Genetic Algorithm (GA) –

Genetic Algorithm is computer algorithm inspired by the procedure of natural evolution, which is the combination of two phenomena – Struggle for existence, and Survival of the fittest. The environment has limited resources but large no of species. The species with better adaptability with the environment survive, and the rest becomes extinct. Survived candidates again changes for better adaptability. This way evolution occurs. The GA algorithm used for the CEED problem is described as below –

1. **Population initialization:** First, a population size is fixed (let p). p no of candidates is randomly generated. Each candidate of the population contains n no of entries corresponding to each generator. Entries are chosen such that they lie in the operation range of the generator, and sum of all entries give the total load.
2. **Cost calculation:** The combined fuel and emission cost for a candidate is calculated using the formula as discussed in the section \*\*\*\* vide equation \*\*\*
3. **Parent Selection:** Half of the candidates from the population with minimum cost are selected as parents for generating the offspring.
4. **Crossover:** Pairs of parent are selected randomly. For each pair (p1 and p2), four children are created, 0.5p1 + 0.5p2; 0.75p1 + 0.25p2; -0.5p1 + 1.5p2; 1.5p1 - 0.5p2; Among these four, best two are kept, rest are discarded.
5. **Mutation:** After crossover, children are selected for mutation with mutation probability **pm**. For selected child, randomly two generators are selected. For the first generator, difference with the maximum allowed value is obtained. For the second, difference with the minimum value is obtained. The lesser between them is multiplied with **pm.** The result is added with the first generator and subtracted from the second generator.
6. **Population selection:** The children are combined with the parents to generate the population for the next iteration.

Artificial Neural Network (ANN):

ANN are very basic approximation of human nervous system. There are a number of neurons placed in distinct layers. There is one input layer, one output layer and one or more hidden layers. Neurons in a layer are connected to all the neurons of the neighbouring layers through weights. According to the Universal Approximation Theorem, only one hidden layer is sufficient to represent any non-linear function. However, multiple layers are also used for better convergence and other reasons.

First, an ANN is required to be trained with a set of training data, which contains both inputs and outputs. During the training phase, the weights are updated. There are two steps. First, the **Feedforward,** where the output is calculated from the input using the weights. Then the error is calculated based on the difference between the calculated output and the actual output. In the second step, the **Backpropagation,** the weights are updated based on the gradient of the error. The two stages are run for a number of iterations or until the error is reduced below a curtained predetermined value.

The ANN is as good as the data is. For using ANN for solving CEED problem, we need training data containing both input and output. In this study, we have first taken the result from the GA as the training set for ANN. We have also first taken the result from the SA as the training set.

A linear regression model is used here with 1 no of input, 5 no of output. The 6th generator value is calculated by subtracting the sum of 5 generators from the total load demand. The mean square error loss is used for calculating the error. For optimization, we have used the Adam optimizer.