Course 6:- Training Program Agenda
RENEWABLE POWER SYSTEM MODEL & STUDIES TRAINING

- **Time domain load flow**
  - Basis of time domain load flow in RMS computational tool (like ETAP) by analysing results of load flow in a typical system by time vary load and renewable inverter based generation (REG) source outputs over a period of time to monitor loading and voltage profile of system due to varying load
- **Solar PV module study modelling: -**
  - Understanding and creation of library of solar PV module based on V & I and Power Voltage characteristics, Model of solar PV panel/module and array, PV DC & AC side modelling. Load flow and reactive power compensation (RPC) in solar farm power plant to meet grid code power factor requirement and identifying need for passive and active reactive power compensation to meet grid POI code. Maximum Power Point Tracking (MPPT) for maximizing power output from PV to grid.
  - Solar PV module model data covering type (monocrystalline, poly crystalline or thin film technology) PV module Pmpp (STC) in W, P tolerance, PV V mpp, PV Impp, PV Voc, PV Isc, temperature coefficient of Voc, Isc and Delta Voc (log change in VOC with irradiance), Module LxWxH in m, Module area in m^2, % fill factor, Module efficiency, STC (standard test condition based on 1000 w/m^2 irradiance, 25 degree C temperature, no wind), NOCT (Nominal Operating Cell Temperature) degree C, NOCT practical realistic power output rating (lower than STC rating) under outdoor conditions of 800 W/m² irradiance, 20°C cell temperature, 1 m/s wind, open rack mounting).
- **Wind turbine generator (WTG) module study modelling: -**
  - Wind Turbine Components turbine blades, generator gear box, transformer, pitch controllers. Wind turbine data sheet for studies/analysis
  - WTG aerodynamic power basic equations & characteristics, MPPT (as function of blade tip sped ratio TSR optimum turning, equation of WTG power in relation to WTG blade swept area, wind velocity, pitch angle, BETZ efficiency constant, coefficient of power (cp fraction of wind captured by WTG blade) and its relation with TSR (lamba or beta) and pitch angle. Calculation of WTG rpm with power variation.
  - Type of WTG type 1`, 2, 3 & 4. Uncontrolled Wind Turb Power as cube of wind velocity, WTG power versus speed characteristics covering cut in speed, rated speed and cut out speed as a function of pitch angle.
  - WTG dynamics and transfer function of feedback control system block diagram model with gain, time constant compensation, reference setting etc covering turbine control and pitch control,

P.Nandakumar, C-203 Akshata Apartments, Tilak Nagar Building No. 1, P.O Tilak Nagar, Chembur Mumbai 400089. email: nanda57@gmail.com; Mobile:-+919821871436

- Model WTG as per data sheet covering kW rating, kV rating, rated PF, % EFF, No. of poles, average wind speed in m/s, kvar limits. Set WTG output based on % of rated wind speed, set limit based on PQ capability limits. Model Aerodynamic data covering rated wind speed m/s, Swept WTG blasé area in m^2, air density kg/m^3, cut in speed in m/s, rpm, cut out speed in m/s, pitch angle. power coefficient Cp evaluation based on Cp vs Lamda (Tip Speed Ratio) characteristic derivation.

- **Battery Energy Storage System BESS**
  - Battery types- Lead Acid, Ni Cd & Li-ion batteries and their comparison in terms of energy density, power density, volumetric power density, efficiency and life cycle
  - Battery Wh/Ah capacity and parameters including C rate (rate at which battery capacity can be built up or given up), terminal and open circuit battery cell voltage, specific power and energy density, state of charge or depth of charge specification without sacrificing life cycle. Battery efficiency and sizing basis.
  - Basics of C rate and battery cell % SOC versus cell Voltage curve model of li-oh for modelling and battery discharge and charging computation
  - Use of Li-ion Shepherd formula for assessment of battery's terminal voltage during discharge.
  - Li-ion Battery AH discharge (battery at 100 % SOC connected to fixed load) and charge (battery of low % SOC connected to an AC generator via rectifier/charger) time domain load flow in RMS computation tool (like ETAP) to study battery charge discharge SOC over time matches the battery AH at different C rate
  - Assessing Battery AH capacity for a microgrid having a common ac bus where a load is supplied from battery (through dc-ac rectifier, and transformer) and Solar PV (through dc-ac inverter and transformer). The PV source is time varying solar irradiation/power supplying solar power to an electrical load varying with time. Study by model ling of a 3-day sun and load profile versus time profile with battery getting charged during periods when solar PV output is more than load and battery discharging into load when there is no sun. The time domain load flow assesses the battery AH capacity adequacy by monitoring battery % SOC and ensuring it varies with specified soc range of 20 to 80 % during the selected time profile.

P.Nandakumar, C-203 Akshata Apartments, Tilak Nagar Building No. 1, P.O Tilak Nagar, Chembur Mumbai 400089. email: nanda57@gmail.com; Mobile:-+919821871436

- **Smart Inverter**
    - Smart inverter model test in RMS computational tool (like ETAP) and test for Volt-Var function by modelled in it predefined Volt-Var (V-Q)curve, or characteristic curve. The smart inverter based on its Volt-Var curve setting will absorb reactive power at higher voltage and inject var to the system when voltage is low
- **Steady state load flow**
    - Understanding Model with WTG, Inverter, Transformer & Grid and running of load flow on RMS computational tool (like ETAP) for various wind speed and grid voltages
    - Understanding Model with PV, Inverter, Transformer & Grid and running of load flow on RMS computational tool (like ETAP) for various wind speed and grid voltages.

        - PV module and PV array modelling based on actual vendor datasheet with PV MW output evaluated in ETAP and EXCEL based on ambient temperature, solar irradiance and nominal cell temperature (NOCT)

        - PV Inverter modelling with inverter P Q limit matching PV array output and load sharing between multiple inverters

    - Understanding Model with BESS using Li-ion battery, Inverter, Transformer & Grid and running of load flow on RMS computational tool (like ETAP) for various wind speed and grid voltages
    - Load flow Reactive Power Compensation and Voltage Control under normal, minimum and maximum grid active power (P) and reactive power (Q) power export / import to the system. Assess plant P & Q capability and adequacy of inverter generation (with inverter Q limits and system P & Q losses) operation, with and without additional captive reactive power compensators (STATCOM), to export import power within the rid code power factor of 0.95 lag to 0.95 lead under all power exchange conditions and grid 10 % voltage operating conditions.

P.Nandakumar, C-203 Akshata Apartments, Tilak Nagar Building No. 1, P.O Tilak Nagar, Chembur Mumbai 400089. email: nanda57@gmail.com; Mobile:-+919821871436

- **Inverter based generator dynamic control system model (based on WECC model)**
  - Model & Explanation of UDM of widely adopted WECC standard PV inverter grid following (GFL) modules for RMS or Phasor domain P & Q control of following
    - Set points and model time constant and gains and limits and various parameter data visualization
    - Ratings, and gain time constants, set points and Q, V or pf model settings, P logic under low voltage (LVPL)
    - Multi inverters central Power Plant Controller,
    - individual electrical or equivalent excitation and voltage, P/Q control and generation control that interface with the grid along with grid LVRT & HVRT ride through with Q priority taking over P priority during grid abnormal voltages
- **Inverter based generator grid code dynamic**
  - Built PV to grid supply system to carry out
    - Dynamic Grid Code Compliance stability analysis studies of grid connected PV inverter generation against local or WECC grid code covering
      - faulted transient to evaluate fault ride through in compliance with grid code and evaluation of and critical fault clearing time for 3 phase, LG and LLL faults
      - non fault transient disturbance on inverters for operating, without tripping, in compliance with grid code as below.
      - Low voltage ride through (LVRT) for grid voltage dip of
    - Low voltage ride through (LVRT) for grid voltage dip of upto < 0.85 PU for 3 s, 0.15 PU for 300 milli s, and 0.9 PU for 10 s with full 100 % and 20 % power transformer from REG inverter to grid.
    - Hugh voltage ride through (HVRT) for grid voltage rise of up to 1.2 PU for 2 s, and 1.3 PU for 200 milli sec with full 100 % and 20 % power transformer from REG inverter to grid.
    - Frequency ride through.
    - Operating frequency range P Q V response under steady state and stage wise sudden change in grid frequency under
      - Rated active power generation between 49.5 Hz to 50.5 Hz
      - Stable power output between 47 Hz to 52 Hz
      - Sudden increase in grid frequency from 50 to 50.5 Hz.
      - Sudden decrease in grid frequency from 50 to 49.5 Hz.
    - Frequency droop check of model.

P.Nandakumar, C-203 Akshata Apartments, Tilak Nagar Building No. 1, P.O Tilak Nagar, Chembur Mumbai 400089. email: nanda57@gmail.com; Mobile:-+919821871436

- Voltage response check of model covering step increase in voltage from 1 to 1.05 PU and decrease from 1 to 0.95 PU

P.Nandakumar, C-203 Akshata Apartments, Tilak Nagar Building No. 1, P.O Tilak Nagar, Chembur Mumbai 400089. email: nanda57@gmail.com; Mobile:-+919821871436