IMPACT OF SMART GRIDS AND GREEN POWER GENERATION ON DISTRIBUTION SYSTEMS

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SMART GRID TECHNOLOGY

- Enables Green Power Interconnected at the Distribution Level
- Smart Grids Most Overcome Many Current Limitations:
  - Overvoltages Including Ferroresonace
  - Loss of Protective System Coordination
  - Voltage Control
  - Restoration Problems
- Technological Advances Need to Handle High Penetrations of Green Power DGs and make DGs a Source of "Firm Power"
- IEEE Standard 1547 Technology Not Good Enough

Why Green Power

- **Federal and State Governments Push for Renewable Resources. "Green Power Is In."**

- **Two Basic Strategies:**
  1. **PUC Mandate that a Percentage of Generation is Green by a Given Date. This typically Fosters Installation of Large Blocks of Green Energy Installation such as Wind Farms.**
  2. **Increase the Buy Back Rate and Let Market Forces (Typically IPPs) Install Green Generation.**
     This typically Fosters Smaller Generators Installed on Distribution Systems.

- **Technological Advances have Reduced Green Power Costs.**

DG: Green or Not Green

- Not Green
  - Burn conventional fuel
    - Gas
    - Diesel, oil, gasoline

- Green
  - Use renewable sources to reduce reliance of fossil fuels:
    - Solar
    - Methane (from decomposition)
    - Wind
    - Hydro
    - Diesels Powered by Syn Fuel
    - Biomass (burn it)

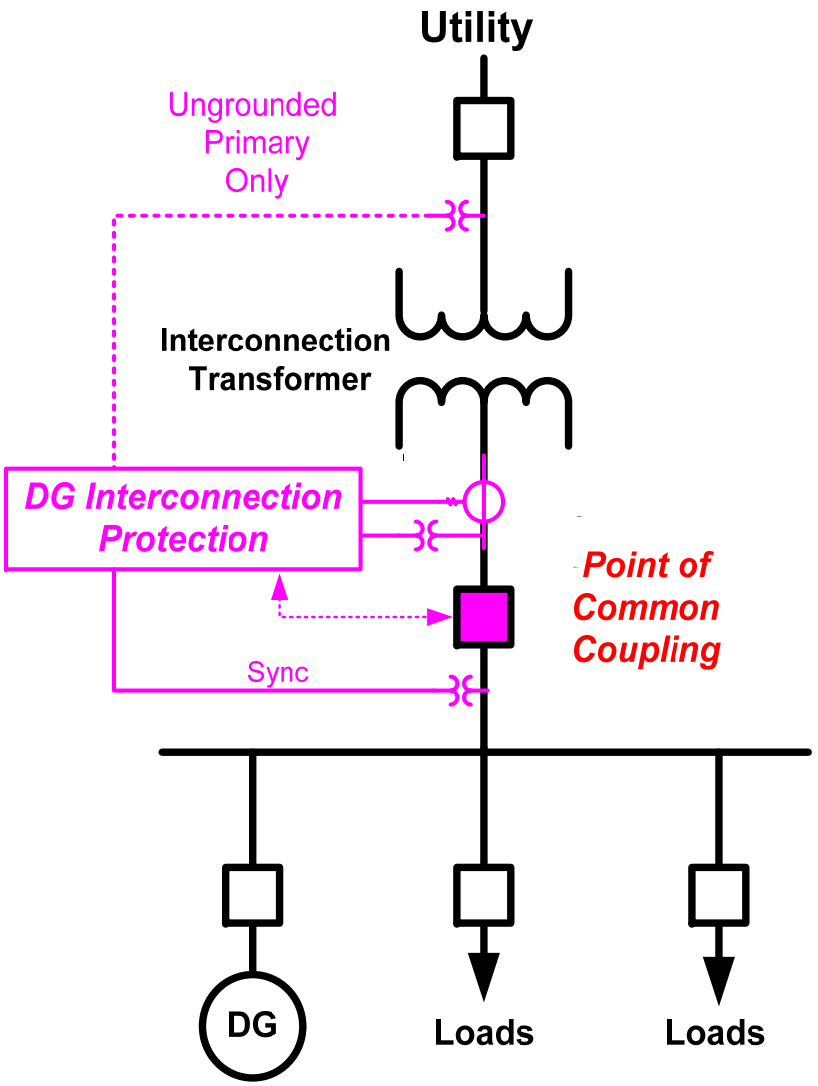
What is DG Interconnection Protection?

- **Protection that allows the DG to operate in parallel to utility**

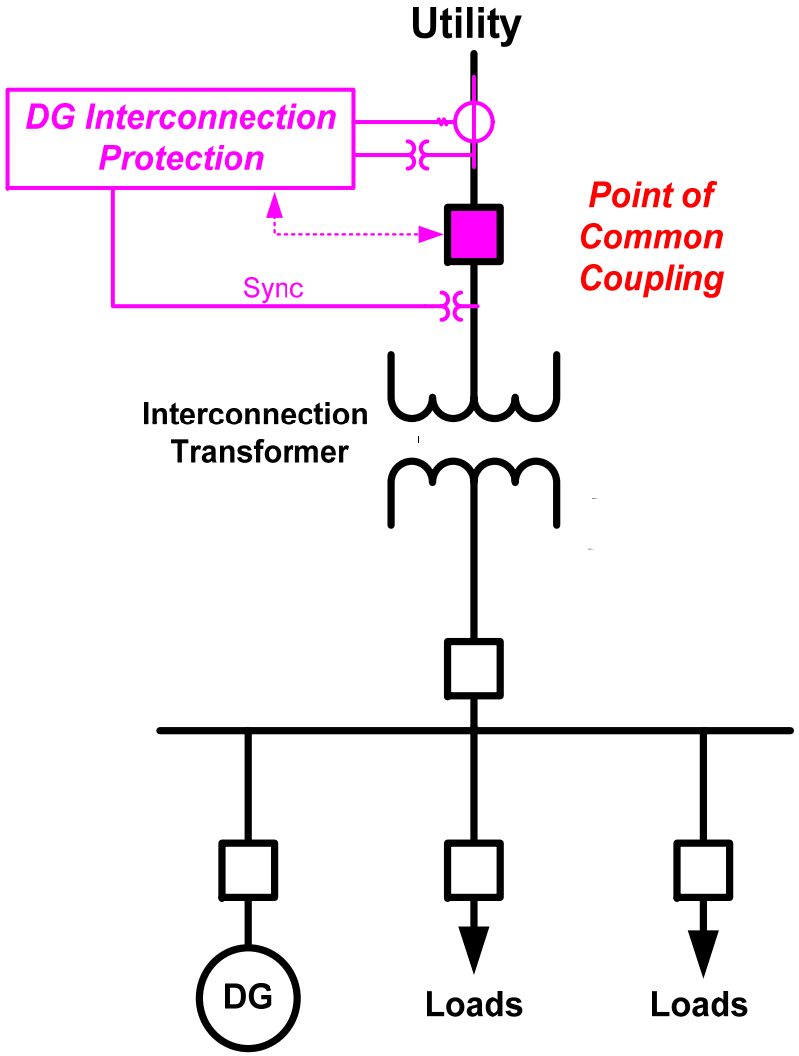
- **Large non-utility generators do not require specific interconnection protection**
  - Integrated into transmission system
  - Breaker(s) are tripped by transmission line/bus/transformer protection

- **Smaller DGs do require specific interconnection protection**

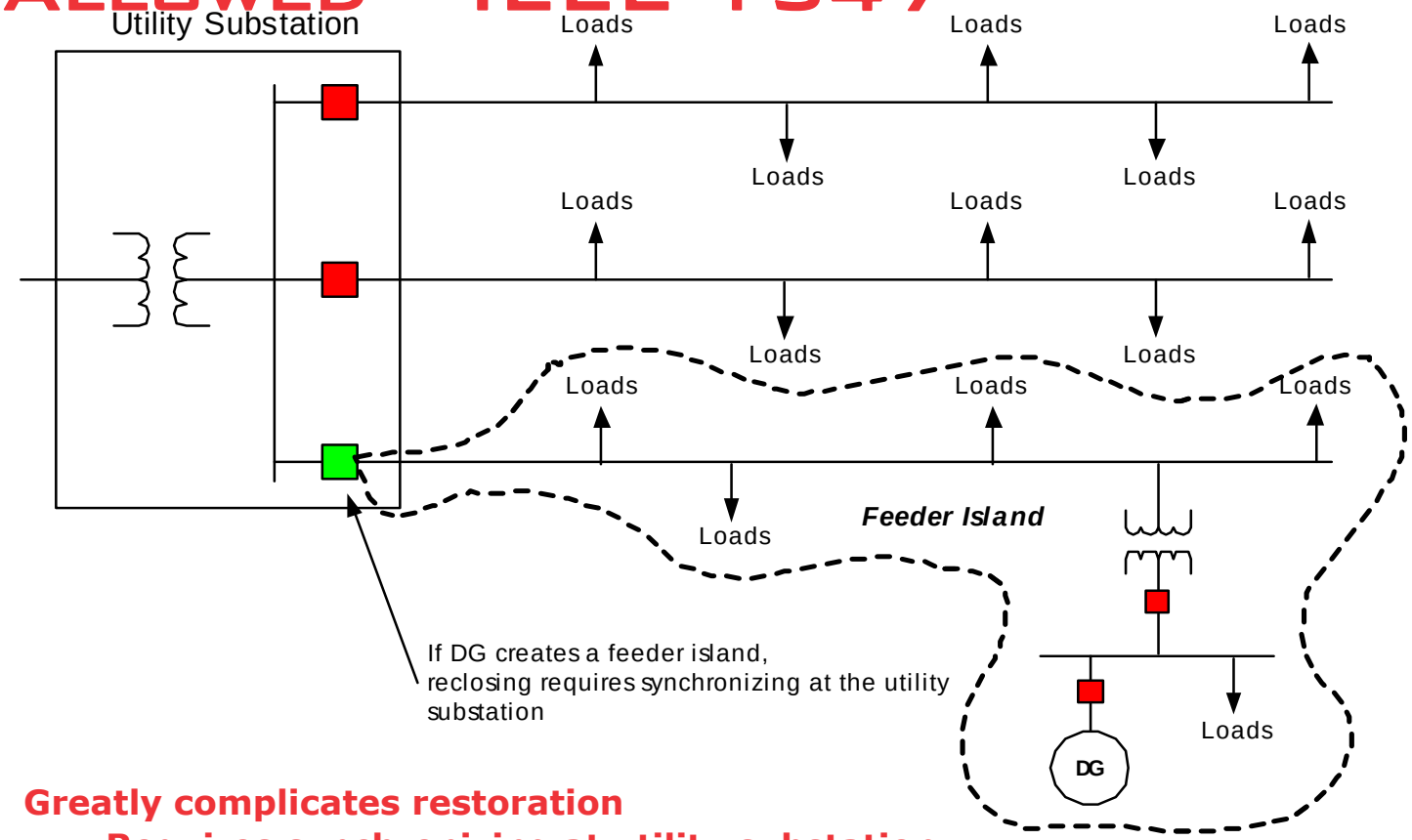
Interconnection Protection Placement



Interconnection Protection Placement

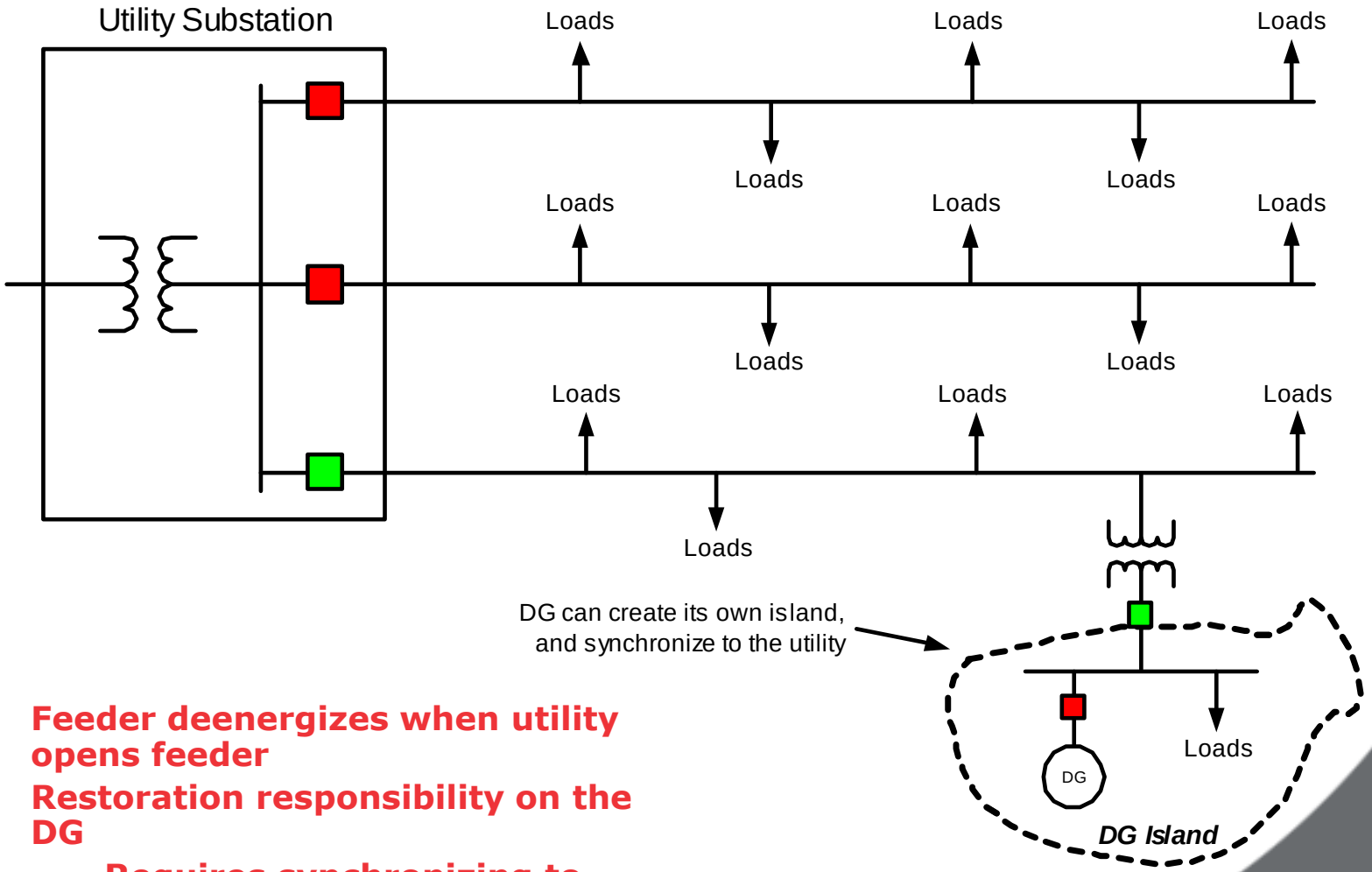


Islanded Operation of DG with Utility Load is Generally Not Allowed – IEEE 1547



- **Greatly complicates restoration**
  - **Requires synchronizing at utility substation**
  - **Inhibits automatic reclosing**
- **Power quality issue**
  - **DG may not be able to maintain voltage, frequency and harmonics within acceptable levels (load ≠ generation; no harmonic "sink")**

DG Facility Islanding to the Utility is Allowed – IEEE 1547



- **Feeder deenergizes when utility opens feeder**
- **Restoration responsibility on the DG**
  - **Requires synchronizing to utility**
  - **Inhibits automatic reclosing**

Types of Green Power Generators

- **Induction**
  - Wind Power
- **Synchronous**
  - Internal Combustion Engines
  - Small Hydro
  - Gas Turbines
- **Asynchronous (Static Power Converters)**
  - Solar PV
  - Fuel Cells
  - Wind

Asynchronous Generator:

Static Power Converter

- **Some have built-in anti-islanding protection**
  - SPC tries to periodically change frequency
    - If grid is hot, SPC cannot change the frequency
    - If grid has tripped, frequency moves and controller trips machine
- **Difficult to test; some utilities do not trust and require other protection**

Asynchronous Generator:

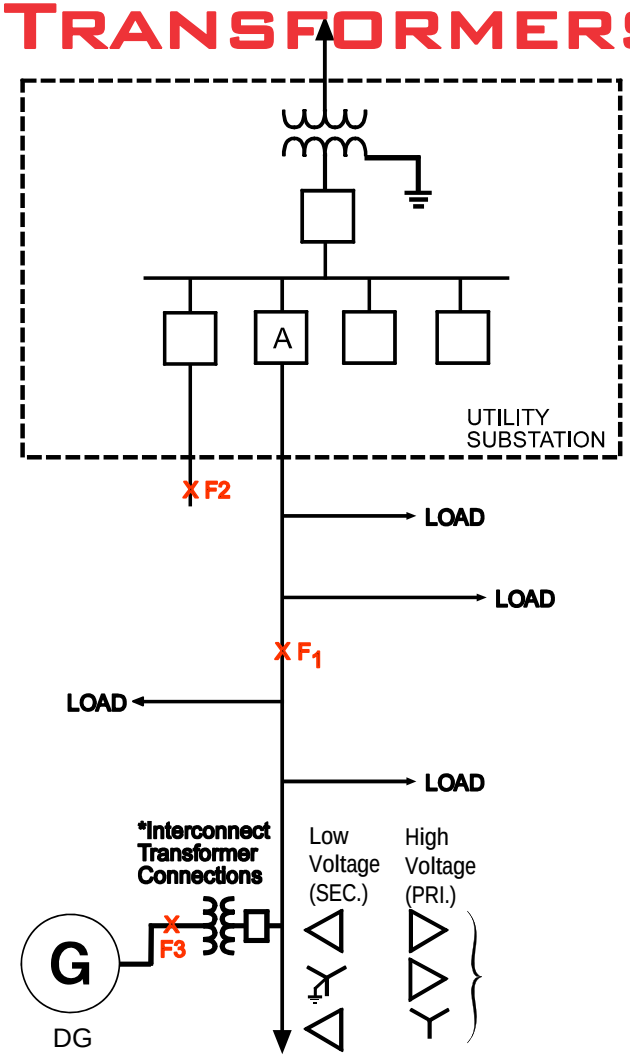
Static Power Inverters (Solar & Fuel Cells)

- **Self-Commutated**
  - + Can Provide Fault Current to the Grid
  - + Current is in the Order of Load Current
- **Line-Commutated Inverters (UL 1741)**
  - + Can Provide Limited Fault Current
  - + Fault will Decay Similar to Induction Generator
  - + If Overloaded Current will Diminish even Faster

Impact of Interconnection Transformer

- **Ungrounded Primary Transformer Winding**
  - Overvoltage may be caused by DG when ungrounded primary transformer windings are applied (no ground source) and DG backfeeds once utility disconnects
- **Grounded Primary Transformer Winding**
  - Ground fault current contribution caused by DG grounded primary transformer windings during utility faults
  - Source feeder relaying and reclosers responding to secondary ground faults within the DG facility

Ungrounded Primary Interconnection Transformers



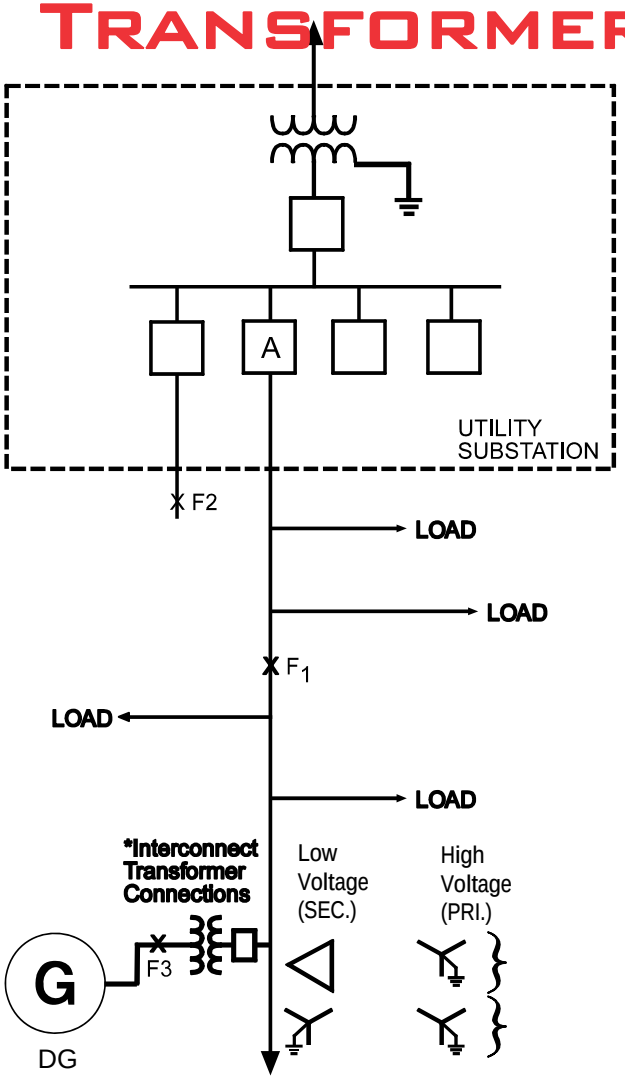
Problems

Can supply feeder circuit from an ungrounded source after substation breaker A trips—causing overvoltage

Advantages

- Provide no ground fault backfeed for fault at F_1 & F_2
- No ground current from breaker A for a fault at F_3

Grounded Primary Interconnection Transformers



Advantages

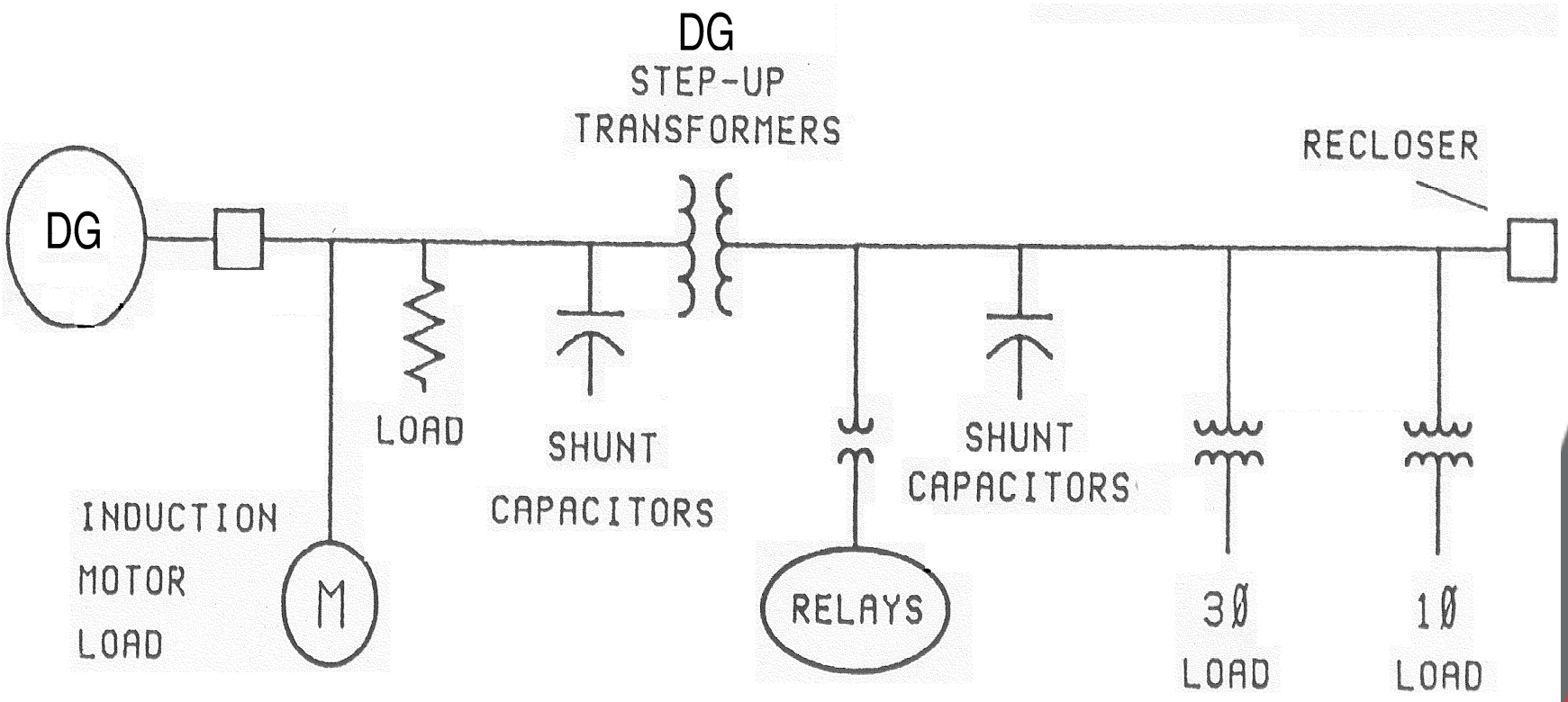
- No ground current from breaker A for faults at F_3 (delta sec. only)
- No overvoltage for ground fault at F_1
- No overvoltage for ground fault at F_2

Problems

- Provides an unwanted ground current for supply circuit faults at F_1 and F_2
- Allows source feeder relaying at A to respond to a secondary ground fault at F_3 (Y_{gnd}-Y_{gnd} only)

Test Circuit Setup

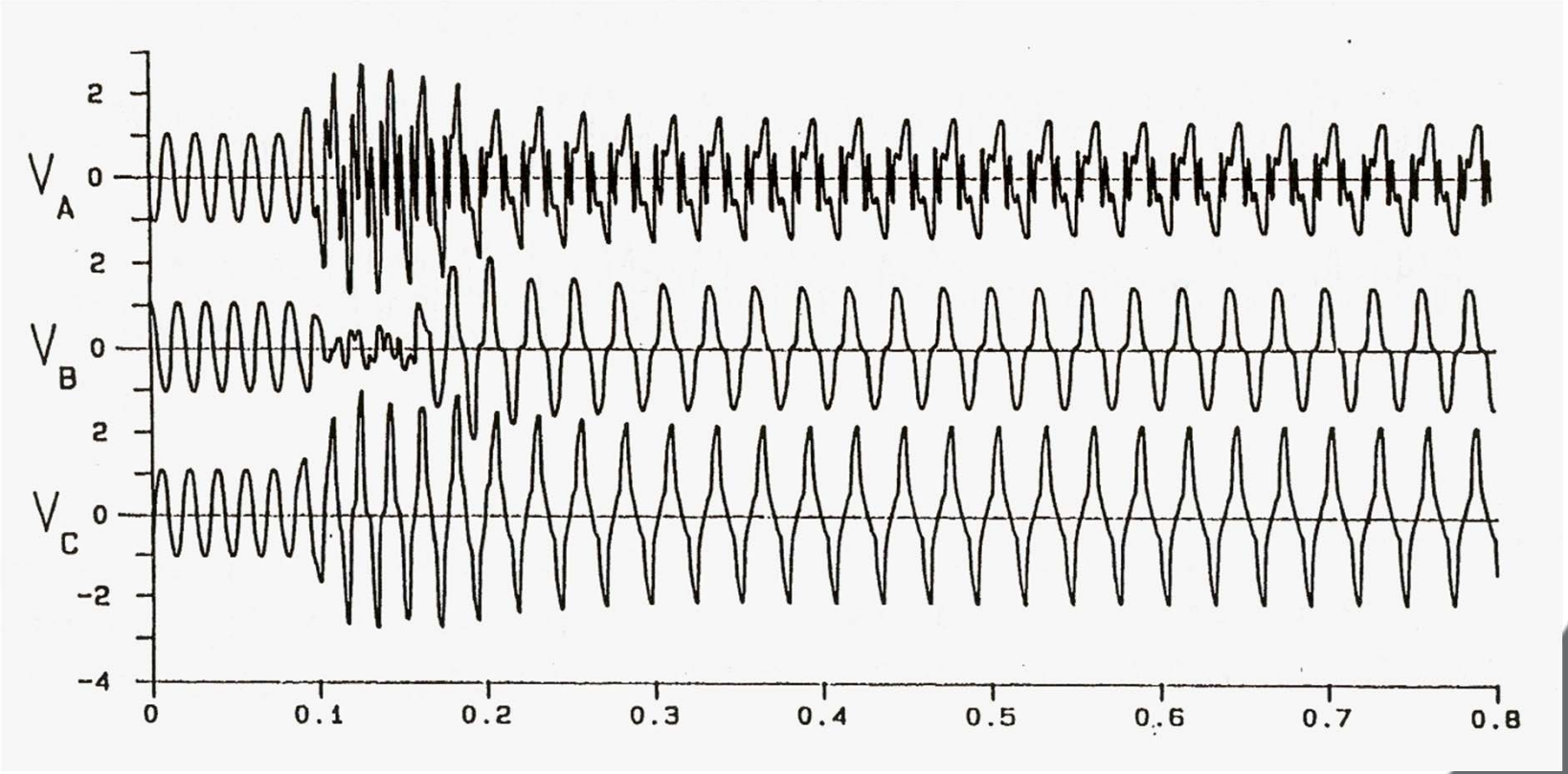
FERRORESONANCE
NEW YORK FIELD TESTS –1989
FIELD TEST CIRCUIT



Schematic of Test Circuit.

Induction/Synchronous Generator

Ferroresonance can also occur on synchronous generators



Conditions for Ferroresonance

1. **DG Must be Separated From Utility System (islanded condition)**
2. **KW Load in Island Must be Less than 3 Times DG Rating**
3. **Capacitance Must be Greater Than 25 and Less Than 500 Percent of DG Rating**
4. **There Must be a Transformer in Circuit to Provide Nonlinearity**

SOLUTION : USE 59I ELEMENT

Smart Grids

- **Full Integration of all Components of Distribution System Through By-Directional Communication**

  + Peer to Peer Relay Communication

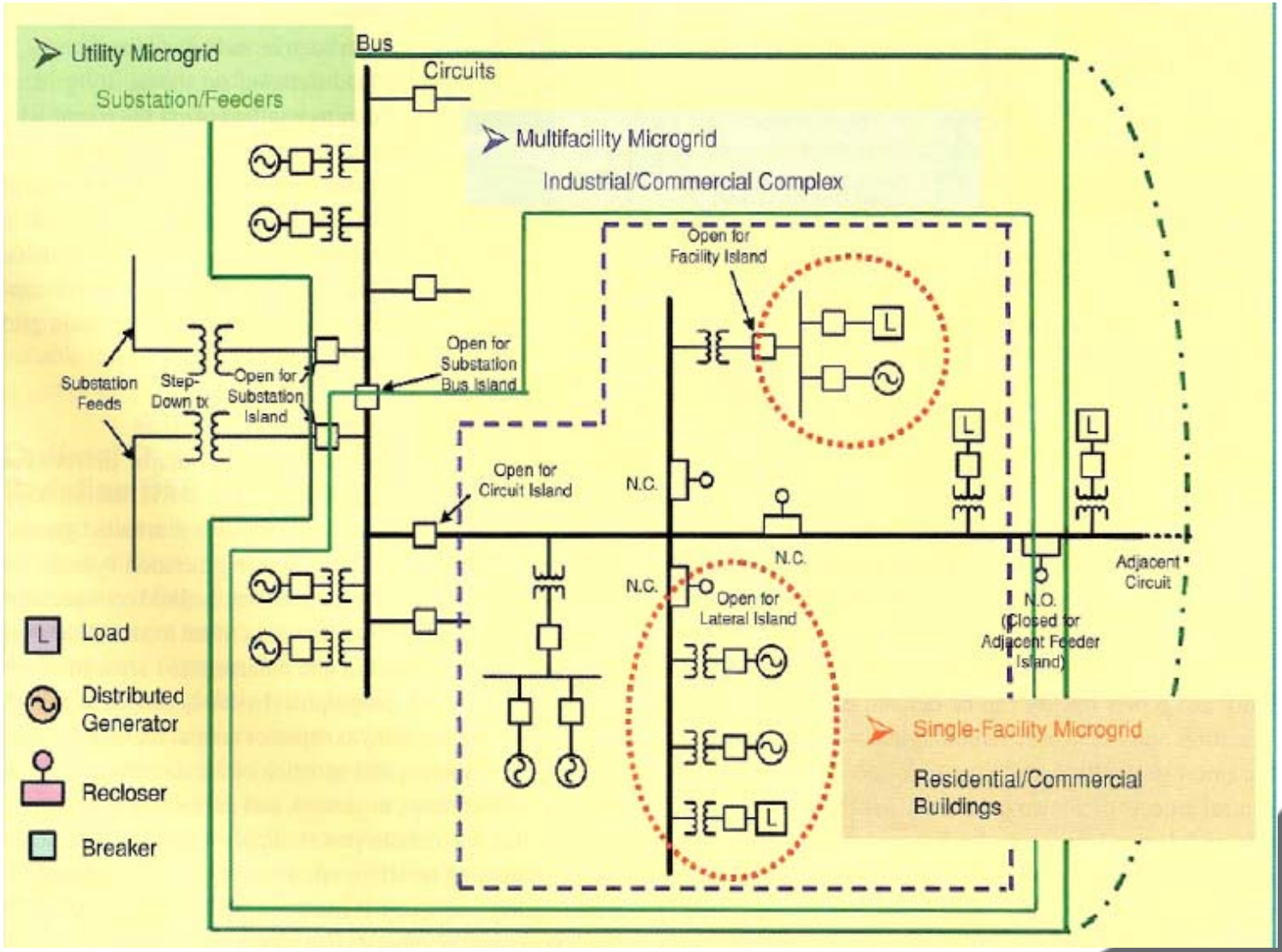
  + Adaptive Relaying

  + Full Control of Load

  + Energy Storage

  + MicroGrid Operation System during Contingencies

Smart Grids --- MicroGrids



Interconnection Transformer

IEEE Distribution Practices Survey – 1/02

- **2002 Survey**
  - *Grounded wye primary – 58%*
  - Delta primary – 9%
  - Other – 33%
- **1995 Survey**
  - *Grounded wye primary – 33%*
  - Delta primary – 33%
  - Other – 33%

DG Impact on Distribution Protection

IEEE Distribution Practices Survey – 1/02

- **No effect – 22%**
- **Revised feeder coordination – 39%**
- **Added directional ground relays – 25%**
- **Added direction phase relays – 22%**
- **Added supervisory control - 22%**
- **Revised switching procedures – 19%**

DG Impact on Utility Reclosing

IEEE Distribution Practices Survey – 1/02

- **Revise reclosing practices – 50%**
- **Added voltage relays to supervise reclosing – 36%**
- **Extend 1st shot reclose time – 26%**
- **Added transfer trip – 20%**
- **Eliminate reclosing – 14%**
- **Added sync check – 6%**
- **Reduce reclose attempts – 6%**

Conclusions

- **Smart Grid Technology can play a key role in Green Power Installed at the Distribution Systems.**
- **Technological Advances are Developing Some Unique Generators, especially in the Wind Turbine Area and PV.**
- **Interconnection Transformer Configuration Continues to Play a Pivotal Role in Interconnection Protection.**
- **State, National Regulators and IEEE Continue to Struggle to Provide Meaningful Interconnection Guidelines.**

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QUESTIONS?