Analysis and UTDQ Control Design for Alleviation of Subsynchronous Resonance Using STATCOM

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***Abstract*—Subsynchronous resonance (SSR) is a drastic phenomenon in electrical power generation that is disastrous to both electrical and mechanical systems as the exchange of energy between the two systems take place. This paper proposes a novel control design based on unit templates and d-q (UTDQ) transformations for static synchronous compensator (STATCOM) to alleviate SSR oscillations. The efficacy of the proposed control design is validated through time domain analysis of IEEE second benchmark model taken as test system. State space analysis of the the mechanical system is formed for eigenvalue analysis, that provide the different torsional modes and their corresponding frequencies. Frequency scan of electrical network is carried out at different compensation levels for obtaining the corresponding resonant frequencies. The level alleviation of SSR achieved with the proposed control design is 97.27 % which is highly compelling as compared to other studies in the literature.**

***Index Terms*—Subsynchronous Resonance, Torsional oscillations, FACTS, STATCOM.**

NOMENCLATURE

Δ	The prefix denotes a small deviation about the initial operating point
$\Delta\omega$	speed deviation of mass in pu
ω	speed of mass in pu
τ	Mechanical torques developed by the turbine sections
'.'	Represents differential operator
D	Damping coefficient in pu torque/pu speed deviation
EXM	subscript denotes excitation
GM	subscript denotes generator
GXM	subscript denotes excitation and generator
HLM	subscript denotes high pressure and low pressure
HPM	subscript denotes high pressure turbine
K	Shaft stiffness in pu torque/electrical rad
LGM	subscript denotes low pressure turbine and generator
LPM	subscript denotes low pressure turbine
M	Inertia constant in MJ/mech rads

I. INTRODUCTION

With the trend of shifting the electric power generation more towards the non–conventional energy sources, their protection and reliability is of great concern [1], [2]. Wind power generation is on the rise, but as soon as they are connected with series compensated transmission networks, heavy damages are caused due to occurrence of subsynchronous resonance (SSR) [3]. It has been found that wind power generation is prone to SSR oscillations, due to the interaction with series compensated transmission networks [4], [5].From the first recorded incident of SSR phenomenon, the series compensation has been the main cause of SSR [6]. The damages are very disastrous as not only the electrical system but the mechanical systems are also heavily damaged.

Defining SSR as a devious problem, IEEE explains the phenomenon as, the exchange of energy takes place between the mechanical and electrical systems at frequency lower than the synchronous frequency [7]. The interaction takes place between the electrical and mechanical systems, when the torsional mode frequency of the mechanical shafts coincide with the frequency of currents induced in the stator of the generator. The induced currents have frequency compliment to the frequency of resonant currents that flow in the electrical network. Since the resonant frequency is less than the synchronous frequency, the phenomenon is termed as subsynchronous resonance. It is a problem for not only the existing plants but also makes it difficult to synchronize the plants with electrical network [8].

To suppress the oscillations caused by SSR, flexible AC transmission system (FACTS) have been used in past [9]. Risk assessment of SSR has been provide in [10]. Series FACTS devices have been designed in [11] to mitigate SSR. In [12], [13], supplementary damping controllers have been used to damp the oscillations. Series compensation and its effects on occurrence of SSR is explained [14], [15]. However, the level of mitigation achieved can be improved and innovative ideas can be implemented to alleviate SSR oscillations.

SSR is studied in this manuscript through different approaches. Mathematical study of mechanical shaft system is presented to obtain different torsional modes and their corresponding modal frequencies. This analysis is carried out eigenvalue analysis of the mechanical mass system. The electrical system is studied through the frequency scan of electrical network, to obtain the frequency of the resonant currents. Frequency scan has been presented for different compensation levels and the corresponding frequencies of induced currents are obtained.

Single machine infinite bus system with two transmission

978-1-7281-2658-6/19/$31.00 ©2019 IEEE