying types and styles and applications, as well as differences in company structures and industry terminology, have hindered the adoption of a standardized system for the evaluation of protective relaying system performance. Such a system, if adopted by a significant portion of the industry, would provide suppliers and users better information with which to improve the product and its application and operation.

The "Protective Relaying Performance Criteria" Working Group of the IEEE Power System Relaying Committee has generated this paper for the purpose of defining a standardized protective relaying performance reporting system.

KEY WORDS: Relay Performance, Data Base, Performance Reporting, Relaying Failures, Equipment Failures

INTRODUCTION

Protective Relaying Performance is not easily quantified. Conventional analysis tools, such as availability or reliability, are difficult to use, or even define, for the variety of protective relaying applications in service.

Common to all forms of analysis is the need for data, specifically failure data. Failure data can be useful in itself or can be used to create performance statistics. Protective system failures encompass failures to clear faults by designed devices or systems or in designed times, false operations, application errors, input or output device failures, control communication failures, in-service failures as detected by alarms or annunciators, and maintenance-detected failures or out-of-tolerance conditions.

Protective systems include the protective relays, the associated auxiliary relays, the input sources, the control communication systems, and the interrupting devices controlled by the relaying.

A comprehensive system of reporting should allow classification of failures and identification of failure modes and failed devices and components.

The gathering of failure data requires the involvement of field personnel who operate and maintain the protective systems. For this reason, terminology must be as universal as possible and data gathering forms must be simple and concise. On the other hand, the data must be complete and detailed enough to be of value to both suppliers and users of protective relaying.

This paper introduces a computer data base program which organizes and simplifies the data gathering process. This computer program allows consistent and clearly defined categorization of the data so that interpretation or statistical analysis is easily derived.

The paper begins with a discussion of the benefits associated with the compilation of protective system performance data. The rest of the paper provides the details necessary to begin implementation of a comprehensive reporting system.

PURPOSES FOR GATHERING PROTECTION PERFORMANCE DATA

In order to make informed decisions, people need information based on data. Data acquisition can be difficult and expensive. In addition to the collection costs, there are usually data processing and data file maintenance costs. It is therefore essential to have an understanding of the penalties involved in making decisions with insufficient data. These penalties, which are related to the costs of incorrect decision making, have to be weighed against the costs of collecting, processing, and maintaining the data.

Data specifically related to performance of protective relaying systems can be used for a number of decisions made by utility planning engineers, purchasing agents, relay designers, application and maintenance engineers, etc. The potential uses of the data will be discussed without considering the cost/benefit function for the data.

Protective relays are used for detection and isolation of power system faults, and for restoration of service with a minimum interruption of power. False operation of the protective relays can lead to unnecessary loss of power or to more equipment damages than expected under correct operating conditions. In both cases, loss of revenues, equipment repair costs, potential legal liabilities, and customer dissatisfaction can result. When relay performance can be accurately predicted from performance data, the aforementioned problems can be minimized.

1. Utility Planning Decisions

The planning engineers have to configure the power system to provide specific targets for quality of service. To do so, the probability of losing a system element must be known or predictable. The consequences of the loss and the restoration time must also be considered. For this consideration, the planners must know the probability for false operation (security violation) of a relay as well as the probability for no operation (dependability violation). For estimation of the restoration times, the planners must also know the probability for repair or replacement of the system element within a given time. Acquiring this information is deceptively complex because of the numerous possible causes of operating problems, not all of which can be described by means of statistically simple functions.

Operating failures can have many causes. Human errors in the application, setting, maintenance, or operation of the relaying systems are one source. Equipment design errors or component failures are other causes. Of these failures, incorrect operations caused by component failures are predictable with relatively high confidence, while the others are not so easy to predict because the available data base may be too small for the use of statistical methods.

Other performance factors, such as the need for periodic maintenance, would also be important for the planners to consider. Maintenance can have a direct impact on the availability of portions of the power system if outages are needed to perform maintenance. Repair times can be predicted within a reasonable time frame by experienced personnel, especially if the problem is well defined.

2. Procurement Decisions

The procurement process for protective system components usually involves the application of performance data for the qualification of suppliers and for awarding of contracts. While there are many factors to consider for qualification of vendors, performance data for protective relays or relay systems from equipment in service can be used to evaluate the vendor's potential performance.

Performance data can also be used for evaluation of a bid or quote related to a new procurement. The bid evaluation should include an estimate of the life cycle costs of different alternative procurements. For this evaluation, one must consider first cost (purchase price, installation, etc.) and maintenance costs, which include the need for spare parts, labor costs, and the predicted number of repair requirements over the expected life of the relay or system. Knowledge about the mean time to failure of the various parts for the relay and relaying system is needed for determination of the spare parts needs and the expected repair costs. This information can and should be used to estimate the true costs of the various bids.

Other performance aspects related to the risk for incorrect operations should also be considered, but could be assumed to have been included in the functional specification that forms the basis for the procurement. If this is not the case, the security and dependability of the proposed alternatives should be evaluated. The estimated outage cost differences should be included in the procurement decisions.

3. Operating Decisions

The operation of a protective relay requires decisions about the specific operating parameters (settings) to install in the relay and the adjustment of these parameters in the event of abnormal power system conditions. Also, the periodic maintenance schedules and procedures and the corrective (repair) maintenance practices must be determined. Relay performance data can be used as inputs for all of these decisions.

The settings are often a compromise between security and dependability. Information about the performance of the relays in different applications can be used to guide the engineers in determining the best settings for each application.

Failure rate data for relays is possibly the single most important factor in establishing periodic maintenance schedules and/or spare parts procurements. By having good performance data for the relay and relaying systems, relay misoperations may be better predicted and thus meet overall cost objectives. One may also estimate the necessary maintenance staffing levels.

Corrective maintenance is normally associated with failures detected by a preventive maintenance test or from discovering that the relay did not operate properly for a disturbance. Detection of the latter normally results from an analysis of the disturbance reports, which are a primary data source for compiling performance statistics. Corrective maintenance data can also be used for administration of product warranties from the suppliers. Preventive maintenance data can yield trends which can indicate the existence of design defects, or end of life, for the relays.

4. Relay Design Decisions

The relay suppliers have to make many trade-offs when a new relay is designed. The manufacturers will normally have specific applications in mind when the relay is designed. However, the user may not be aware of the design application and may apply the relay to systems for which they were not intended. Feedback from the users can be used to inform the supplier of these applications which can be useful to enhance the product or for the development of new products. The supplier with the best information should have an advantage in the marketplace.

The designers have reasonably good tools for prediction of the component reliability. Component reliability data is helpful and, along with vendor quality control, can be useful in designing the right test points into the system. Tests at the factory of the assembled relays or relay systems can also be designed to maintain the product at an appropriate quality level.

It should be clear though, that there is a limit to how much quality the manufacturer can afford to build into a product.

Too much quality would make the product unacceptably expensive. However, even with all of the efforts by the manufacturers to produce quality products, defective components can get into the products. Component failure rate information feedback to the manufacturers can indicate at an early stage if there are any weak components in the relays. This information can be used to alert the users to the problem, which in turn can let the users perform the appropriate modifications to the relay before more failures occur. It should, therefore, be in the best interest of the utilities to share available performance data of this type with the relay suppliers.

DATA COLLECTION

The form used to collect data for the Protective System Problem Reporting System may vary from company to company. These variations may be caused by the need to comply with existing procedures and requirements that may contain data not of general interest to others.

Examples include Substation Names, Dates, Times, and Report By data. A sample data collection form is included as Appendix A.

The data collection form shown as Appendix A has been designed with several features considered important in order to gain acceptance by field personnel and also to produce meaningful information. The form should use easily understood or "universal" terminology. The form should be short and easily completed in the field. The use of codes has been avoided. Even though codes shorten the process of data entry, the requirement to have access to code lists is considered to be a negative. The form allows the field personnel to either check a block or to enter text in the blanks. The interpretation of the text is done when the field form is then entered into the data base.

Certain data has been identified as essential to this data collection system. This data will be described in detail, along with the data base structure and the reporting format. By carefully defining the treatment of this core data, this system allows the sharing of the information among interested parties.

The following data has been identified as essential to all Protective System Problem Report Systems:

Problems Detected by - the possible responses to this data field are Fault, Non-Fault Operation, Annunciator/ Alarm, Preventive Maintenance, or Acceptance Testing.

Problem Result - responses to this data field are Caused Unnecessary Operation, Equipment Unable to Perform Designed Function, Out of Calibration/Range, or Other.

System Involved - responses are Relaying, Communications, CT's, VT's, DC System, Breaker, or Other.

Device Involved - the form allows text entry to identify the specific device with the problem. The data base allows the following entries for this field: Relay/Relay System, Carrier Equipment, Fiber Optics Equipment, Other Communications, Switchgear/Breaker, Unlisted Major Equipment, Capacitor VT, Voltage XFMR, Current XFMR, SCADA, Monitor Equipment, Cable, Other.

Manufacturer - text entry on the form of the manufacturer's name. The data base provides a menu with the names of most manufacturers listed.

Device Identification - text entries to allow model numbers, serial numbers, etc.

Application Description - the form allows text entry of the type scheme in which the problem equipment is being applied. The data base provides the following selections: Other, Line Protection, Line Protection - Primary, Line Protection - Back Up, Bus Protection, Transformer Protection, Generator Protection, Motor Protection, Capacitor Protection, Shunt Reactor Protection, Breaker Protection, Local Back Up, Auxiliary Tripping, Reclosing, Synchronizing, Monitoring, Alarms/ Annunciators, Voltage Regulating, Relaying Input (CT, VT, etc.), Frequency Relaying, SCADA, Communications (Non-relaying).

Trouble Description - the form allows text entry by the person detecting the problem to describe it in his words. The data base provides the following choices: Alignment, Animals, Blown Fuse, Broken, Burned, Calibration Incorrect, Connection, Corrosion, Dirty, Foreign Matter, Ground, Missing Part, Moisture, Open Circuit, Short Circuit, Tension Incorrect, PC Board Problem, Software Problem, Unknown, Other.

Corrective Measures - the form allows text entry by the person correcting the problem to describe it in his words. The data base allows the following options: Other, Adjusted, Calibrated, Changed Setting, Cleaned, Corrected Error, Inspected/Tested, Modification Applied, None, Notified Supervisor, Removed, Repaired in Shop, Repaired Permanent, Repaired Temporary, Replaced, Reported Problem, Returned to Manufacturer, Tested Good, Trouble Still Exists.

In order to further translate the information from the field form to the data base, menus have been provided which offer choices to better define "Trouble Type", the equipment "Subunit", and the equipment "Component". The choices provided by these menus are shown in Appendix B, as are all the other menus for the data listed above.

DATA BASE STRUCTURE

In order to standardize the data collection, storage, and reporting, a standard data base structure is proposed for the portion of the data considered essential for inter-company reporting. The standard data base would use the dBase III Plus software. Appendix C is a listing of the fields and field structure for a data base file which would accept the proposed data inputs.

Data entry has been simplified by the creation of data entry screens, using pop-up menus to enter the essential information. These data entry screens were created using a software program called SoftCode. SoftCode creates the screens and also produces documentation of the codes. This documentation is too lengthy to be included in the paper, but can be provided by request.

OUTPUT REPORTS

The data gathering program described in this paper has been provided with a menu to produce output reports. The standard output report provides one record per page with all data reported in essentially the same order it was entered. An example of this Output Report is shown as Appendix D. Reports which have a different format or which leave out some of the fields could be developed by users who have a basic knowledge of dBase III Plus.

In addition to the standard output report, the output menu also allows data sorting using any two of the fields. This feature allows one to produce output reports for only those records that have specific responses in one or two of the data entry fields. As an example, a report could be generated containing all records in which the System Involved was "Relaying" and the Problem Result was "Caused Unnecessary Operation."

Additional sorting of the data could be achieved by sorting the first time, as described above, and then creating a new data base file with this data. The new file could then be sorted using two new fields.

Output reports, using the data available, could be used in many ways. One use would be to report to equipment suppliers the problems which have been detected with a specific piece of equipment. For this purpose, an output report sorted by Manufacturer and by Device Type would be used. Additional sorting could isolate the records by Catalog/Model/Style No. or by Subunit or Component. A further use of this data would be to determine spare part requirements based on failure histories or to make procurement decisions.

As these data bases become large and as several utilities begin to share or combine their results, the value and the effect on these equipment suppliers should be substantial. Common or generic problems will become evident more quickly. Manufacturers will be made aware of problems faster and more forcefully.

Individual utilities can benefit from an output report which identifies the effect of the problem on the electric system. This report would use data sorted on the field, Problem Result. These reports would be useful to analyze the causes of system misoperations. If coupled with data such as the operating or in-service time for all devices of a certain type, this data could be used to produce statistical information. These statistics could include annual failure rates, system availability (where "Equipment Unable to Perform Designed Function" is a known Problem Result), and several other common industry statistical measures.

An important use of the data may be to determine how problems are being found. The Problem Detected By field could be used to analyze the effectiveness of preventive maintenance and of monitoring systems or self-checking features. The Problem Detected By responses of "Fault" and "Non-Fault Operation" could be evaluated to direct future maintenance efforts or to determine other means to identify the problems before they cause misoperations.

There are many other possible uses of this data. The sort features built into the program allow easy use of much of the data. The standard output report provides all of the input data for each record in a clear, logical format. Users with a basic knowledge of dBase can add fields, create custom output reports, or produce other ways of analyzing the data. It is important to emphasize that the basic structure of the data base should not be changed if data is to be shared with other users.

CONCLUSIONS

This paper has described a system for gathering, reporting, analyzing, and sharing data on protective system problems. Protective systems are defined as the relays, their inputs (which include the DC system, communications, current sources, and voltage sources), and their outputs (which include breakers, switches, annunciators, SCADA, and fault recorders).

The need for this system, as well as the uses of the data once it has been gathered, has been explained. It is hoped this paper will encourage the use of this data gathering system and the subsequent sharing of data among users. The Working Group within the Power System Relaying Committee that has produced this paper should remain available to provide the program to potential users, to make whatever modifications become necessary, and to serve as a catalyst in the process of data centralization and analysis.

For more information or a copy of the software, contact:

John Appleyard
Secretary PSRC
Wisconsin Power & Light Co.
500 Townline Road, Rte. 3
Beloit, WI 53511

APPENDIX A
SAMPLE FIELD REPORT FORM

PROTECTIVE SYSTEM PROBLEM REPORT

Report By: ________________________ Report Date: ___/___/___ REPORT # __________

Date Problem Detected: ___/___/___ Time: __________

Substation: ________________________ Location/Identifier: ________________________

Problem Detected By:

☐ Fault ☐ Non-Fault Operation ☐ Annunciator/Alarm ☐ Preventive Maintenance ☐ Acceptance Testing

Problem Result:

☐ Caused Unnecessary Operation ☐ Equipment Unable to Perform Designed Function

☐ Out of Calibration/Range ☐ Other ________________________

System Involved:

☐ Relaying ☐ Communications ☐ CTs ☐ VTs ☐ DC System ☐ Breaker

☐ Other ________________________

IEEE Device Number: ________________ Device: ________________

Manufacturer: ________________ Cat/Model/Style No.: ________________

Unit/Component: ________________________

Date Code/Serial Number/Other Identifier: ________________________

Application: ________________________

____

Trouble Description: ________________________

____

Corrective Measure: ________________________

____

Associated Outage Report? ☐ Yes ☐ No Investigation/Report Complete? ☐ Yes ☐ No

Time Out of Service: __________ Hours Repair Time: __________ Hours Repair Cost: __________

PROBLEM DETECTED BY

0	Other
1	Fault
2	Non-Fault Operation
3	Annunicator/Alarm
4	Preventive Maintenance
5	Acceptance Testing

PROBLEM RESULT

0	Other
1	Caused Unnecessary Operation
2	Equipment Unable to Perform Designed Function
3	Out of Calibration/Range

SYSTEM INVOLVED

0	Other
1	Relaying
2	Communications
3	CT's
4	VT's
5	DC System
6	Breaker

DEVICE

000	Other
005	Relay/Relay System
012	Carrier Equipment
015	Fiber Optics Equipment
018	Other Communications
020	Switchgear/Breaker
030	Unlisted Major Equipment
040	Capacitor VT
050	Current XFMR
060	SCADA
065	Monitor Equipment
070	Cable

MANUFACTURER

000	Other
110	ABB
120	Agastat
130	Allis-Chalmers
140	ASEA
150	Basler
160	BBC
170	Beckwith
180	Chrysler
190	Cogenel
195	Cooper Power Systems
200	Dacon
210	Doble Engineering
220	Dranetz Eng. Labs
230	Electro Devices
240	Electrocon
250	Electroswitch
260	E-MAX
270	Federal Pacific
280	General Dynamics
290	General Electric
300	GEC Measurements
310	Hathaway Instruments
320	HVB
330	ITE Corp.
340	Joslyn
350	Licom
360	Macrodyne
370	McGraw-Edison
380	Multi-Amp Corp.
390	Raychem
395	Relay Associates
400	RFL Industries
410	Rochester Instrument
420	RTE
430	Sangamo
432	Schlumberger
440	S&C Electric
450	Schweitzer Eng. Labs
460	Siemens
470	Siemens-Allis
472	Square D
475	WABB
480	Westinghouse
490	WEMCO
500	Wilmar

UNIT

000	Other
021	Base Housing
029	Bushing
034	Circuit Board
036	Clutch/Magnet Assembly
040	Comparator unit
043	Contact Assembly
050	Converter
054	Current XFMR
059	Detector
063	Disk/Shaft Assembly
064	Discriminator
074	Fault Detector
092	Hybrid
094	Impedance Unit
096	Instantaneous Unit
099	Interlocking Unit
110	Magnet/Coil Assembly
113	Meter
114	Meter Switch
115	Mho Unit
117	Mixer
120	Module
121	Monitor
122	Motor Assembly
123	Motor/Clutch Assembly
137	Phase Unit
145	Power Supply
154	Receiver
162	Seal-in Unit
178	Synchroscope
183	Target Unit
188	Terminal
190	Time Delay Unit
194	Transceiver
196	Transmitter
197	Tuning Pack
198	Tuning Unit
203	Voice Unit
207	Voltage XFMR
237	Line tuning Unit
260	Line Trap
261	Coupling Capacitor

COMPONENT

000	Other
001	N/A
003	Ammeter
004	Amplifier
007	Attenuator
008	Auxiliary Relay
010	Barrier
011	Battery
012	Battery Charger
013	Bearing
016	Blade
018	Board
019	Bracket
021	Brush
023	Bushing
025	Cam
030	Capacitor
032	Chassis
033	Circuit Board
039	Clutch
041	Coil
042	Compensator
045	Connector
047	Contacts
050	Counter
051	Cover
052	Cradle/Case
055	Crystal
056	Current XFMR
057	Dial
059	Diode
061	Disc
062	Display
063	Drainage Coil
068	Filter
069	Fuse
070	Fuse Holder
074	Gasket
080	Handset
081	Hardware
082	Heat Sink
086	IC
087	Inductor
092	Insulator
095	Jack
098	Lamp
102	Lever
106	Magnet
100	LED
109	Micro-switch
110	Motor
111	MOV
125	Pivot Assembly
126	Plug
128	Potentiometer
130	Press Relief Valve

131 Pressure Switch
137 Rack
138 Reactor
142 Rectifier
144 Relay
145 Resistor
148 SCR
149 Sensor
150 Shaft
154 Sliding Link
156 Socket
159 Springs
160 Stepping Switch
163 Surge Arrestor
164 Surge Protection
165 Switch
167 Tap Block
170 Target
171 Terminal Block
172 Termination
173 Test Block
174 Test Switch
176 Transformer
177 Transistor
179 Trip Coil
180 Tube
181 Valve
182 Variable XFMR
185 Voltage XFMR
186 Voltmeter
189 Wiring

APPLICATION

00 Other
01 Line Protection
02 Line Protection - Primary
03 Line Protection - Back Up
10 Bus Protection
20 Transformer Protection
30 Generator Protection
35 Motor Protection
36 Capacitor Protection
38 Shunt Reactor Protection
40 Breaker Protection
45 Local Back Up
51 Auxiliary Tripping
60 Reclosing
65 Synchronizing
70 Monitoring
71 Alarms, Annunciators
72 Voltage Regulating
80 Relaying Input (CT, VT, etc.)
81 Frequency Relaying
85 SCADA
90 Communications (Non-relaying)

TROUBLE TYPE

00 Other
01 Electrical
10 Electronic
20 Mechanical
30 Setting
40 Application
50 Human Error

TROUBLE DESCRIPTION

00 Other
01 Alignment
03 Animals
05 Blown Fuse
07 Broken
09 Burned
10 Calibration Incorrect
12 Connection
14 Corrosion
18 Dirty
20 Foreign Matter
22 Ground
25 Missing Part
27 Moisture
30 Open Circuit
40 Short Circuit
50 Tension Incorrect
60 PC Board Problem
70 Software Problem
90 Unknown

CORRECTIVE MEASURES

00 Other
01 Adjusted
02 Calibrated
03 Changed Setting
08 Cleaned
10 Corrected Error
17 Inspected/Tested
20 Modification Applied
22 None
25 Notified Supervisor
34 Removed
37 Repaired in Shop
38 Repaired Permanent
39 Repaired Temporary
40 Replaced
42 Reported Problem
44 Returned to Manufacturer
57 Tested Good
61 Trouble Still Exists

APPENDIX C - STRUCTURE FOR DATABASE

Field	Field Name	Type	Width
1	REPORT_BY	Character	15
2	REPORTDATE	Date	8
3	PROB_DATE	Date	8
4	PROB_TIME	Character	6
5	STATION	Character	20
6	LOCAT_ID	Character	34
7	PR_DET_BY	Character	25
8	PROBRESULT	Character	45
9	SYSTEM_INV	Character	25
10	IEEE_NUMB	Character	3
11	DEVICE	Character	25
12	CAT_MOD_ST	Character	15
13	MANUFACTURER	Character	25
14	COMMENTS1	Character	50
15	COMMENTS2	Character	50
16	SUBUNIT	Character	25
17	COMPONENT	Character	22
18	OTHER_ID	Character	40
19	APPLICATION	Character	35
20	TROUB_TYPE	Character	15
21	TROUB_DESC	Character	25
22	CORR_MEAS	Character	30
23	OUTAGE_REP	Logical	1
24	INVES_REPT	Logical	1
25	TIME_OUT	Numeric	6
26	TIME_REPAR	Numeric	6
27	COST-REPAR	Numeric	6
28	COMMENT1	Character	50
29	COMMENT2	Character	50

APPENDIX D
SAMPLE OUTPUT REPORT

REPORT BY: ROCKHOLD

RECORD NO.:

REPORT DATE: 01/24/91

PROBLEM DATE: 1/01/91

PROBLEM TIME: 23:45

SUBSTATION: LOUISIANA

LOCATION: TAYLOR LINE PANEL

PROBLEM DETECTED BY: 1 FAULT

PROBLEM RESULT: 1 CAUSED UNNECESSARY OPERATION

SYSTEM INVOLVED: 1 RELAYING

EXPLANATION OF: BRAND X IMPEDANCE RELAY

OTHER CHOICES:

DEVICE: 005 RELAY/RELAY SYSTEM

APPLICATION: 02 LINE PROTECTION - PRIMARY

IEEE NUMBER: 21

MANUFACTURER: 999 OTHER

CATALOG/MODEL/STYLE NO.: ABC-1234

OTHER ID: DIODE - D12

COMPONENT: 059 DIODE

SUBUNIT: 034 CIRCUIT BOARD

TROUBLE TYPE: 10 ELECTRONIC

TROUBLE DESCRIPTION: 09 BURNED

CORRECTIVE MEASURES: 40 REPLACED

ASSOCIATED OUTAGE REPORT: NO

INVESTIGATION/REPORT COMPLETE: YES

TIME OUT OF SERVICE: 3 DAYS

TIME FOR REPAIR: 2 HRS.

COST OF REPAIR: $250

COMMENTS: NORMAL DIODE REPLACEMENT