

Workshop Nazionale Cigre Italia

ATTIVITÀ DI RICERCA – UNIVERSITÀ DI PADOVA

SANNITI FRANCESCO



cigre

For power system expertise

Palau - 4 maggio 2022

Gruppo LTEE

dii DIPARTIMENTO
DI INGEGNERIA
INDUSTRIALE

motto: anchora inparo

1222-2022
800
A N N I



UNIVERSITÀ
DEGLI STUDI
DI PADOVA



- 2 Super computer (512 GB RAM)
- **Dotazione software:** DigSILENT, EMTP–RV, FLUX 3D, COMSOL Multiphysics, Matlab-Simulink, FAMOS, Syncrophasor;
- **Attività sperimentale:** Terna, RSE, CESI, Prysmian e vari operatori del sistema elettrico

1) Rilevazione distanza di guasto su rete a Neutro Isolato

2776

IEEE TRANSACTIONS ON POWER DELIVERY, VOL. 33, NO. 6, DECEMBER 2018

An Online Travelling Wave Fault Location Method for Unearthed-Operated High-Voltage Overhead Line Grids

Roberto Benato , Senior Member, IEEE, Sebastian Dambone Sessa , Member, IEEE, Michele Poli, Cristiano Quaciari, and Giovanni Rinzo, Graduate Student Member, IEEE

Abstract—In this paper, a single-ended travelling wave-based fault location algorithm is presented with reference to HV (i.e., 60 kV) overhead unearthed operated lines. The main novelty of this contribution lies in the method of calculating the speed of the earth mode component of the travelling wave, which exploits the earth mode impedance and capacitance, and of simplifying the fault location procedure. The developed procedure has been applied to a real double-circuit overhead line modeled by EMTP-rv, whereas the fault location algorithm has been implemented in a MATLAB environment. In order to validate the proposed method, a sensitivity analysis has been performed by varying the fault position, the fault resistance and the fault inception angle. The proposed approach has proven to be independent of all these parameters.

Index Terms—Continuous wavelet transform, fault location, phase to modal transform, travelling wave.

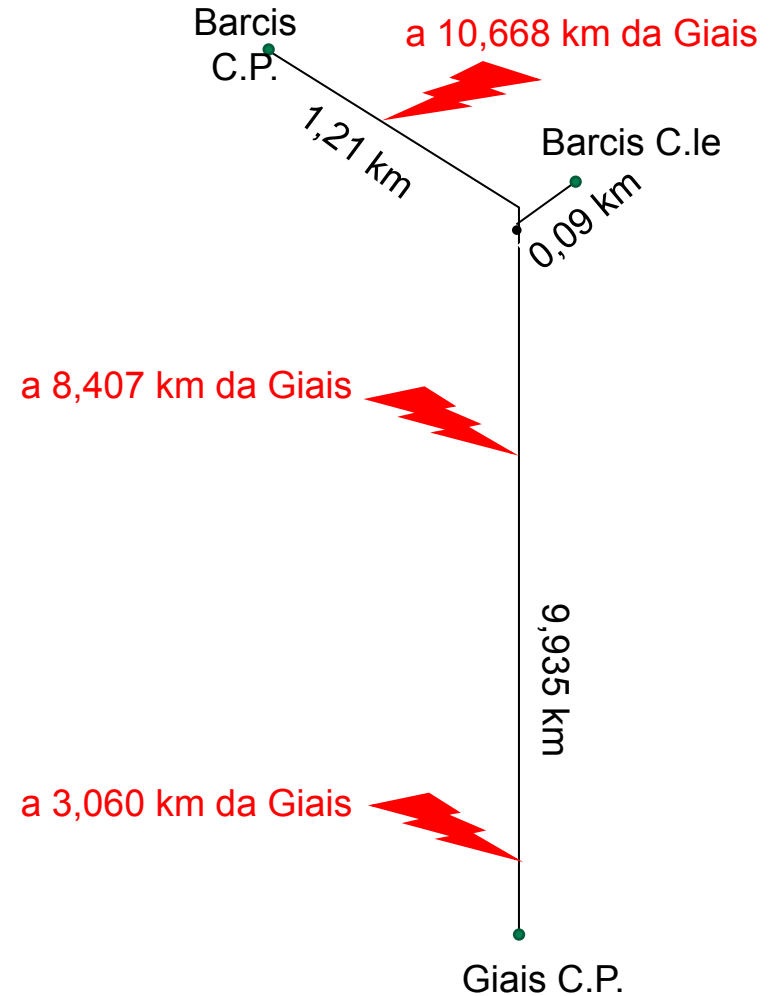
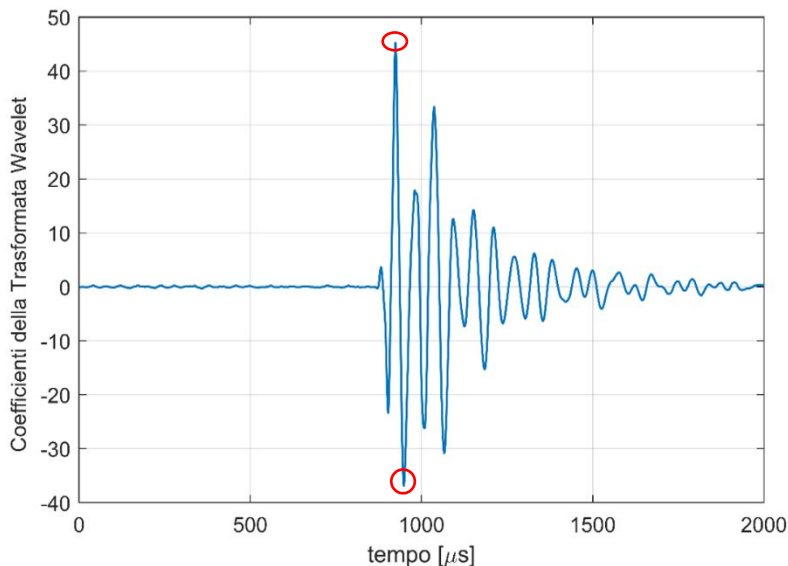


Fig. 1. Insulator cracking (impossible to detect by means of off-line methods).

1) Rilevazione distanza di guasto su rete a Neutro Isolato



1) Rilevazione distanza di guasto su rete a neutro isolato metodo monoterminale



2) Riaccensione del sistema elettrico

Received March 11, 2019, accepted March 29, 2019, date of publication April 4, 2019, date of current version April 18, 2019.

Digital Object Identifier 10.1109/ACCESS.2019.2909321

A Novel Modeling for Assessing Frequency Behavior During a Hydro-to-Thermal Plant Black Start Restoration Test

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SEBASTIAN DAMBONE SESSA¹, (Member, IEEE), GIORGIO MARIA GIANNUZZI²,
LUCA ORTOLANO², GIANNI PEDRAZZOLI¹, (Member, IEEE), MICHELE POLI²,
FRANCESCO SANNITI¹, (Member, IEEE), AND ROBERTO ZAOTTINI²

¹Department of Industrial Engineering, University of Padova, 35131 Padua, Italy

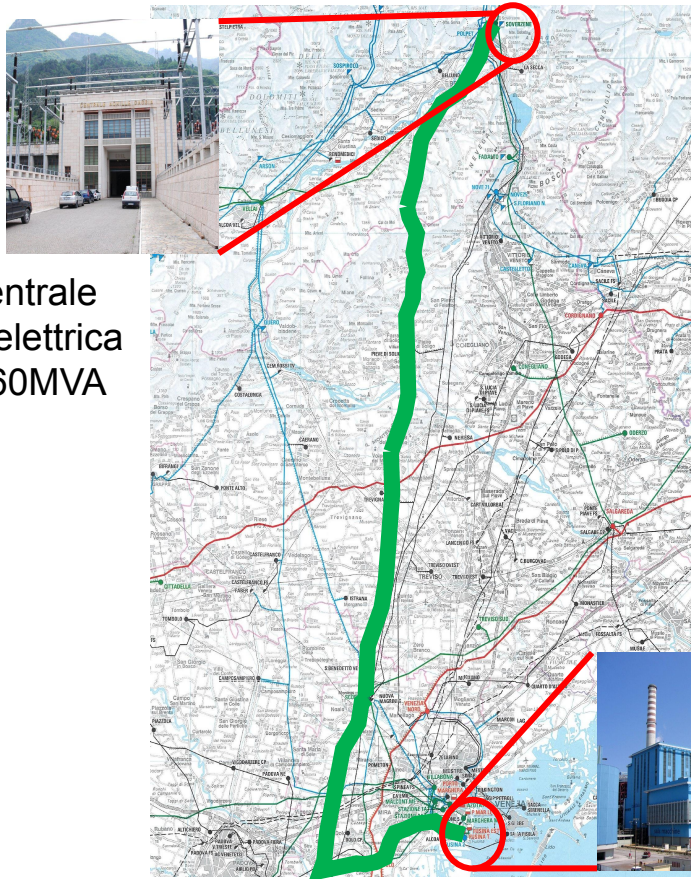
²Terna S.p.A., 00156 Rome, Italy

Corresponding author: Roberto Benato (roberto.benato@unipd.it)

ABSTRACT Northern electric grid of Italy was involved in a black start mock drill. This test took place on November 2016 in order to check the coordination and efficiency of all the operational staffs and the automatic regulators involved in the case of a real blackout scenario. This paper presents the results of a research carried out in collaboration with Terna Rete Italia (the Italian Transmission System Operator), in order to find strengths and weaknesses and eventually to upgrade the existing restoration plan. Starting from the measures coming from generating plants and substations bars, the model of frequency regulation system for both the participating hydro and thermal power plants is developed. This work gives the system operator an essential tool to understand many complex dynamics and phenomena occurred during the test. At the same time, a robust model simulating the system behavior with different grid configurations is presented: it gives the opportunity to enhance both the classical power system control theory and the black start practices.

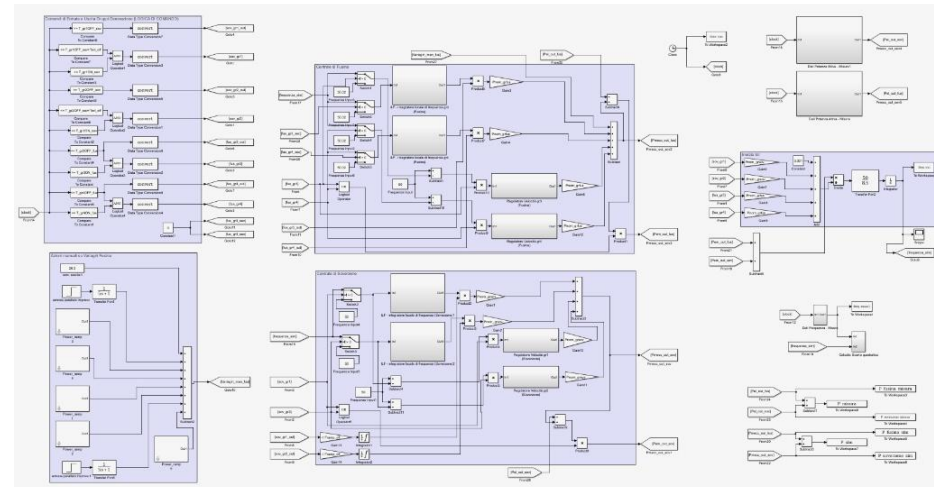
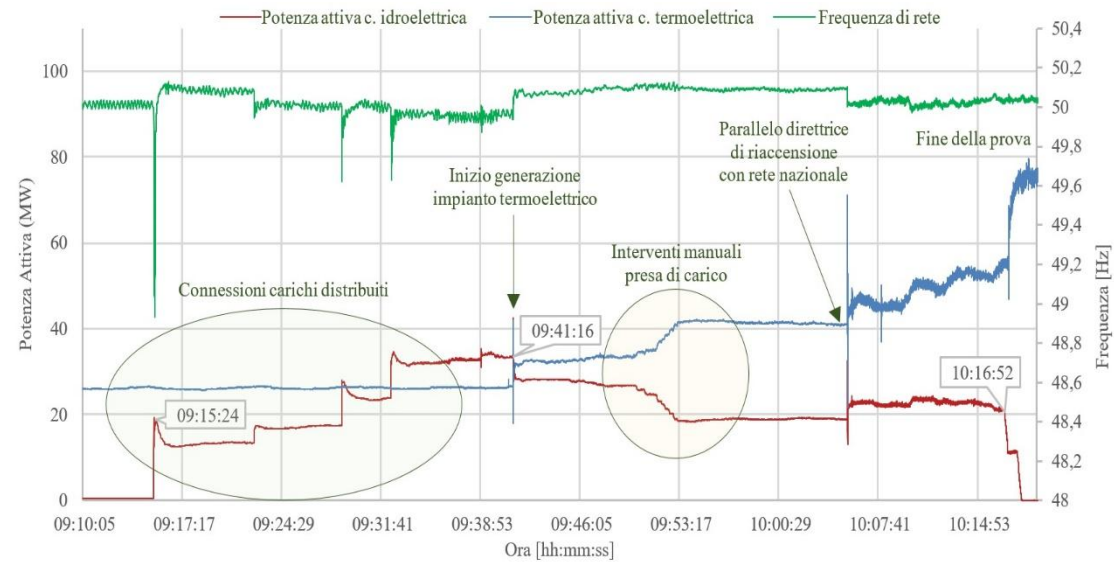
2) Riaccensione del sistema elettrico

a) Simulazioni e analisi post di prove di riaccensione



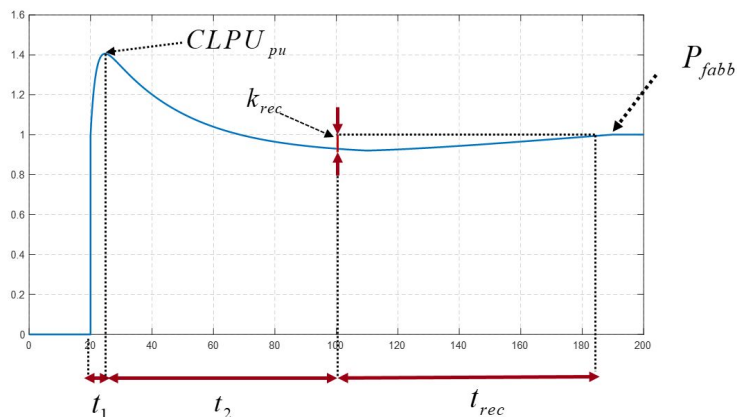
Centrale
droelettrica
2x60MVA

Centrale
termoelettrica
2x330MVA

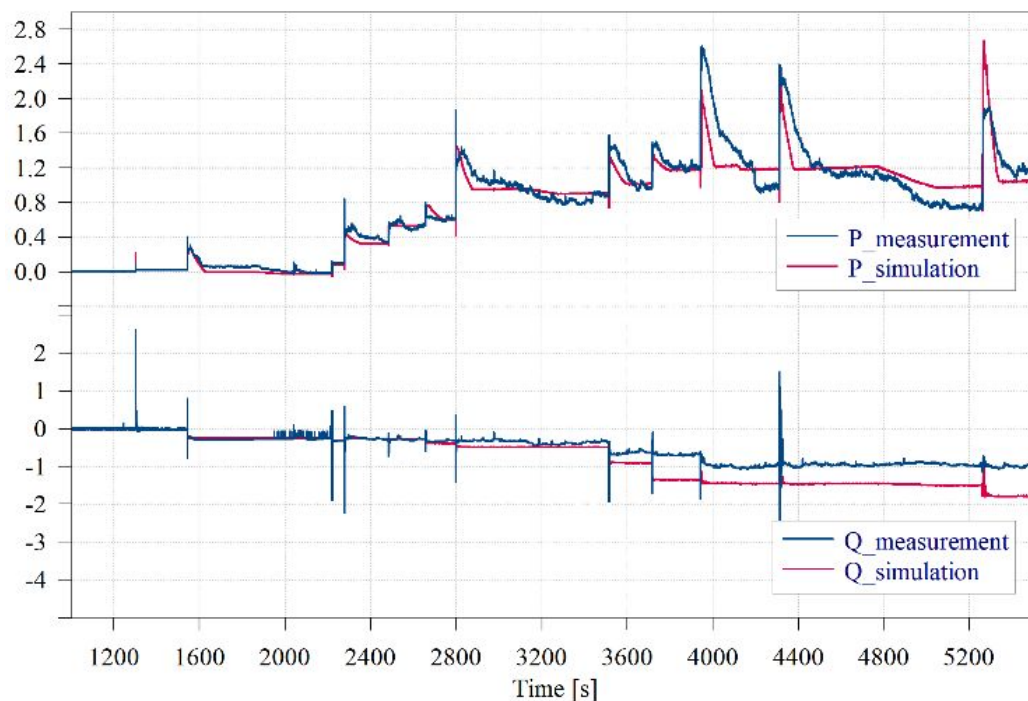
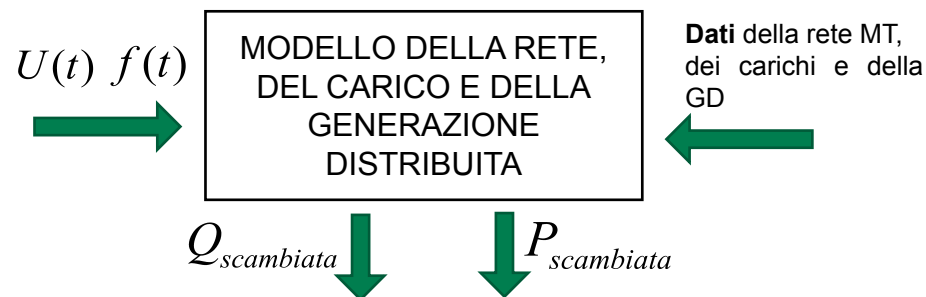
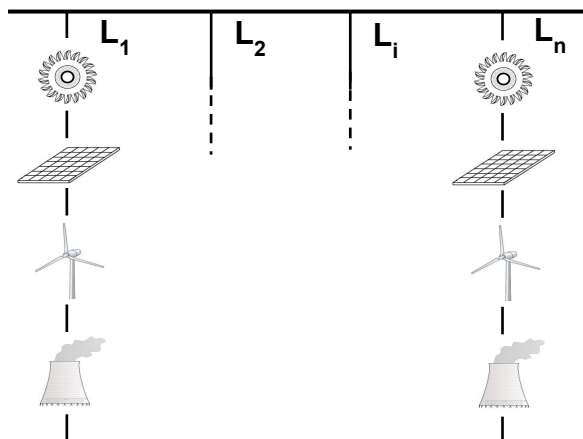


2) Riaccensione del sistema elettrico

b) Modello del carico e della generazione distribuita



Con n Linee MT



3) Tecnologie innovative per la trasmissione

a) Cavi tripolari armati sottomarini – FEM vs MCA

1636

IEEE TRANSACTIONS ON POWER DELIVERY, VOL. 33, NO. 4, AUGUST 2018

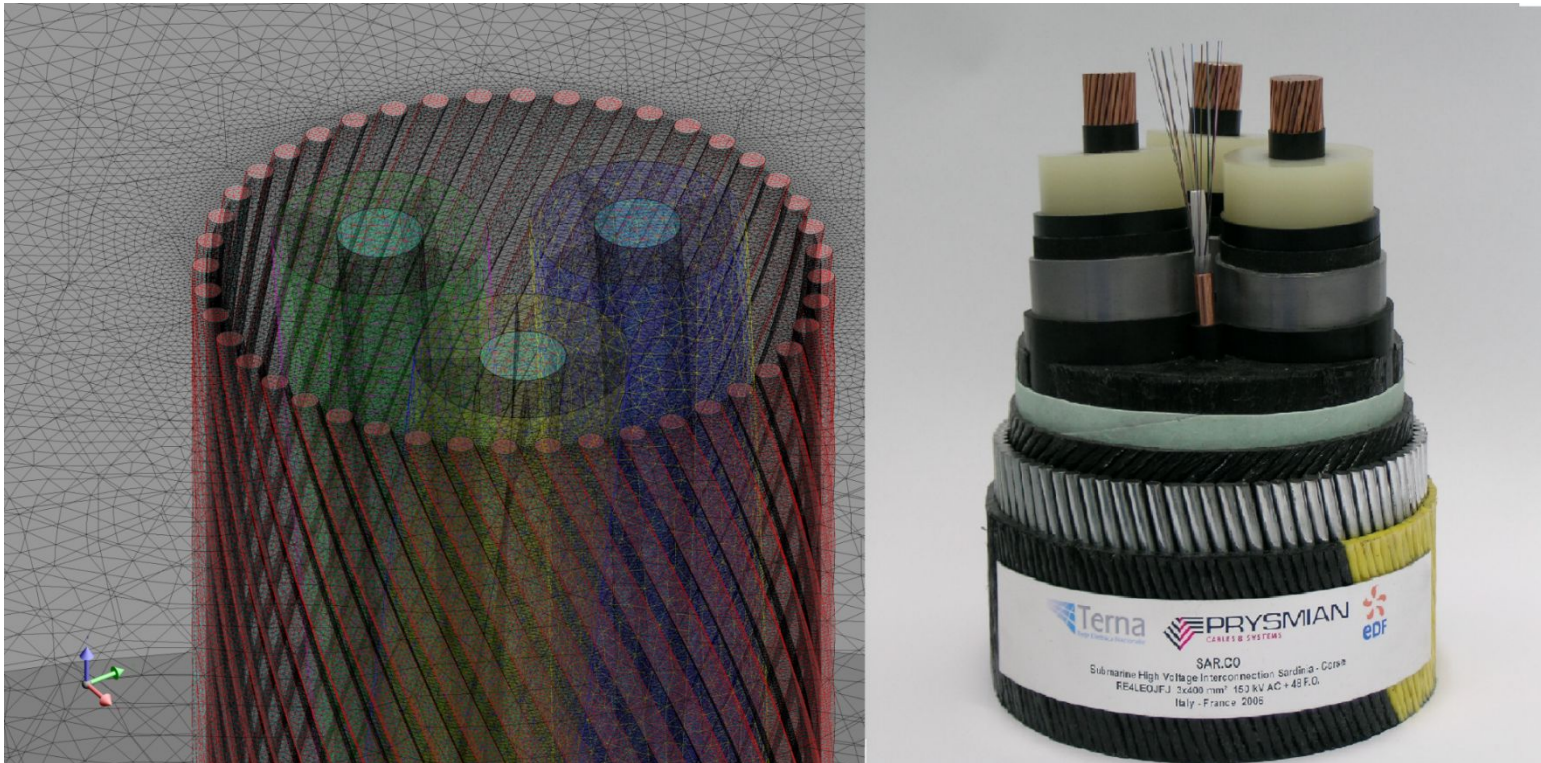
A New Multiconductor Cell Three-Dimension Matrix-Based Analysis Applied to a Three-Core Armoured Cable

Roberto Benato¹⁰, *Member, IEEE* and Sebastian Dambone Sessa¹⁰

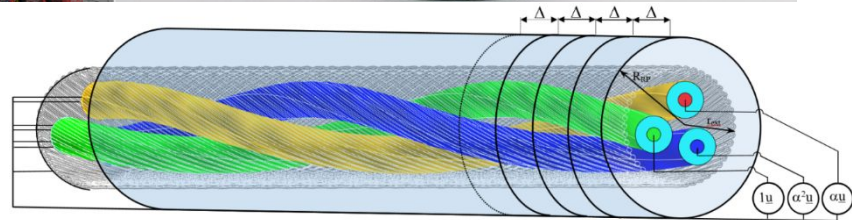
Abstract—In this paper, a procedure based on three-dimension matrices is presented: it is the generalization of multiconductor cell analysis to any transmission line where the positions of all the active and passive conductors may change with continuity along their length. A meaningful example of this is given by a three-core single lead-screened armoured cable where cores and armour wires are wound helically with different lay lengths. Therefore, this generalization is presented with reference to these cables but it can be applied to any transmission line. The proposed matrix procedures can be implemented in any standard computer by means of a mathematical software (e.g., MATLAB). The computational complexity of this novel method is shown in comparison with the finite element method commercial software FLUX 3D, which takes 70 h for meshing and solving a 3-m long model. On the contrary, the present matrix algorithms take from minute fractions to maximum 2 min (depending on subconductor number) to obtain results having negligible differences with respect to FEM FLUX 3D ones if paramagnetic materials are involved and differences up to maximum 7% with ferromagnetic ones (which imply, for submarine cable installations, a current rating computation difference lower than 3%).

the other two cores and of the screens and armour. Differently, three-core armoured cables represent a completely general case since the cores and screens are stranded with a given lay length and the armour wires are stranded with a different lay length in the same direction (often called unilay) or in the opposite direction (often called contralay). In other words, the active and passive conductors change their positions with continuity along the cable length. The authors have already published, for the first time in technical literature, a paper [9] with a three-dimensional 3 m long model ($\ell_{\text{mod}} = 3 \text{ m}$) of this cable by means of a finite element method (with the commercial software FLUX 3D ver. 11). Unfortunately, this model runs only on a super PC and takes about three days (exactly 70 h) to give a solution. Moreover, it is worth noting that a length of three meters is not sufficient to know the exact steady-state regime of real installations with kilometeric lengths. This is due to the fact that, in the real installations, a periodicity of both armour and core lay lengths, γ and β respectively, occurs for a minimum stretch

a) Cavi tripolari armati sottomarini – FEM vs MCA



70h FEM – 60s MCA





3) Tecnologie innovative per la trasmissione

a) Cavi tripolari armati sottomarini – FEM vs MCA

2910

IEEE TRANSACTIONS ON POWER DELIVERY, VOL. 33, NO. 6, DECEMBER 2018

Experimental Validation of Three-Dimension Multiconductor Cell Analysis by a 30 km Submarine Three-Core Armoured Cable

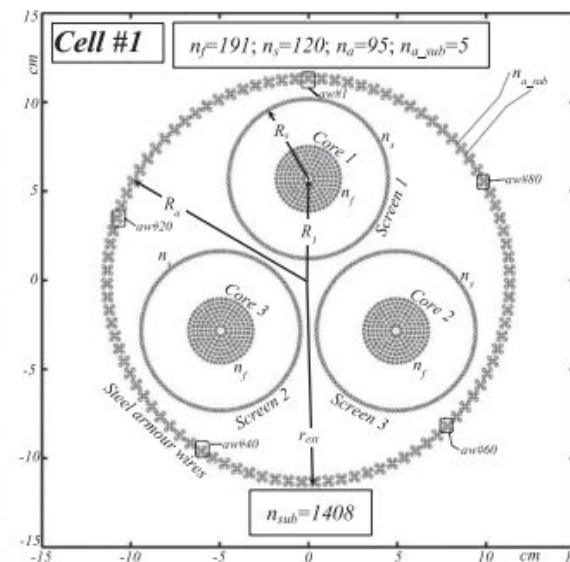
Roberto Benato , Senior Member, IEEE, Sebastian Dambone Sessa , Member, IEEE, and Michele Forzan, Member, IEEE

Abstract—In this paper, an experimental validation of three-dimension multiconductor cell analysis (MCA) is presented: a measurement campaign has been performed on Capri-Torre Annunziata three-core 29.5 km long submarine cable link. All the theoretical conclusions derived by the authors in a previous paper are now experimentally confirmed and the model is, therefore, validated. Based on the example in this paper, the maximum difference between MCA results and measurements is 7% on the positive sequence resistance at power frequency. A 10% difference occurs in the evaluation of positive sequence reactance. The agreement between MCA and real measurements in zero sequence impedance is very good with differences lower than 5% in real and imaginary parts.

Index Terms—Three-core armoured cables, multiconductor cell analysis, kilometric submarine installations.

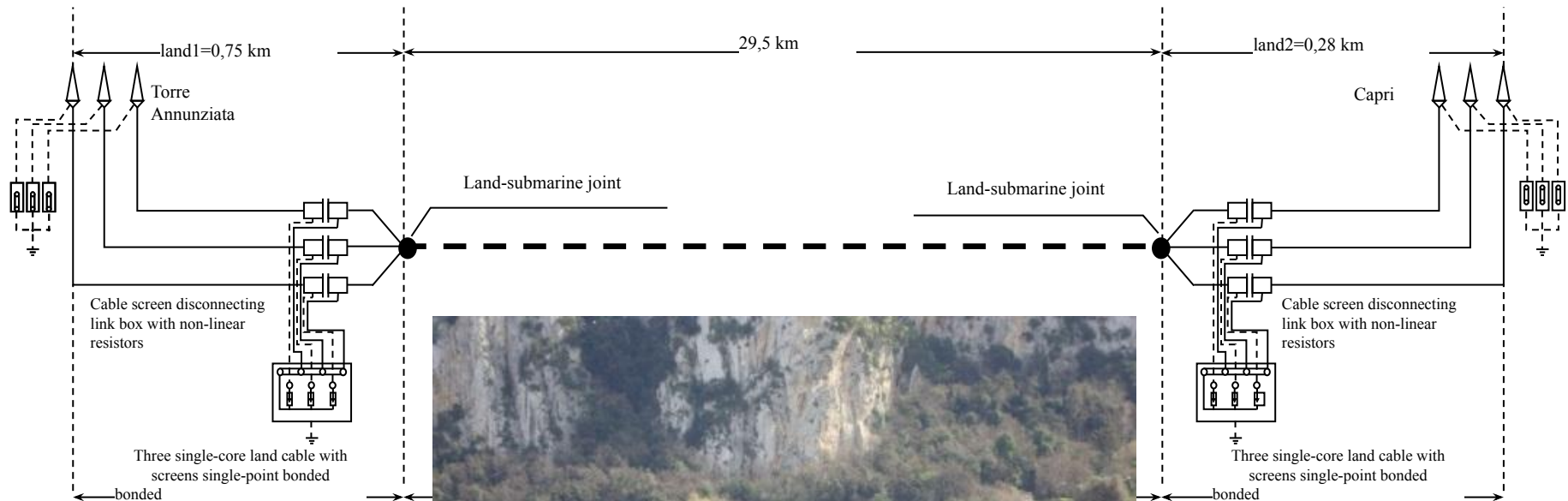
I. INTRODUCTION

IN 2017 the authors have published a paper in this Journal [1] which presents a completely general Multiconductor Cell Analysis (MCA) applied to a three-core submarine armoured cable which allows to dramatically reduce CPU times with respect to a commercial FEM software [2]: MCA is about 4200



3) Tecnologie innovative per la trasmissione

a) Cavi tripolari armati sottomarini – FEM vs MCA





3) Tecnologie innovative per la trasmissione

a) Cavi tripolari armati sottomarini – Harmonic validation

IEEE TRANSACTIONS ON POWER DELIVERY, VOL. 00, NO. 00, 2021

1

Experimental Harmonic Validation of 3D Multiconductor Cell Analysis: Measurements on the 100 km Long Sicily-Malta 220 kV Three-Core Armoured Cable

Roberto Benato , *Senior Member, IEEE*, Sebastian Dambone Sessa , *Member, IEEE*, Giovanni Gardan, *Member, IEEE*, Francesco Palone, and Francesco Sanniti, *Member, IEEE*

Abstract—The paper deals with a final experimental validation of three-dimensional Multiconductor Cell Analysis (MCA) developed by the Electric Energy Transmission Laboratory of the University of Padova. This final confirmation comes from the measurement campaign carried out on one of the longest (100 km) HVAC submarine three-core cables: the Sicily-Malta interconnector. The considered frequency measurements range from 0 to 40th harmonic order with both positive and zero sequence supplies. In this overall harmonic interval and with both supplies, the comparison between measurements and MCA results highlights a very good agreement (maximum differences of 10%). These differences are negligible if measurement uncertainties are considered.

Index Terms—Insulated cable, harmonic behaviour, HVAC three-core submarine cable, multiconductor cell analysis.

2009. In that paper, MCA is applied to a single and double circuit system composed of three single-core cables without stranding and magnetic materials. Nine years later, in 2018, always Benato together with Dambone Sessa have generalized the abovementioned MCA in order to consider three-core armoured submarine cables [14]. In the paper [14], the authors can take into account:

- 1) the stranding of the cores and of the armour wires in the same direction (in cable jargon often called *equilay* or *unilay*) or in the opposite one (often called *contralay*);
- 2) the presence of magnetic materials (steel wires of the armour).

This generalized MCA is called three-dimensional MCA or

3) Tecnologie innovative per la trasmissione

a) Cavi tripolari armati sottomarini – Harmonic validation

220 kV 100 km MALTA - SICILIA

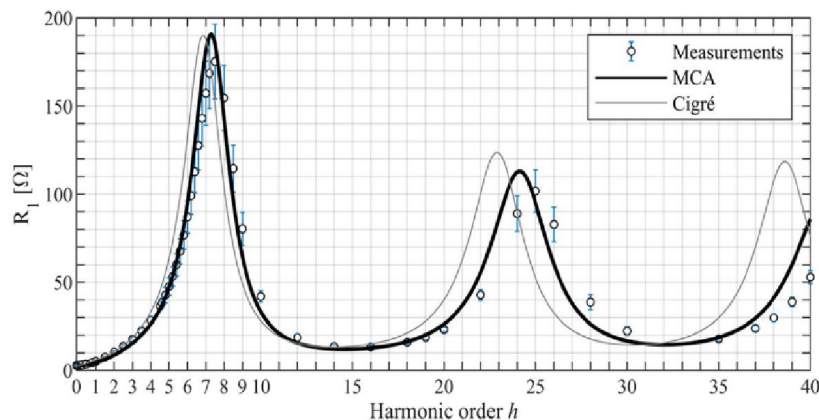
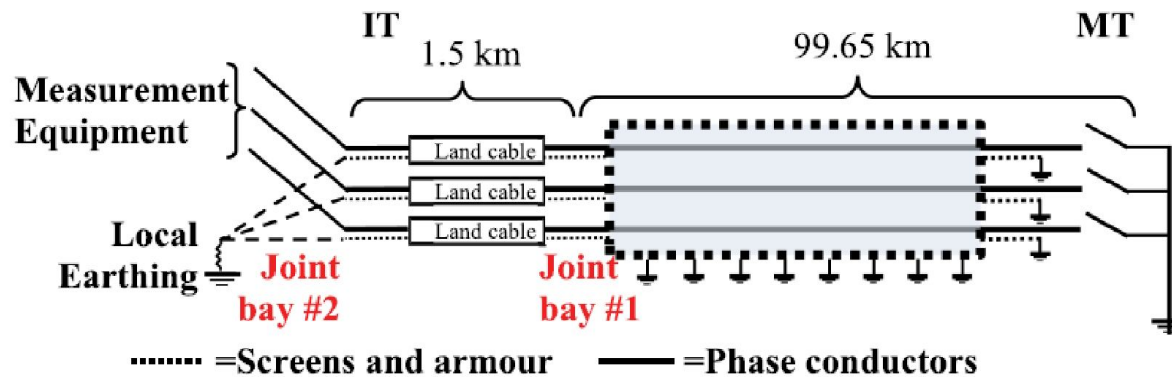


Fig. 8. Comparison between measurements and MCA, Cigré method: positive sequence resistance with Malta end earthed.

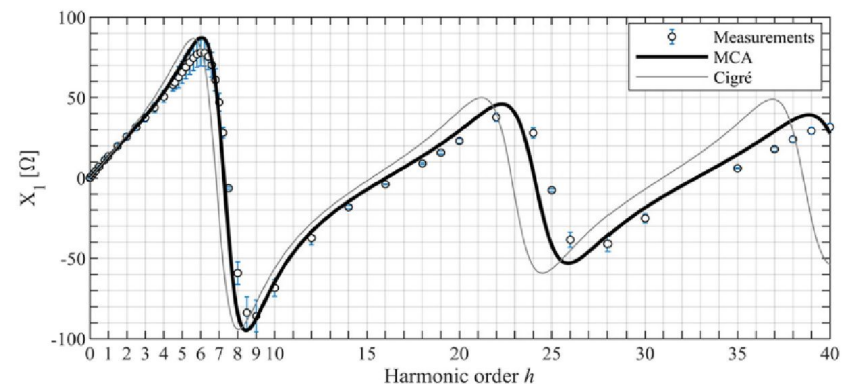


Fig. 9. Comparison between measurements and MCA, Cigré method: positive sequence reactance with Malta end earthed.




3) Tecnologie innovative per la trasmissione

b) CALA JOULE: corde innovative per linee aeree



Article

CALAJOULE: An Italian Research to Lessen Joule Power Losses in Overhead Lines by Means of Innovative Conductors

Roberto Benato ^{1,*} , Roberto Caldon ¹, Antonio Chiarelli ¹, Massimiliano Coppo ¹, Claudio Garescì ², Sebastian Dambone Sessa ¹ , Debora Mimo ³, Michele Modesti ¹ , Luca Mora ³ and Francesca Piovesan ¹

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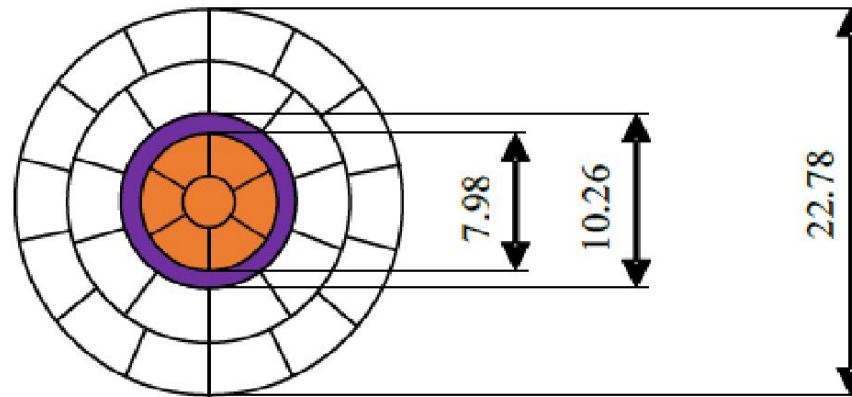
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Received: 15 July 2019; Accepted: 6 August 2019; Published: 13 August 2019



3) Tecnologie innovative per la trasmissione

b) CALA JOULE: corde innovative per linee aeree







- conci trapezoidali con nucleo di fibra di carbonio e mantello di alluminio

3) Tecnologie innovative per la trasmissione

c) Strutture metalliche di protezione per cavi terrestri

HVAC Single Core Insulated Cables With Steel Reinforced Mechanical Protections: Effect on Sequence Impedances

Roberto Benato , Senior Member, IEEE, Sebastian Dambone Sessa , Member, IEEE, Michele Forzan, Member, IEEE, Michele Poli, Francesco Sanniti , Member, IEEE, and Riccardo Torchio 

Abstract—In this paper the sequence impedances of an existing HVAC insulated cable, protected by a steel reinforced concrete structure, are estimated. The paper aims at investigating if the presence of metallic protective structures significantly affects the sequence impedances of the line. The present analyses are carried out by applying both the multiconductor cell analysis and the finite element method in order to model the HVAC line with and without protective structure. The results arising from the use of the different modelling approaches are compared.

Index Terms—Finite element method, HVAC cables, insulated cables, multiconductor cell analysis, sequence impedances.

I. INTRODUCTION

NOWADAYS high voltage alternating current (HVAC) insulated cables represent a key technology for power transmission systems. Their versatility fits well with the necessity of rationalizing the territory resources since it allows exploit-

infrastructures, and a very meaningful experimental study has been carried out in [6], where the external effect of short circuits in high voltage cables installed within tunnels has been studied.

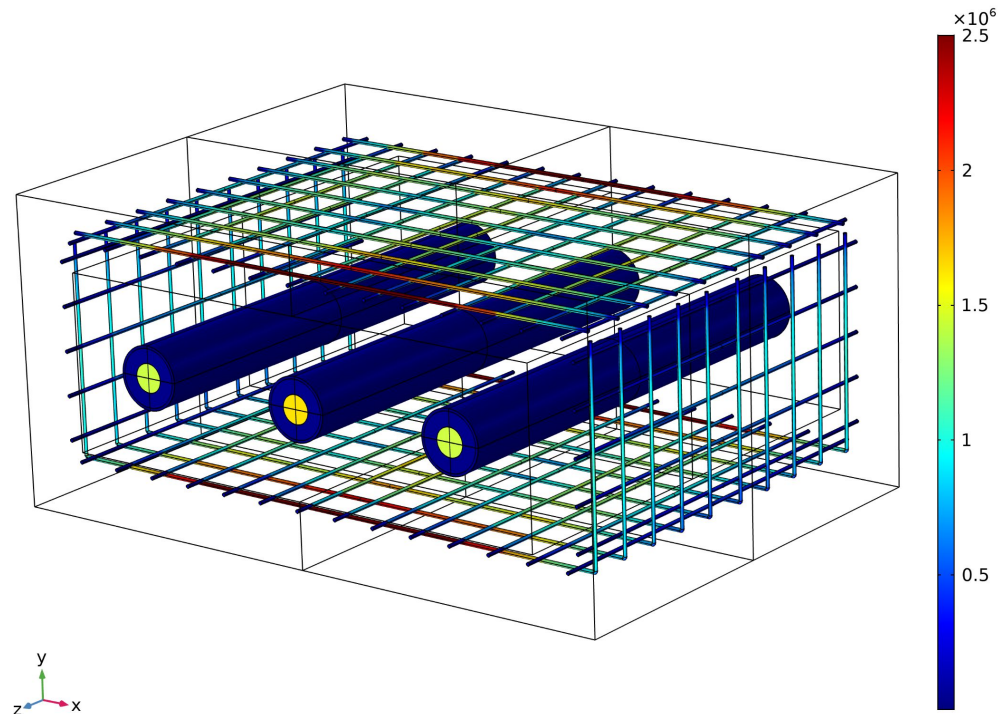
Very often, in particular installation conditions as those mentioned above, power cable lines are equipped with steel reinforced protective structures in order to protect the cable line from third-part damages. As it is possible to infer from the Cigré TB n° 379 [7], this practice increases the reliability of the transmission line since, for power cables inside structures, the proportion of the cable failure rate related to external origin is null. Since this component counts for about 50% of the total failure rate [7], the cable arrangements within structures halve the cable failure rates [8].

However, such structures can electromagnetically interact with the cable line, so that the sequence impedances of the multi-conductor system “*protective structure-cable line*” differ

3) Tecnologie innovative per la trasmissione

c) Strutture metalliche di protezione per cavi terrestri

- Correnti indotte nelle protezioni metalliche modificano reattanza longitudinale: importante per taratura distanziometriche e distanza di guasto



4) Studio sui sistemi HVDC: simulazione dinamica e affidabilità

Converting Overhead Lines from HVAC to HVDC: an Overview Analysis

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Abstract—Several contributions in technical literature highlight the potential offered by the conversion of an existing HVAC overhead line into a HVDC one. In the context of the world's energy transition from fossil fuel-based to higher and higher renewable energy sources power generation, the HVAC-to-HVDC overhead line conversion is an option that deserves to be considered. In fact, without withdrawing further land resources, it is possible to increase the transmitted power significantly by exploiting the existing corridors. In this paper, an overview of the main issues to be considered when converting a HVAC lines into a HVDC one is presented, by describing technical, economical and environmental features in order to achieve the maximum benefits from this conversion. Moreover, some investigations about ongoing projects and studies around the world are reported.

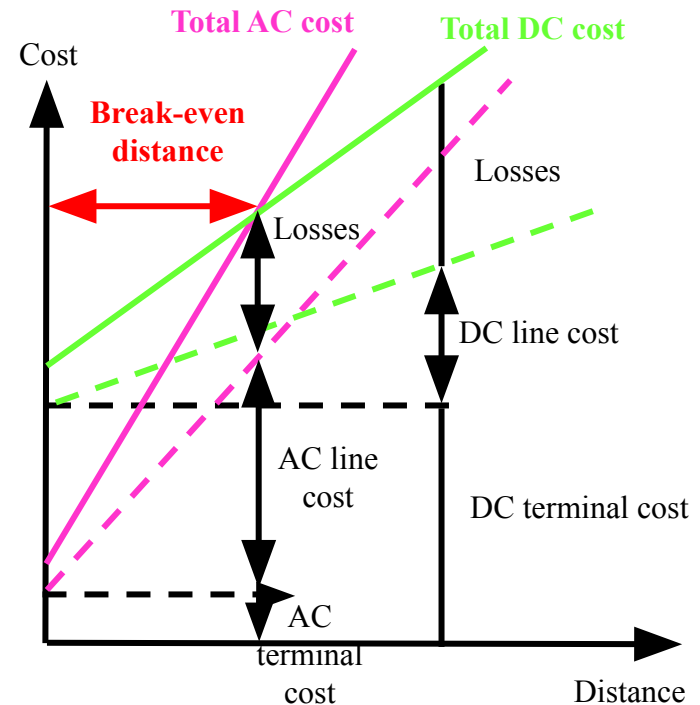
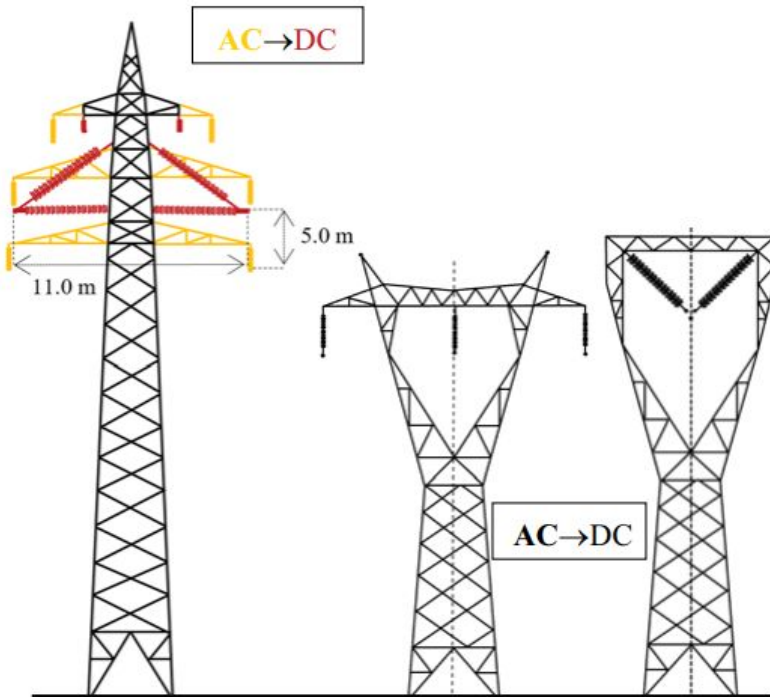
have been carried out about this topic. In this paper, an overview of the main issues related to the conversion of a HVAC OHL into a HVDC one is presented, by considering the most used formulations and the studies available in literature. Moreover, some of the key existing and potential HVAC-to-HVDC conversion projects around the world are described.

II. TRANSMITTABLE POWER FOLLOWING HVAC-TO-HVDC CONVERSION

Different technological options are currently available to enhance the transmission capacity of existing HVAC lines, by means of current uprating or voltage upgrading. The current uprating options may include the deployment of conventional series compensators, phase shifting

4) Studio sui sistemi HVDC: simulazione dinamica e affidabilità

- Conversione HVAC – HVDC e costi installazione





4) Studio sui sistemi HVDC: simulazione dinamica e affidabilità



Review

Availability Analysis of HVDC-VSC Systems: A Review

Sebastian Dambone Sessa * , Antonio Chiarelli and Roberto Benato 

Industrial Engineering Department, University of Padova, 35131 Padova, Italy

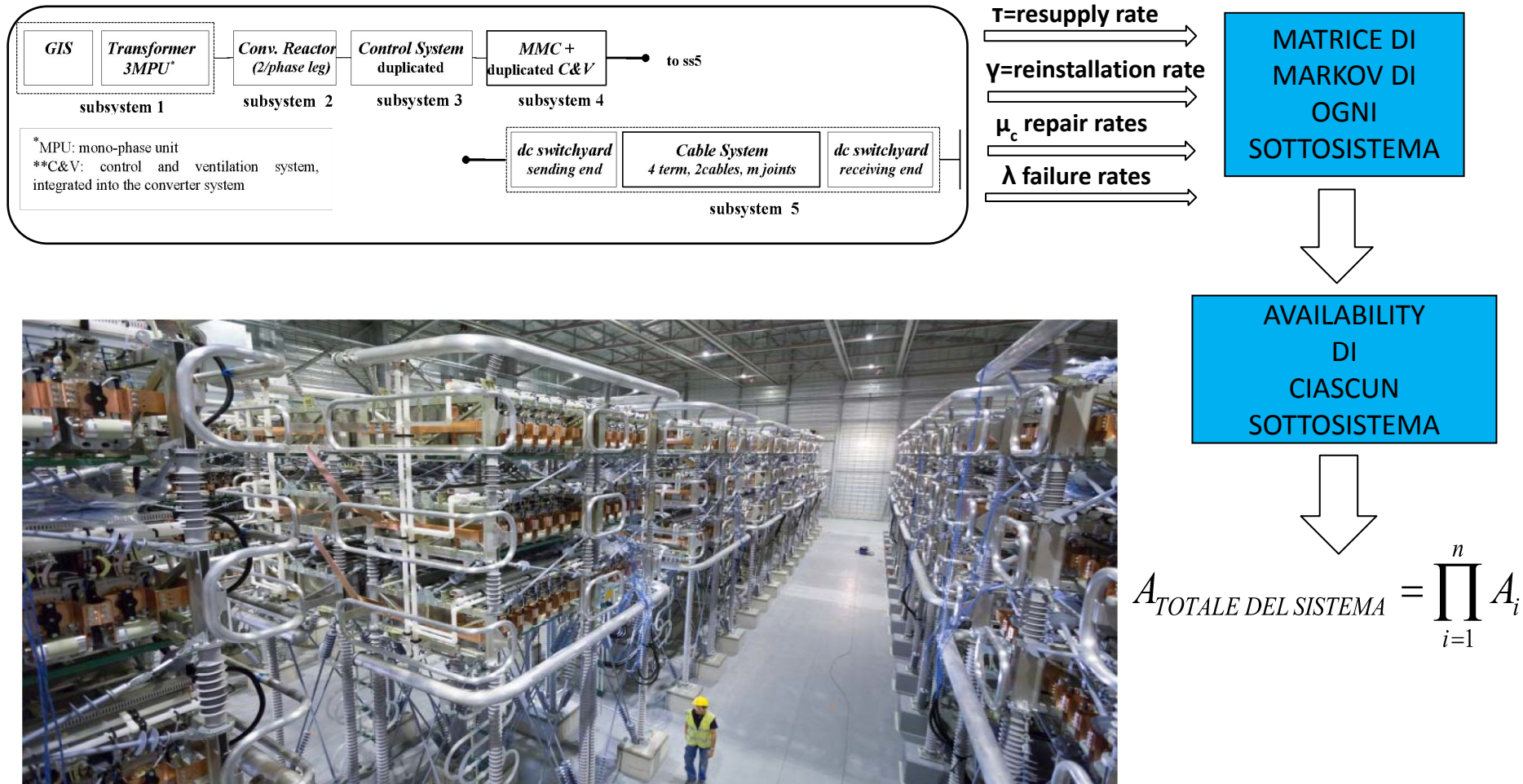
* Correspondence: sebastian.dambonesessa@unipd.it

Received: 15 June 2019; Accepted: 9 July 2019; Published: 15 July 2019



Abstract: This work stems from the worldwide increasing need to precisely consider, in the design phase of an HVDC project, the availability of the HVDC system. In this paper, an overview of the availability assessment methods for HVDC-VSC transmission systems is presented. In particular, the state of the art of the procedures to estimate the availability of both the HVDC link reparable components and the conversion system on the basis of the converter configuration is given. The theoretical fundamentals of each method, together with their practical applications, have been described, in order to highlight the limits and the potentialities of each approach. The authors aim at giving a guide to choosing the best computation approach on the basis of the specific needs of the users and at summarizing all the key aspects which can be taken into account during the availability assessment of HVDC-VSC links.

4) Studio sui sistemi HVDC: simulazione dinamica e affidabilità



5) Sistemi di accumulo per AT: Batterie, Supercap, Flyweel, sistemi ibridi



Article

Li-Ion Battery-Flywheel Hybrid Storage System: Countering Battery Aging During a Grid Frequency Regulation Service

Sebastian Dambone Sessa ^{*}, Andrea Tortella, Mauro Andriollo and Roberto Benato

Department of Industrial Engineering, University of Padova, 35131 Padova, Italy;
andrea.tortella@unipd.it (A.T.); mauro.andriollo@unipd.it (M.A.); roberto.benato@unipd.it (R.B.)

* Correspondence: sebastian.dambonesessa@unipd.it

Received: 30 October 2018; Accepted: 19 November 2018; Published: 21 November 2018



Abstract: In this paper, a hybrid storage system solution consisting of flywheels and batteries with a Lithium-manganese oxide cathode and a graphite anode is proposed, for supporting the electrical network primary frequency regulation. The aim of the paper is to investigate the benefits of flywheels in mitigation of the accelerating aging that li-ion batteries suffer during the grid frequency regulation operation. For this purpose, experimental aging tests have been performed on a lithium-manganese oxide battery module and an electrical battery model which takes into account the battery aging has been developed in a Simulink environment. Then, a flywheel electrical model has been implemented, taking into account the thermal and the electromechanical phenomena governing the electrical power exchange. This more complete model of a hybrid storage system enables us to simulate the same aging cycles of the battery-based storage system and to compare the performances of the latter with the hybrid storage system. The simulation results suggest that suitable control of the power shared between the batteries and the flywheels could effectively help in countering Li-ion battery accelerated aging due to the grid frequency regulation service.

- Misure contro l'invecchiamento delle batterie per la servizio di regolazione primaria

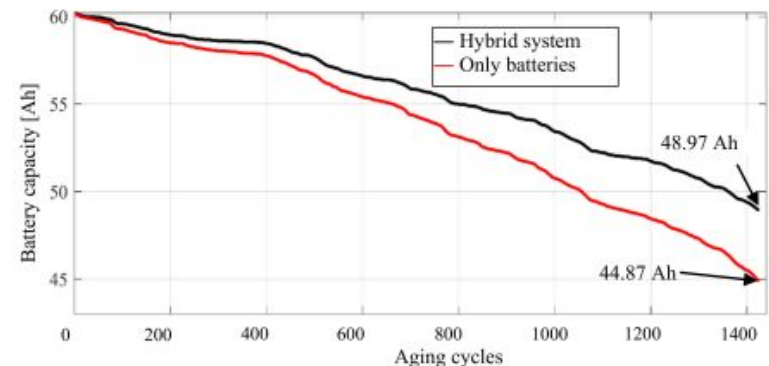


Figure 15. Comparison between the battery residual capacity after 1424 aging cycles for the two systems.

6) Algoritmi matriciali per lo studio dei flussi di potenza

ETEP

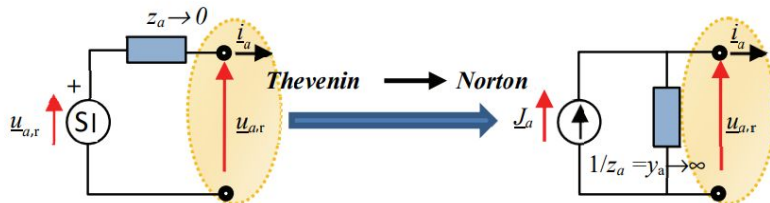
Power Flow Solution by a Complex Admittance Matrix Method

R. Benato, A. Paolucci, R. Turri

Abstract

The paper describes a newly developed algorithm for power flow solution based on a complex admittance matrix. The conciseness and close-to-reality iterative procedure make the method extremely attractive for self-made software implementation. The complex algorithm approach enables network connections, loads, generators, controlled bus voltages, including slack bus, to be considered in a single complex matrix. The power flow solution is achieved with iterations in complex form without the need of real/imaginary decomposition. The method has shown to have advantages over other traditional and available methods in terms of accuracy and convergence also in highly ill-conditioned cases. The cpu-time is comparable and sometimes competitive with those derived from Newton-Raphson methods.

- **2022:** inclusione slack bus nella Y , eliminazione partizioni e aumento velocità di convergenza



- **2001:** algoritmo basato su matrice delle ammettenze con slack bus come generatore quasi ideale di tensione

IEEE TRANSACTIONS ON POWER SYSTEMS, VOL. 37, NO. 2, MARCH 2022

1363

A Basic AC Power Flow Based on the Bus Admittance Matrix Incorporating Loads and Generators Including Slack Bus

Roberto Benato , Senior Member, IEEE

Abstract—This paper presents an algorithm for solving the AC basic power flow based on some enrichments provided in the bus admittance matrix methods findable in the literature. In particular, the interpretation of the slack bus generator as a current source rather than a voltage one and its inclusion inside an “all-inclusive” admittance matrix allows obtaining strong performances of the algorithm. In fact, this method gives both a well conditioning of the admittance matrix and the reduction of matrix partitioning for each iteration. As a result, a greater precision of the solution, a shorter execution time compared to classical commercial methods, a decreasing number of iterations and optimal convergence properties are obtained. Eventually, in order to show the efficiency of the method, real and fictitious networks are tested, by comparing its results and performances with robust open source/commercial software packages that use well-known methods (i.e., Newton-Raphson and Fast Decoupled Load Flow methods).

Index Terms—AC basic power flow, correcting current method, iterative methods, nodal admittance matrix.

$\underline{\Delta i}$
 $\delta_b \dots \delta_g$
 \underline{L}_x
 $\text{diag}(\underline{X})$

Correcting current vectors
Set of $b \neq g$ generator voltage angles
Transformation matrix
Main diagonal vector of \underline{X}

B. Variables and Parameters

\underline{u} Complex voltage
 $|\underline{u}|$ Voltage magnitude
 $\underline{u}_{a,r}$ Constrained slack bus voltage phasor
 \underline{i} Complex nodal current
 \underline{y} Complex admittance
 \underline{S} Complex power
 p Active power
 q Reactive power
 n_G Number of generator buses
 r Constrained value
 c Corrected value

6) Algoritmi matriciali per lo studio dei flussi di Potenza

a) collegamenti VSC-HVDC e LCC-HVDC

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Digital Object Identifier 10.1109/ACCESS.2022.3165183

A Novel AC/DC Power Flow: HVDC-LCC/VSC Inclusion Into the PFPD Bus Admittance Matrix

ROBERTO BENATO¹, (Senior Member, IEEE), AND **GIOVANNI GARDAN**, (Member, IEEE)

Department of Industrial Engineering, University of Padova, 35131 Padova, Italy

Corresponding author: Roberto Benato (roberto.benato@unipd.it)

ABSTRACT In this paper, the matrix algorithm PFPD is generalized in order to compute the power flow solution of real and large AC/DC transmission networks. In particular, it is demonstrated that the HVDC-VSC/LCC links can be seen from the AC power systems as PV/PQ constraints, which englobe both the AC and DC characteristics of the HVDC links. The proposed analytical formulation to assess the PV/PQ constraints is valid for any other numerical methods (*e.g.*, Newton-Raphson and derived, Gauss-Seidel, *etc.*). Furthermore, an iterative procedure for estimating the reactive power absorption of HVDC-LCC links from the power system is proposed. In order to validate the algorithm, solution comparisons with the commercial software DlgSILENT PowerFactory are presented. This validation procedure shows that the algorithm can analyse large and real HVAC/HVDC networks (*e.g.*, the Italian transmission one with its five HVDC links). Therefore, the conciseness, accuracy and performances of PFPD for studying real and large AC/DC power systems is confirmed.

6) Algoritmi matriciali per lo studio dei flussi di Potenza

a) PFPD collegamenti VSC-HVDC e LCC-HVDC



FIGURE 10. The Italian AC/DC network: the dotted arrows represent the HVDC links.

- **Potenza assorbita HVDC-LCC**
MON.ITA: confronto tra dati sperimentali e calcoli di rete

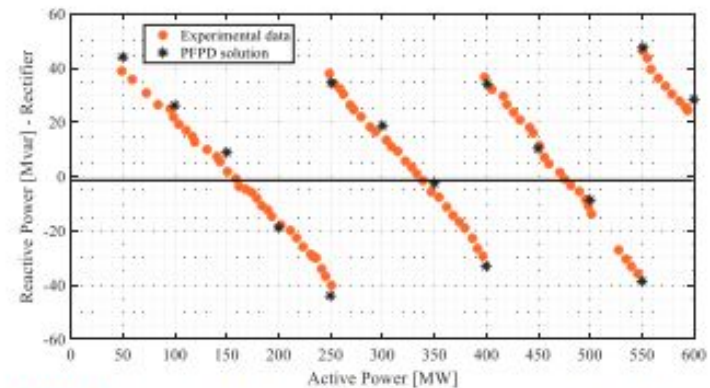
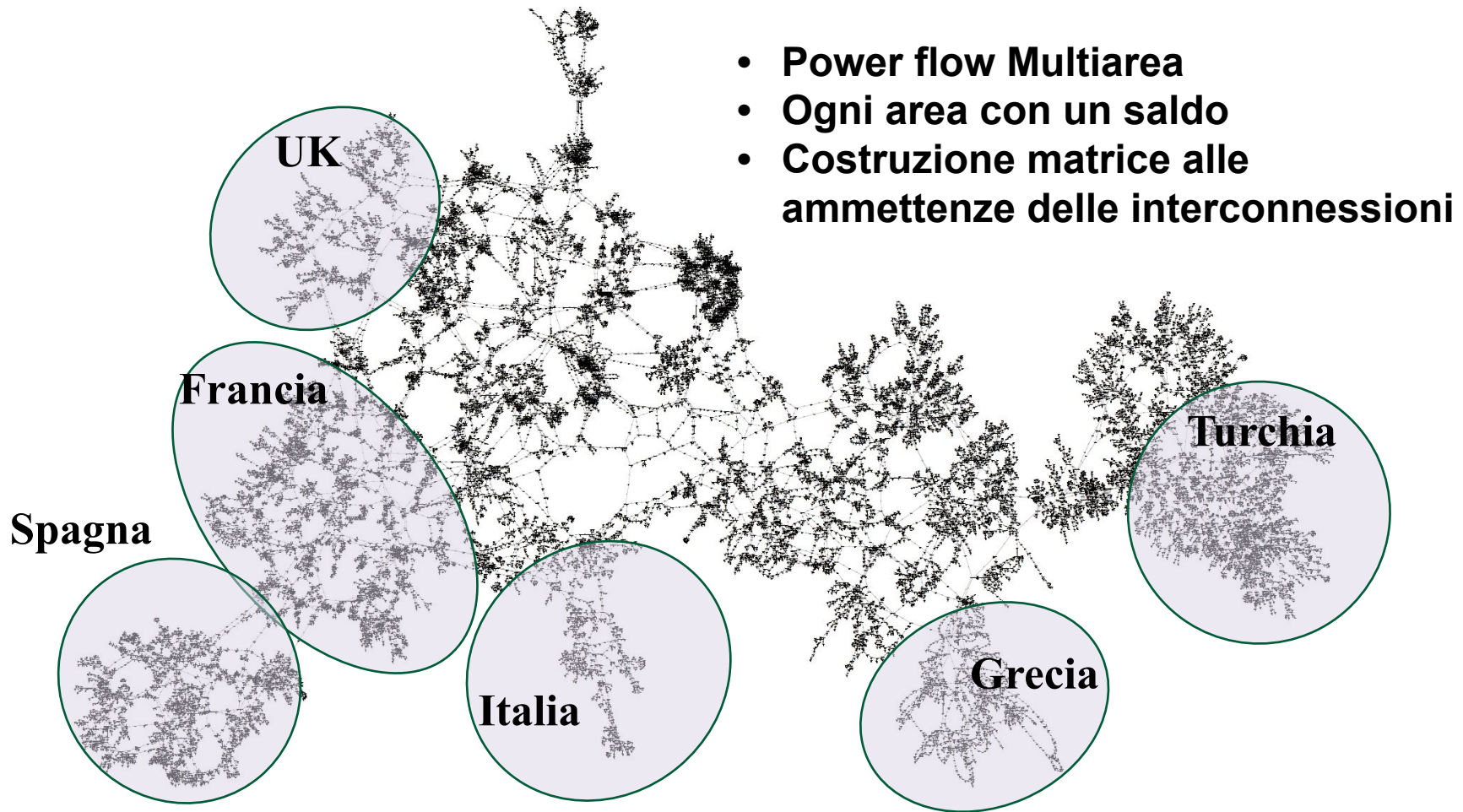


FIGURE 8. Comparison between experimental measurements and PFPD results for the MON.ITA HVDC link.

6) Algoritmi matriciali per lo studio dei flussi di Potenza

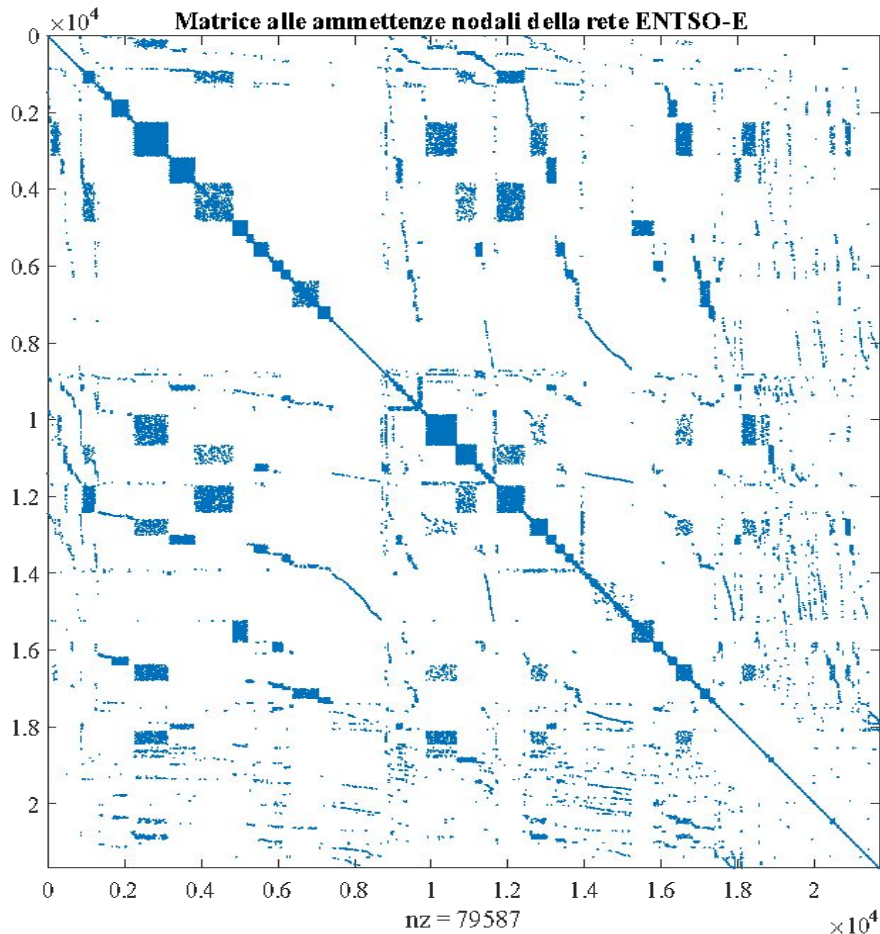
b) PFPD monofase su rete europea fornita da ENTSO-E



La rete ENTSO-E rappresentata in ambiente PowerFactory

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b) PFPD monofase su rete europea fornita da ENTSO-E



N. nodi = **21677**

N. elementi matrice alle ammettenze =
= $21677 \times 21677 = \mathbf{469.892.329}$

Percentuale elementi non nulli **0,017%**

La matrice alle ammettenze nodali alla sequenza diretta della rete europea


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c) PFPD trifase per studi di unbalance

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A Three-Phase Power Flow Algorithm for Transmission Networks: A Hybrid Phase/Sequence Approach

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AND LUCA RUSALEN, (Member, IEEE)

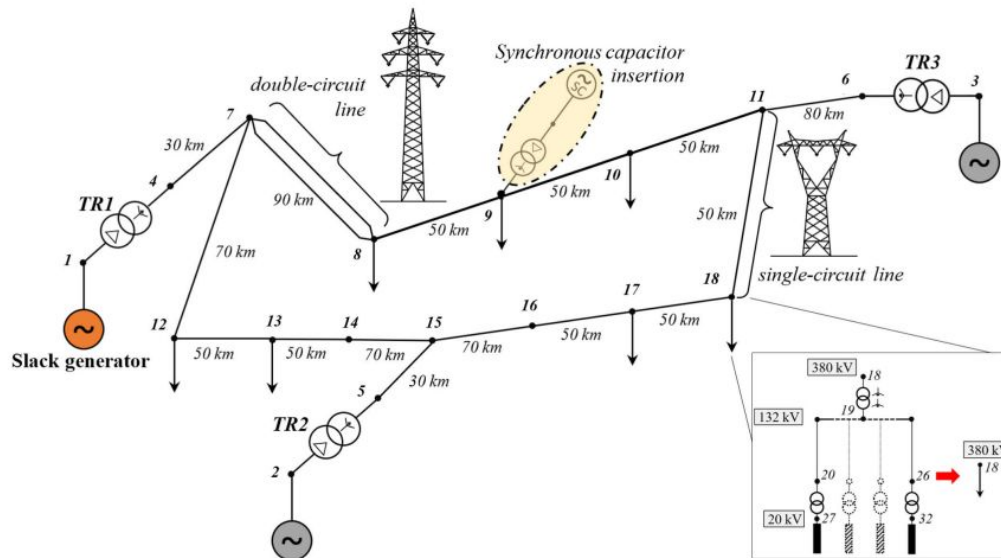
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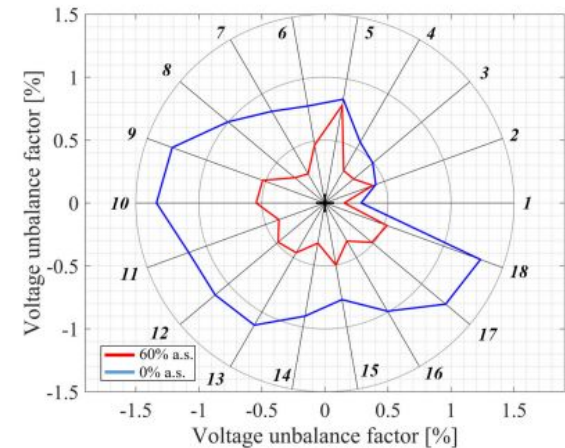
ABSTRACT In this paper, the three-phase generalization of a single-phase power flow (named PFPD) developed by the first author is presented. This three-phase formulation is chiefly conceived for HV/EHV transmission network applications, but it preserves a general validity for any power system. An iterative method for the solution achievement is throughout expounded. The algorithm quantitatively aims at investigating the impact of the asymmetrical transmission structures on power systems. This impact is evaluated in terms of voltage and current sequence components. Moreover, discussions on possible improvement actions to enhance the power quality are developed. The algorithm is implemented in Matlab environment and tested by several fictitious networks. Eventually, extensive comparisons in terms of execution time, number of iterations and solution accuracy with the software DIGSILENT PowerFactory are presented.

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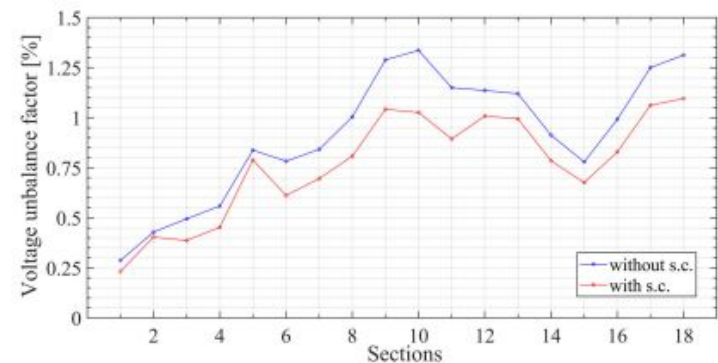
c) PFPD trifase per studi di unbalance



- Influenza del carico asincrono sulla dissimmetria delle tensioni



- Effetto simmetrizzante dei compensatori sincroni



- Linee rappresentate tramite approccio multiconduttore a cella con presenza di conduttori passivi (MCA)

6) Algoritmi matriciali per lo studio dei flussi di Potenza

d) PFPD trifase sistema elettrico italiano

- Analisi dei flussi di potenza trifase della rete italiana con inclusione dell'HVDC e conseguente calcolo delle tensioni complesse sulle tre fasi
- Inclusione dei conduttori passivi: funi di guardia, schermi, armature e studio del regime elettrico

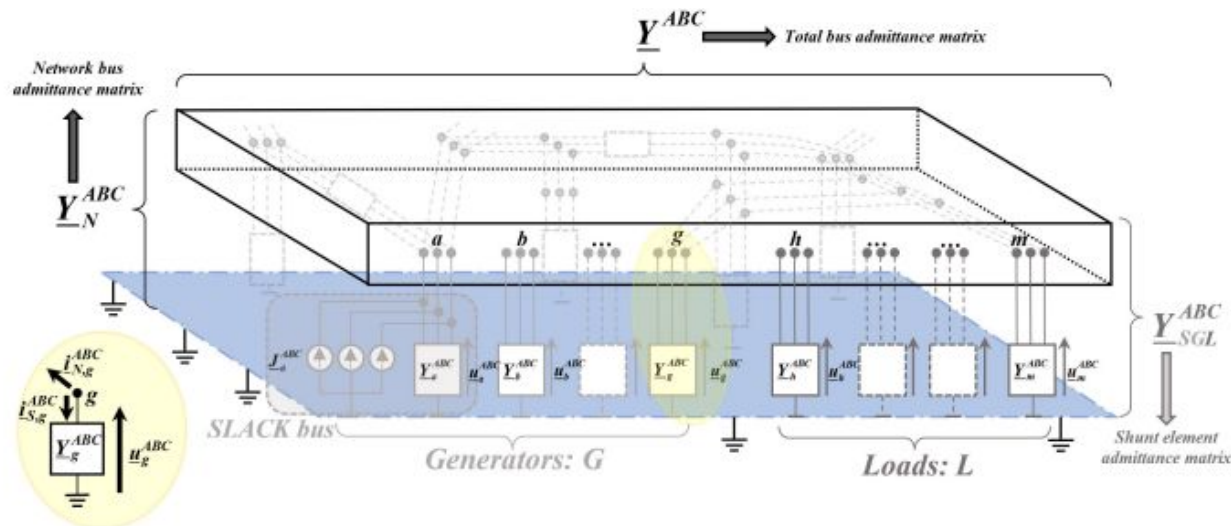


FIGURE 2. Schematic representation of the three-phase power system (a: slack generator section, G: generator sections, L: load sections).

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 - a) Simulazioni e analisi post di prove di riaccensione
 - b) Modello del carico e della generazione distribuita
3. Tecnologie innovative per la trasmissione
 - a) Cavi tripolari armati sottomarini – FEM vs MCA
 - b) CALA-JOULE: corde innovative per linee aeree
 - c) Strutture metalliche di protezione per linee aeree
4. Sistemi HVDC: simulazione dinamica e affidabilità
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6. Algoritmi matriciali per lo studio dei flussi di potenza: PFPD
 - a) collegamenti VSC-HVDC e LCC-HVDC
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