Shippensburg University

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SUPPLEMENT 1
Electrical Coordination Study

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August 24, 2004

Electrical Coordination Study
Table of Contents

EXECUTIVE SUMMARY **1**

INTRODUCTION **2**

DISCUSSION **2**

RECOMMENDATIONS **3**

CONCLUSIONS **7**

Appendix A – Existing Curves

Appendix B – Recommended Curves

EXECUTIVE SUMMARY

As a supplement to the Shippensburg University Medium Voltage Distribution Study conducted by Entech Engineering Inc., the coordination of the medium voltage distribution system was analyzed. Time current curves (TCC's) used in this analysis are included in Appendix A of this report. The names of these TCC's coincide with feeder or building and transformer names as indicated on the site plans and single-line diagrams included with the main report. This analysis revealed that, in general, the system over-current protection is coordinated. However, there are several areas of concern where coordination can be improved.

Setting Adjustments

Coordination in the following areas of the system can be corrected by adjusting settings on relays and circuit breakers, or replacing fuses:

1. TCC 1201
2. TCC1202
3. TCC1203
4. TCC 1204
5. TCC TR1-1 McCune Hall
6. TCC TR3-4 Franklin Science Center

Appendix B of this supplement contains TCC's that indicate these device adjustments. The cost of making these corrections is estimated to be $6,500.

Upgrade or Replacement

Other areas will require upgrade or replacement of over-current devices or equipment. These areas are as follows:

1. TCC TR1-3 Henderson Gym
2. TCC TR1-9 Tennis Courts & Multi Use Field
3. TCC TR2-8 Cora Grove Spiritual Center
4. TCC TR3-1 Ezra Lehman Library
5. TCC TR4-5 Cumberland Student Union

The approximate cost to upgrade this equipment is $75,000.

INTRODUCTION

Entech Engineering, Inc. was asked to analyze the 12.47kV medium voltage distribution system at Shippensburg University. As a supplement to that analysis, a coordination study of the system's protective devices was completed with information attained as part of that analysis. The following is a discussion of the findings and recommendations that resulted from the coordination study. The majority of the information for this study came from Entech's field surveys. However, since the system was energized at the time of the surveys and some devices could not be accessed, the University's electrical staff assisted with data collection.

DISCUSSION

Appendix A of this supplemental report contains time current curves (TCC's) for each of the system's main feeders (1201, 1202, 1203, and 1204) and each transformer serving Campus buildings (Old Main, Franklin Science Center, etc.). The TCC's for each feeder typically indicate the following:

1. TCC for the associated Main Substation bus circuit breaker over-current relay #1 or #2.
2. TCC for the feeder circuit breaker over-current relay.
3. TCC for the largest over-current device (fuse, circuit breaker, etc) on the feeder.

In some cases additional information, such as the inrush current point for the largest transformer on the feeder, was also shown based on importance to the analysis.

The TCC's for each of the Campus building transformers generally indicate the following:

1. TCC for the primary over-current device (typically fuses).
2. TCC for the secondary main over-current device (typically a circuit breaker).
3. Transformer damage curves (these are modeled based on industry standards, rated input impedance, and temperature rating).

Upon review of the TCC's it appears in some cases that the primary protective device doesn't protect the transformer because it is not entirely "left" of the transformer damage curve, especially in the "longtime" (overload) region of the TCC. These occurrences are not typically highlighted as concerns in this report, since most every transformer on the system has only one main secondary over-current protective device directly inline. If properly sized, this device should clear overload faults caused by down stream loads. Only an overload fault between the primary and secondary over-current protective devices can damage the transformer. Typically,

a fault in this area of the system will be a direct phase-to-phase or phase-to-ground fault (short circuit), and will likely be cleared by the primary device with out damage to the transformer. Also, most of the primary over-current devices on each feeder are fuses with predetermined (non-settable) curves. As result, the designer choosing fuses must pick a best-fit curve for transformer protection without allowing nuisance tripping on the power up inrush current of the transformer. For this reason, when cost is not of concern, many system designers will use a protective device with settable curves, such as relay and circuit breakers.

The TCC's in Appendix A indicate that the system is generally coordinated. There are, however, some areas of concern that are discussed later in this report. In some cases these issues are easily resolved by changing relay or breaker settings. In others, device or equipment upgrades should be considered.

RECOMMENDATIONS

As mentioned above, there are some areas of concern throughout the system. The following is a list the issues by TCC, as found in Appendix A. These TCC names coincide with feeder, or building and transformer names, as indicated on the site plans and single-line diagrams included with the main report. For each item, there is a brief discussion of the reason for concern, followed by a recommendation for correction. Where a new TCC is relevant to the recommendations for correction, a recommended TCC is included in Appendix B of this supplement.

TCC 1201, TCC 1202, TCC 1203, TCC 1204: These curves show coordination between each of the four main feeder relays, the upstream 12.47kV main bus relays, and the largest down stream overcurrent device on each feeder. No information was available for the high voltage fuses for the Franklin Science Center transformer (TR3-4) on feeder 1203. For the purposes of this study, it was assumed that class C fuses similar to those found in outdoor transformers on Feeder 1201 were used. A 100A fuse was chosen based on the transformer kVA rating (2000kVA). Using this assumption and data collected from the field, the TCC's indicate the following coordination issues:

1. The feeder 1201 circuit breaker relay is not coordinated with the high voltage fuses for Horton Hall (TR1-4) in the short time and instantaneous area.
2. The feeder 1202 circuit breaker relay is not coordinated with the high voltage fuses for Old Main (TR2-9) in the short time and instantaneous areas.

3. The Main Bus #2 relay is not properly coordinated with the assumed medium voltage fuses for TR3-4 on feeder 1203 in the short time region.
4. The 1203 feeder relay trip curve crosses the inrush point for the Franklin Science Center transformer(TR3-4). Therefore, the 1203 relay could trip before the TR3-4 fuses on a down stream fault or on power up of TR3-4.

The existing settings for the feeder (1201, 1202, 1203, 1204) breaker relays and the main 12.47kV bus (1, 2) breaker relays are shown in the table below:

EXISTING RELAY SETTINGS*						
Setting	**Main #1**	**Main #2**	**1201**	**1202**	**1203**	**1204**
Curve	I2T	I2T	I4T	I4T	I4T	I4T
LTPU	1.0	1.0	0.75	0.75	0.75	0.75
LTD	2.5	2.5	0.2	0.2	0.2	0.7
STPU	2.25	2.25	1.0	2.5	2.5	4.0
STD	0.5	0.5	0.05	0.1	0.1	0.3
INST	25	25	—	—	—	—

*Note: CTs for main relays and feeder relays are 400:5 and 200:5 respectively.

The coordination issues above can be corrected by resetting the relays as indicated in the following table:

RECOMMENDED RELAY SETTINGS*						
Setting	**Main #1**	**Main #2**	**1201**	**1202**	**1203**	**1204**
Curve	I4T	I4T	I4T	I4T	I4T	I4T
LTPU	0.8	0.8	1.2	1.2	1.2	1.2
LTD	2.25	2.25	12.5	12.5	12.5	12.5
STPU	4.5	4.5	9.0	9.0	9.0	9.0
STD	0.5	0.5	0.1	0.1	0.1	0.1
INST	25	25	—	—	—	—

*Note: CTs for main relays and feeder relays are 400:5 and 200:5 respectively.

TCC's 1201, 1202, 1203, and 1204 in Appendix B of this supplement show the recommended curves based on these settings. The actual fuse rating for TR3-4 should be determined prior to resetting relay values as lower values may be possible.

Although the coordination issues above could be corrected without resetting the main 12.47kV bus relay #1 and the feeder 1204 relay, it is recommended that both main 12.47kV bus relays have the same settings and that the feeder relays have the same settings. This will help with load balancing across all four feeders as new loads are added to the system and facilitates coordination of the tie-breaker between the main 12.47kV buses. Also, it is important to note that the recommended curve for the main 12.47kV bus relays is an I4T curve versus the original I2T curve. I4T changes one decade of current over four decades of time. This curve fits standard fuse curves more closely than the I2T curve, which changes one decade current over two decades of time.

Changes to the medium voltage breaker relays should be completed by a certified relay testing company that is capable of testing and verifying that the breakers trip at the proper overcurrent levels.

TCC TR1-1 McCune Hall: Although the primary fuses for TR1-1 and secondary main breaker are coordinated, the primary fuses do not properly protect the transformer. Using a 3A C rated fuse instead of a 20A C rated fuse would improve transformer protection (refer to TCC TR1-1 McCune Hall in Appendix B). As far as secondary protection is concerned, replacement of the secondary distribution panel should be considered based on age and configuration. A new static trip (solid state) secondary main breaker with long-time, short-time, and instantaneous pickup and delay settings is advised. This would allow greater flexibility in coordinating with the upstream primary fuses.

TCC TR1-2 Reed Operations Center: The existing low voltage secondary main breaker is reported to be Westinghouse 500A thermal magnetic breaker. This breaker does not coordinate well with the primary fuse. To improve coordination, the existing thermal magnetic breaker could be replaced with a static trip (solid state) main breaker with long-time, short-time, and instantaneous pickup and delay settings. However, due to age of the existing equipment, replacement of the existing unit substation and secondary distribution panel is recommended.

TCC TR1-3 Henderson Gym: The existing low voltage secondary main breaker is not coordinated with the primary fuse. To improve coordination, the existing thermal magnetic breaker could be replaced with a static trip (solid state) main breaker with long-time, short-time, and instantaneous pickup and delay settings.

TCC TR1-9 Tennis Courts and Multiuse Field: The existing low voltage secondary main breaker is not coordinated with the primary fuse in the short time region. Coordination could be improved by replacing the existing secondary main breaker with a static trip (solid state) main breaker with long-time, short-time, and instantaneous pickup and delay settings.

TCC TR1-10 Shearer and Rowland: The existing C rated 20A primary fuse does not properly protect the transformer TR1-10. According to University personnel, the service for Rowland and Shearer Halls is being redesigned at this time. It is recommended that the primary protection for the new service be selected to adequately protect the transformer. The new secondary of this service should be provided with a static trip (solid state) main breaker with long-time, short-time, and instantaneous pickup and delay settings to provide greater flexibility in coordinating with the upstream devices.

TCC TR2-4 Wright Hall: The existing low voltage secondary main breaker is not coordinated with the primary fuse in the short time region. Replacement of the secondary distribution panel should be considered based on age and configuration. A new static trip (solid state) secondary main breaker with long-time, short-time, and instantaneous pickup and delay settings is advised. This would allow greater flexibility in coordinating with the upstream primary fuses.

TCC TR2-8 Cora Grove Spiritual Center: The actual size of primary fuses for TR2-8 could not be determined during our surveys or form the information provided by the University. Therefore, a fuse size and rating (class C, 12A) was assumed based on similarly sized transformers on the campus. Based on analysis using this assumed data, the secondary main circuit breaker and primary fuses for transformer TR2-8 are not coordinated in the short time region. Coordination could be improved by replacing the existing secondary main breaker with a static trip (solid state) main breaker with long-time, short-time, and instantaneous pickup and delay settings. However, the actual rating of the primary fuses should be verified before any changes to the system are made.

TCC TR3-1 Ezra Lehman Library: In the short time region, the secondary main circuit breaker is not coordinated with the primary fuses for transformer TR3-1. This could result in the primary fuses tripping before the secondary breaker on a down stream fault. A static trip (solid state) breaker with long-time, short-time, and instantaneous pickup and delay settings could be installed in place of the existing secondary main circuit breaker. The addition setting would allow for better coordination with the up stream primary fuses.

TCC TR3-4 Franklin Science Center: No information was available on the actual primary fuse sizes and ratings. Therefore, a similar style fuse (class C) to those used elsewhere on Campus was assumed with size (100A) based on the transformer kVA rating. With this assumed fuse information, it is possible that the secondary main circuit breaker and primary fuses are not coordinated. Better coordination may be achieved by resetting the following (refer to TCC TR3-4 Franklin Science Center in Appendix B):

1. The longtime (LTD) setting from 24 to 12.
2. The instantaneous (INST) setting from 6 to 3.

Before changing any settings, the actual size of the primary fuses should be verified.

TCC TR4-5 The Cumberland Student: The main secondary circuit breaker and primary fuses are not coordinated in the short time and long time regions. Although there is an instantaneous pickup dial on the circuit breaker, there is not enough adjustment to coordinate it with the primary fuses. Therefore, replacement of this breaker is recommended. A static trip (solid state) breaker with long-time, short-time, and instantaneous pickup and delay settings could be installed in place of the existing secondary main circuit breaker. A static trip breaker would permit greater flexibility for coordinating with the primary fuses.

CONCLUSIONS

Correction of the concerns listed above will not only improve system coordination, but will also allow fault sources to be isolated more efficiently and minimize the unnecessary interruption of power to loads not directly down stream of a fault. The concerns for the following feeders and building can be resolved by adjusting settings on relays and circuit breakers or replacing fuses:

1. TCC 1201
2. TCC 1202
3. TCC 1203
4. TCC 1204
5. TCC TR1-1 McCune Hall
6. TCC TR3-4 Franklin Science Center

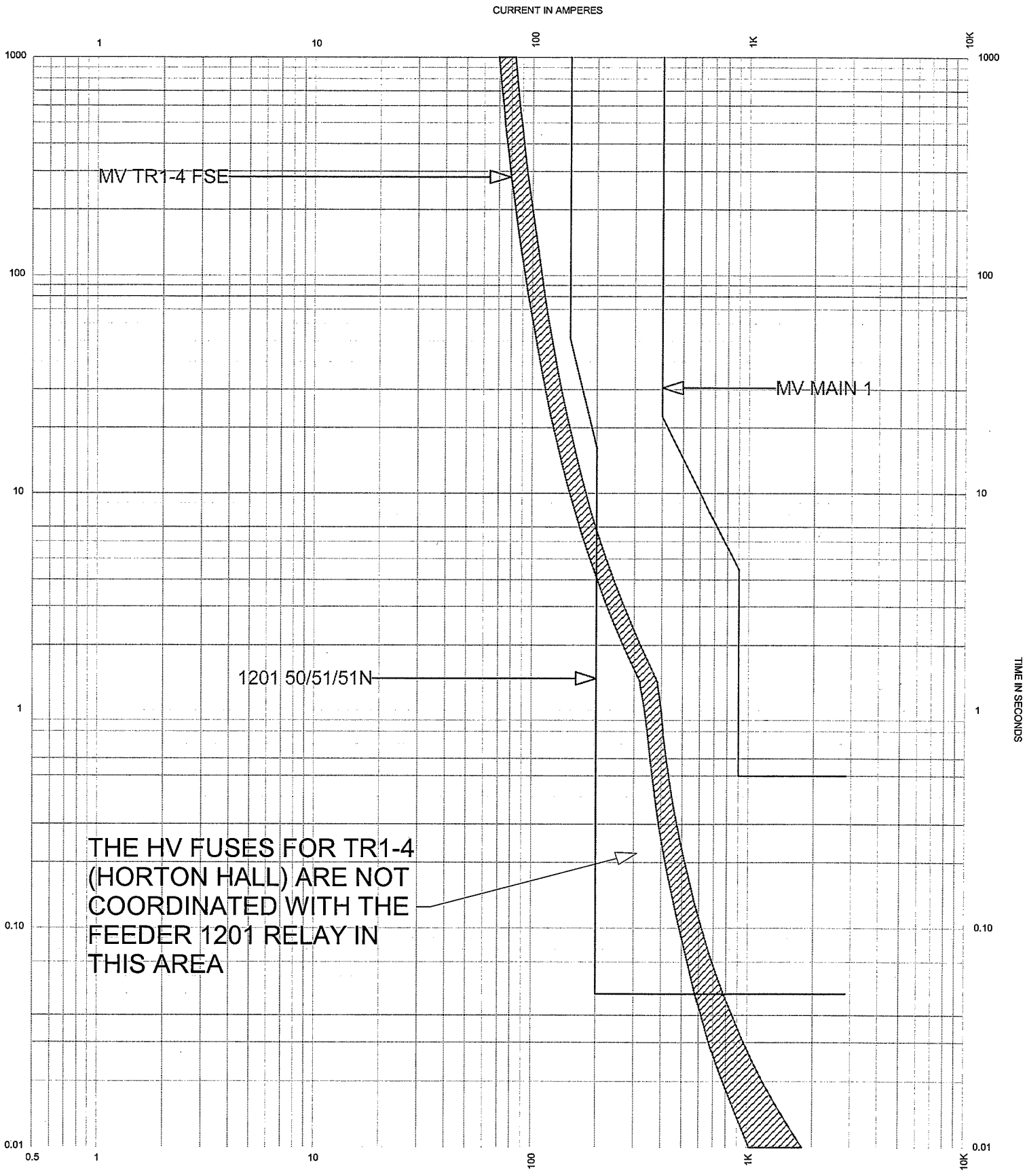
The cost of making these corrections should be approximately $6,500.

Proper coordination in the following areas will require replacement of secondary main over-current device and associated equipment:

1. TCC TR1-3 Henderson Gym
2. TCC TR1-9 Tennis Courts & Multi Use Field
3. TCC TR2-8 Cora Grove Spiritual Center
4. TCC TR3-1 Ezra Lehman Library
5. TCC TR4-5 Cumberland Student Union

The approximate cost of upgrading this equipment is $75,000.

Since it has been recommended in the main report that equipment for McCune Hall, The Reed Operations Center, Wright Hall, and Shearer and Roland Halls be replaced due to age and condition, costs for making coordination adjustments are not included in the estimates prepared above.



Project Name: Shippenburg 12.47kV Distribution
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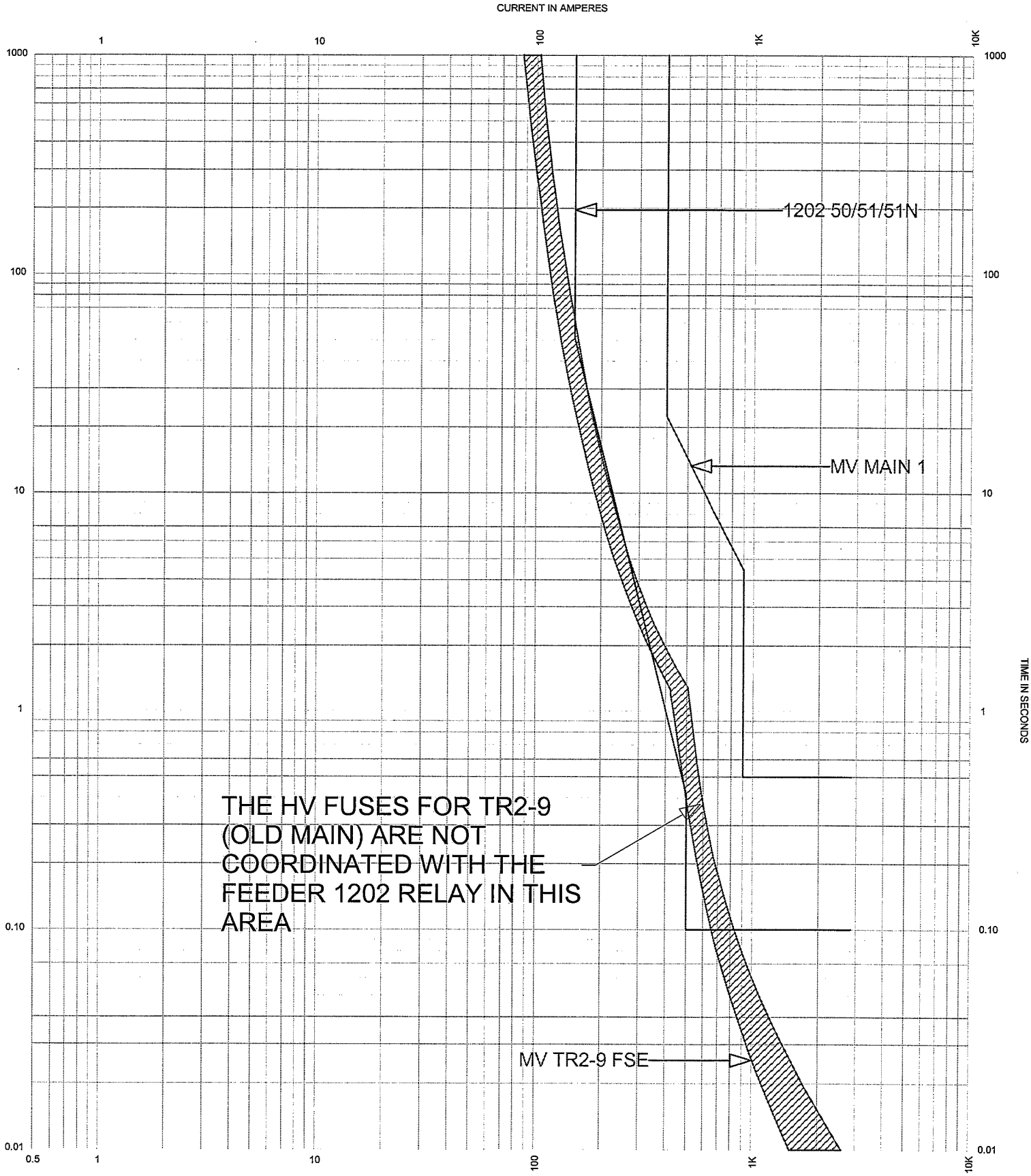
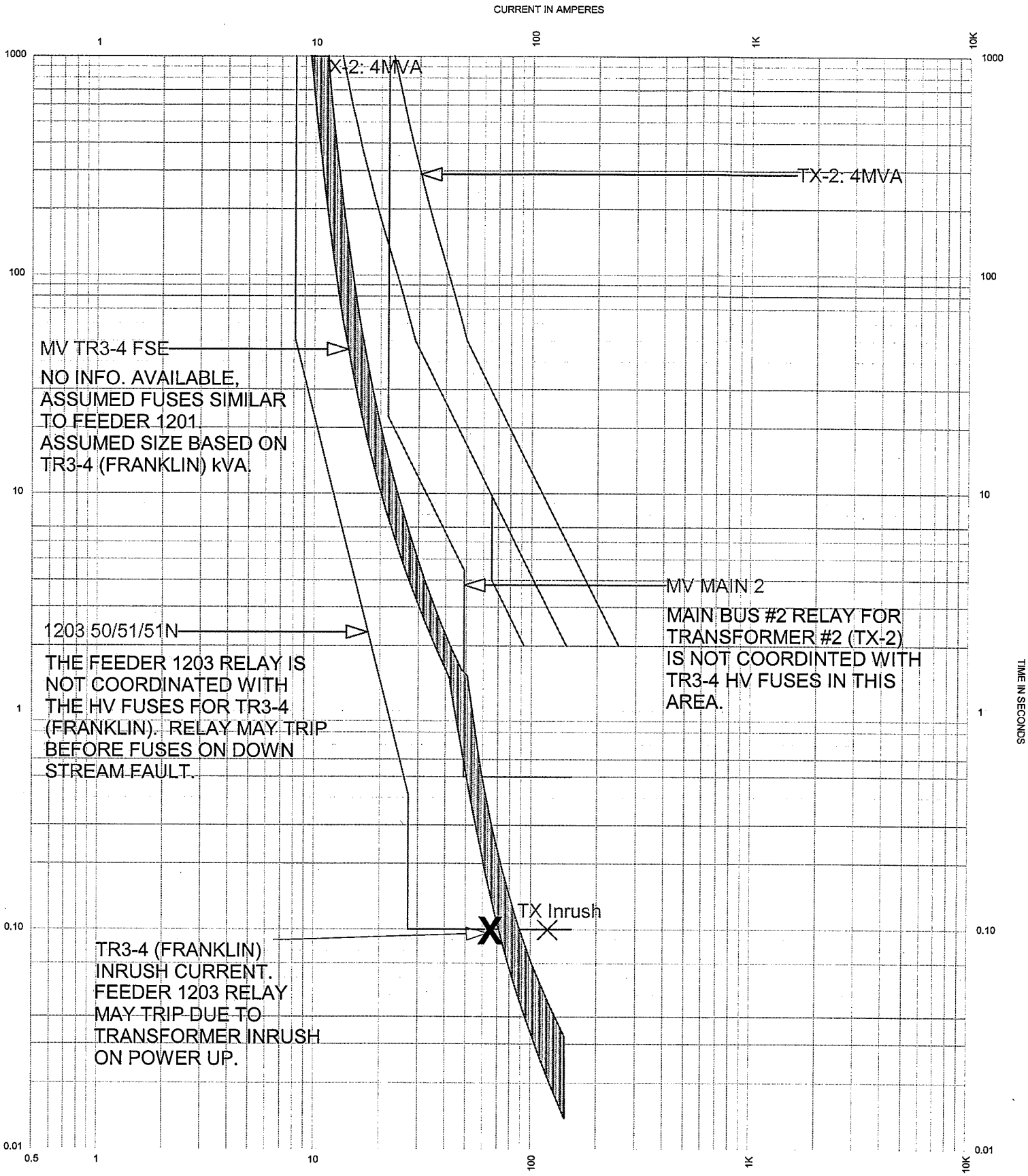
Plot Scale: X 10^0 Amps
Entech Eng #2184.22

TCC Name: 1201
Rev. 0.0
Date: March 11, 2004



Project Name: Shippenburg 12.47kV Distribution
Plot Voltage: 12470 Volts
Plot Scale: X 10^0 Amps
Entech Eng #2184.22

TCC Name: 1202
Rev. 0.0
Date: March 11, 2004



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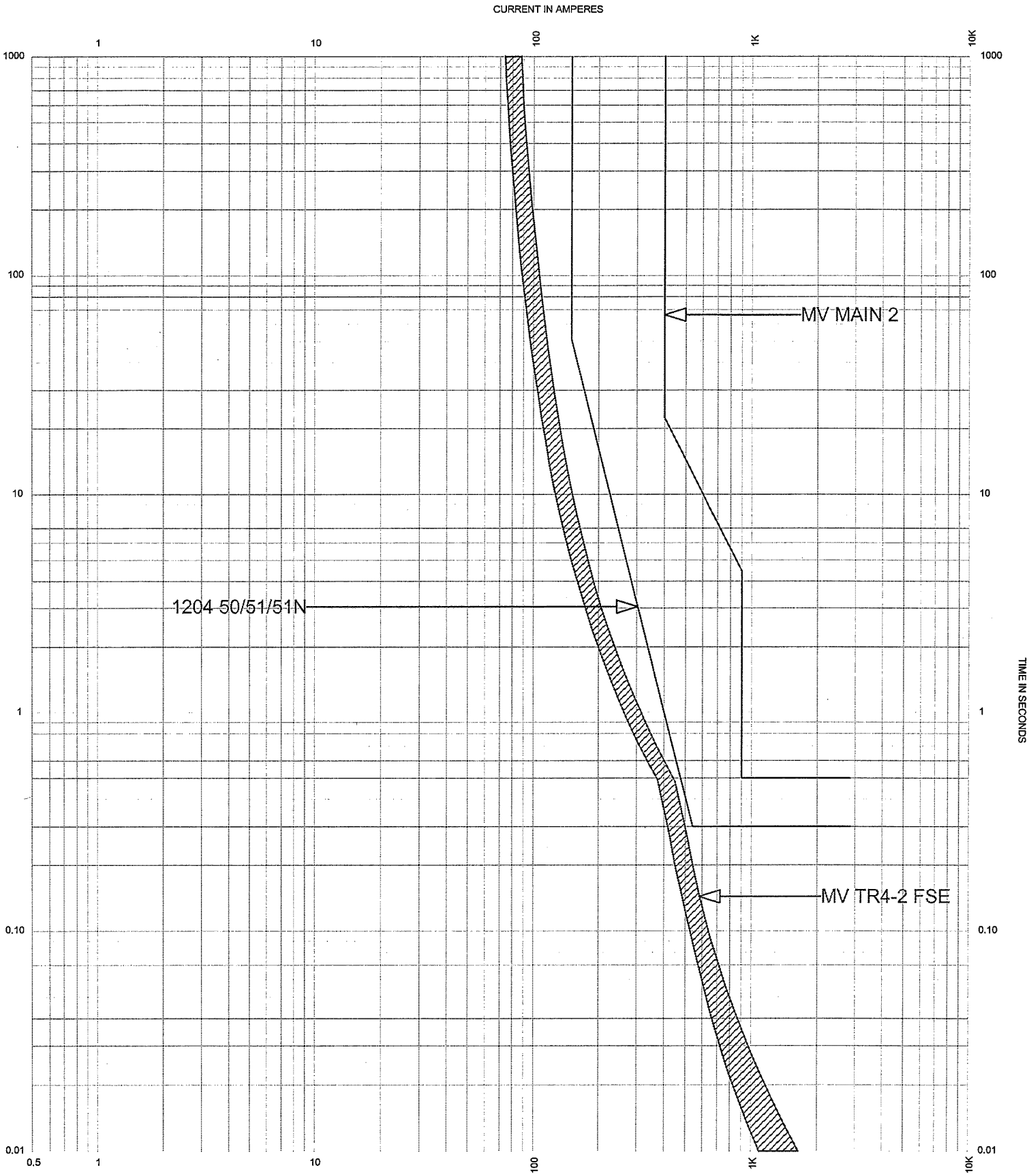
Plot Scale: X 10^1 Amps
Entech Eng #2184.22

TCC Name: 1203
Rev. 0.0
Date: March 12, 2004



Project Name: Shippenburg 12.47kV Distribution
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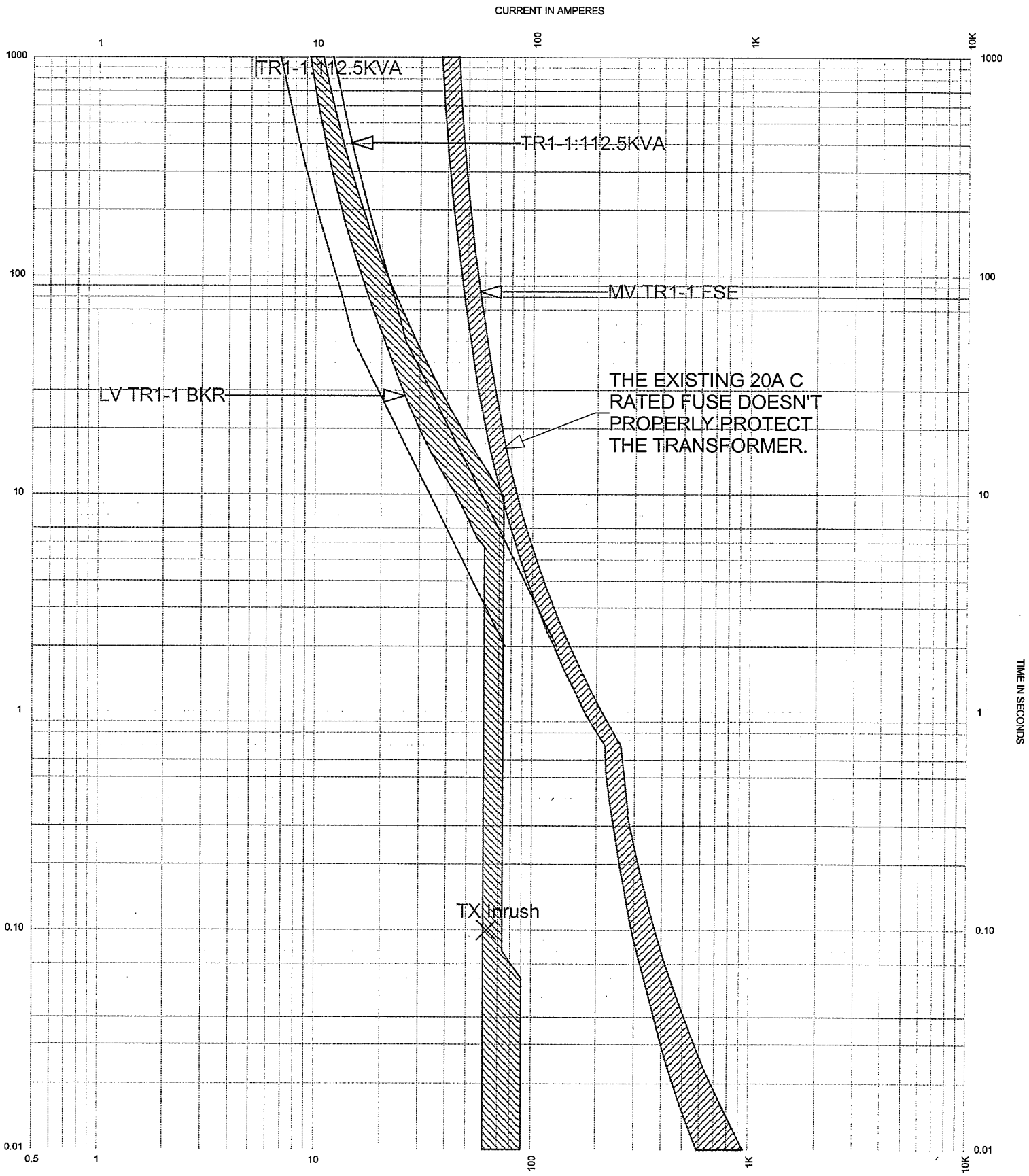
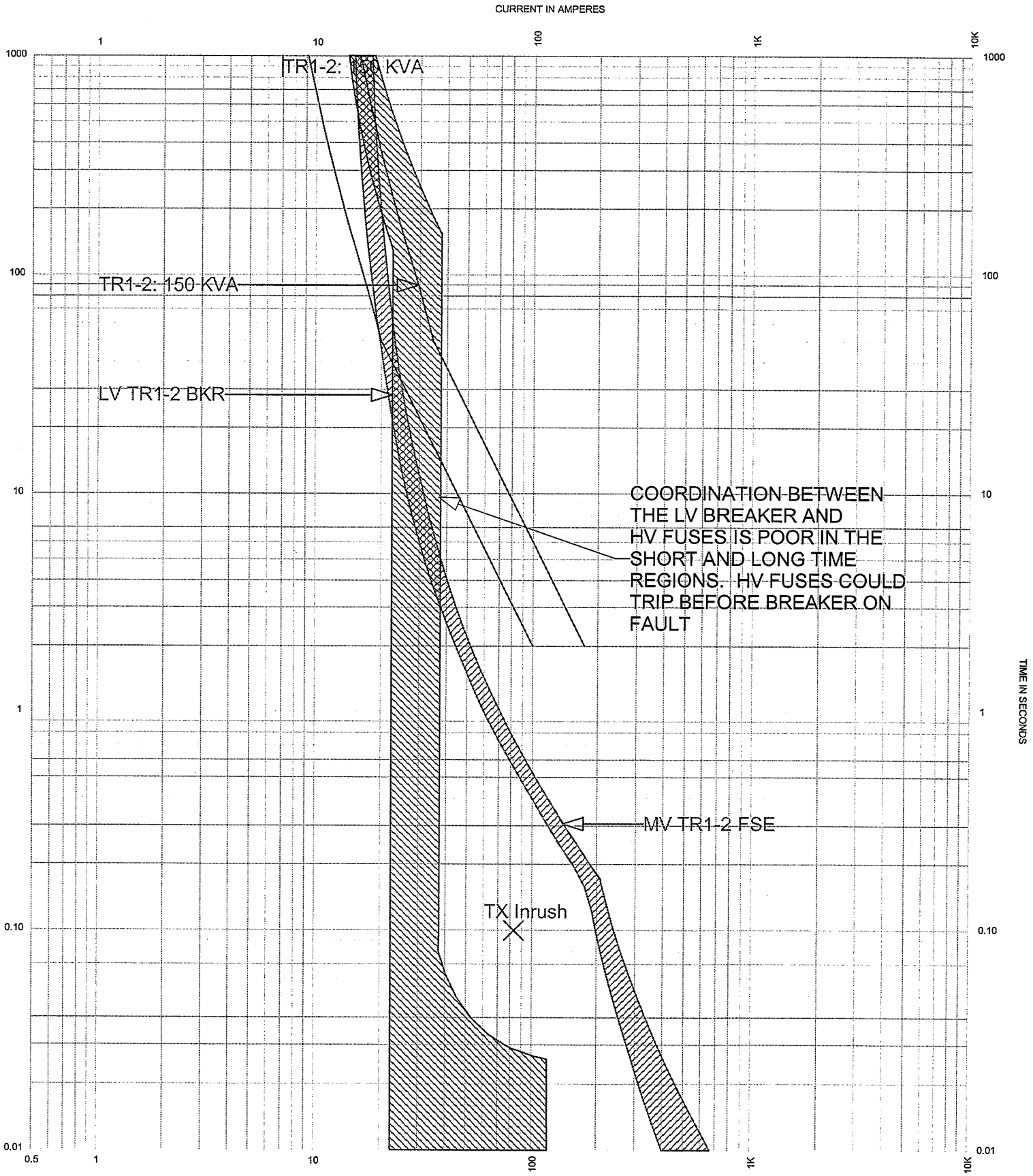
Plot Scale: X 10^0 Amps
Entech Eng #2184.22

TCC Name: 1204
Rev. 0.0
Date: March 12, 2004



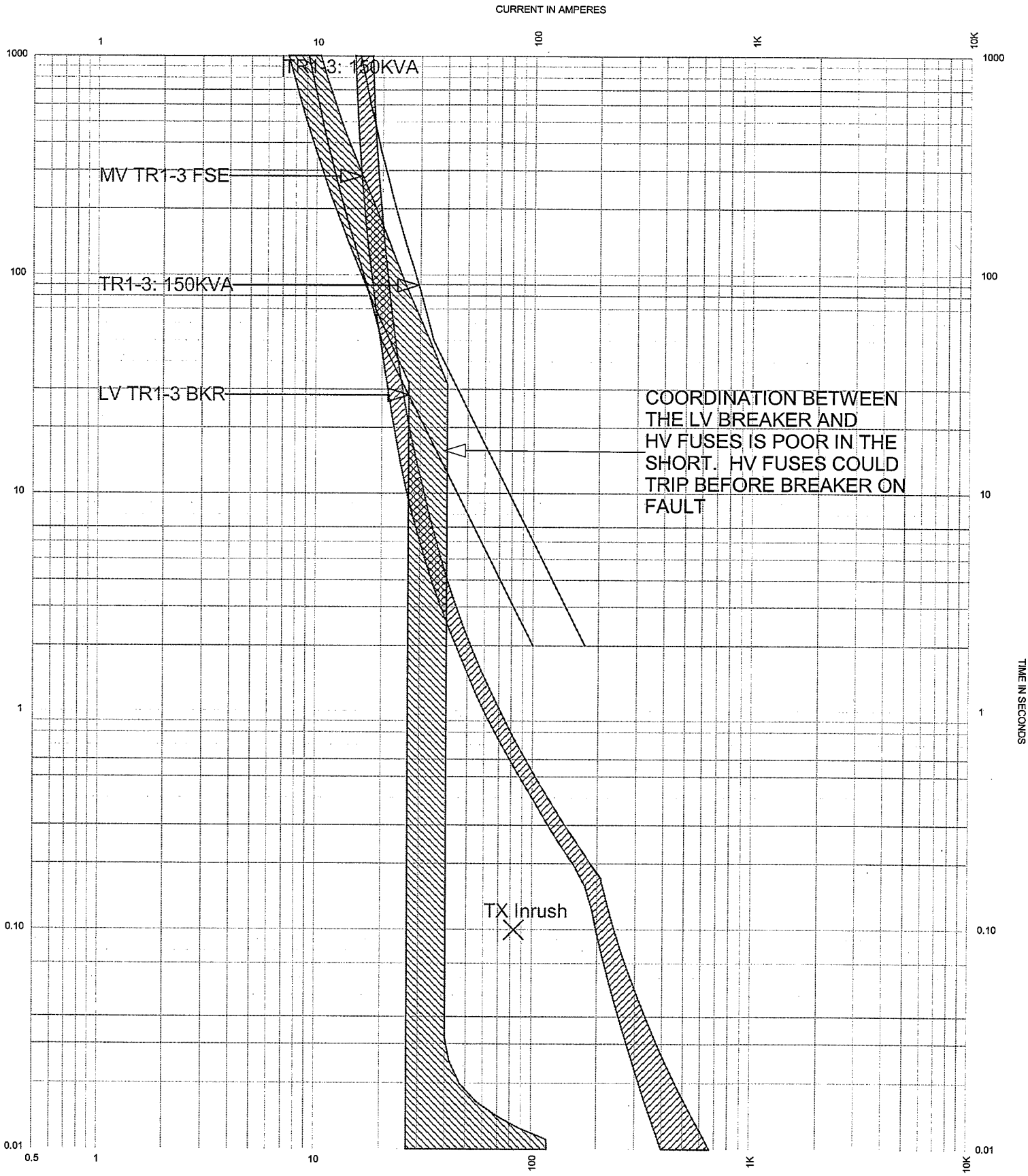
Project Name: Shippenburg 12.47kV Distribution
Plot Voltage: 12470 Volts
Plot Scale: X 10^0 Amps
Entech Eng #2184.22

TCC Name: TR1-1 McCUNE HALL
Rev. 0.0
Date: March 12, 2004



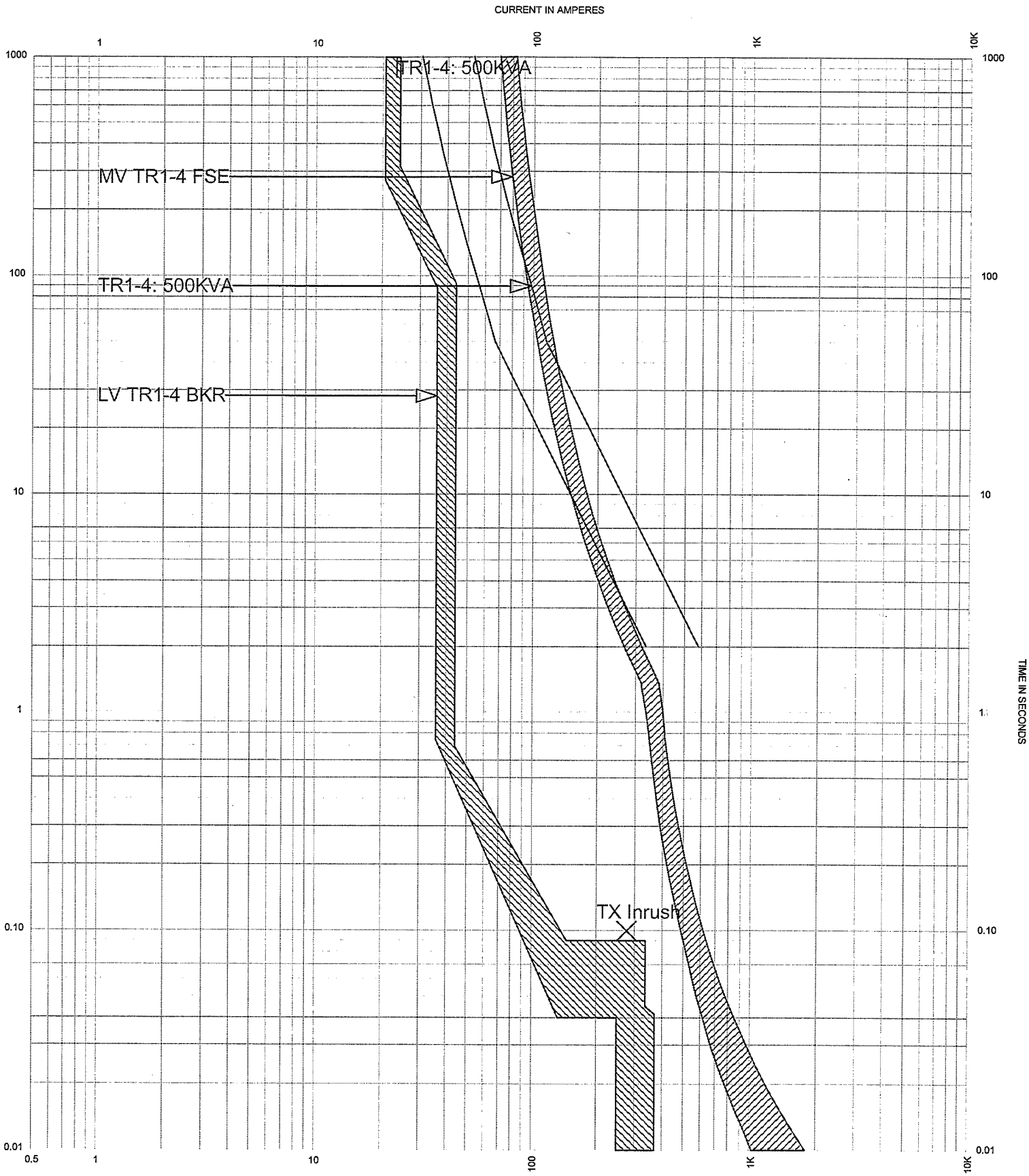
Project Name: Shippenburg 12.47kV Distribution
Plot Voltage: 12470 Volts
Plot Scale: X 10^0 Amps
Entech Eng #2184.22

TCC Name: TR1-2 REED OP
Rev. 0.0
Date: March 12, 2004



Project Name: Shippenburg 12.47kV Distribution
Plot Voltage: 12470 Volts
Plot Scale: X 10^0 Amps
Entech Eng #2184.22

TCC Name: TR1-3 HENDERSON GYM
Rev. 0.0
Date: March 12, 2004



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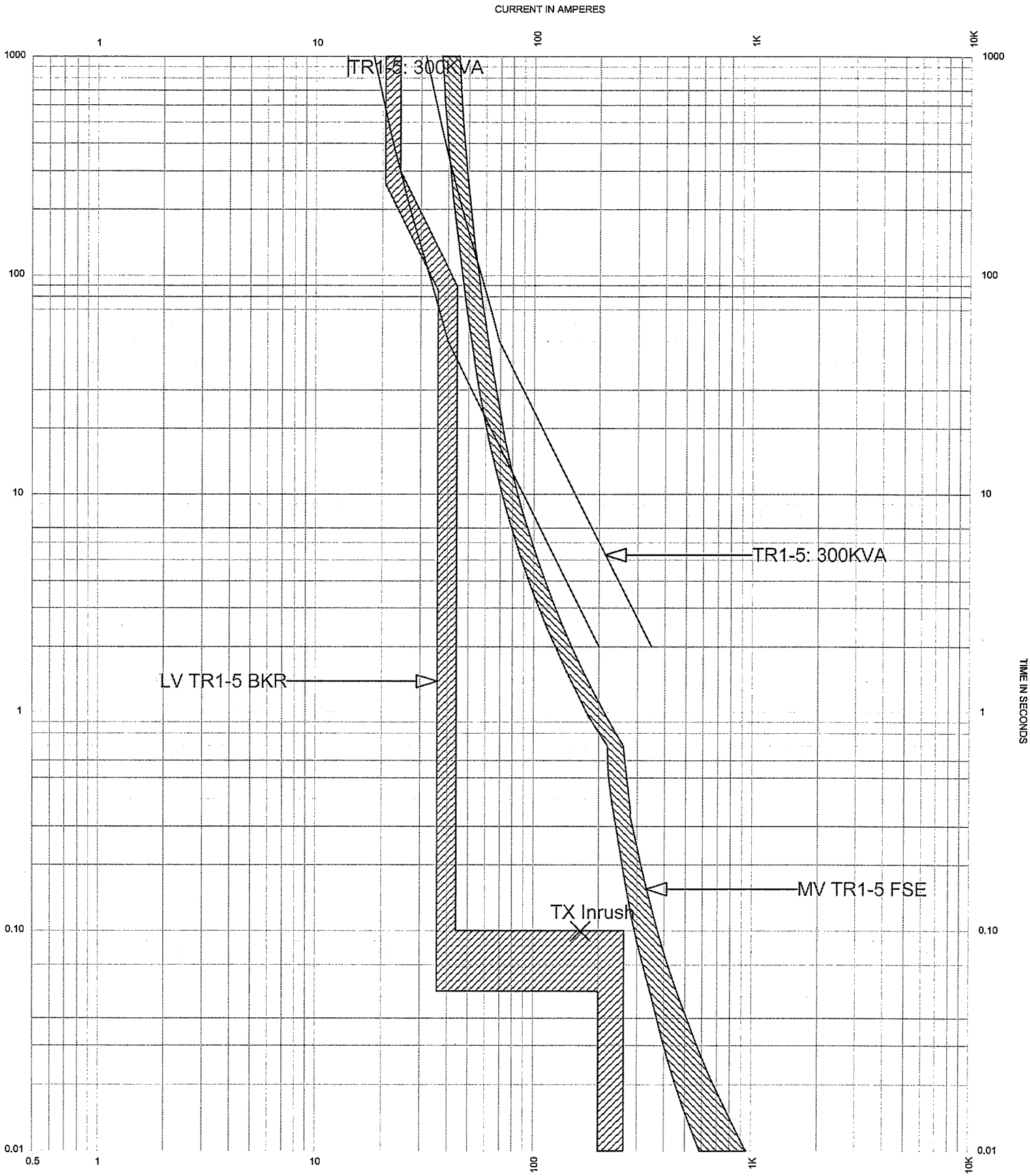
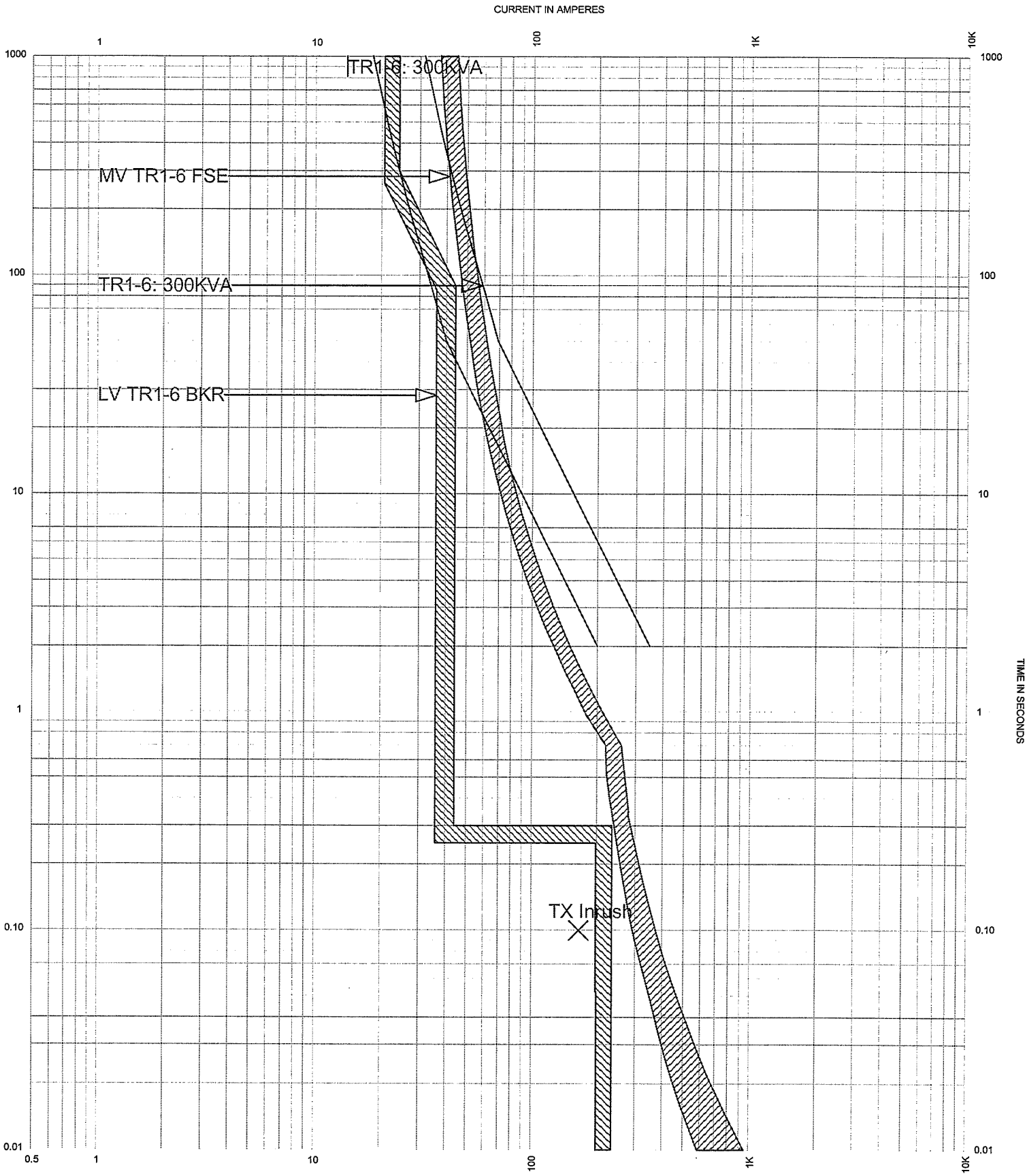
Plot Voltage: 12470 Volts
Plot Scale: X 10^0 Amps
Entech Eng #2184.22

TCC Name: TR1-4 HORTON HALL
Rev. 0.0
Date: March 12, 2004



Project Name: Shippenburg 12.47kV Distribution
Plot Voltage: 12470 Volts
Plot Scale: X 10^0 Amps
Entech Eng #2184.22

TCC Name: TR1-5 KRINER HALL
Rev. 0.0
Date: March 12, 2004



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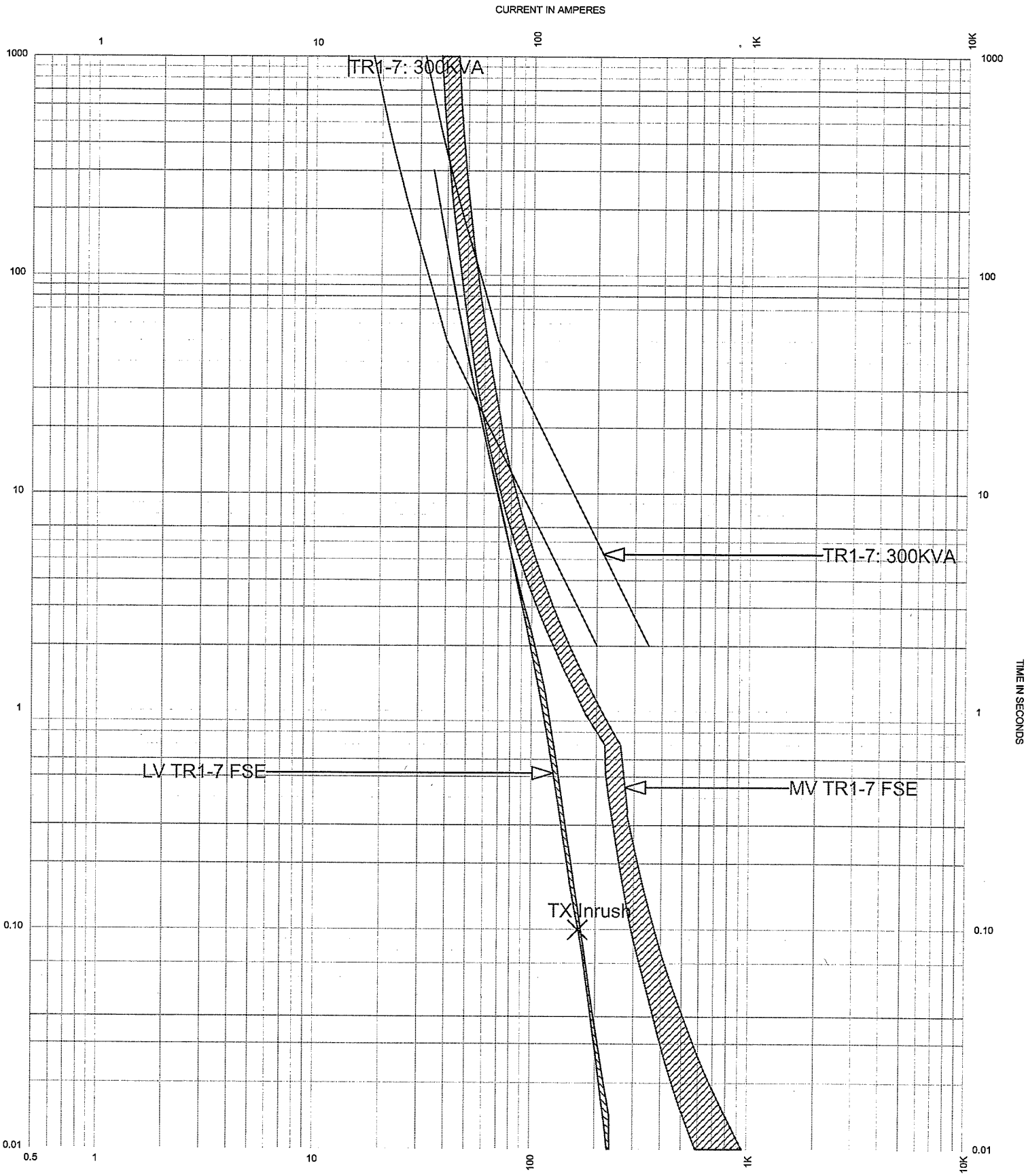
Plot Scale: X 10^0 Amps
Entech Eng #2184.22

TCC Name: TR1-6 HUBER ART CENTER
Rev. 0.0
Date: March 12, 2004



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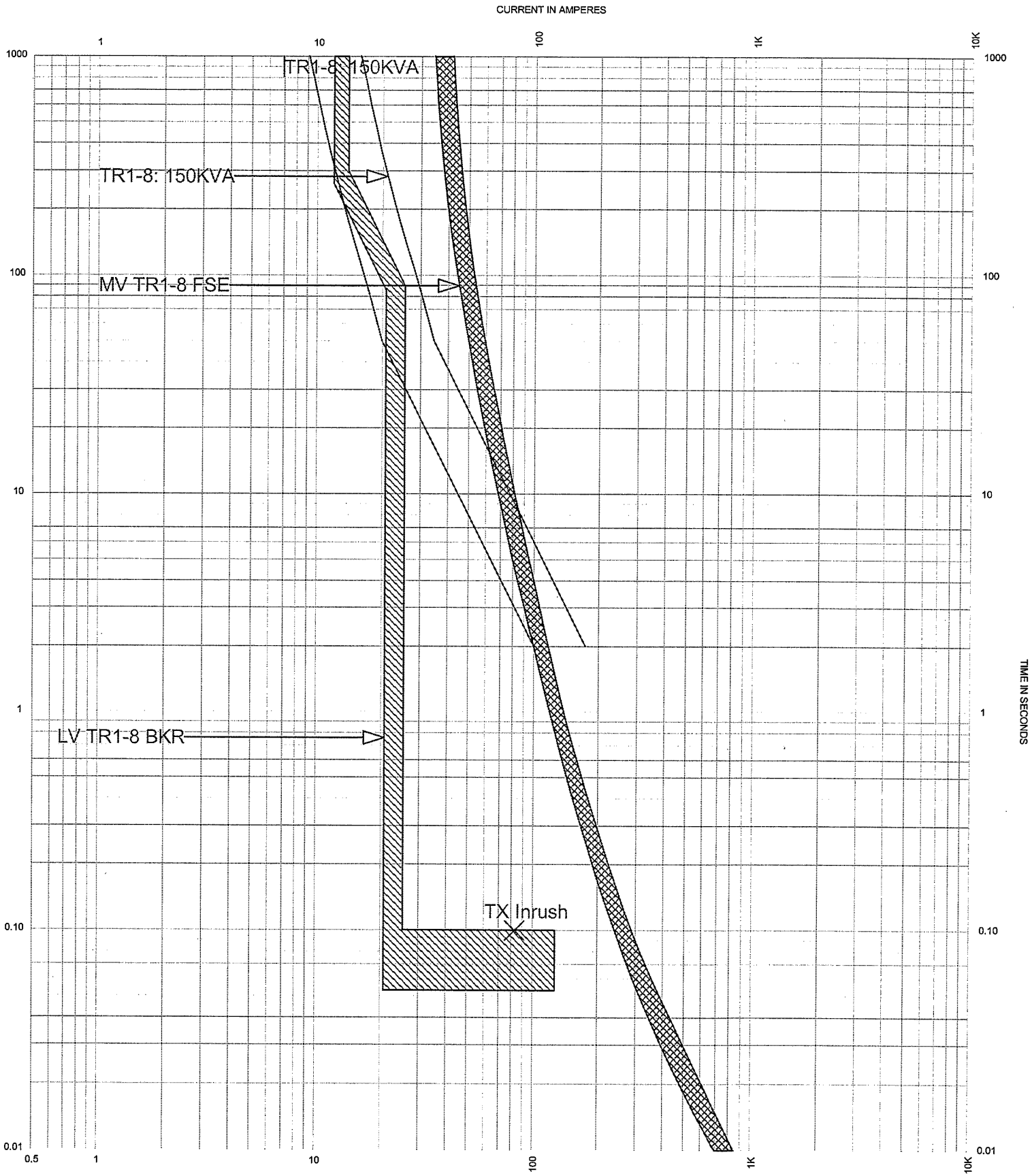
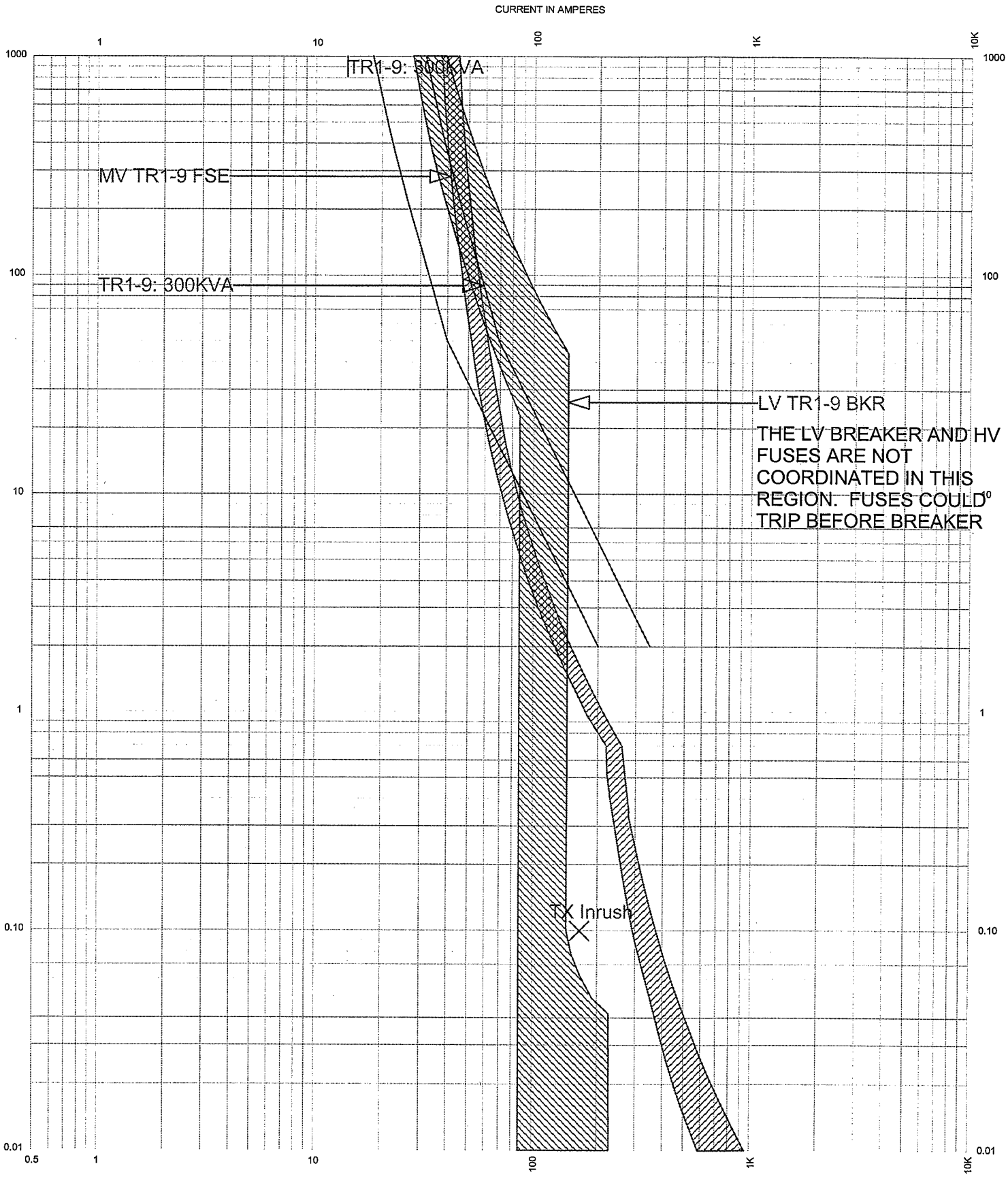
Plot Voltage: 12470 Volts
Plot Scale: X 10^0 Amps
Entech Eng #2184.22

TCC Name: TR1-7 MEMORIAL HALL
Rev. 0.0
Date: March 12, 2004



Project Name: Shippenburg 12.47kV Distribution
Plot Voltage: 12470 Volts
Plot Scale: X 10^0 Amps
Entech Eng #2184.22

TCC Name: TR1-8 FACULTY OFFICE BUILDING
Rev. 0.0
Date: March 12, 2004



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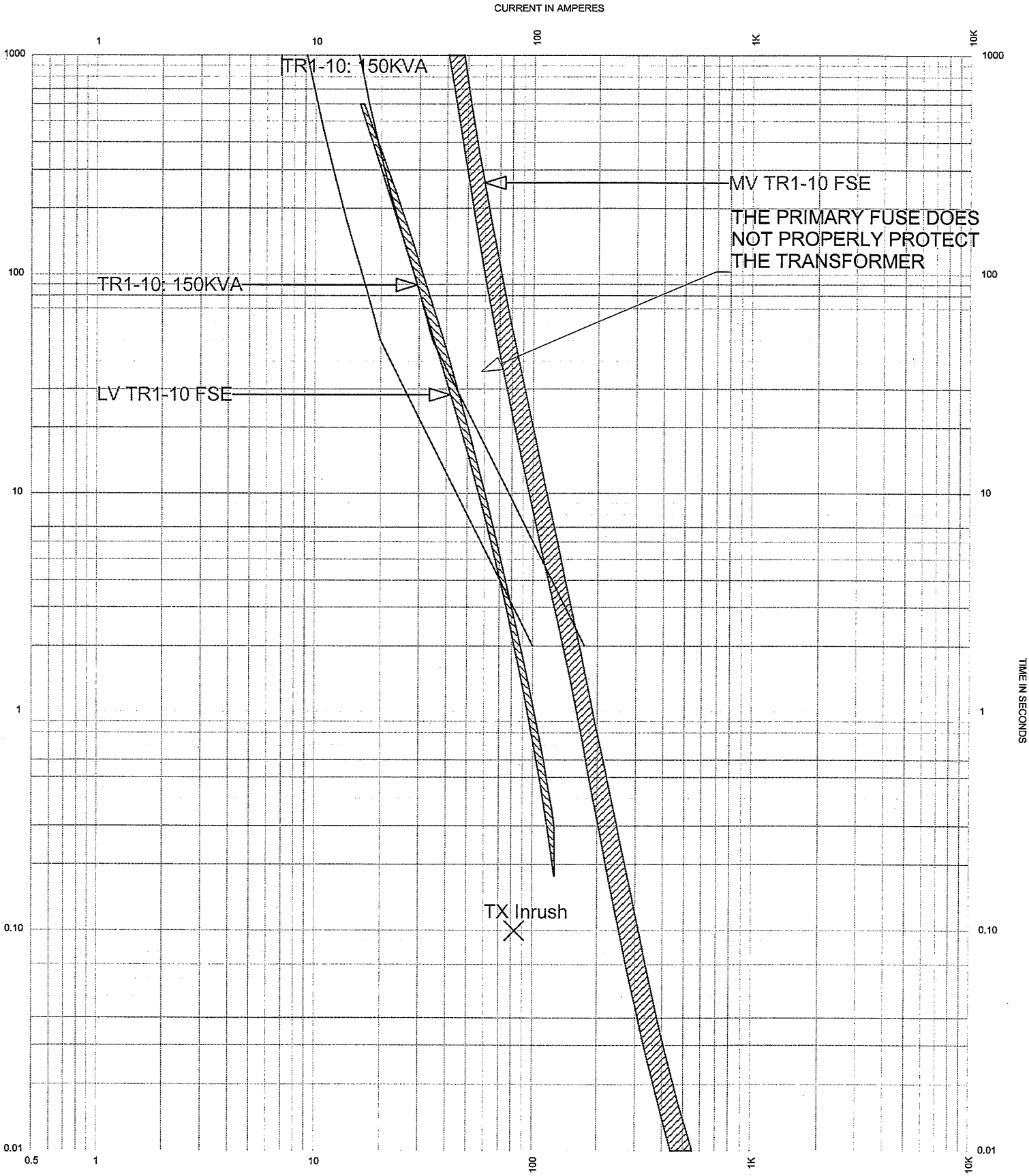
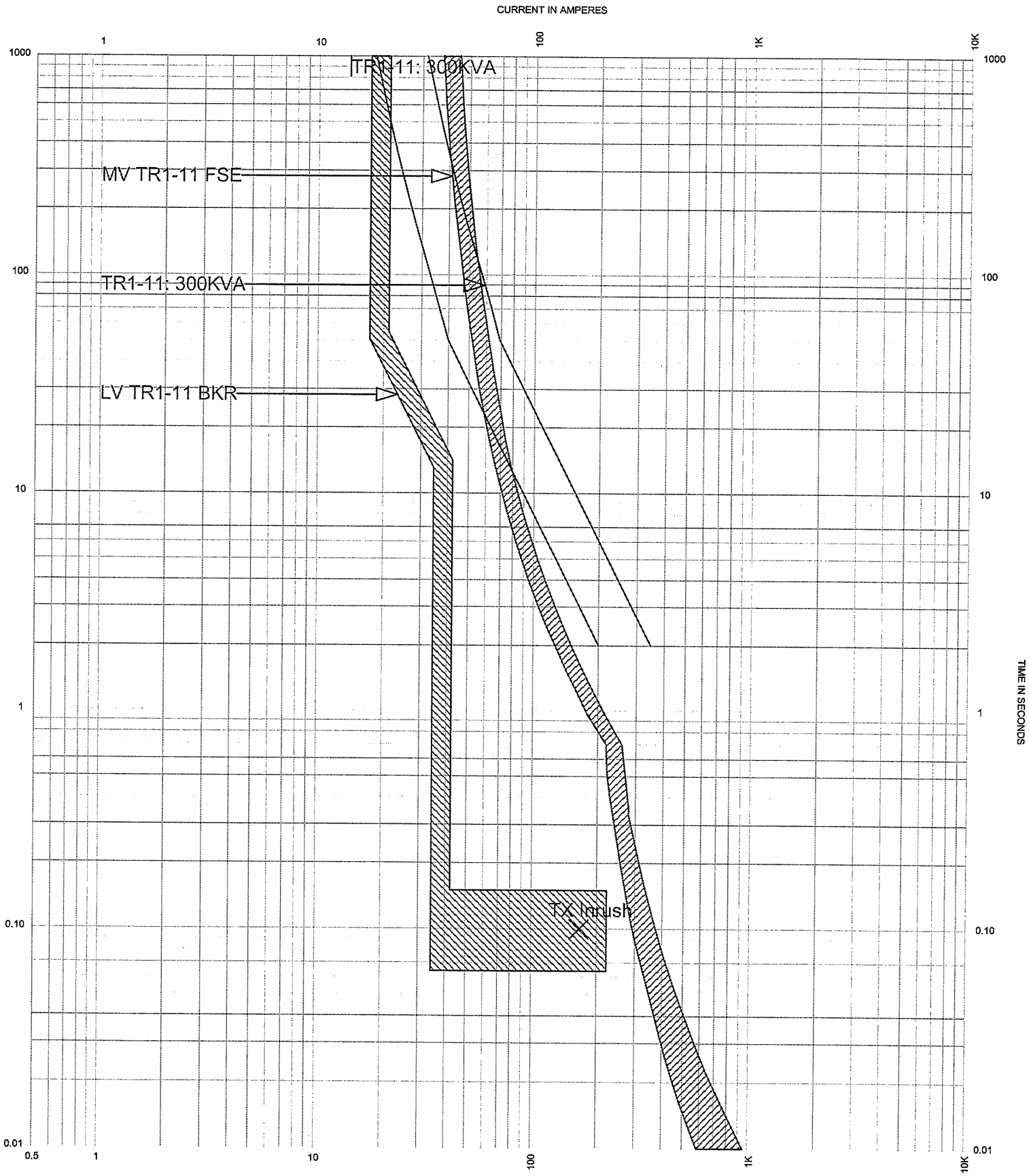
Plot Voltage: 12470 Volts
Plot Scale: X 10^0 Amps
Entech Eng #2184.22

TCC Name: TR1-9 TENNIS & MULTI-USE
Rev. 0.0
Date: March 12, 2004



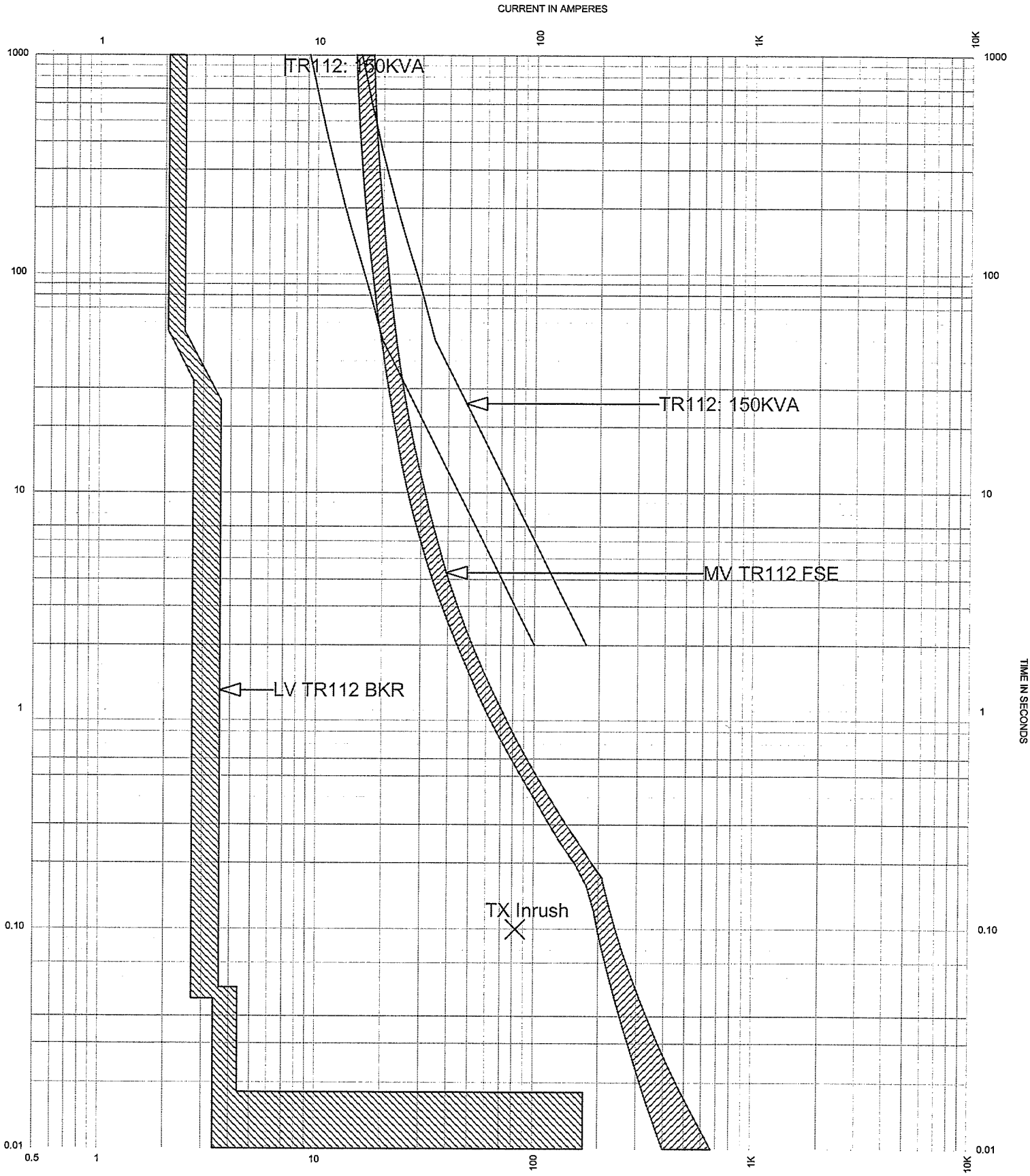
Project Name: Shippenburg 12.47kV Distribution
Plot Voltage: 12470 Volts
Plot Scale: X 10^0 Amps
Entech Eng #2184.22

TCC Name: TR1-10 SHEARER & ROWLAND
Rev. 0.0
Date: March 12, 2004



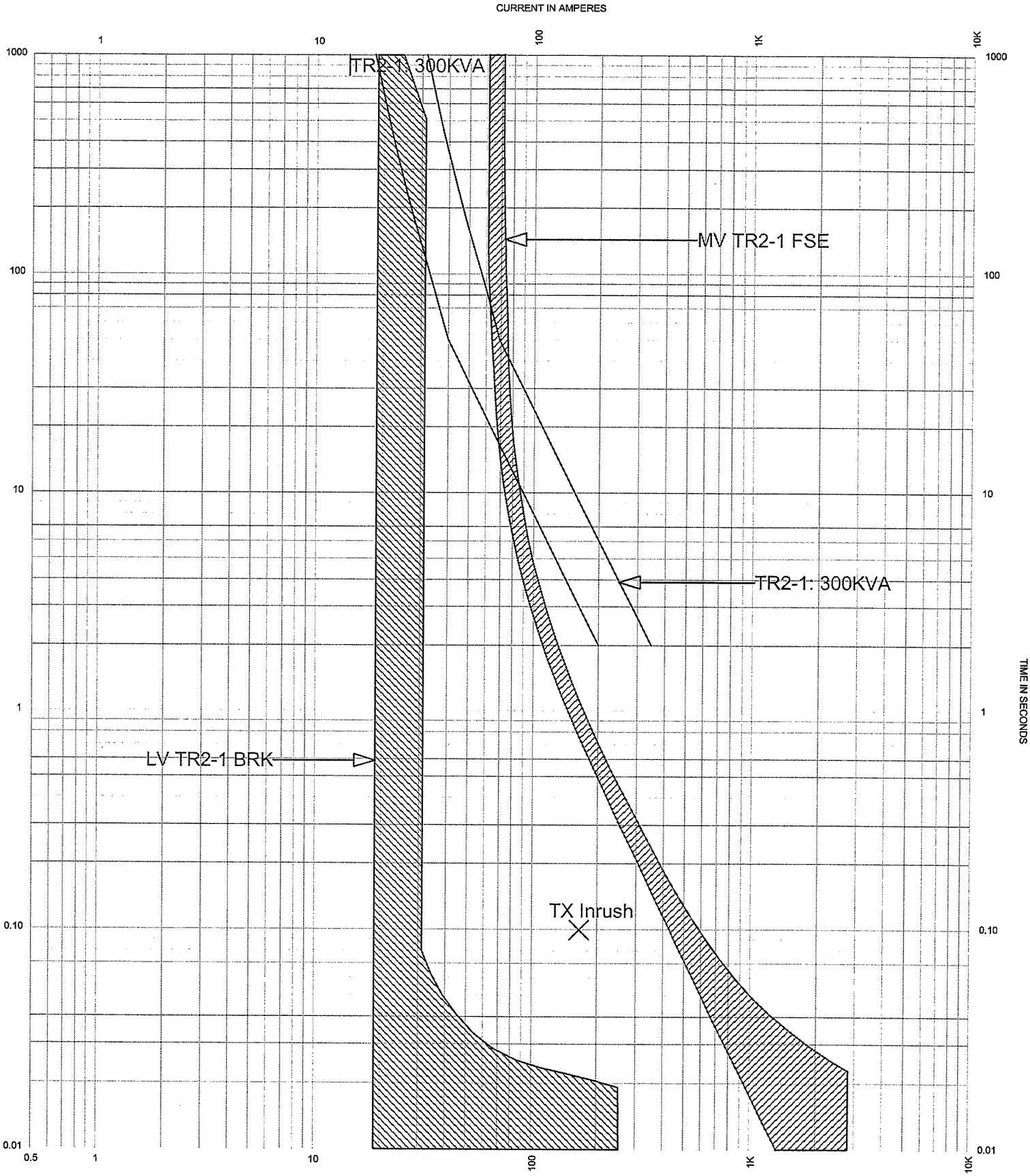
Project Name: Shippenburg 12.47kV Distribution
Plot Voltage: 12470 Volts
Plot Scale: X 10^0 Amps
Entech Eng #2184.22

TCC Name: TR1-11 STEAM PLANT
Rev. 0.0
Date: March 12, 2004



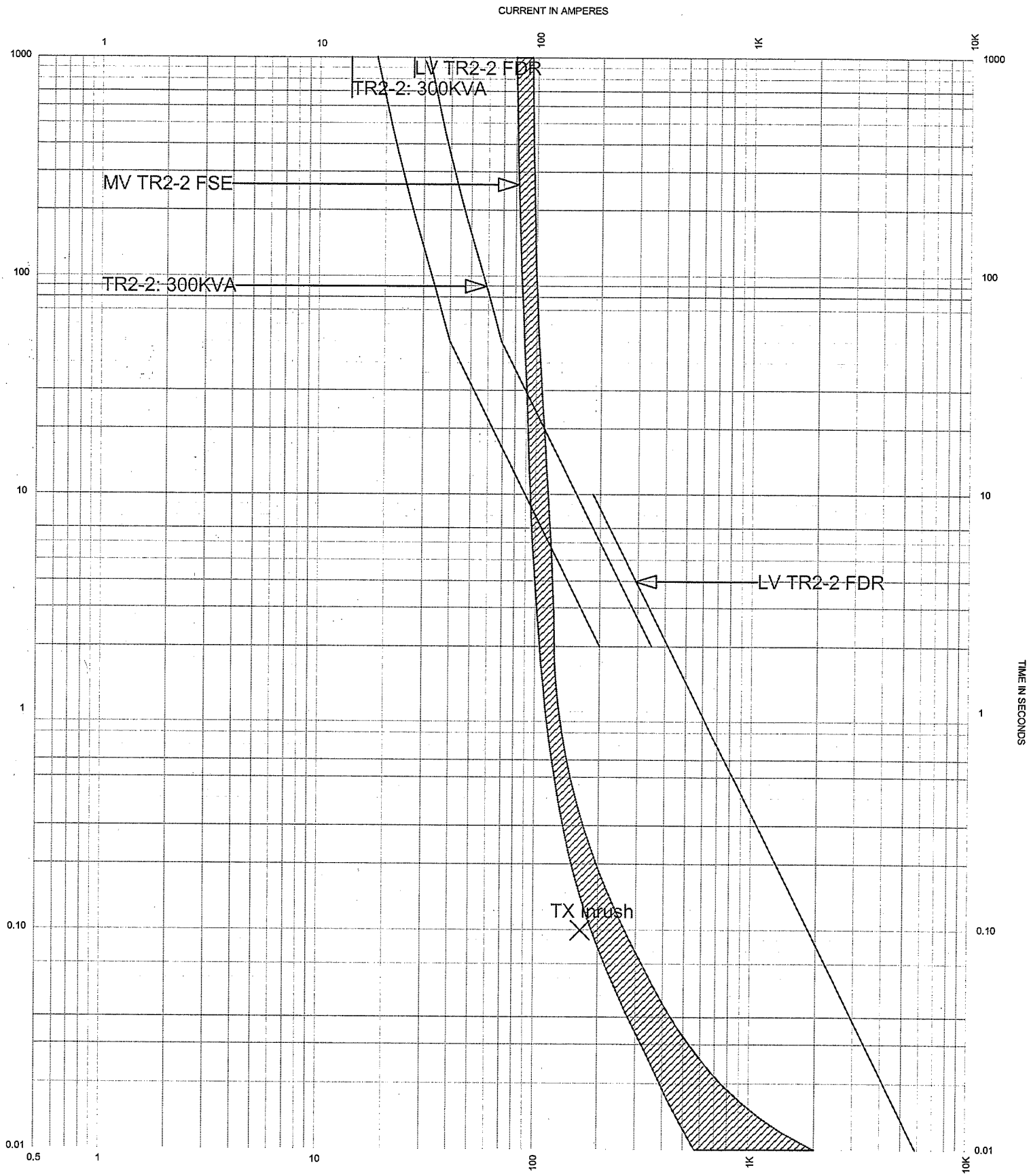
Project Name: Shippenburg 12.47kV Distribution
Plot Voltage: 12470 Volts
Plot Scale: X 10^0 Amps
Entech Eng #2184.22

TCC Name: TR1-12 GILBERT HALL
Rev. 0.0
Date: March 12, 2004



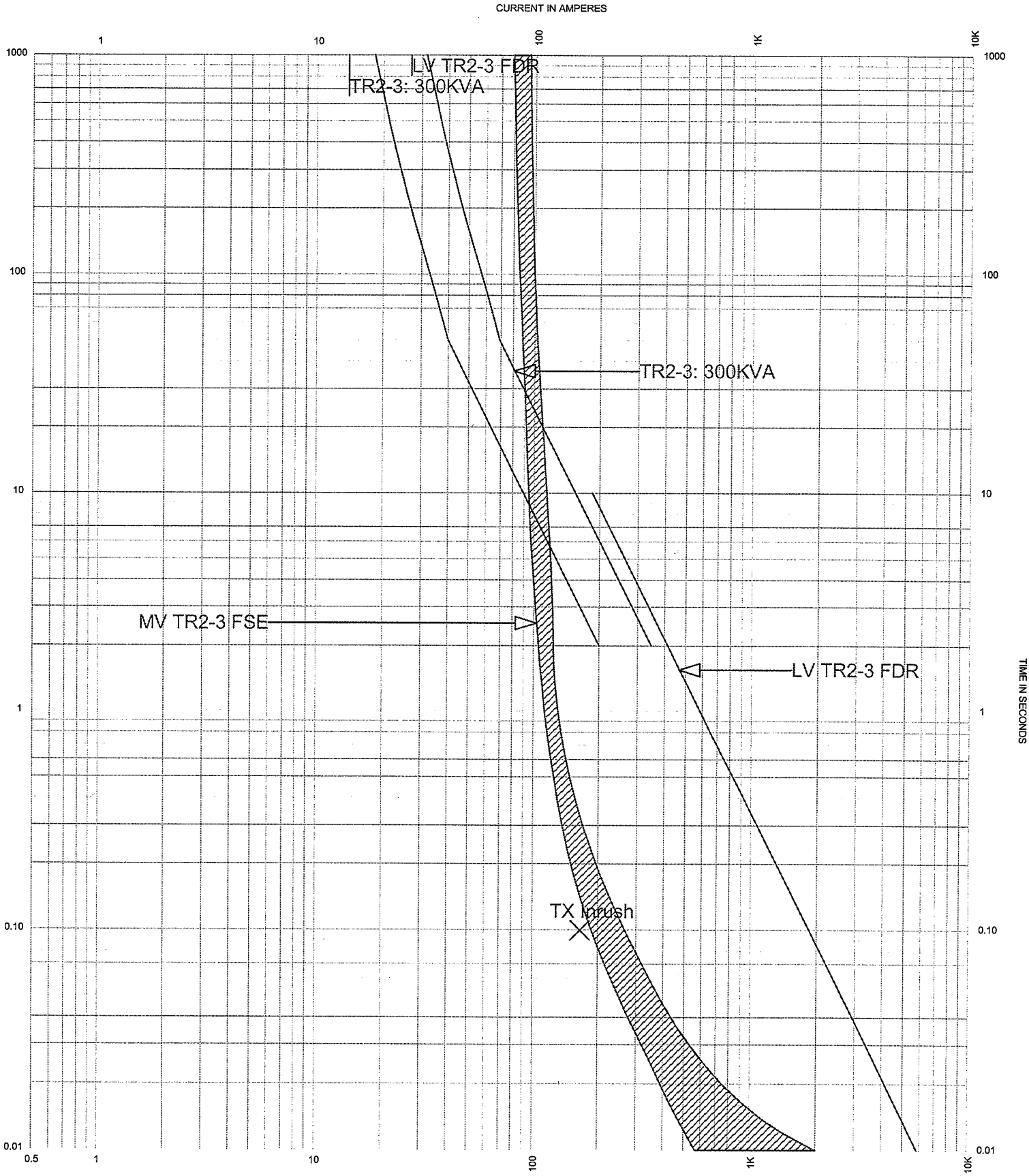
Project Name: Shippenburg 12.47kV Distribution
Plot Voltage: 12470 Volts
Plot Scale: X 10^0 Amps
Entech Eng #2184.22

TCC Name: TR2-1 HARLEY HALL
Rev. 0.0
Date: March 12, 2004



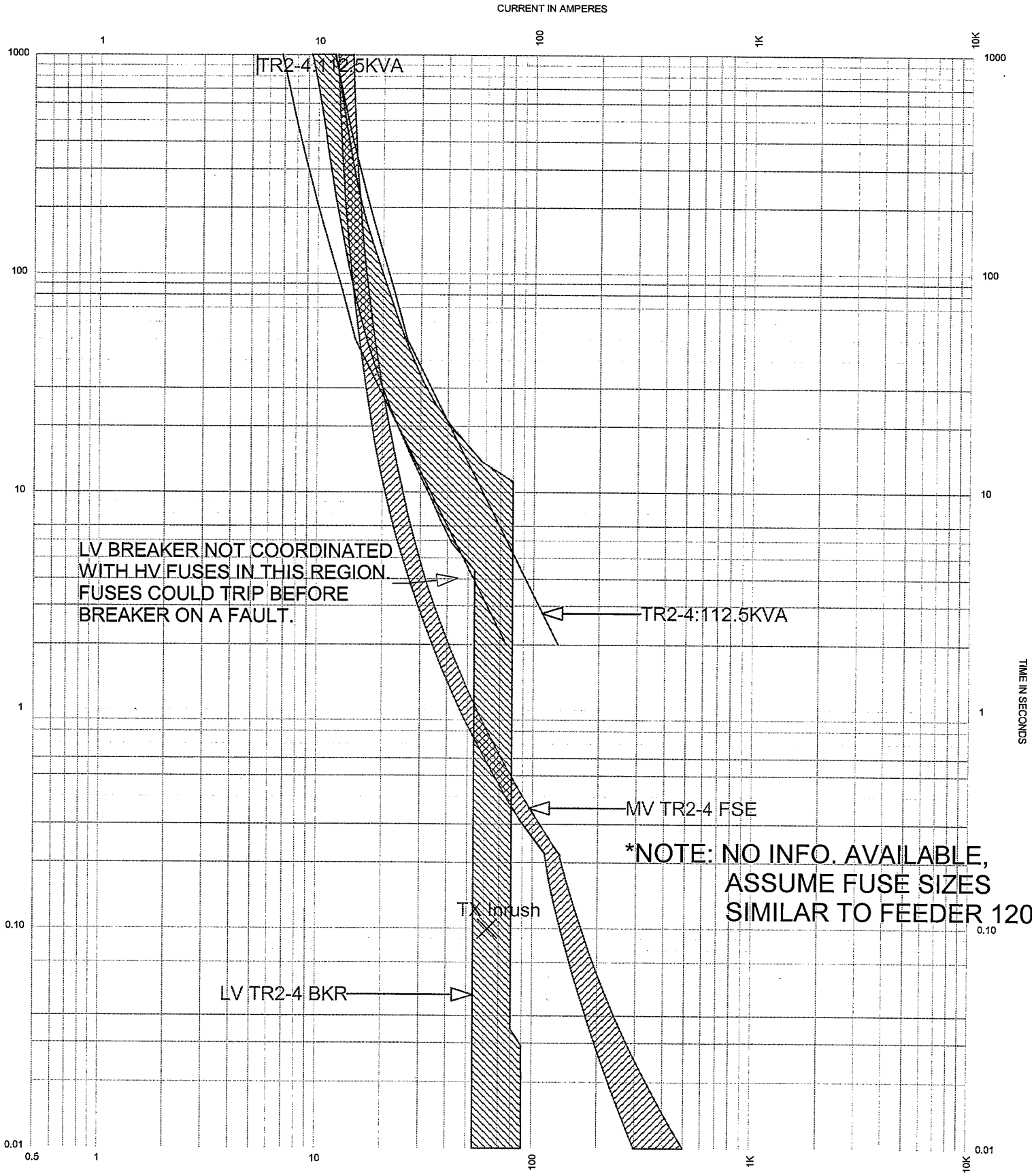
Project Name: Shippenburg 12.47kV Distribution
Plot Voltage: 12470 Volts
Plot Scale: X 10^0 Amps
Entech Eng #2184.22

TCC Name: TR2-2 KIEFER HALL
Rev. 0.0
Date: March 12, 2004



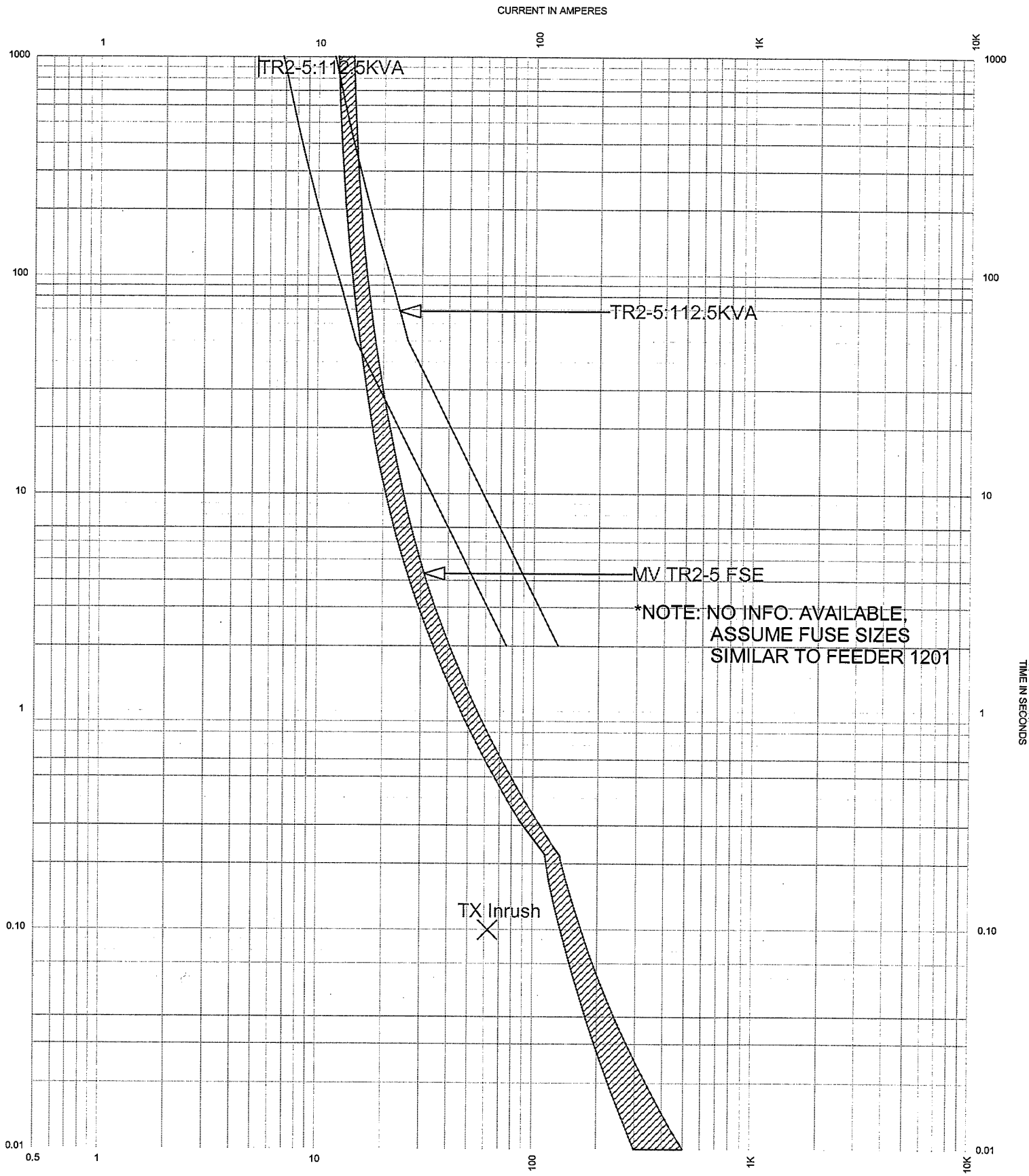
Project Name: Shippenburg 12.47kV Distribution
Plot Voltage: 12470 Volts
Plot Scale: X 10^0 Amps
Entech Eng #2184.22

TCC Name: TR2-3 LOCKHOVE HALL
Rev. 0.0
Date: March 12, 2004



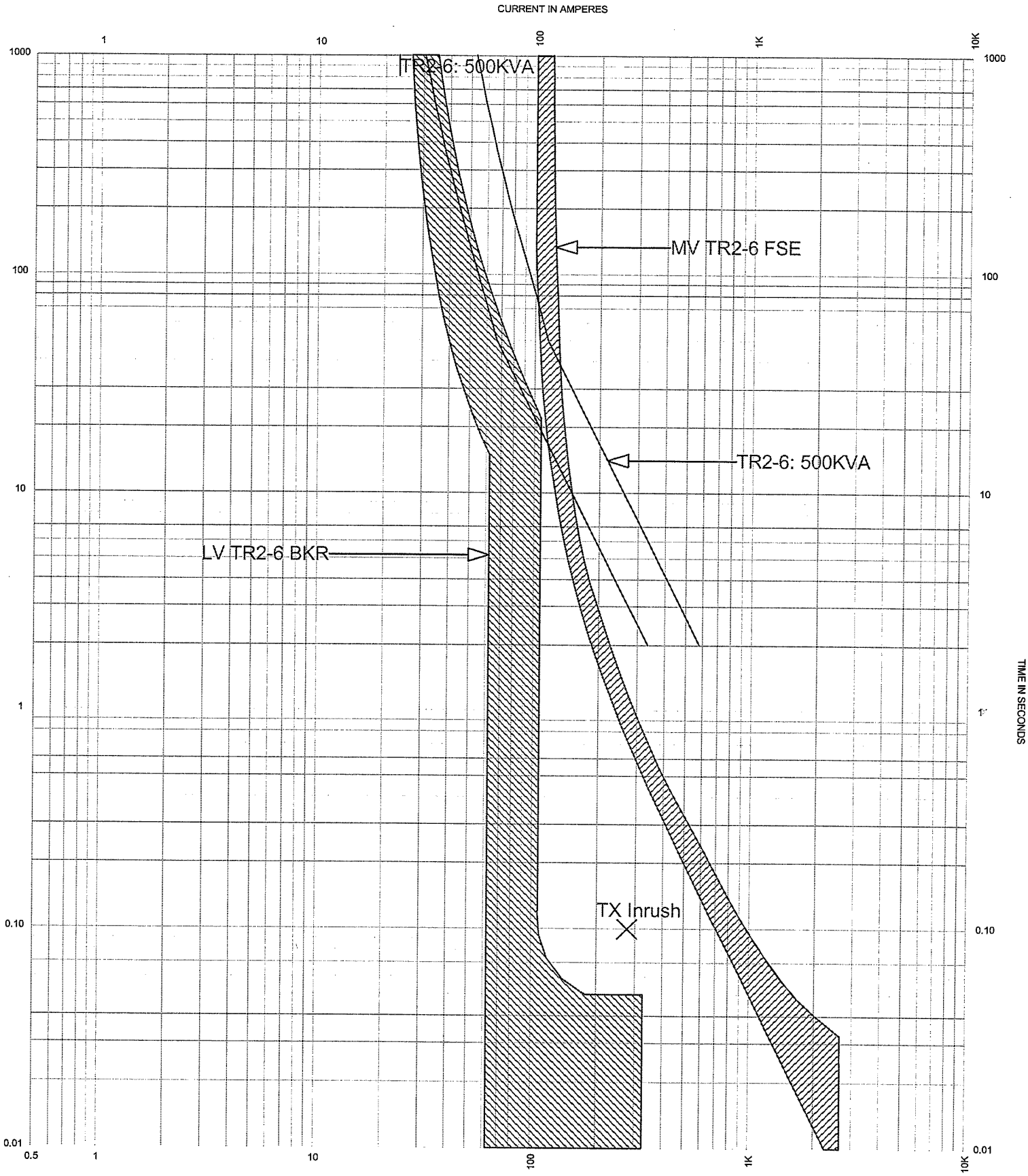
Project Name: Shippenburg 12.47kV Distribution
Plot Voltage: 12470 Volts
Plot Scale: X 10^0 Amps
Entech Eng #2184.22

TCC Name: TR2-4 WRIGHT HALL
Rev. 0.0
Date: March 12, 2004



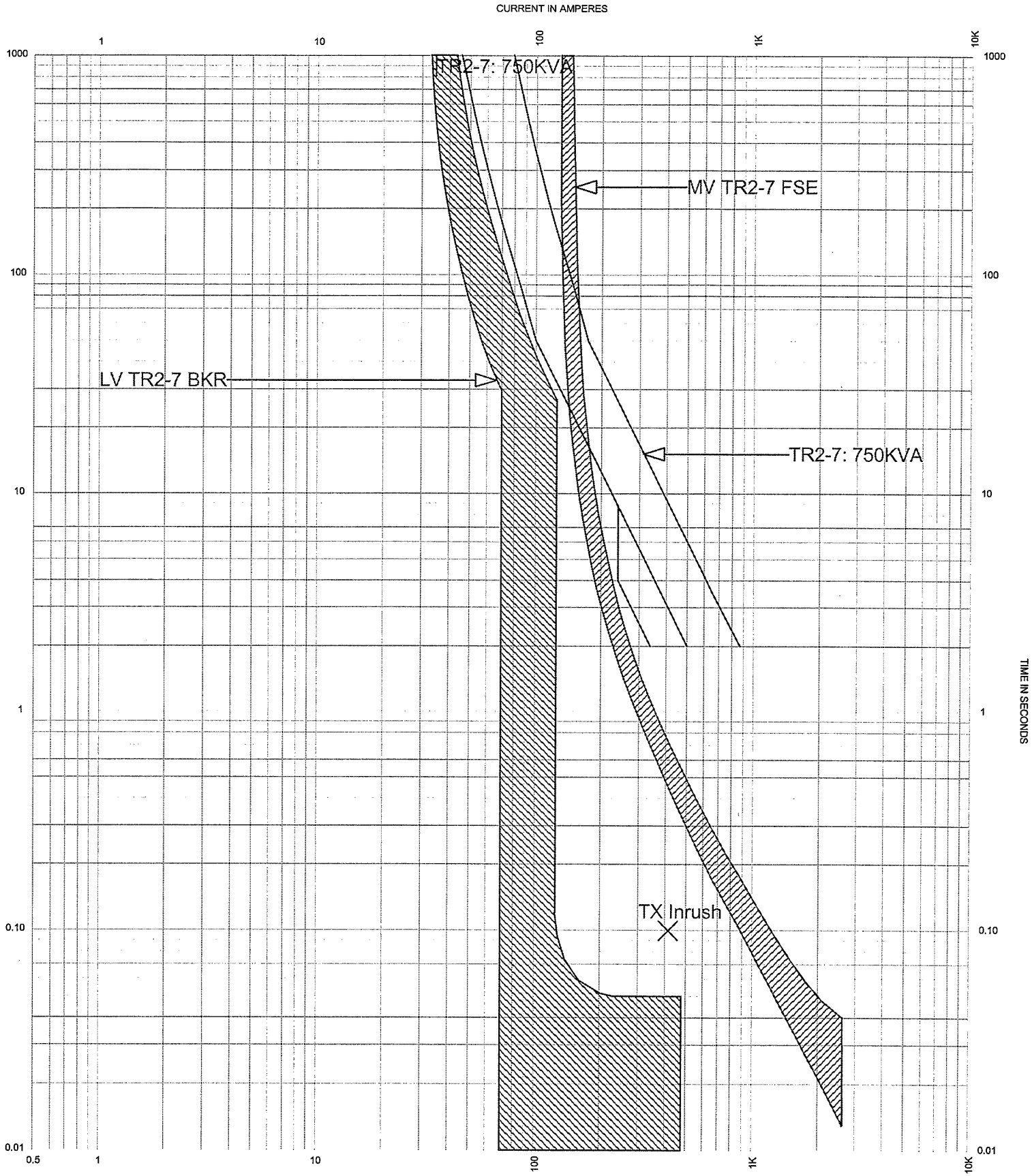
Project Name: Shippenburg 12.47kV Distribution
Plot Voltage: 12470 Volts
Plot Scale: X 10^0 Amps
Entech Eng #2184.22

TCC Name: TR2-5 TENNIS COURTS
Rev. 0.0
Date: March 12, 2004



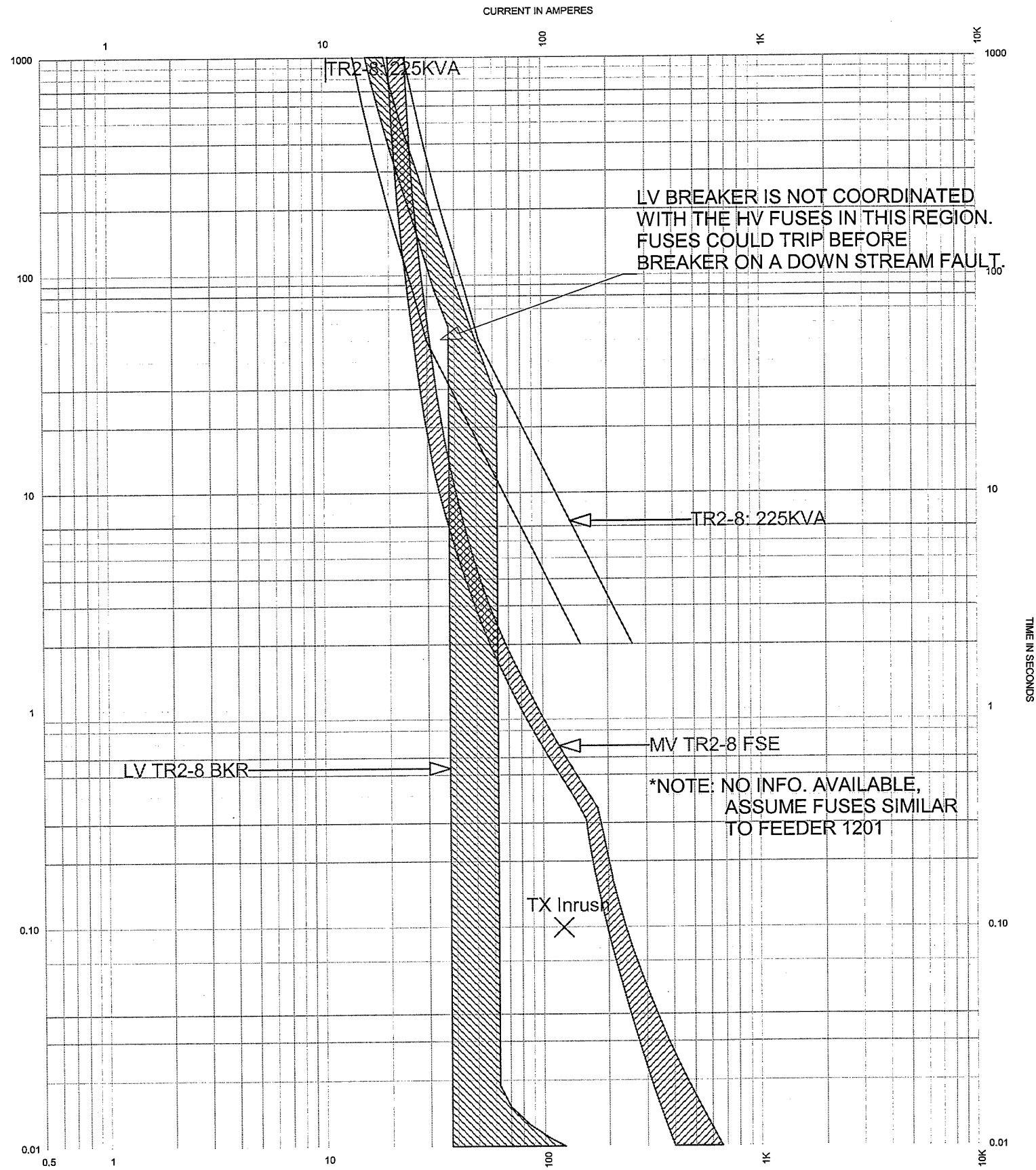
Project Name: Shippenburg 12.47kV Distribution
Plot Voltage: 12470 Volts
Plot Scale: X 10^0 Amps
Entech Eng #2184.22

TCC Name: TR2-6 NAUGLE HALL
Rev. 0.0
Date: March 12, 2004



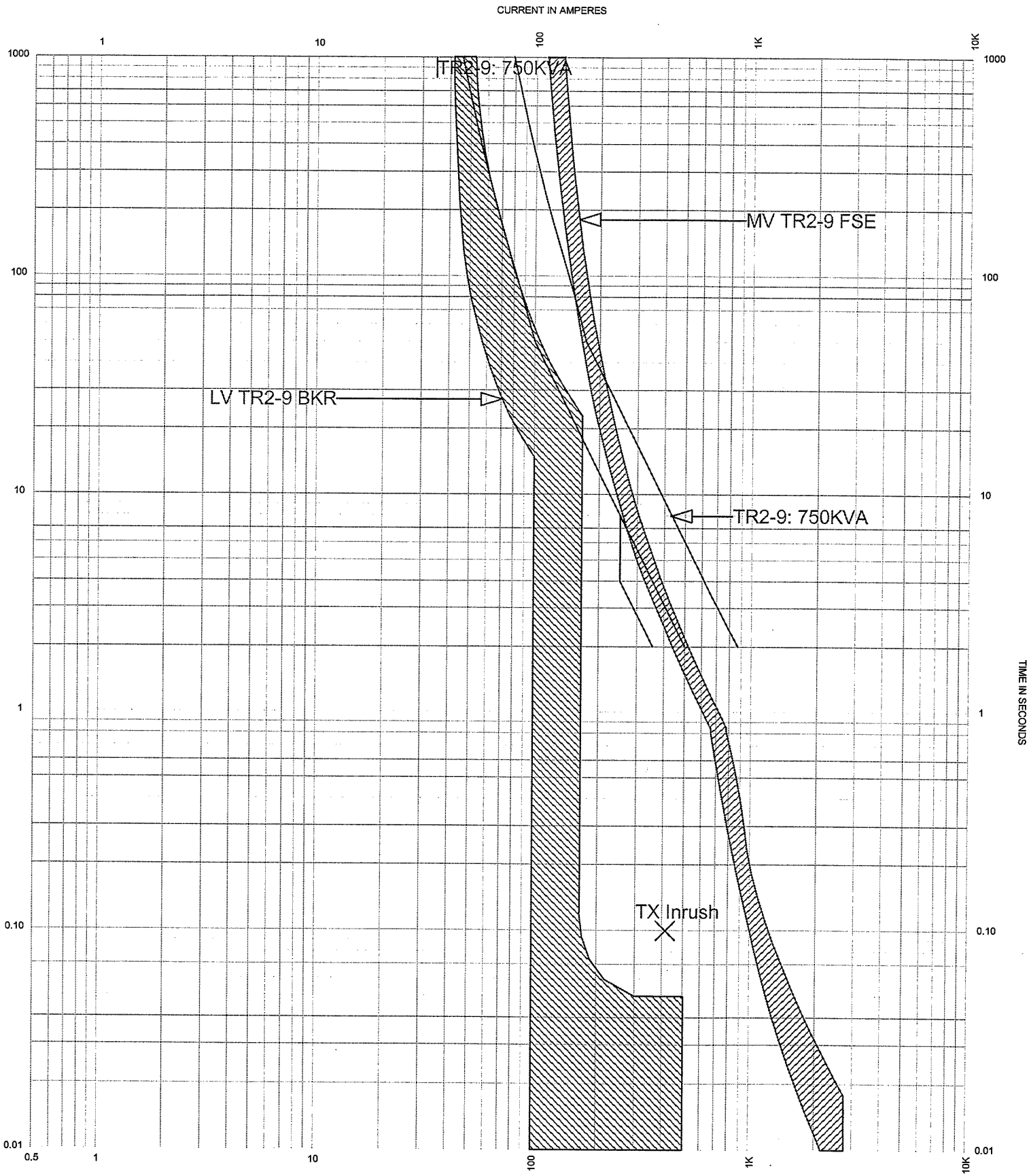
Project Name: Shippenburg 12.47kV Distribution
Plot Voltage: 12470 Volts
Plot Scale: X 10^0 Amps
Entech Eng #2184.22

TCC Name: TR2-7 McLEAN HALL
Rev. 0.0
Date: March 12, 2004



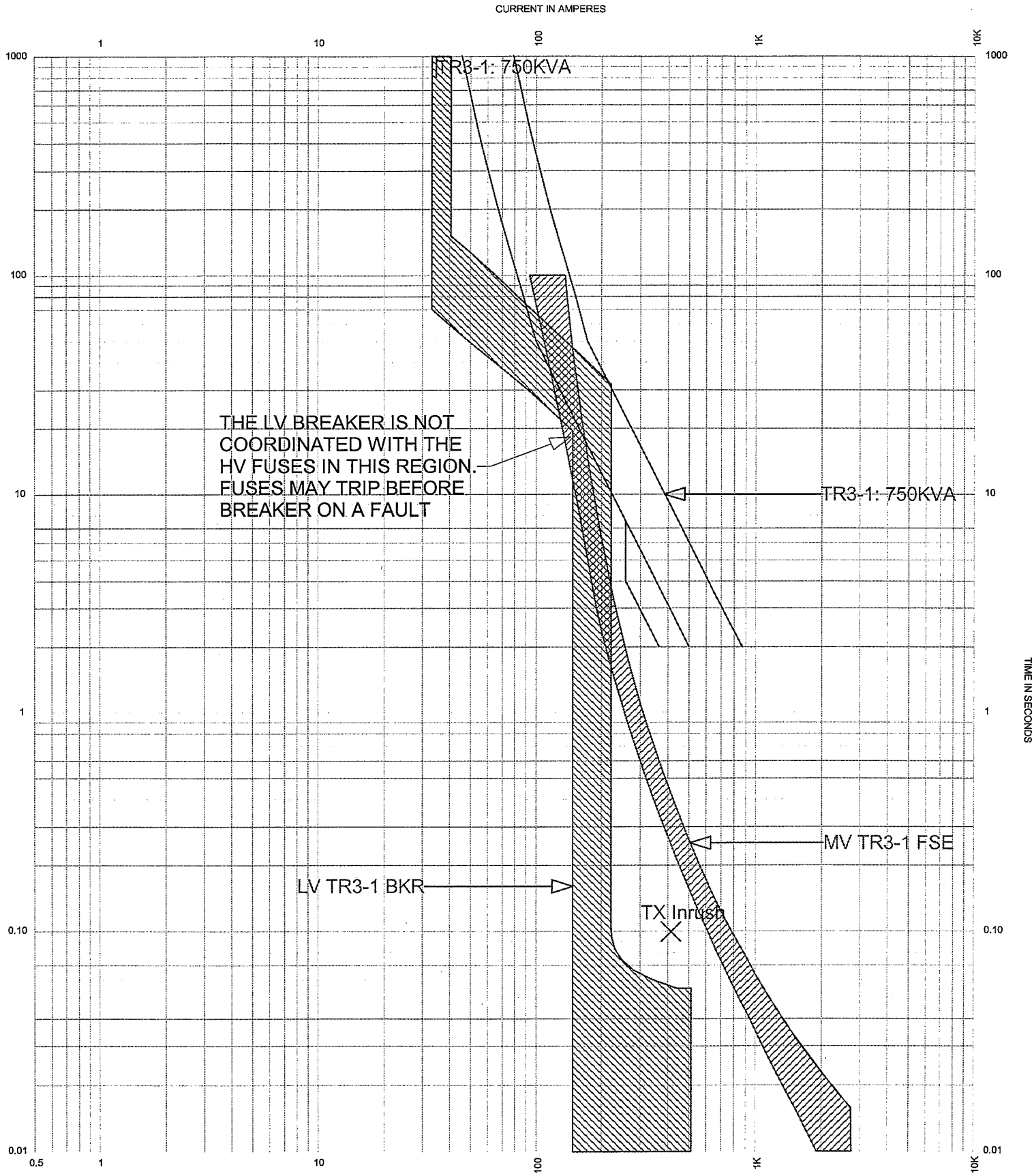
Project Name: Shippenburg 12.47kV Distribution
Plot Voltage: 12470 Volts
Plot Scale: X 10^0 Amps
Entech Eng #2184.22

TCC Name: TR2-8 C.G
Rev. 0.0
Date: March 12, 2004



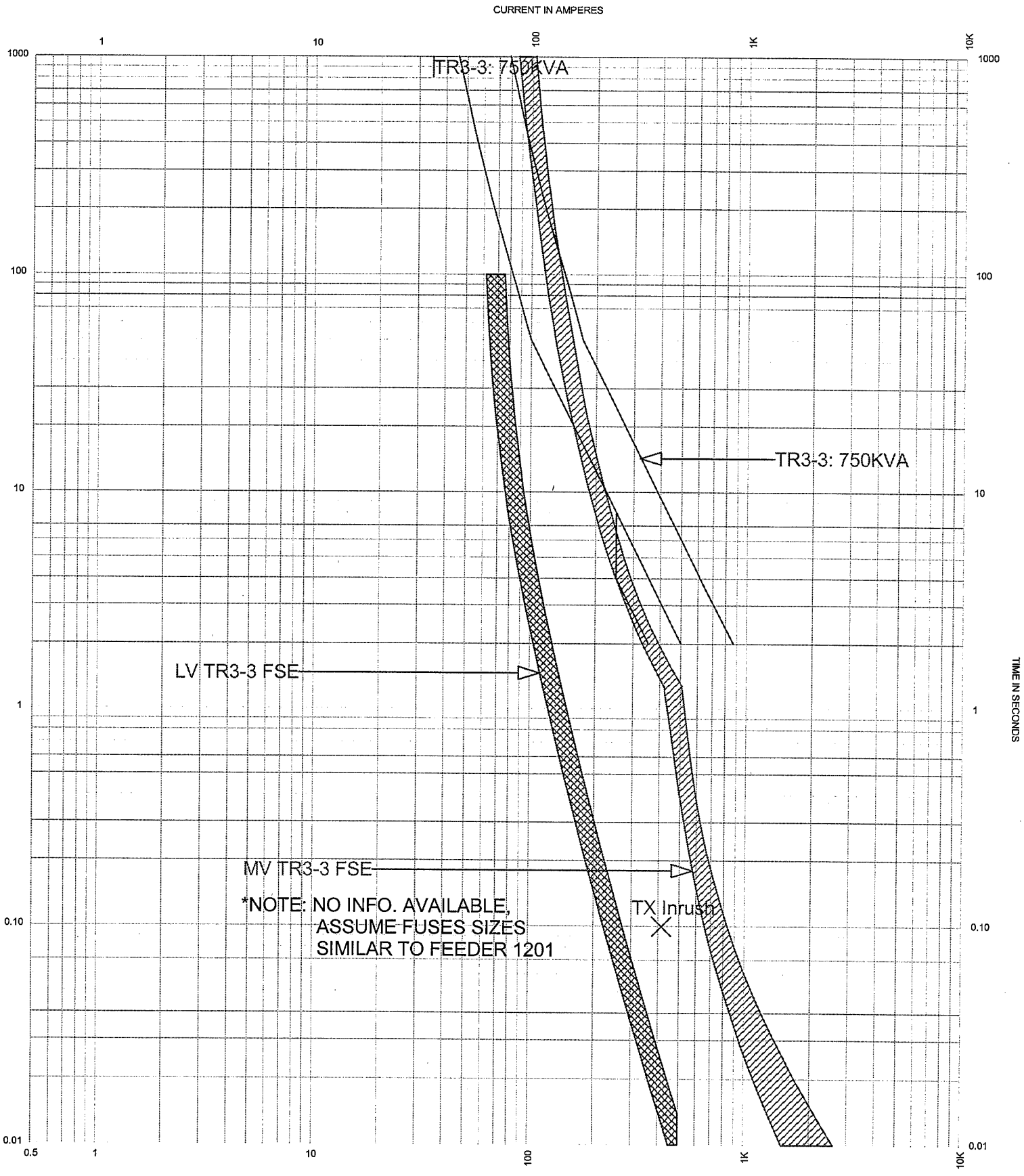
Project Name: Shippenburg 12.47kV Distribution
Plot Voltage: 12470 Volts
Plot Scale: X 10^0 Amps
Entech Eng #2184.22

TCC Name: TR2-9 OLD MAIN
Rev. 0.0
Date: March 12, 2004



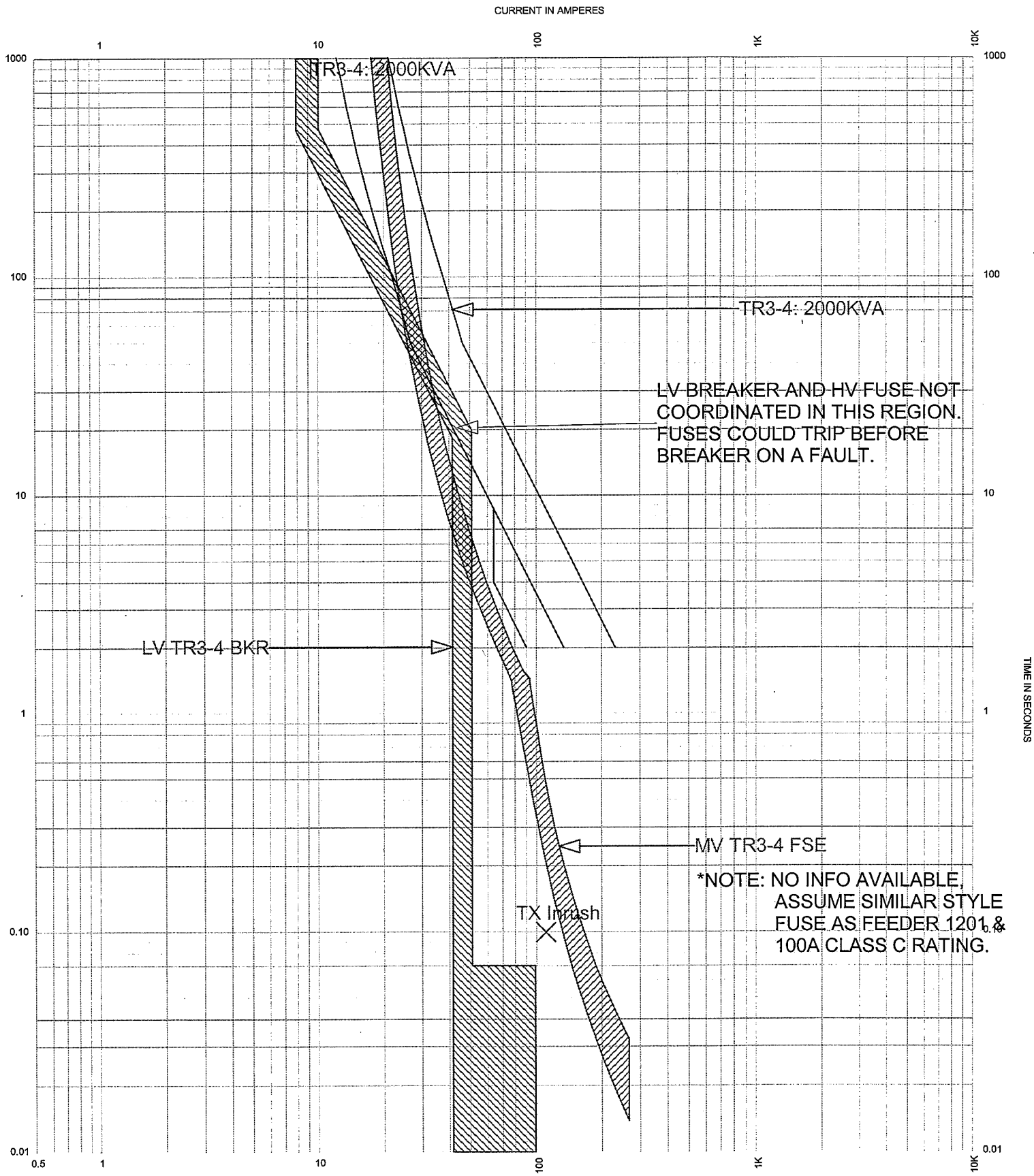
Project Name: Shippenburg 12.47kV Distribution
Plot Voltage: 12470 Volts
Plot Scale: X 10^0 Amps
Entech Eng #2184.22

TCC Name: TR3-1 EZRA LEHMAN LIBRARY
Rev. 0.0
Date: March 12, 2004



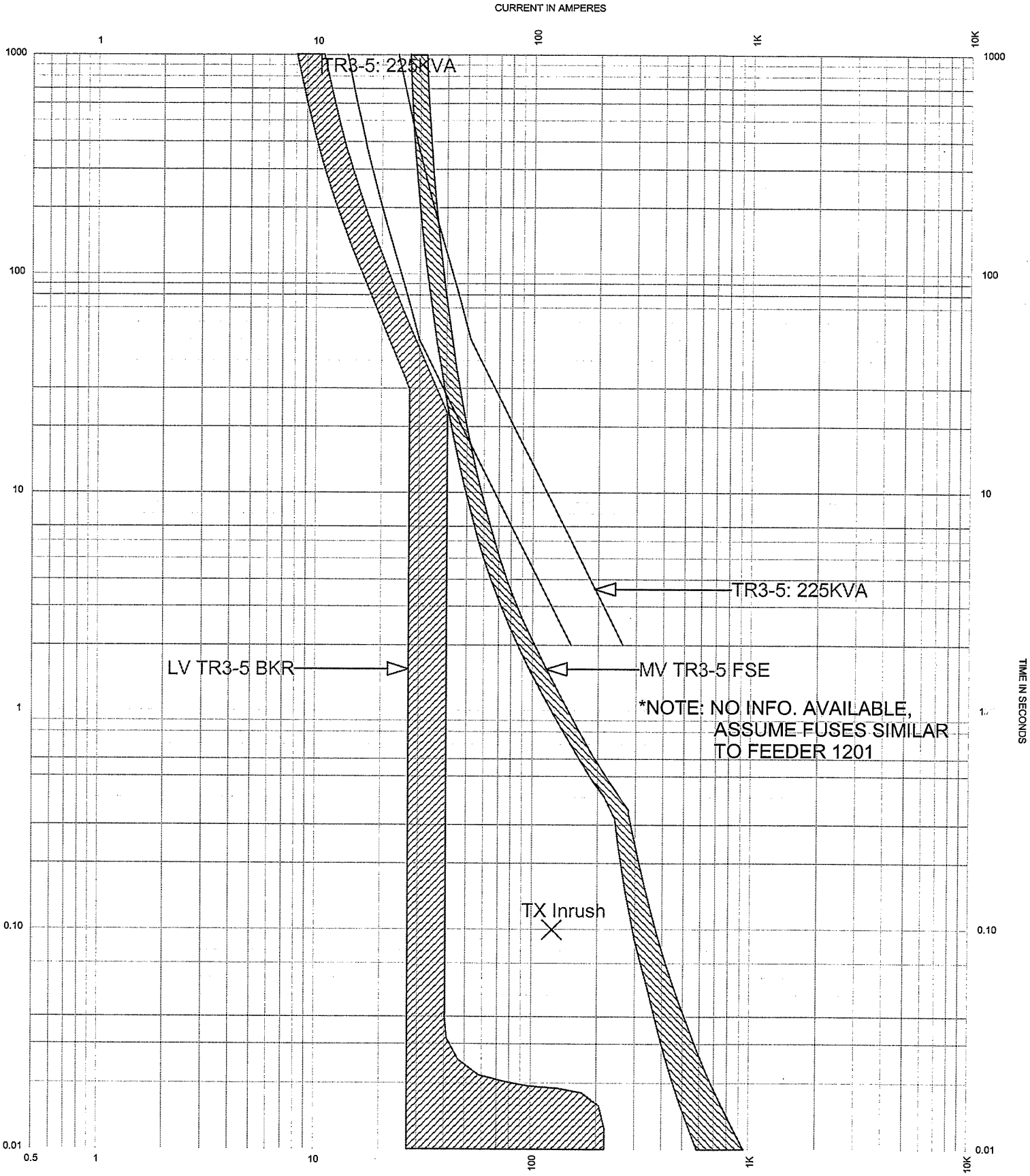
Project Name: Shippenburg 12.47kV Distribution
Plot Voltage: 12470 Volts
Plot Scale: X 10^0 Amps
Entech Eng #2184.22

TCC Name: TR3-3 SHIPPEN HALL
Rev. 0.0
Date: March 12, 2004



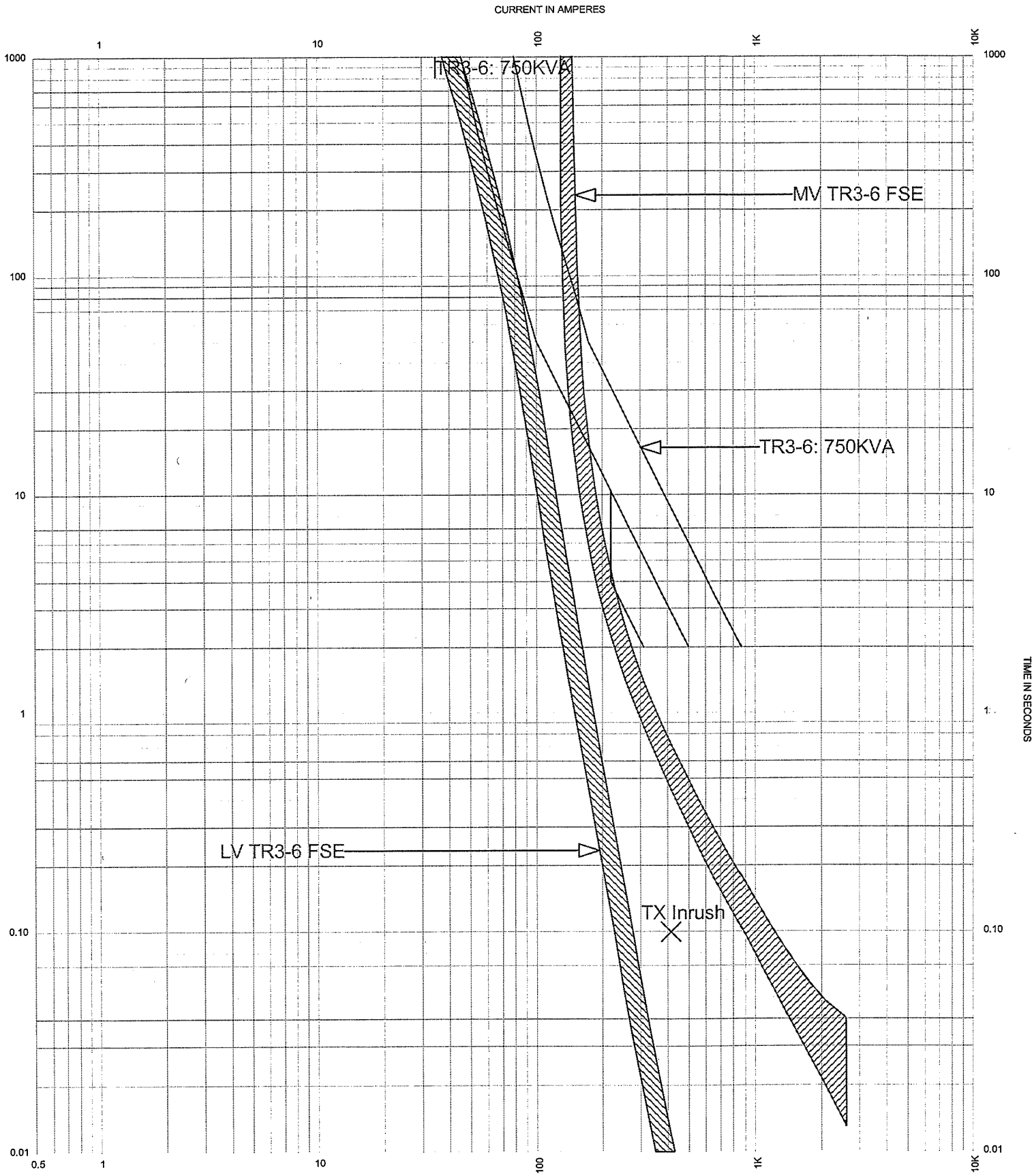
Project Name: Shippenburg 12.47kV Distribution
Plot Voltage: 12470 Volts
Plot Scale: X 10^1 Amps
Entech Eng #2184.22

TCC Name: TR3-4 FRANKLIN SCIENCE CENTER
Rev. 0.0
Date: March 12, 2004



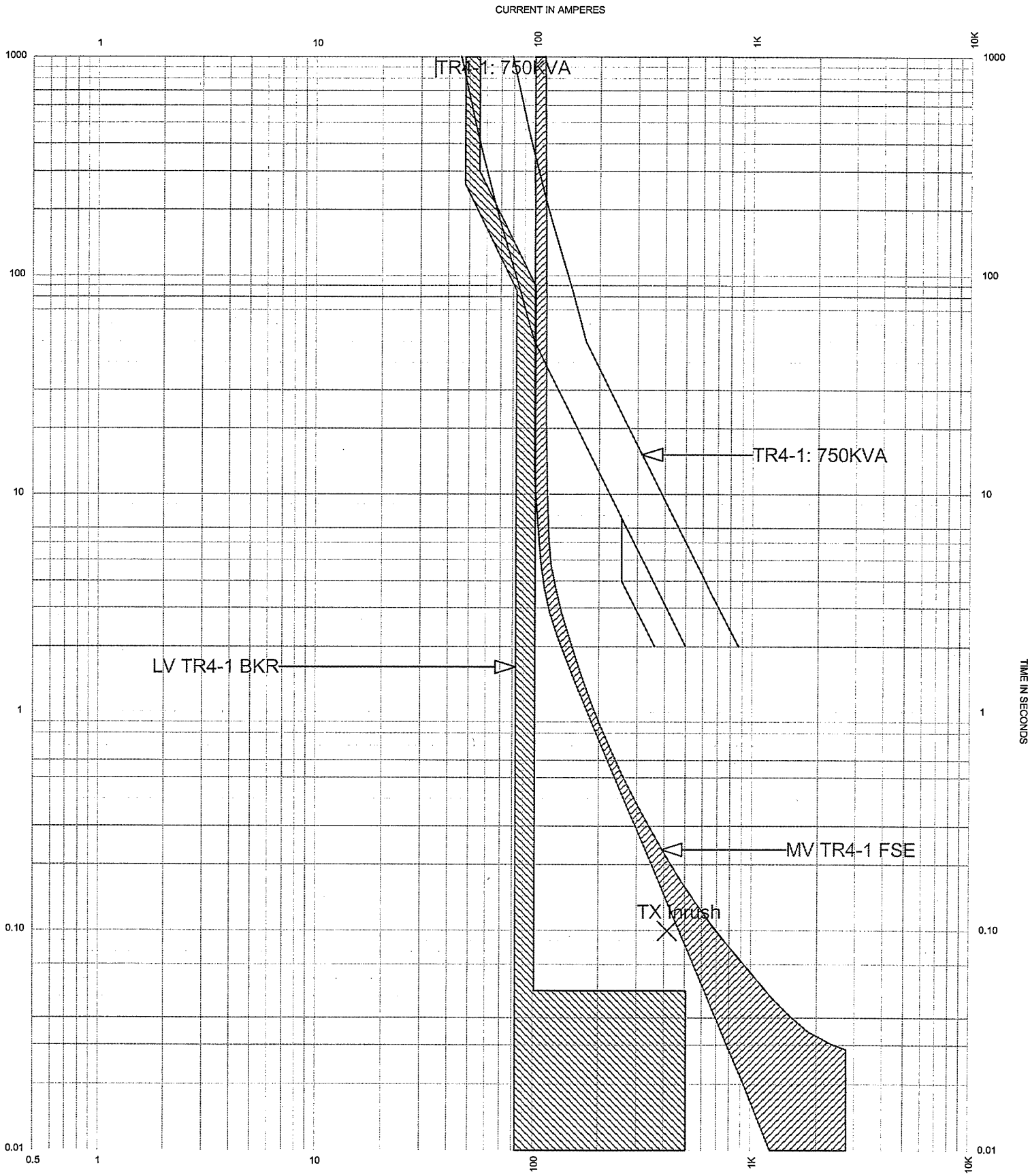
Project Name: Shippenburg 12.47kV Distribution
Plot Voltage: 12470 Volts
Plot Scale: X 10^0 Amps
Entech Eng #2184.22

TCC Name: TR3-5 REISNER CHILLER
Rev. 0.0
Date: March 12, 2004



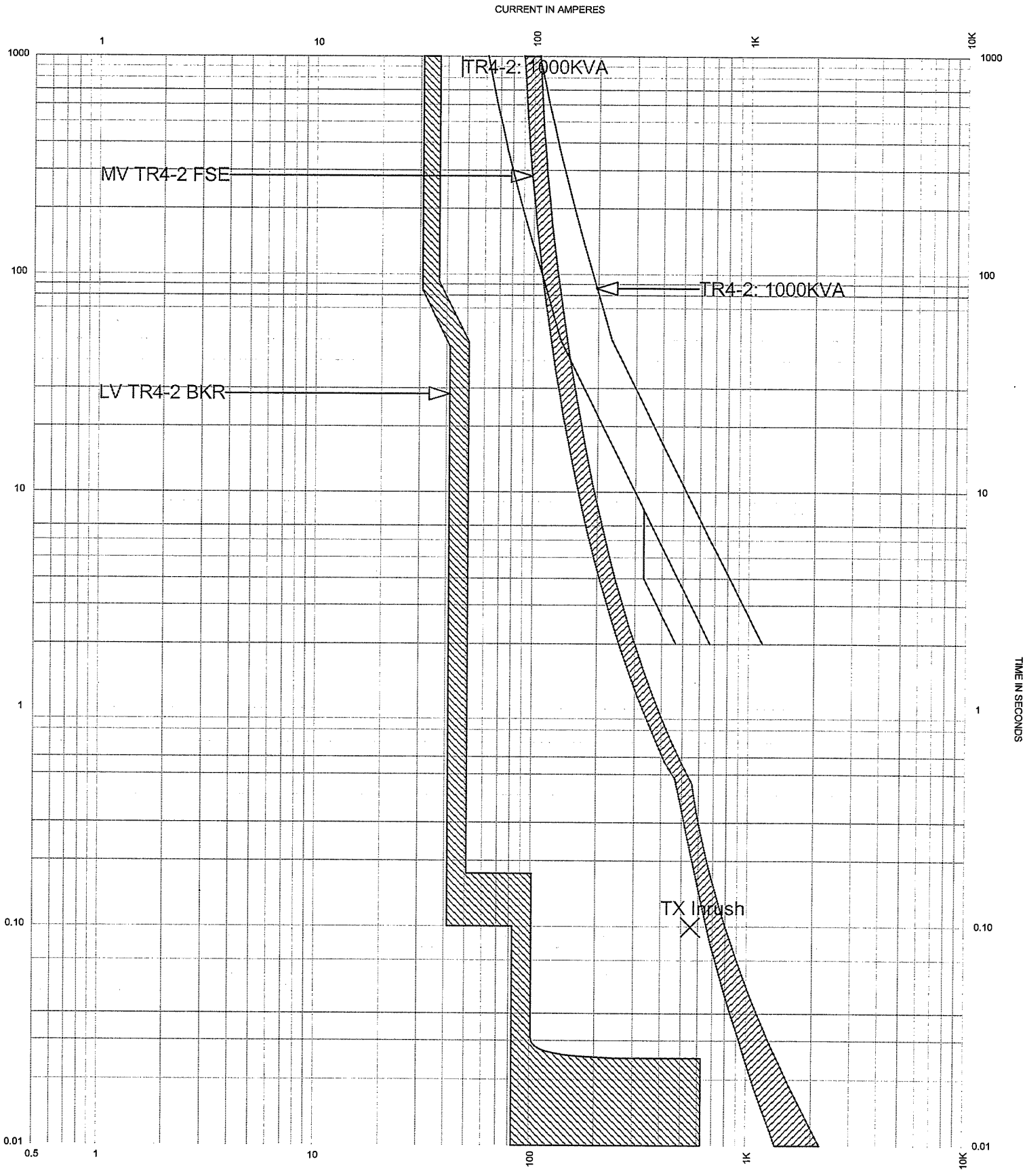
Project Name: Shippenburg 12.47kV Distribution
Plot Voltage: 12470 Volts
Plot Scale: X 10^0 Amps
Entech Eng #2184.22

TCC Name: TR3-6 RIESNER HALL
Rev. 0.0
Date: March 12, 2004



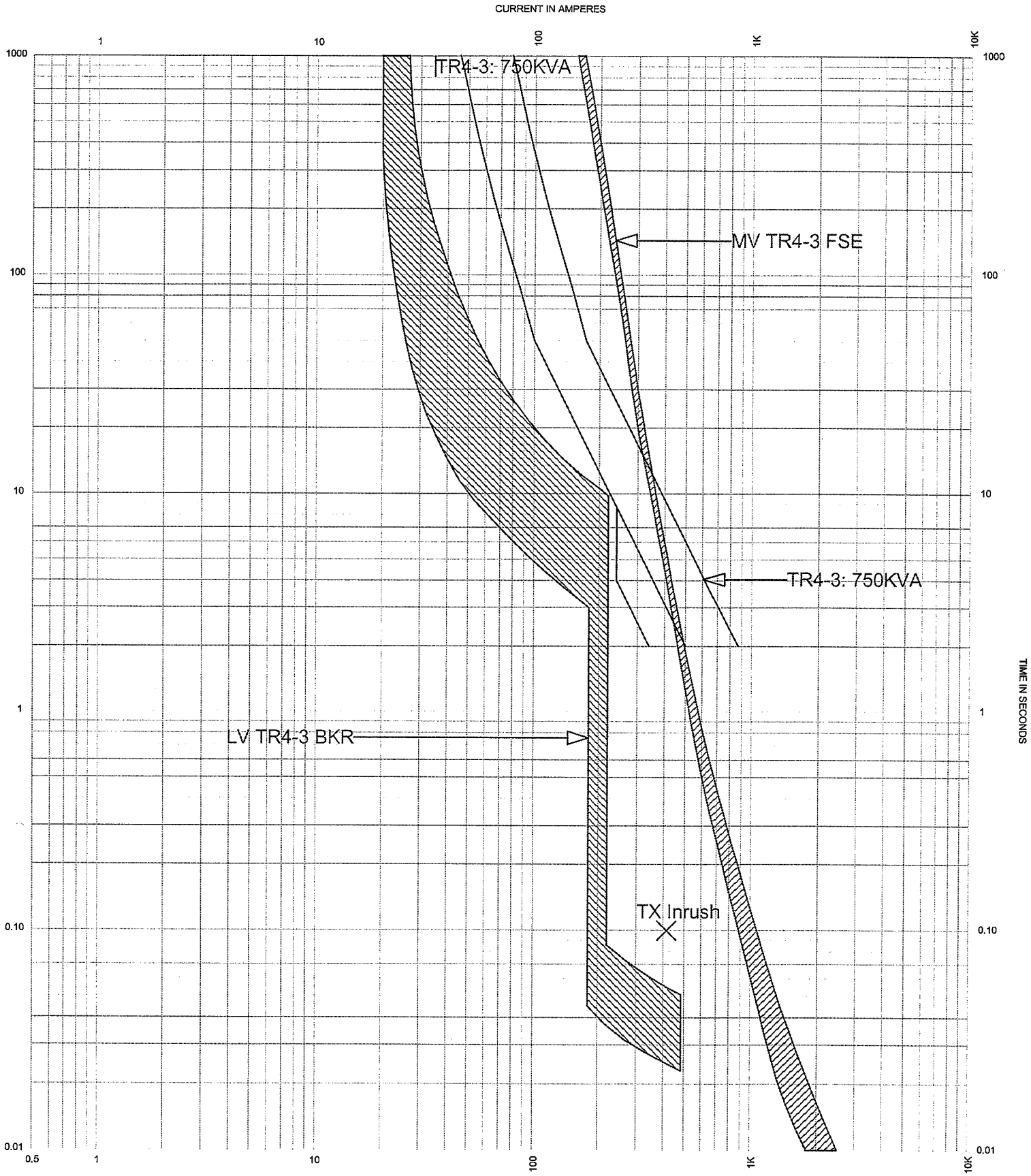
Project Name: Shippenburg 12.47kV Distribution
Plot Voltage: 12470 Volts
Plot Scale: X 10^0 Amps
Entech Eng #2184.22

TCC Name: TR4-1 MATH/COMPUTER CENTER
Rev. 0.0
Date: March 12, 2004



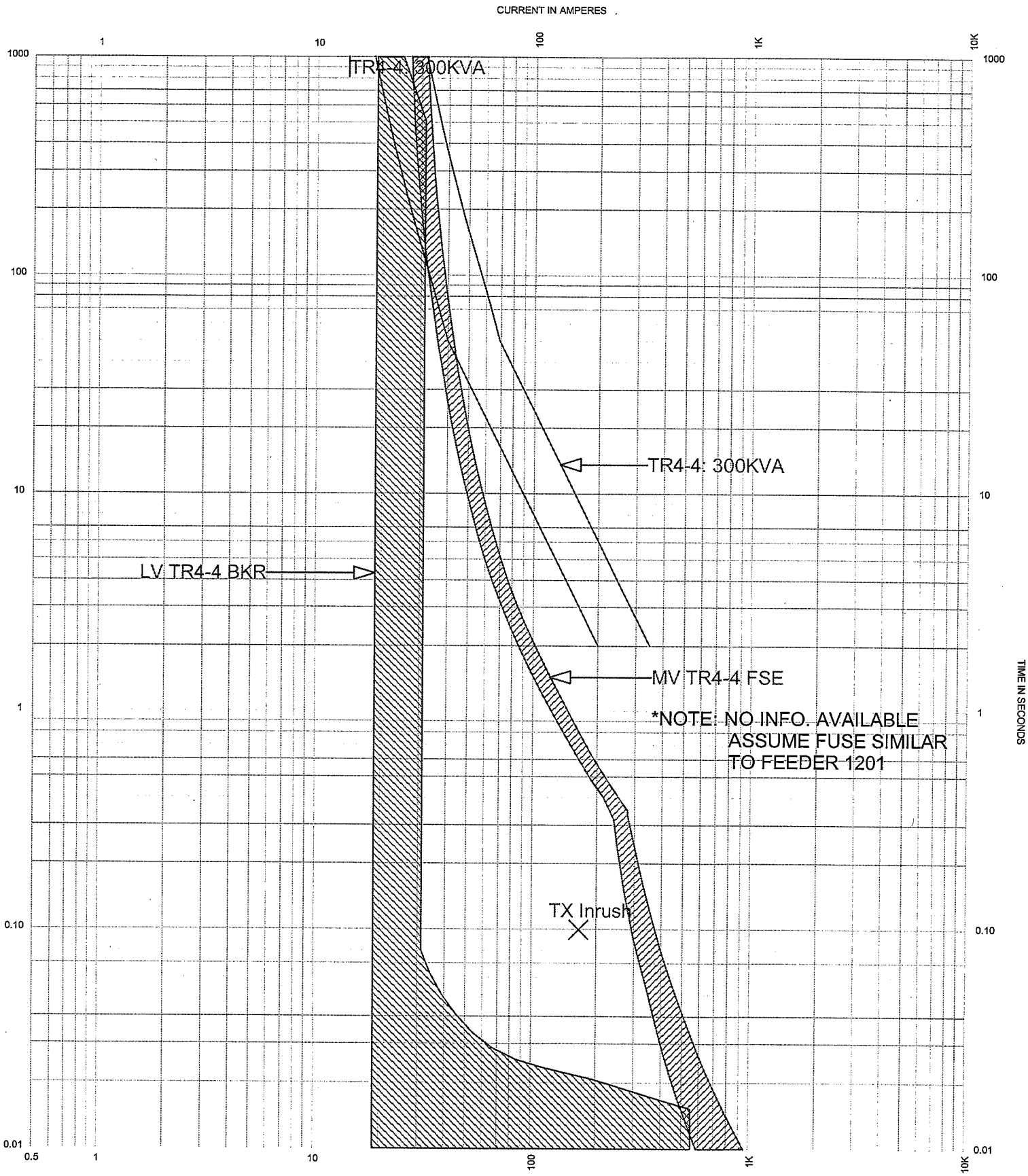
Project Name: Shippenburg 12.47kV Distribution
Plot Voltage: 12470 Volts
Plot Scale: X 10^0 Amps
Entech Eng #2184.22

TCC Name: TR4-2 GROVE HALL
Rev. 0.0
Date: March 12, 2004



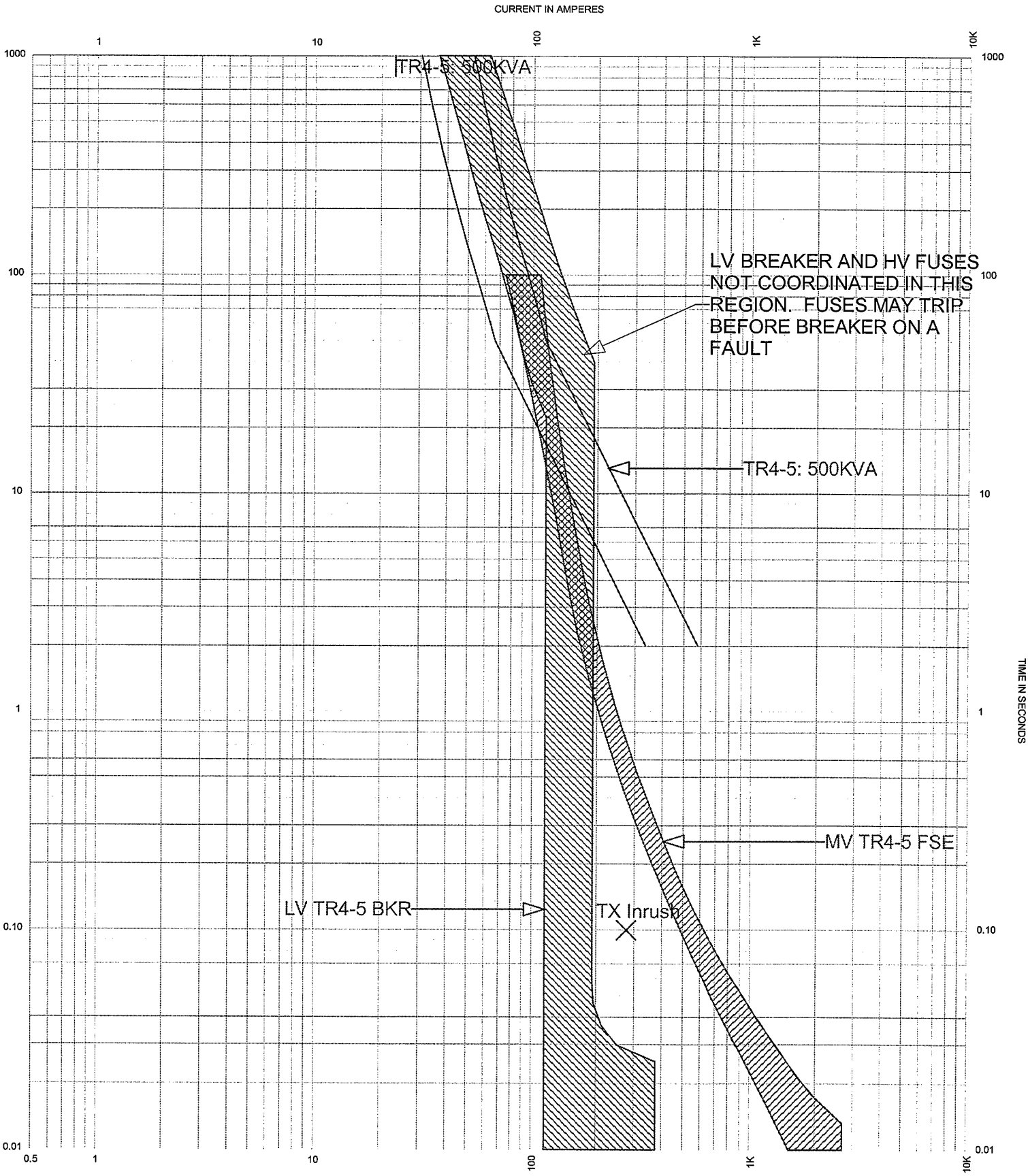
Project Name: Shippenburg 12.47kV Distribution
Plot Voltage: 12470 Volts
Plot Scale: X 10^0 Amps
Entech Eng #2184.22

TCC Name: TR4-3 HEIGES FIELD HOUSE
Rev. 0.0
Date: March 12, 2004



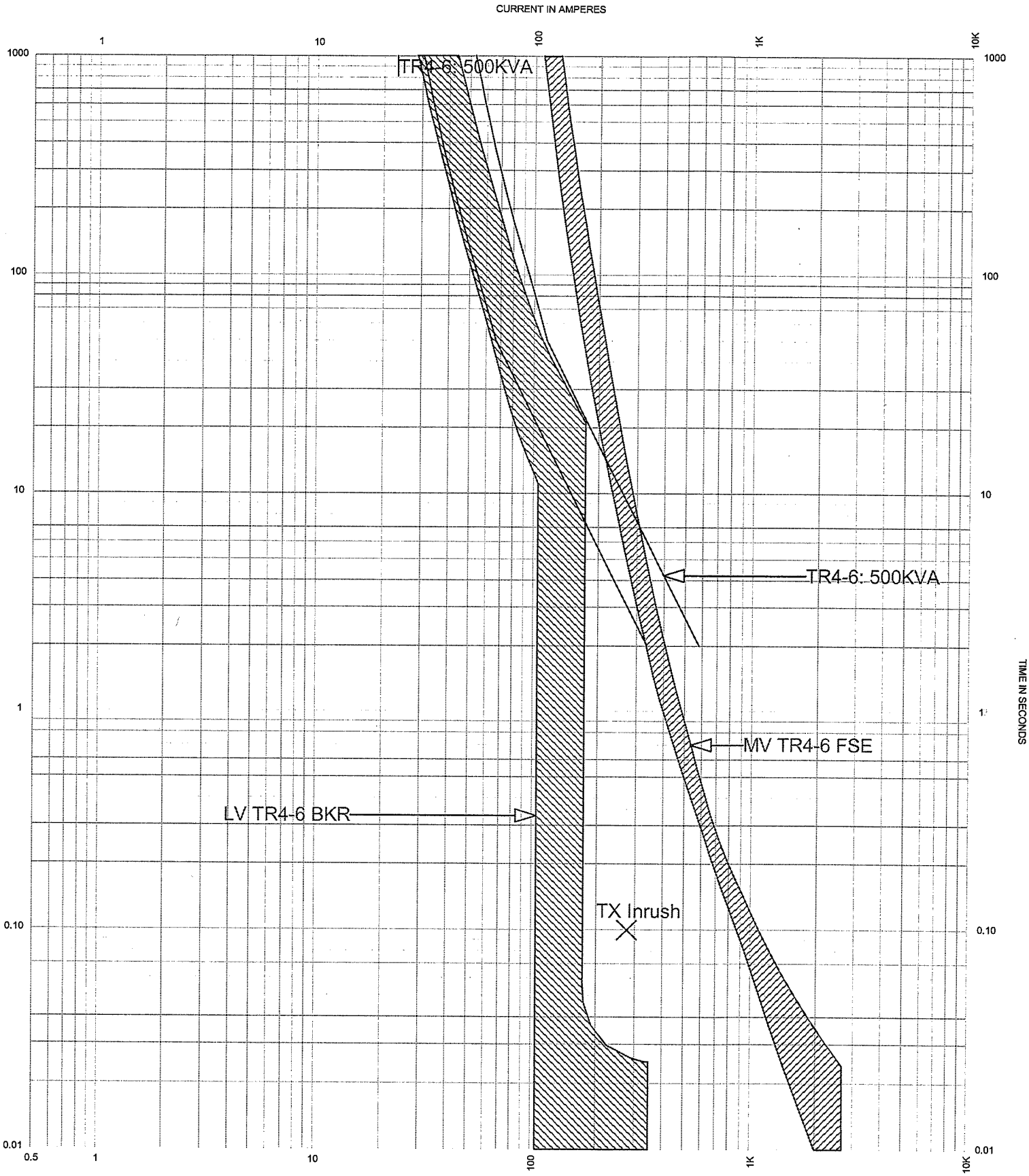
Project Name: Shippenburg 12.47kV Distribution
Plot Voltage: 12470 Volts
Plot Scale: X 10^0 Amps
Entech Eng #2184.22

TCC Name: TR4-4 SETH GROVE STADIUM
Rev. 0.0
Date: March 12, 2004



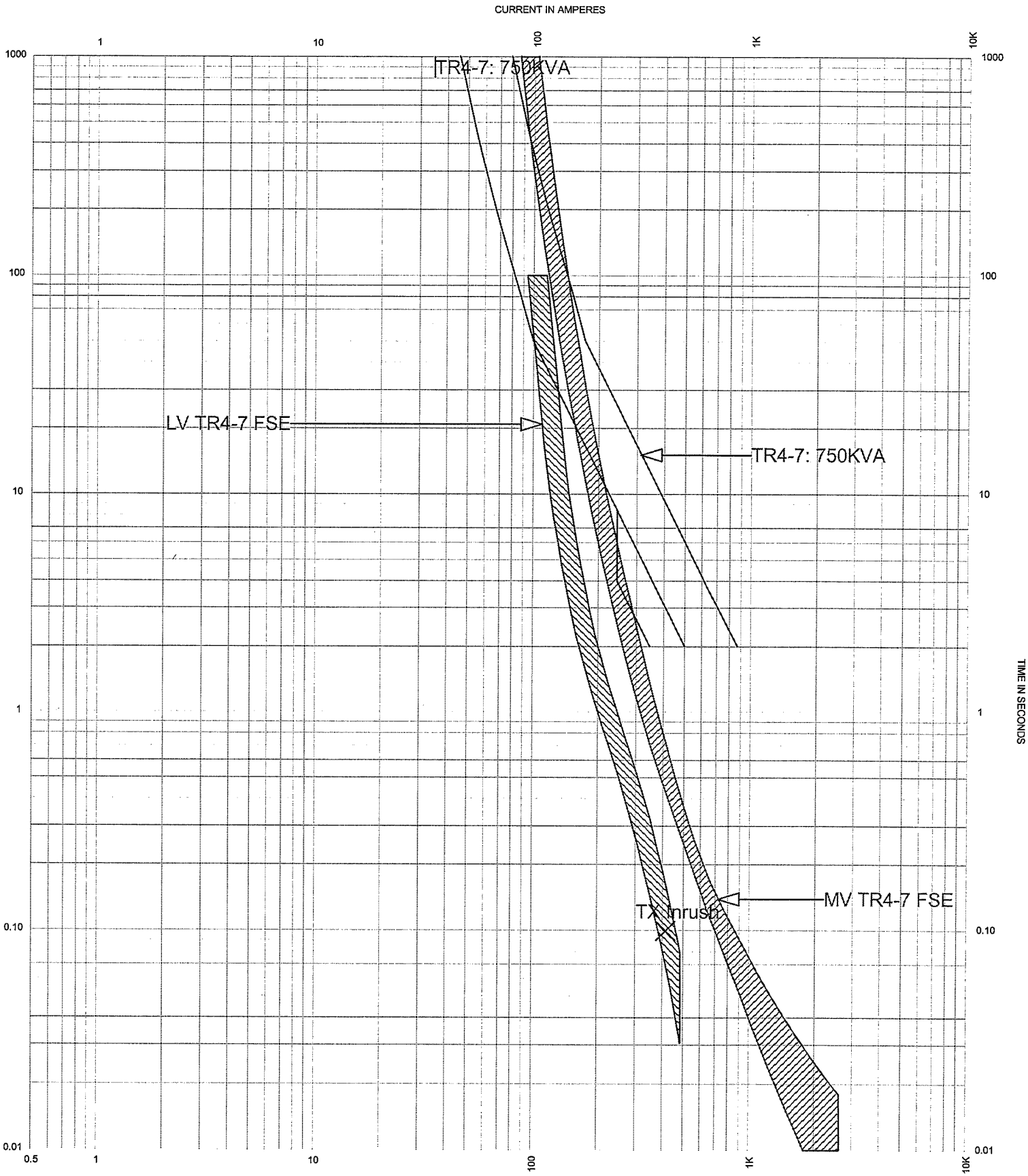
Project Name: Shippenburg 12.47kV Distribution
Plot Voltage: 12470 Volts
Plot Scale: X 10^0 Amps
Entech Eng #2184.22

TCC Name: TR4-5 CUMBERLAND STUDENT UNION
Rev. 0.0
Date: March 12, 2004



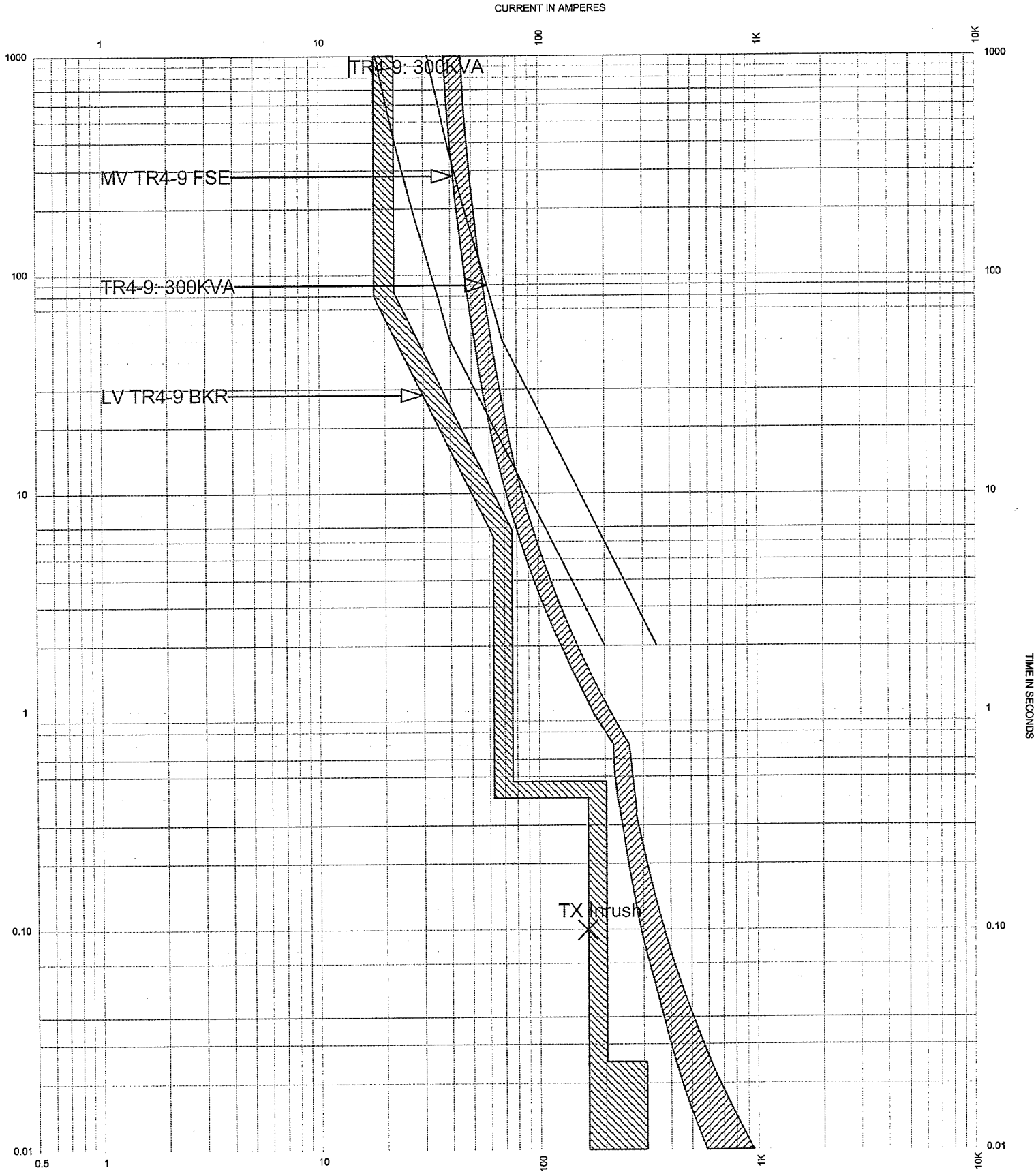
Project Name: Shippenburg 12.47kV Distribution
Plot Voltage: 12470 Volts
Plot Scale: X 10^0 Amps
Entech Eng #2184.22

TCC Name: TR4-6 CUMBERLAND ADDITION
Rev. 0.0
Date: March 12, 2004



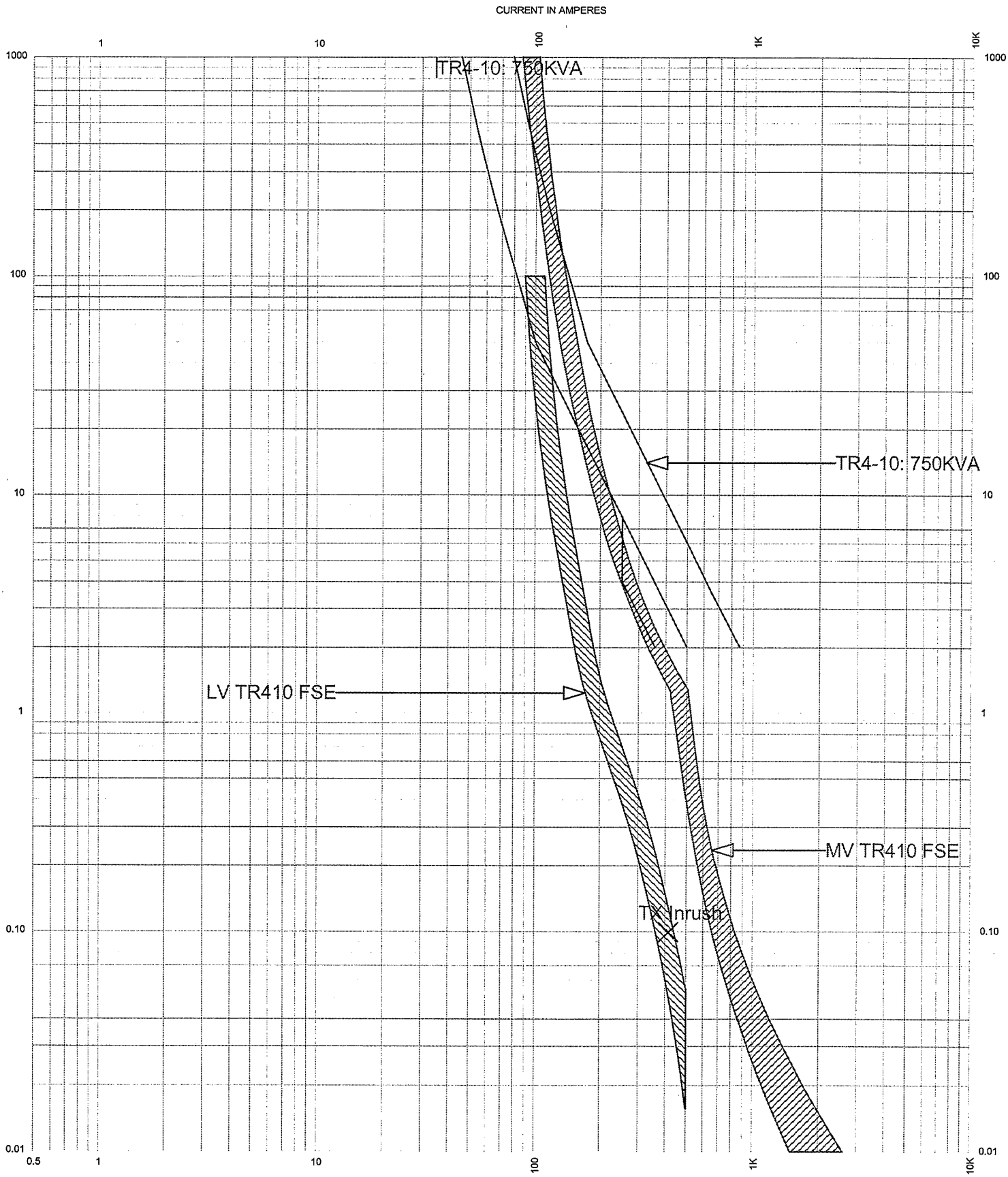
Project Name: Shippenburg 12.47kV Distribution
Plot Voltage: 12470 Volts
Plot Scale: X 10^0 Amps
Entech Eng #2184.22

TCC Name: TR4-7 MOWERY HALL MAIN
Rev. 0.0
Date: March 12, 2004



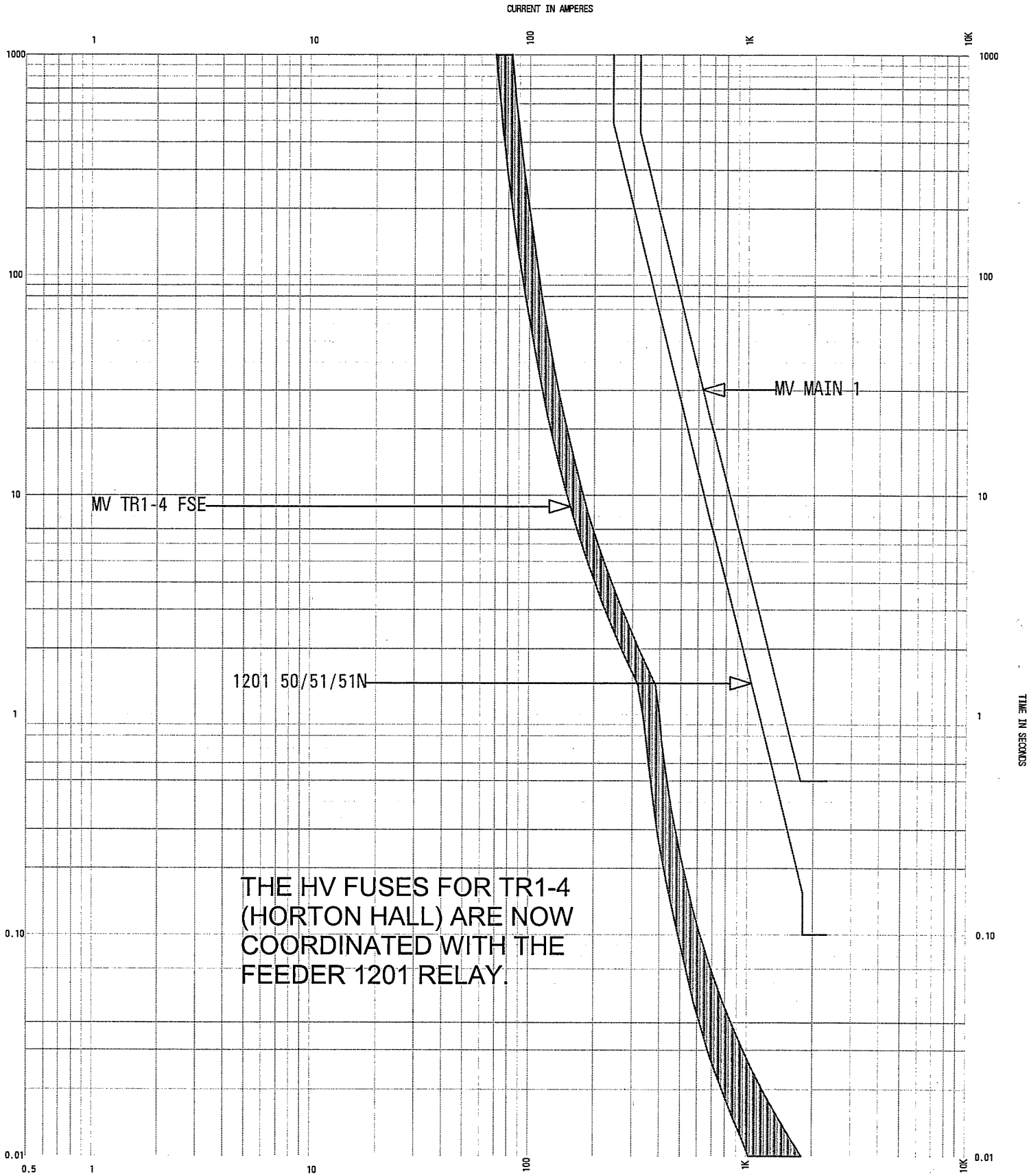
Project Name: Shippenburg 12.47kV Distribution
Plot Voltage: 12470 Volts
Plot Scale: X 10^0 Amps
Entech Eng #2184.22

TCC Name: TR4-9 STUDENT RECREATION CENTER
Rev. 0.0
Date: March 12, 2004



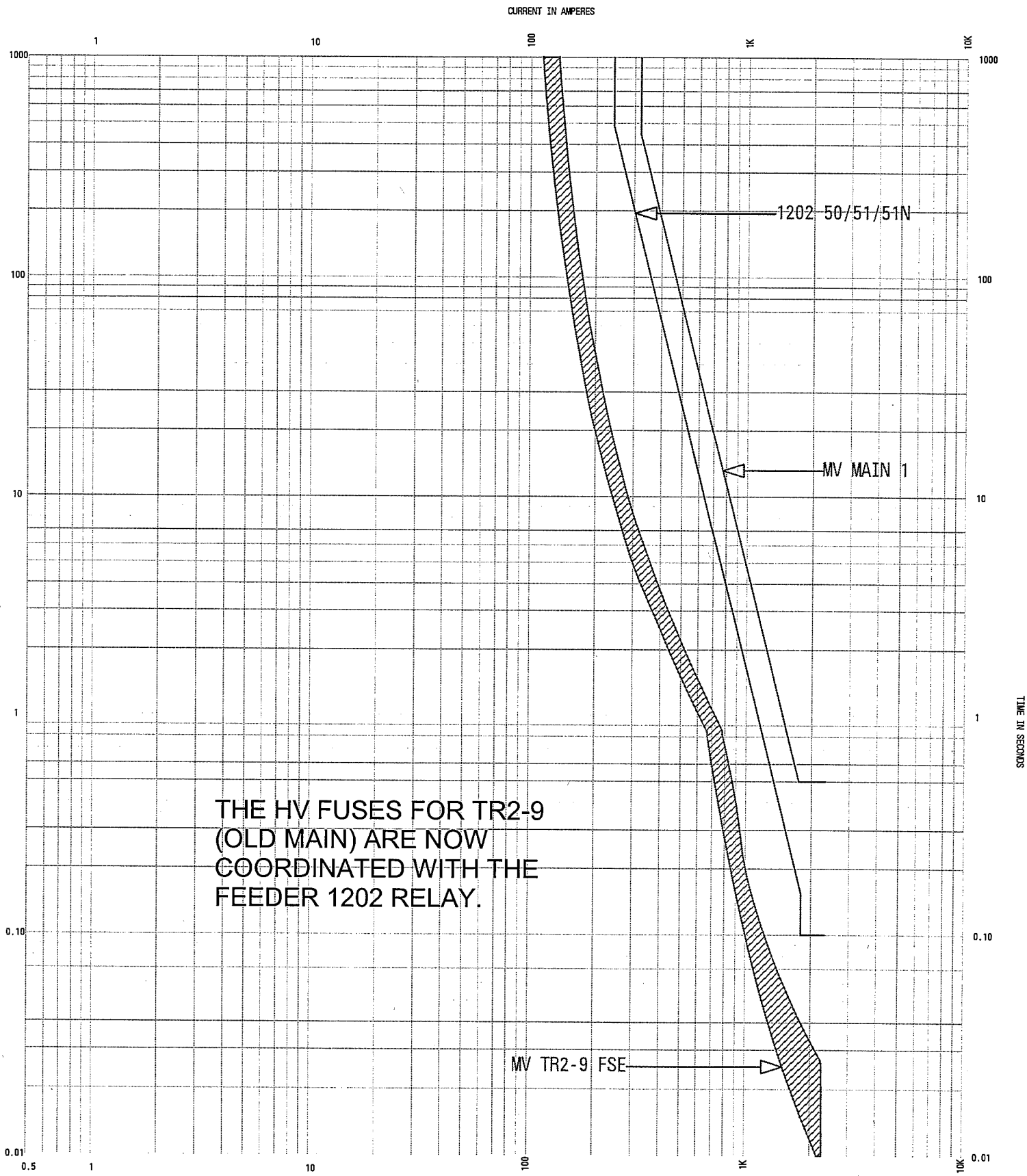
Project Name: Shippenburg 12.47kV Distribution
Plot Voltage: 12470 Volts
Plot Scale: X 10^0 Amps
Entech Eng #2184.22

TCC Name: TR4-10 SEAVERS COMPLEX
Rev. 0.0
Date: March 12, 2004



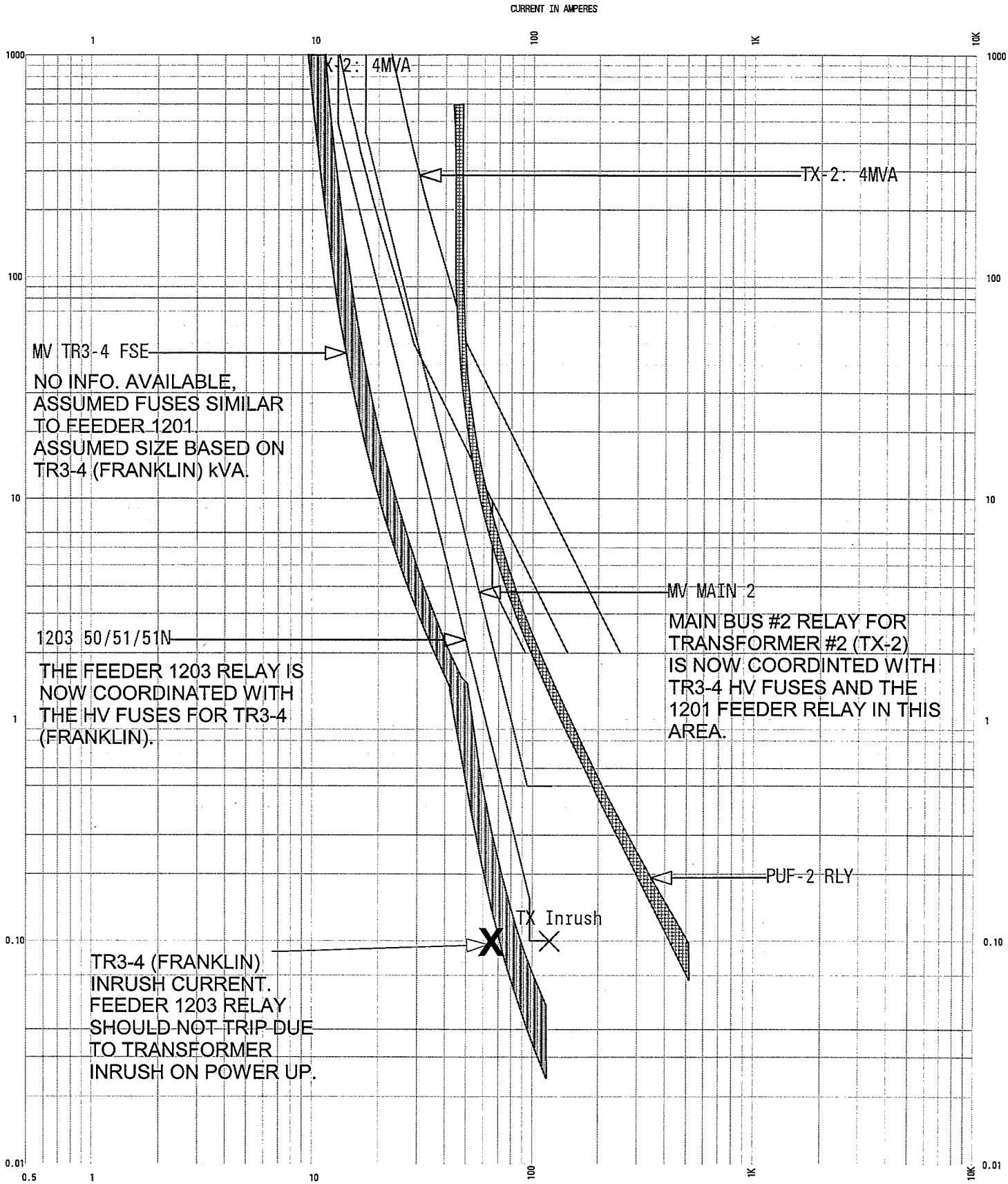
Project Name: Shippenburg 12.47kV Distribution
Plot Voltage: 12470 Volts
Plot Scale: X 10^0 Amps
Entech Eng #2184.22

TCC Name: 1201
Rev. 0.0
Date: August 12, 2004



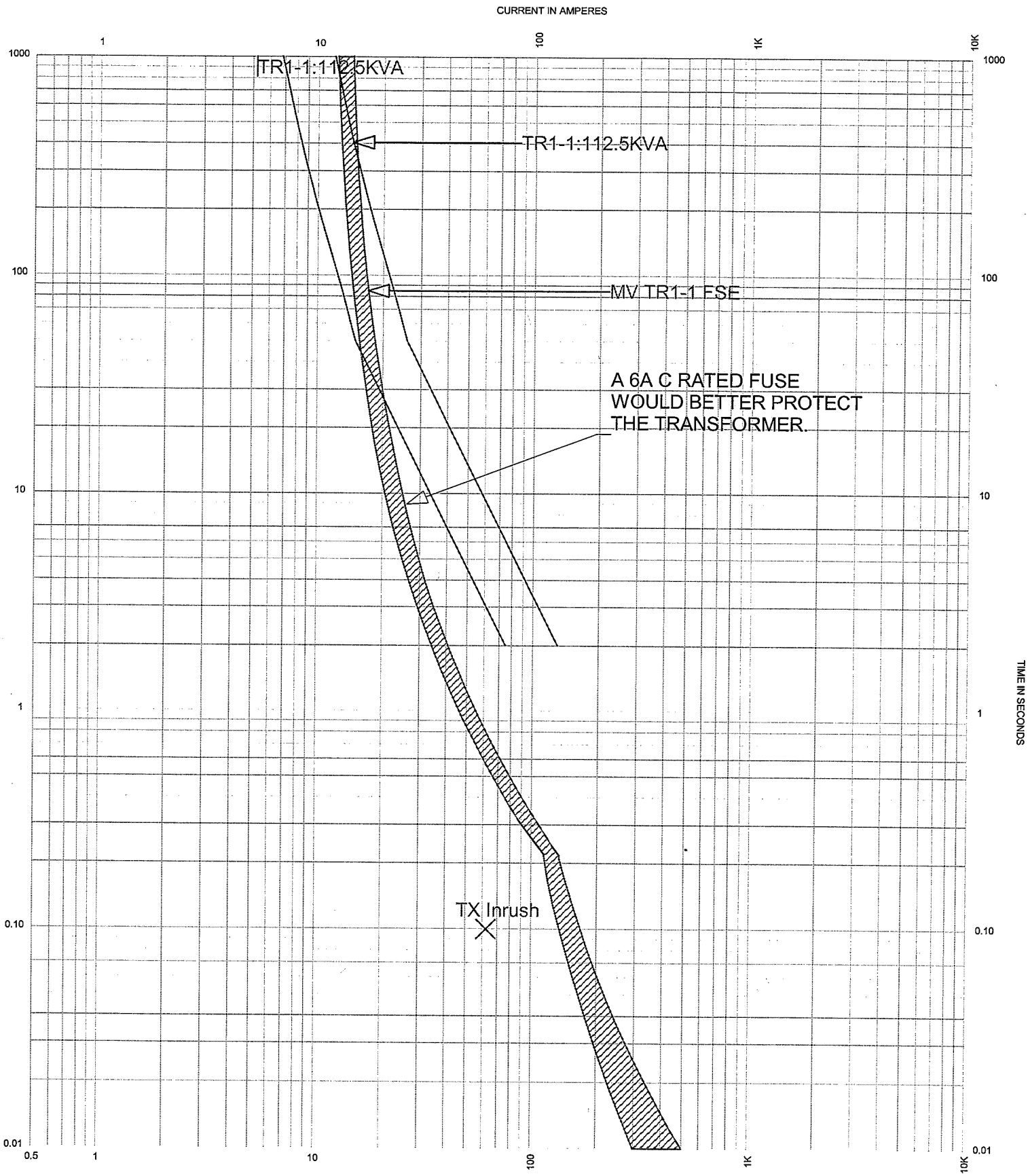
Project Name: Shippenburg 12.47kV Distribution
Plot Voltage: 12470 Volts
Plot Scale: X 10^0 Amps
Entech Eng #2184.22

TCC Name: 1202
Rev. 0.0
Date: August 12, 2004



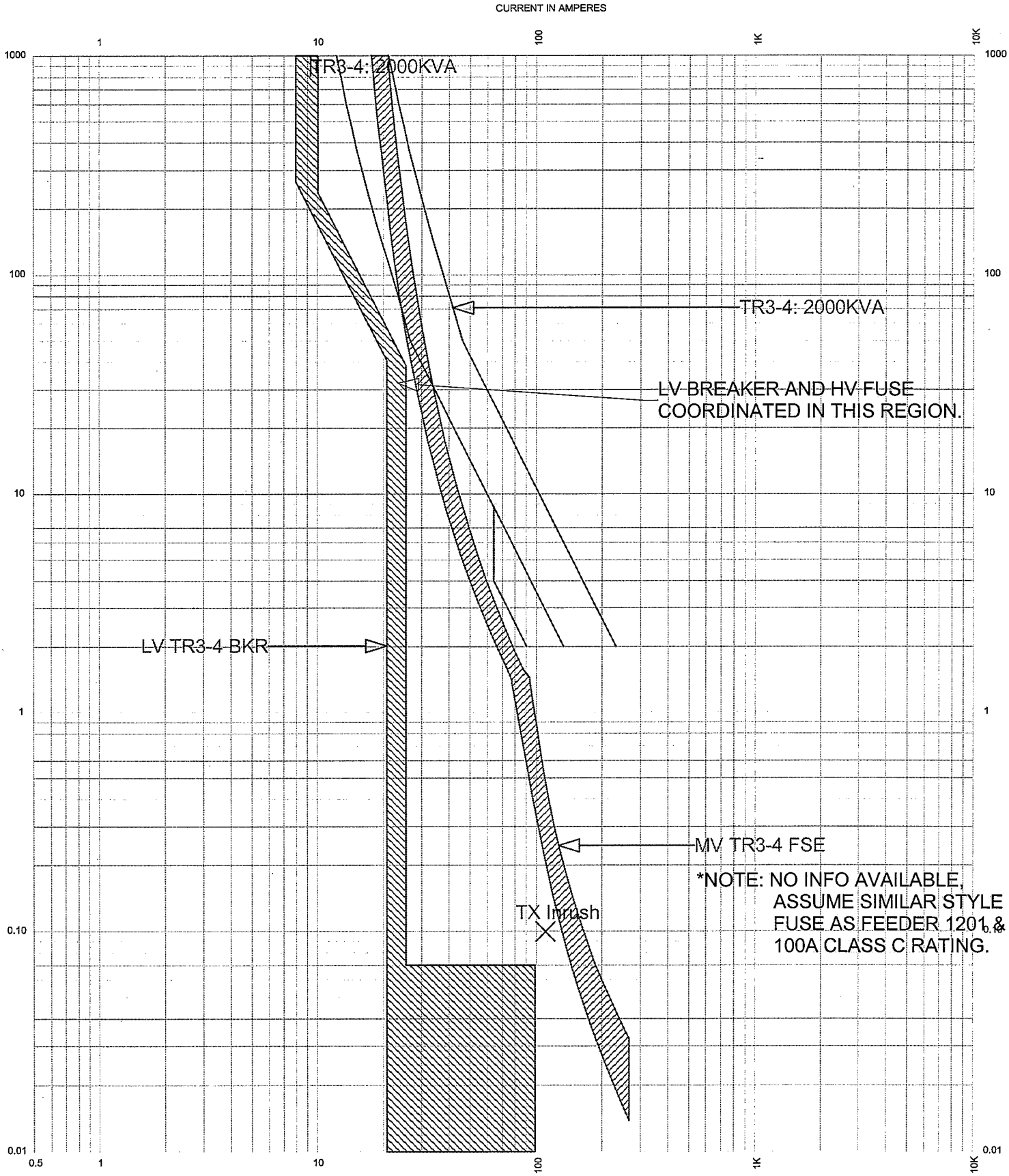
Project Name: Shippenburg 12.47kV Distribution
Plot Voltage: 23000 Volts
Plot Scale: X 10^1 Amps
Entech Eng #2184.22

TCC Name: 1203
Rev. 0.0
Date: August 12, 2004



Project Name: Shippenburg 12.47kV Distribution
Plot Voltage: 12470 Volts
Plot Scale: X 10^0 Amps
Entech Eng #2184.22

TCC Name: TR1-1 McCUNE HALL
Rev. 0.0
Date: March 12, 2004



Project Name: Shippenburg 12.47kV Distribution
Plot Voltage: 12470 Volts
Plot Scale: X 10^1 Amps
Entech Eng #2184.22

TCC Name: TR3-4 FRANKLIN SCIENCE CENTER
Rev. 0.0
Date: March 12, 2004