POWER SYSTEM MODELLING AND ANALYSIS OF A COMBINED CYCLE POWER PLANT USING ETAP

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Abstract-*This paper presents a methodology for keen assessment of power supply reliability and quality of electrical network. Now a days power supply reliability and quality are major concern. Study of electrical power system is an essential element in power system planning and design. The power system studies are conducted for ensuring the designed network is meeting the required specifications and standards with respect to safety, flexibility in operation, etc.,. In this paper the major emphasis will be given on performing load flow analysis, short circuit analysis, transient stability analysis and relay coordination. These analyses are done in this paper by using ETAP (Electrical Transient Analyser Program).*

Key Words: ETAP software, over current relays, relay settings, relay coordination and Transient stability analysis.

1. INTRODUCTION

Availability of various generation sources such as conventional and non-conventional sources. These sources can significantly impact the power flow and voltage profile as well as other parameters at customers and utility side. Electrical networks/installations are designed based on national and international standards depending on the type of the project and its requirements. In addition, some initial FEED (Front End Engineering Design) studies are taken before the system single line diagram is frozen. The power system Studies are essential to pre-confirm the parameters of various equipments/components of the planned electrical facility. In electrical power systems, most of the electrical parameters variation occurs dynamically due to sudden addition or sudden tripping of generators. The faulted/disturbance occurred part of the network is isolated by analysing the electrical power system.

Electrical power generation broadly classified into two types based on the utilization of power. The first one is captive power plants, it refers to power generated from the plant set up by an industry is used for its own exclusive consumption. Second one is utility power plants, it refers to generated power is sold or supplied to various customers and not for its own use. Combined cycle power plant is a type of captive power plant and it is the combination of steam turbine and diesel turbine. Each captive power plant has to be tailor made to suit particular customer/industry need. It includes setting up and commissioning of generators, hooking up with grid, catering to the power plant auxiliaries as well as customer's industrial loads to ensure availability of adequate reliable power supply to the industry.

1.1 Designing Objectives:

While designing a captive power plant and offerings as a business solution, following are the major objectives to be met:

i. Ensuring optimization in equipment selection.
ii. Identifying and rectifying deficiencies in the system at the design stage itself before it goes into operation.
iii. Analysing different power plant operating scenarios for economic operation.
iv. Establishing system performance and guarantees.
v. Ensuring safe and reliable operation.
vi. Establishing the provisions of the system's future expansion plans.

2. SINGLE LINE DIAGRAM USING ETAP

Fig. 1 shows the combined cycle power plant consisting of two steam turbine generators (STG) with a capacity of 36MW each, two gas turbine generators (GTG) with a capacity of 34.5MW each and it is connected to grid [1]. Different loads are connected at different bus levels (33KV, 6.6KV, 415V). Different types of loads are lump loads, HT motors and LT motors. Lump loads are the combination of 70% motor load and 30% non-motor load operating with a power factor of 0.88 lag. IEC standard ETAP software library data [2] is considered as default data for impedances of the system components.

3. LOAD FLOW ANALYSIS AND ITS RESULTS

Checking of the system performance i.e., checking of the adequacy of all system component ratings, transformer sizes and their impedances and tap changer settings under a variety of operating conditions including contingency conditions [1]. The main objective of the load flow analysis [3] is determination of the steady state active and reactive power flows, current flows, system power factor and system voltage profiles (magnitudes and phase angles of load and generator bus voltages). Fig. 2 shows the load flow analysis results of a combined cycle power plant.

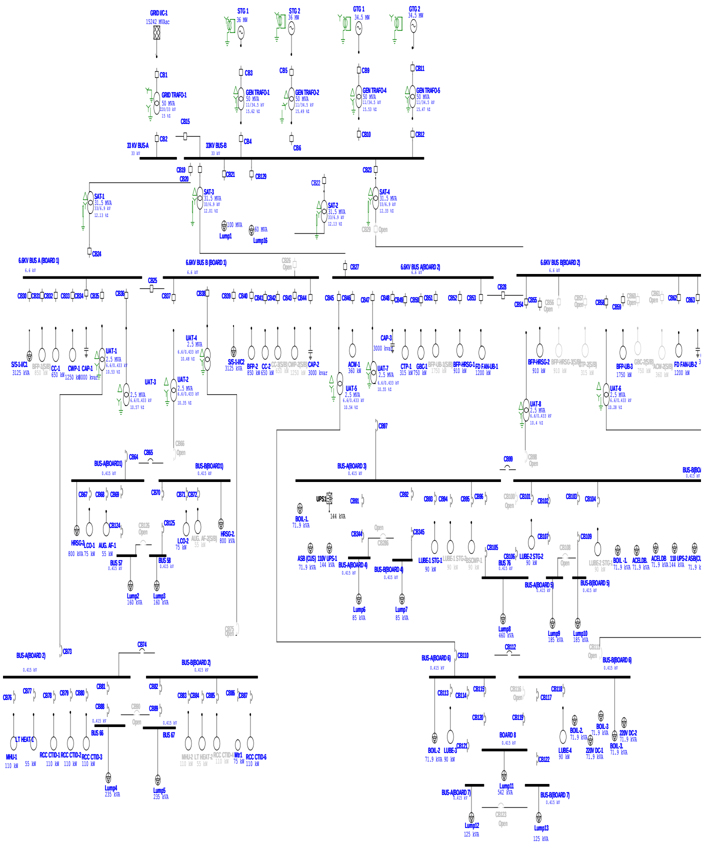

Fig-1: Single line diagram of combined cycle power plant

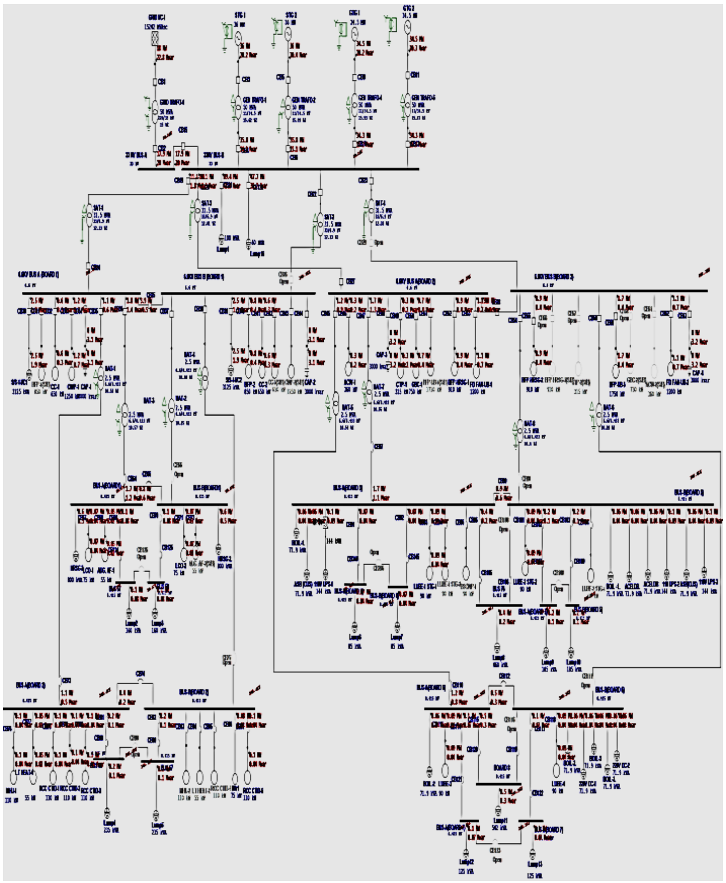

Fig-2: Load flow analysis results

4. SHORT CIRCUIT ANALYSIS AND ITS FAULTS

Fault level (short circuit) analysis are used to determine both maximum and minimum three phase faults and earth fault level at all switch boards under fault make and fault break conditions including the dc component [4]. Types of short circuit faults are line to ground (LG) fault, line to line (LL) fault, double line to ground (LLG) fault, three phase (LLL) fault and three phase to ground (LLLG) fault.

IEC standards use the following definitions, which are relevant in the calculations and outputs of ETAP for Short circuit analysis.

Initial Symmetrical Short Circuit Current (I''_K): This is the RMS value of the AC symmetrical component of an available short circuit current applicable at the instant of short circuit if the impedance remains at zero time value.

Peak Short Circuit Current (I_p): This is the maximum possible instantaneous value of the available short circuit current.

Symmetrical Short Circuit Breaking Current (I_b): This is the RMS value of an integral cycle of the symmetrical AC component of the available short circuit current at the instant of contact separation of the first pole of a switching device.

Steady-State Short Circuit Current (I_k): This is the RMS value of the short circuit current, which remains after the decay of the transient phenomena.

Voltage Factor (c): This is the factor used to adjust the value of the equivalent voltage source for minimum and maximum current calculations.

4.1 CALCULATION METHODS:

Initial Symmetrical Short Circuit Current Calculation: Initial symmetrical short-circuit current (I_k'') is calculated using the following formula:

$$I_k'' = \frac{cU_n}{\sqrt{3}Z_k} \quad \text{... Eqn (1)}$$

Where, Z_k is the equivalent impedance at the fault location.

Peak Short Circuit Current Calculation: Peak short-circuits current (i_p) is calculated using the following formula:

$$i_p = \sqrt{2}kI_k'' \quad \text{... Eqn (2)}$$

Where, k is a function of the system R/X ratio at the fault location.

In this paper, we considered three faults i.e., LG, LLG and three phase faults at randomly considered buses. The following table-1 gives the short circuit fault current at different buses considering LG Fault.

Table-1: Fault currents at different buses considering LG Fault

FAULTED BUS	VOLTAGE (KV)	FAULT CURRENT (KA)
33KV BUS-A	19.76	32.07
6.6KV BUS-A (BOARD 1)	6.55	0.63
415V BUS-A (BOARD 1)	0.26	41.09
415V BUS-B (BOARD 3)	0.25	37.97
415V BUS-B (BOARD 6)	0.25	38.32

The following table-2 and table-3 gives the short circuit fault currents and voltages at different bus boards considering LLG Fault and three phase fault respectively.

Table-2: Fault currents at different buses considering LLG Fault

FAULTED BUS	VOLTAGE (KV)	FAULT CURRENT (KA)
33KV BUS-A	19.67	31.9
6.6KV BUS-A (BOARD 1)	5.64	0.311
415V BUS-A (BOARD 1)	0.26	37.26
415V BUS-B (BOARD 3)	0.25	35.93
415V BUS-B (BOARD 6)	0.26	36.1

Table-3: Fault currents at different buses considering LLL Fault

FAULTED BUS	FAULT CURRENT (KA)
33KV BUS-A	33.1
6.6KV BUS-A (BOARD 1)	25.9
415V BUS-A (BOARD 1)	46.1
415V BUS-B (BOARD 3)	40.5
415V BUS-B (BOARD 6)	41.1

5. TRANSIENT STABILITY ANALYSIS

Determination of the system response due to different disturbances which are the source of instability i.e., which lead to loss of synchronism or stalling or overloading of generators and motors. Switching transients [5] are mostly associated with mal-functioning of circuit breakers and switches, switching of capacitor banks and other frequently switched loads.

In this we considered that three phase fault is occurred at 0.5 Sec on 33KV bus, then the system may goes into unstable condition. After making some trails we can conclude that the critical clearing time [6] is 0.74

Sec i.e., the system is stable if the fault is cleared before 0.24 Sec after the fault is created otherwise the system goes into unstable condition. The following fig. 3 and fig. 4 shows the power angle of the system and speed of the generator respectively.

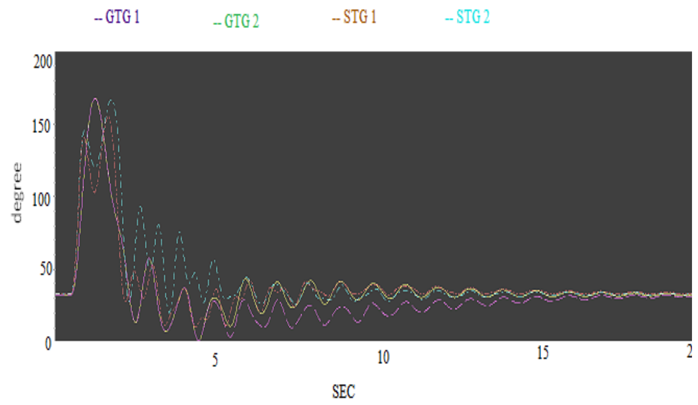

Fig-3: Power angle

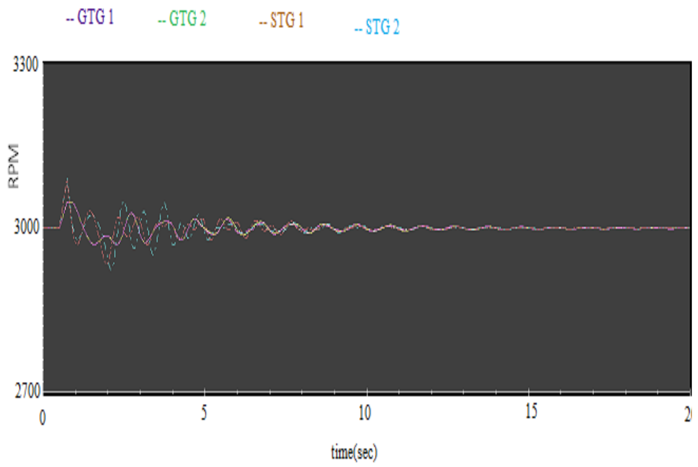

Fig-4: Generator speed

6. RELAY CO-ORDINATION

Typical power system comprises number of important equipments which have to be protected. In order to provide sufficient reliable protection to ensure smooth working of power system, installation of relay and circuit breaker sets are required. Primary protection relay must operate within its pre-determined time period [7]. In case of failure of primary protection relay operation which may be because of any reason, back-up protection [8] has to take care by its operation and hence relay coordination is very important to minimize the outages which are occurring frequently. Over current relays [9]is one of the most important protection devices in the captive power plants. The primary protection and backup protection are provided by co-ordinating the relays which are placed at different branches in the network. In this paper, we considered the relays of relay140, relay146, relay157, relay198, relay205 and relay 382 and the characteristics of these all relays are shown in following fig. 5.

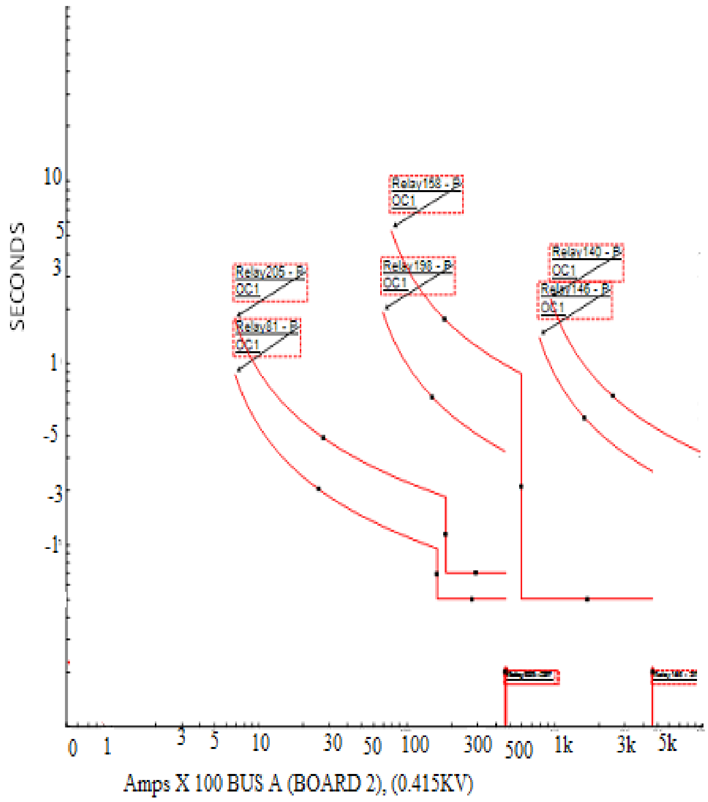

Fig-5: Characteristics of relays

Plug setting multiplier (PSM) and time setting multiplier (TSM) are to be calculated for the co-ordination of the relays. The definitions which are relevant in the calculations and outputs of ETAP are as follows:

TMS adjusts the operating time of the relay. If the TMS value is low then the operation of relay is fast.

$$PSM = \frac{\text{Fault current}}{\text{Plug setting } \times \text{ CT ratio}}$$
...Eqn (3)

In this paper we considered that if the three phase fault is occurred at lump load of 235KVA which is connected at bus6, then the relays will operate as follows:

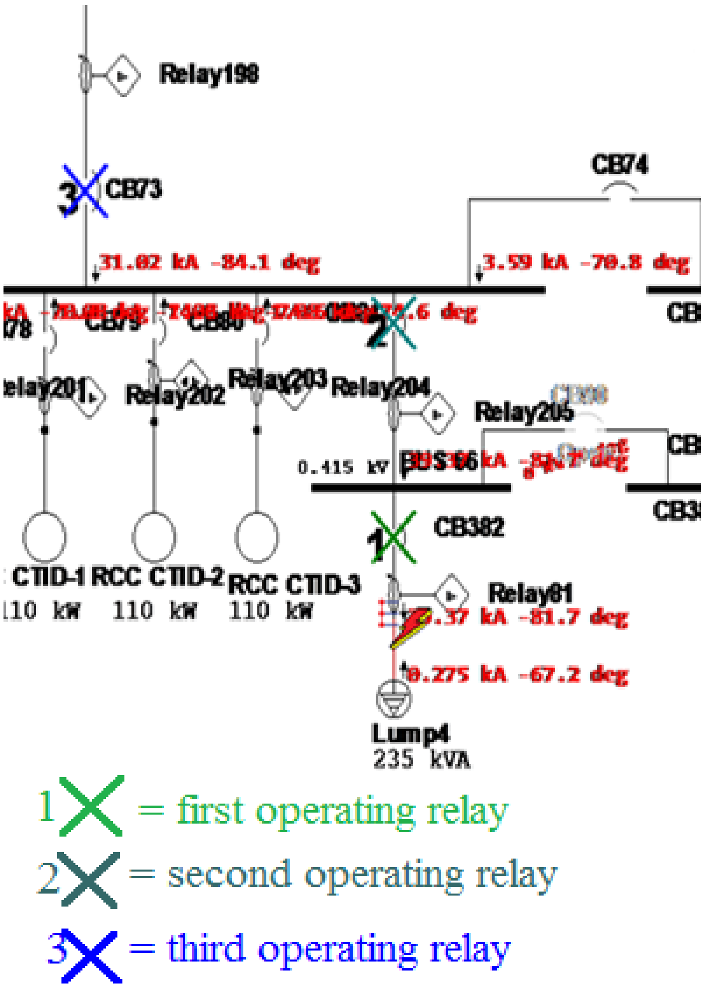

Fig-6: Relay co-ordination of the system

7. CONCLUSION

Thus, in this paper, we have modelled the combined cycle power plant in the ETAP software and different power system analyses are done in single network. The network is very complicated, so the calculations can't able to do by hand calculation. ETAP is very helpful to reduce the malfunctioning of network and to increase the efficiency of the system by operating proper relay co-ordination within less time.

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